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Уважаемые читатели!

Перед вами номер журнала "Известия вузов. Технология текстильной промышленности", изданный на английском языке. В нем опубликованы статьи ученых из вузов России (Московского государственного текстильного университета им. А.Н. Косыгина, Ивановской государственной текстильной академии) и вузов Чехии и Турции. Страницы нашего журнала всегда были открыты для зарубежных авторов. В нем печатались исследования ученых по актуальным проблемам текстильной промышленности из Великобритании, Румынии, Германии, США, Китая, Монголии и других стран.

Однако развитие науки у нас в стране и в мире и развитие отношений между странами требуют все большего углубления взаимоотношений ученых с целью дальнейшего развития науки о текстиле. Отвечая требованиям времени, по инициативе коллектива ученых и ректора МГТУ им. А.Н. Косыгина проф. С.Д. Николаева и при поддержке редколлегии и главного редактора журнала проф. Г.И. Чистобородова было принято решение об издании такого номера.

Впервые за 50 лет издания нашего журнала редакция выпускает номер на английском языке и заранее благодарит авторов и читателей за оказанное нам доверие и приносит извинения за возможные допущенные опечатки, возникшие при первом опыте такого издания, которые при дальнейшей работе будут обязательно устранены.

Надеемся, что выход в свет специального номера журнала позволит ученым зарубежных стран лучше узнать об исследованиях, проводимых в вузах России, а российским ученым – познакомиться с успехами зарубежных коллег.

Редакция журнала "Известия вузов. Технология текстильной промышленности".

Dear readers!

This is an issue of the “Proceedings of higher education institutions. Textile industry Technology” journal published in English. Within it there are articles of scientists from Russian institutions (Moscow State Textile University named after A. N. Kosygin and Ivanovo State Textile Academy) and from Czech universities. The pages of our journal have always been opened for the authors from abroad. Accounts of studies of important issues of the textile industry carried out by scientists of the United Kingdom, Romania, Germany, the United States of America, China, Mongolia and other countries were published in it.

However the development of science in our country as well as worldwide and of international relations requires greater improvement of interactions between the scientists in order to develop further the textile science. Meeting the needs of our time, on initiative of the scientists of MSTU named after A.N. Kosygin and its rector, Prof. S.D. Nikolaev, and with support of the editorial board and the chief editor , Prof. G.I. Chistoborodov, the decision to publish this issue has been made.

For the first time in 50 years of publishing our journal the editorial board issues the journal in the English language. The board thanks the authors and readers for the credit given and apologises for possible mistakes made in the first experience of such publishing, which will be certainly precluded in the future.

We hope that the publishing of this special issue will allow the scientists from abroad to gain better knowledge about the studies carried out in Russian institutions and help the Russian scientists to know about the successes of foreign colleagues.

Editorial board of the “Proceedings of higher education institutions. Textile industry Technology” journal.

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ORDER ANALYSIS OF A TEXTILE ENTERPRISE AT THE STAGE OF ITS MAKING-UP

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(The Moscow State Textile University named after A.N. Kosygin)

Manufacture of goods under order is the most viable method of production. However, there is still no unified method for evaluation and analysis of orders from the point of view of their technological peculiarities and economic benefit for manufacturers. Therefore, order analysis is quite complicated for manufacturers and hinders textile enterprise to determine real terms of execution of order, price and other terms and conditions promptly and adequately.

Any order consists of the following phases: Making-up of an order (Phase 1); Preparation for execution of order (Phase 2); Execution of order (Phase 3).

In this paper methodology of order analysis at the stage of its making-up is proposed.

Any order begins with obtaining an application by a textile enterprise from a trading company. Parameters of the ordered fabric are to be specified in the inquiry. Depending upon initial information in the order, terms and conditions for its fulfillment can be as follows (Fig. 1):

Herewith for each enquiry it is assumed that a certain task is to be solved. Nevertheless, all tasks, finally, are reduced to the following two:

– determination of the price, delivery date, and volume of output which the customers need to know to take decision regarding placement of order in this enterprise;

– determination of terms of manufacturing which the manufacturing enterprises need to know to accept the order for execution.

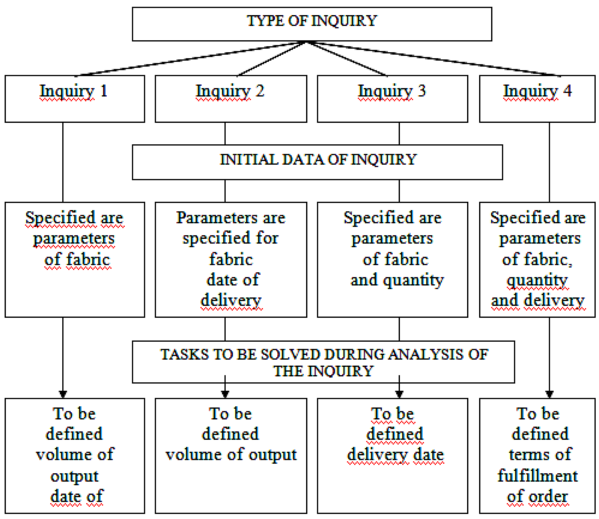

Fig. 1. Clarifying terms of fulfillment of order with different variants of enquiry

Therefore analysis method in a general view can be illustrated by the following block of algorithm (Fig. 2).

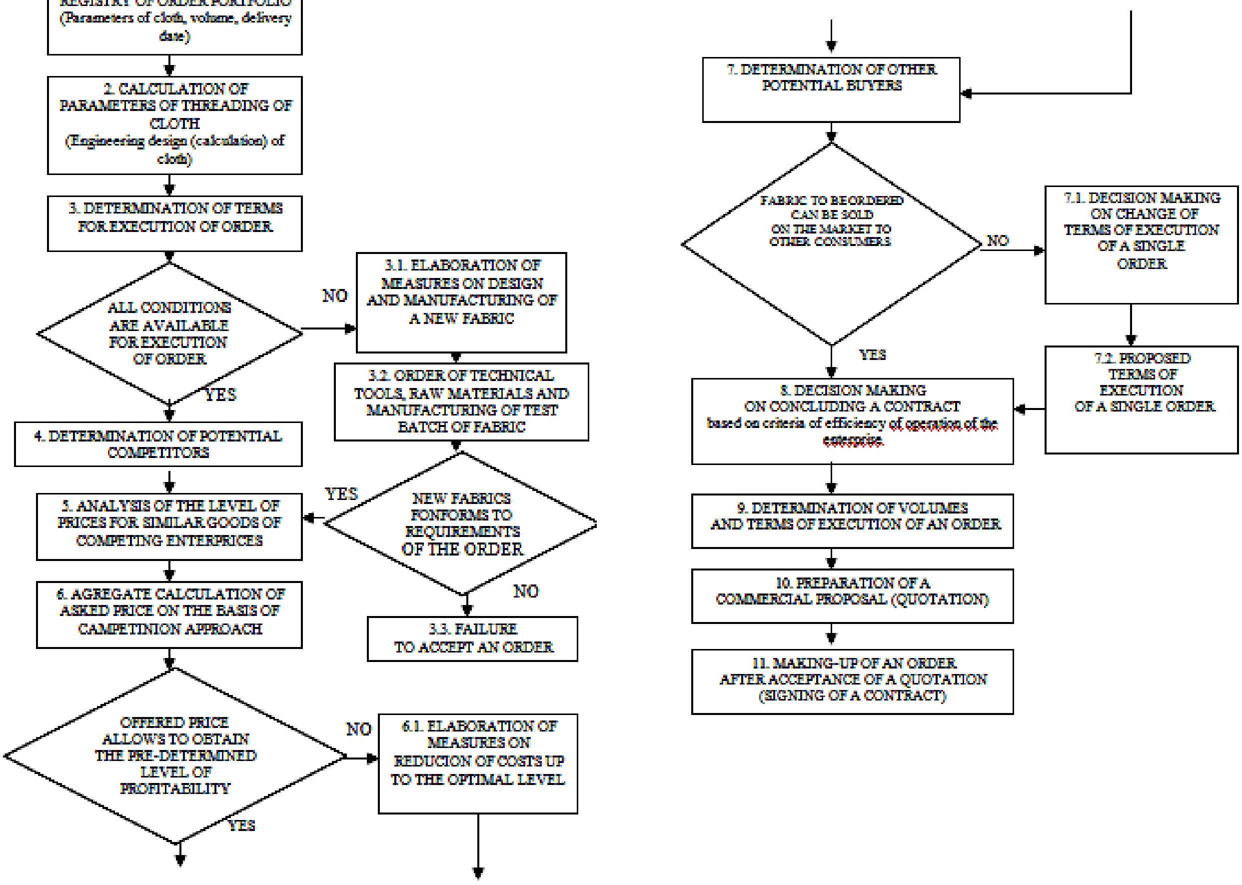

Fig. 2. Block-algorithm of order analysis of the textile enterprise

Calculation of parameters of threading of cloth (technical calculation of cloth) is to be carried out by means of any methods which allow to determine parameters of threading of cloth without test batch operation, including methods of the author of this paper [1], [2].

Determination of terms for execution of order can be carried out by means of standard methods and includes the following actions:

1. Calculation of process planning indices;
2. Rate setting for consumption of material resources by production stages;
3. Labour rate setting by production stages;
4. Development of a plan for supply of resources;
5. Determination of terms for execution of order by production stages.

Determination of potential competitor and analysis of prices for similar finished goods are needed for carrying out aggregate calculation of asked price on the basis of competition approach.

Determination of other potential buyers is important for evaluation of promising outlook of the received order and for determination of optimal volume of production output with the aim to reduce costs for execution of order. On the basis of this information decision is taken on acceptance or rejection of the order.

Determination of volumes and terms of order execution. At this stage it is proposed to use methods, presented in the paper[2], which enable to determine terms of execution of order according to schedules depending upon the way to change article, number of machines to be threaded and volume of an order.

Finally, commercial proposal (quotation) is prepared and after its acceptance by the customer contract for execution of order is concluded.

CONCLUSIONS

Block-algorithm for order analysis of textile enterprise at the stage of its making-up and sequence of actions during order analysis have been proposed.

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FEATURES OF FORMING COST-CUTTING PRODUCTION STRATEGY IN A SUBSIDIARY OF THE HOLDING STRUCTURE

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One of the profound elements of the macroeconomic system of the country in existing conditions is holding structure. Holdings are widespread in both big businesses and small and middle businesses. The aim of a holding structure is to concentrate the financial, intellectual and material resources in the key areas of the company's business development.

In conditions of innovation economy, holdings gain competitive advantages by converting tangible, financial and intellectual resources into the source of revenue. Capitalizing this revenue, holdings are able of securing the increase of their market value. It is essential, because world practice gives examples that security of the enterprise's market value increase for a sufficiently long period of time is a criteria of securing sustainable development.

The holding itself can be very efficient as an organizational management structure to manage innovation business. In this case, a parental company forms a group of subsidiaries, specializing in the creation of different types of product innovations. Besides that, auxiliary companies (e.g., financial, consulting, insurance) that service the whole holding, typically from the headquarter, regardless of geographical location or industry membership of subsidiaries, may be formed as a part of the holding structure [2].

The realization of the competitive strategy must enable the increase in market value of the holding structure in a long run. And this increase may be secured in different ways, because a number of both external and internal environment factors influence the forming of the final level of value. Thus, from the point of cost estimation method, the competitive strategy is a strategy of increasing its market value (business value) [1].

On corporate level, the developed strategy of the holding maximizes the company's market value. The value maximization strategy of a holding structure often comes into being as a result of integration of subsidiaries' strategies, based on the thorough analyze of these strategies.

The competitive strategy of a subsidiary must include a system of steps, resulting in subsidiary's competitive advantages. Later, these advantages will enable the subsidiary to create economic added value. The strategy must be based both on a well thought market analyze, competitors, tangible and intangible assets, and other intangible production factors (including the intellectual potential of labor resources) that the subsidiary possesses.

For effective development of the holding structure it is necessary to take into consideration that the redistribution of financial and other resources in the holding among certain parts of innovation business is a very difficult managerial task. Thus, adoption of product innovations (new types of products) in holding's subsidiaries requires not only the usage of production systems, combining a high level of flexibility and automation, but also changing the mechanism of operational-calendar planning and managing product processes within the whole holding structure. Also it is necessary to take into account the possibility of new costs in the holding company that are linked with the change in product manufacturing technology. For the holding company these costs are objective, as they are the results of creating process innovations (new product manufacturing technologies). The development of the innovation activity makes holding companies distribute optimally costs of all types of resources and consolidate the company's positions in different product spheres of the market.

However, in practice the adoption of new types of products is usually linked with changes in the sequence of production processes that may in turn increase the time of technological processes. There are also problems with fast adaptation of production systems to the requirements of process innovations. The current habits and corporate rules in production activities of working people are violated. This situation has a significant impact on the work coordination and organization of all the subsidiaries of the holding company. Under these circumstances, unexpected production costs and undisclosed losses may emerge.

In this case, there may be a situation when investment and current costs of the holding, as well as undisclosed loss, will be higher than achieved results. The difference between the sum of discounted results and the sum of discounted cost will be negative. Thereby, in these conditions the subsidiary in the holding structure starts to generate negative funds flow. However, in the process of creating the holding value within the whole structure this negative influence has undisclosed character and might not influence the positive rate of the market value due to the positive difference that is formed by another subsidiaries.

In order to eliminate negative influence of the increased costs and undisclosed loss it is necessary to supplement the strategy of the market value maximization of the holding company with cost-cutting production strategies of the subsidiaries. Forming of the cost-cutting strategy in the production within the subsidiary is based on the following basic principles:

1. Carrying out the diagnostics of company's value curb.

The aim of the diagnostics is to find out factors that restrain the value increase and lead to destruction of company's value, and also to identify the dominant curb or a major group of curbs.

2. The development and realization of the conception of managing costs and the results of company's activity.

At this stage of the strategy the revelation and management of the factors that determine unexpected production costs is carried out. Program of measures is created to enable rational combination of functional potential of the organization and the ability to generate positive value of net funds flow, and also to capitalize the profit from the investments, using the cost optimization.

3. Development and realization of the lean production concept – elimination of company's undisclosed loss [4].

At this step of the strategy an action, operation or process that does not add value to the product from the client's point of view is defined. Afterwards, this action, operation or process is regarded as company's loss. All undisclosed losses are divided into:

– unavoidable, i.e. from the client's point of view, the concerned process does not add value to the product, but it is impossible to maintain company's efficiency. In this case, it is possible to optimize the costs, though it is impossible to eliminate them;

– avoidable, they are subdivided into seven categories: overproduction, defective goods, movements, transportation, stocks, waiting, excessive processing.

Thus, the development of the cost-cutting strategy in the production of a subsidiary is based on the synthesis of the process of the company's value curb diagnostics, conception of managing costs and results of company's activity, and on the conception of lean production – elimination of the company's undisclosed losses.

During the development and realization of the strategy these elements cover all the organizational structure of the holding company's subsidiaries, uniting all its chains together (including particular business processes and particular operations). Achieving the goal of the elimination of the emerged costs and undisclosed losses negative influence, all functional strategies and target standards on all levels of the management must be coordinated with the main strategic goal of the holding structure.

Important tools that contribute to the effective realization of the holding company's competitive strategy are such functional strategies as financial and investment [1, 2, 3], and also the strategy of cutting production costs in subsidiaries of the holding structure. Namely, the realization of these strategies plays the utmost important role in creation of the new value in the holding company and contributes to the forming of the cost estimation method in running the company.

It is also important to take into consideration whither subsidiaries and the whole holding structure in general under existing parameters (organizational structure, production capacity, quality of the manufactured product) is able to increase the value, i.e. what internal and external factors mainly influence the forming of the holding company's market value.

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COMPARATIVE ASSESSMENT OF QUALITY OF PARA-ARAMIDE RUSAR FIBERS AFTER NATURAL AND ARTIFICIAL LIGHT AND WEATHER EXPOSURE

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Para-aramide Rusar fibers have a broad field of application. They are used for production of different types of products for industrial use: heavily stressed textile materials, rescue-aid and safety means, optical and electrical cables, ballistic protection means, high-tenacity composites and others. In storage and during use, products made of para-aramide fibers experience exposure to different environmental impacts, including humidity of air, insolation and others that can reduce their operating reliability and terms of potential service life. Products should withstand long-term affect of these factors with maximum possible retention of initial physical-mechanical characteristics, i.e. quality of these products. Quality improvement of products, starting from the phase of planning up to the phase of exploitation, requires first of all, knowledge of properties which determine quality of products, abilities to correctly and objectively measure, evaluate and monitor quality characteristics, to have purposefully an influence on conditions and factors, which significantly affect quality of products. To the factors, which have main affect on quality of products, belong light and weather exposure.

High-tenacity high-modulus fibers heterocyclic para-aramide Rusar fibers of different types that are manufactured in Russia by NPP "Thermotex", are intended for manufacture of ballistic protection means: #1 – nascent Rusar fiber; #2 – heat-treated Rusar fiber; #3 – additionally heat-treated Rusar fiber; #4 – high-tenacity Rusar fiber.

Fibers have been subjected to natural light and weather exposure within six months during the spring-summer-autumn period in North-Western area in Moscow region. Insolation in artificial conditions has been carried out during 24 hours in the daylight device DLD in accordance with GOST 10793 [1] and in Xenotest device.

Main criterion for evaluation of light and weather fastness is relationship of values of rupture-stress characteristics of yarn before and after insolation.

Determination of mechanical properties of para-aramide Rusar fibers has been carried out in accordance with GOST 6611.2 [3] with the Instron test system of 4411series. Clamp length of samples is 500mm, movement speed of the the upper clamp is 200 mm/min.

Results of tests are given in Table 1. From data in Table 1 conclusion can be made that the minimal change of mechanical properties is observed in the sample #4, the maximum change – in sample # 1. It can be noted that sharpest decrease of tenacity in all samples under investigation is observed during first months of natural light and weather exposure and during the first hours of artificial insolation.

Table 1

Type of exposure	Insolation time	Breaking load, cN				Elongation at rupture, mm				Relative breaking load, cN/tex				Relative elongation at rupture, %			
		№ 1	№ 2	№ 3	№4	№ 1	№ 2	№ 3	№4	№ 1	№ 2	№ 3	№4	№ 1	№ 2	№ 3	№4
Without exposure	0	4938	14864	14174	16180	20,95	17,51	20,95	16,51	71,94	245,69	232,82	267,17	4,19	3,50	4,19	3,30
Natural light and weather, months	1	3054	10750	11590	13702	14,84	13,30	15,10	15,20	44,01	176,00	189,63	223,31	2,97	2,66	3,02	3,04
	2	2572	7850	10440	10500	9,09	10,21	12,60	13,60	35,92	121,79	158,47	163,93	1,82	2,04	2,52	2,72
	3	1492	5870	8000	8852	5,96	7,93	10,70	12,70	20,53	85,46	117,22	127,69	1,19	1,59	2,14	2,54
	4	1392	4570	7390	7940	5,44	6,50	9,50	11,10	19,99	71,22	120,08	124,66	1,09	1,30	1,90	2,22
	5	1115	3125	5500	7251	4,15	4,89	7,00	9,58	16,15	49,15	89,85	115,66	0,83	0,98	1,40	1,92
	6	975	2867	3723	6187	3,25	3,87	4,98	7,25	14,14	45,65	61,05	99,84	0,65	0,77	1,00	1,45
DLD, hours	6	3054	10240	12000	13702	14,84	12,5	15,3	16,4	44,01	167,65	196,34	223,31	2,97	2,50	3,06	3,28
	12	2572	7990	10760	10540	9,09	10,21	12,6	15,05	36,97	126,01	172,08	167,74	1,82	2,04	2,52	3,01
	18	1492	5950	9732	8852	5,96	7,93	11,79	13,89	20,20	91,69	148,82	135,27	1,19	1,59	2,36	2,78
	24	1392	5302	8892	8270	5,44	7,67	10,66	13,59	20,02	84,08	140,94	132,00	1,09	1,53	2,13	2,72
Xenotest, hours	6	3158	9350	10958	13888	14,14	11,94	14,87	14,16	45,64	147,06	170,66	218,43	14,14	11,94	14,87	14,16
	12	2358	7100	8220	9722	8,25	9,51	11,75	12,21	31,93	105,03	119,18	146,00	8,25	9,51	11,75	12,21
	18	1644	4300	6070	8987	5,16	7,23	8,50	10,74	20,50	55,71	85,01	119,64	5,16	7,23	8,50	10,74
	24	889	2321	3035	5915	2,85	3,27	4,48	6,85	12,14	35,24	45,06	81,07	2,85	3,27	4,48	6,85

In order to compare the degree of affect of exposure duration of natural and artificial insolation conditions on mechanical properties of para-armide fibers, relationships have been made, which are illustrated in Fig. 1, 2.

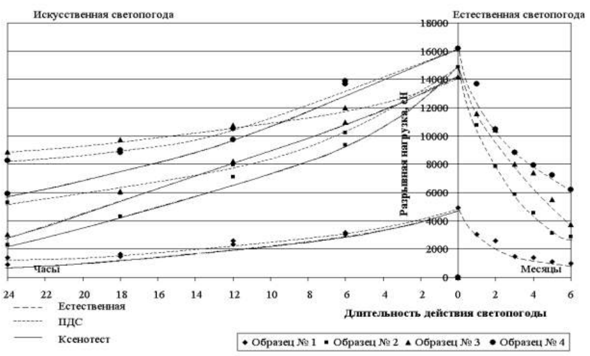

Fig. 1

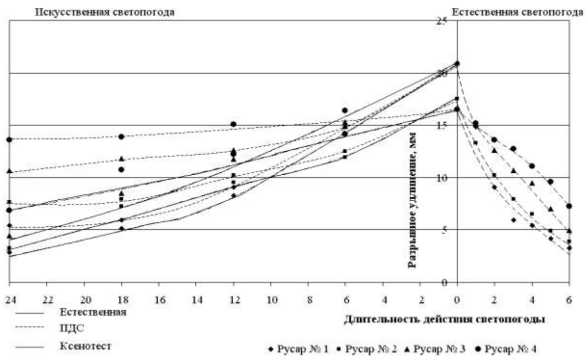

Fig. 2

It can be seen from the diagrams that test values, obtained after insolation in Xenotest device, are close to results obtained after natural insolation. Consequently, 24 hours of light and weather exposure in Xenotest device correspond to 6 months of exposure under natural conditions.

Affect of light weather in DLD on para-aramide fibers is less destructive.

On Fig. 1, 2 diagrams of change of breaking load and elongation at rupture of fibers under investigation depending on insolation time are given. Based on analysis of approximation results of obtained values, conclusion can be made that dependence of breaking load from elongation at rupture of these Rusar fibers from exposure duration with a high degree of accuracy is determined by the following exponential function:

$$y = ae^{-bx}, \quad (1)$$

where y – breaking load, cN or elongation at rupture, mm; x – durability of light and weather exposure, month or hours; a, b – design coefficients.

As a result, change of radiant energy source does not effect the character of change of mechanical characteristics, but intensity of reduction of strength characteristics does change.

CONCLUSIONS

Investigation of influence of different methods of treatment of Rusar fibers on change of mechanical characteristics after light and weather exposure has been carried out. It has been established that heat-treated Rusar fibers have a more ordered structure and, as a sequence, higher tenacity as well as light and weather fastness. Consequently, it is advisable to employ this yarn during manufacture of different products that are used for operations carried out in conditions of natural light and weather, including cloths for protective vests providing reliable ballistic protection in case of active light and weather exposure.

Radiation with Xenotest device takes places more rapidly than in DLD, therefore testing by means of the weathering testing equipment Xenotest can be called as express method.

When selecting test conditions, nature of radiation source is to be taken into consideration in order to obtain more accurate results.

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APPLICATION OF IMAGE ANALYSIS IN THE TEXTILE METROLOGY*

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Image analysis is the method for replacement of the human subjective meaning by objective parameters. Digital camera connected with optical devices is used for creation of digital images. This combination enables the investigation of samples in wide scale, from microscopic to macroscopic dimensions. It is possible to use thin (light transparent) samples and thick (nontransparent) ones as well. From point of view of practical applications the sample preparation and interpretation of results are decisive. Image analysis has been successfully used for solving a lot of problems. In this contribution the practical application of image analysis for evaluation of yarns' selected properties and fabric surface roughness are presented.

From the point of view of internal geometry and macroscopic structure textiles are very complex. Their description or modeling requires investigation of some geometric features of longitudinal or cross sectional images. The core problem is identification of typical image feature embedded in the noise. The main problems are:

– blurred images due to techniques of sample preparation, no constant focusing and high level of noise signal;

– poor resolution due to colored background and contacts between individual features;

– presence of non-standard shapes.

Methods of automatic feature detection are not generally applicable and it is still necessary to correct some images manually. It is for example very complicated to identify quantitatively tips on the surface of rotor yarns.

Image analysis techniques in the textile branch are complicated due to high stochastic variability of products. It is necessary to use a huge amount of images from properly selected spots to avoid artifacts.

* This work was supported by the research project "Textile center" 1M4674788501 of Czech Ministry of Education.

Second problem is preparation of digital images containing required structural information. The utilization of special samples, selection of right illumination and viewing angles not only enhance resolution but also are core of success. These problems are specific for textile branch and in many cases are solved by trial and error method only.

Technical problems with preparation of samples based on the optical and technical requirements are similar to digital photography.

In many cases it is necessary to build special models for interpretation of image analysis results or for deeper investigation of obtained information.

The result is that the image analysis methods are still applicable for the research purposes or for identification of faults only. In this contribution the practical application of image analysis for evaluation of yarns' selected properties and fabric surface roughness are presented.

IMAGE ANALYSIS. Image analysis is the method for replacement of the human subjective meaning by objective parameters. Generally, the whole process of image analysis can be divided to five parts:

(1) Sample preparation and pretreatment

(2) Image creation (replacement of classical photography)

(3) Computer assisted image preprocessing (image enhancement, image threshold, and elimination of signal noise, change of brightness)

(4) Image treatment (image coding - compression detection of lines, areas, shape information, saving of data files)

(5) Interpretation and quantification of results.

Parts 3 and 4 realized on the computer by suitable software are the core of so called image analysis. Digital images (part 2) are created by the digital camera connected with suitable optical devices. This combination enables the investigation of samples in wide scale, from microscopic to macroscopic dimensions.

It is possible to use thin (light transparent) samples and thick (nontransparent) ones as well. Image analysis has been successfully used for solving of a lot of problems connected with geometrical characteristics of textile materials. Generally the images can be obtained from surface (longitudinal views) or from cross section (perpendicular views). Individual methods are dependent on the form of material.

Basic fiber characteristics evaluated by image analysis are:

1. Longitudinal views: length, diameter (for round profile), crimping, surface peculiarities.

2. Cross-sections: area, perimeter, fineness, shape factor, specific surface, degree of conversion into ultimate flax fibers, cotton maturity.

Basic yarns characteristics evaluated by image analysis are:

Longitudinal views: hairiness, diameter, surface twist, belt fibers on rotor yarn, cover factor of wrapped core yarn, thickness unevenness, compression between two parallel plates.

Cross-sections: fiber number, packing density, diameter, porosity, blending uniformity, mass (volume) blend portion.

Basic woven fabric characteristics evaluated by image analysis are:

Longitudinal views: cover factor, porosity, surface roughness, hairiness, pilling, abrasion, textural characteristics, surface creasing, and bended fabric shape.

Cross-sections: binding point geometry, thickness.

Examples of image analysis application in the textile metrology area are: trash content and shade uniformity of cotton fibers (Xu et all. (1997)), evaluation of fibers' geometrical characteristics (Xu and Ting (1996)), analysis of yarn thin places and unevenness (Zhang, Iype and Oxenham (1998)), uniformity of weave set (Fisker and Carstensen (1997)), pore size analysis in textiles (Gong and Newton (1992)), drape characterization (Jeong (1998)) and objective characterization of pilling (Hsi, Brese and Annis (1998)).

Yarn cross-section analysis. The analysis of yarn cross-section enables to estimate the fiber number in yarn cross-section, mean yarn-packing density, porosity and yarn diameter. It is possible to construct the radial course of packing density as well.

The important part of the whole analysis is preparation of the yarn cross-sectional images. From various places of yarn fiber cross-sections of thickness about 15 μm were prepared. For preparation of cross-section the soft method (i e. fiber pretreated by glue are sealed by mixture of beeswax and paraffin) was used. The main problem is to obtain images having well defined boundaries of fibers in the whole surface of yarn cross-section. The automatic detection of fibers cross-sections is very complicated and therefore the manual selection and correction of fibers profiles have to be applied (LUCIA D - Laboratory Imaging software was used).

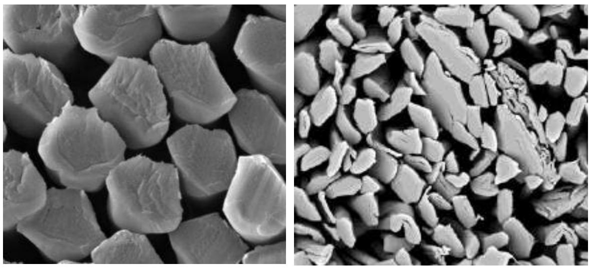
Two methods for yarn packing density evaluation were compared direct method and Secant method (Křemenáková and Rubnerová (2001)). Direct method is based on the detection of real fibers area. Real fiber images have to be pretreated before evaluation. The separation of individual images, transformation to binary form and noise removing is necessary. Secant method requires the measurement of fibers center of gravity only. Other required parameters are fiber fineness and volume density, yarn fineness and twist. The analysis is based on the idealized reconstruction of fibers' cross-sections around their measured center of gravity. By using fiber fineness and mass fiber density the equivalent circle having the same area of cross-section is created and then the correction to the non-circularity caused by the twist and fiber position in yarn is applied.

Yarn Packing Density. Fiber compactness varies at different places in yarn, so that it is reasonable to use the radial packing density curve to characterize the packing density changes from yarn axis to yarn surface. The system of annular rings centered on yarn axis (yarn center of gravity) is used. The packing density is then expressed as function of distance from yarn axis. Local packing density is expressed as the ratio of the fibers' cross sectional area in annular ring to the total area of annular ring.

For comparison of direct method and Secant method the following yarns were selected:

– ring yarn 100% PET fibers, round profile, 20 tex , twist 940 m^{-1} (Fig. 1-a);

– rotor blended yarn 50% cotton / 50% cottonized flax, 24 tex, 1260 m^{-1} (Fig. 1-b).



a) PET fibers b) 50%cotton/ 50%cottonized flax fibers

Fig. 1. Cross sections of tested yarns

The lower and upper limits of 95 % confidence intervals for both methods are shown on the Fig. 2 and 3. It is clear that for PET circular fibers it is possible to use Secant method because the packing density traces are similar. In yarn 50% cotton / 50% cottonized flax the cotton fibers of various maturity and bundles of flax ultimate fibers are occurred. In the central part of yarn packing density computed from real cross section shapes is systematically lower (smaller fiber cross sections) and in subsurface layers packing density has the opposite tendency.

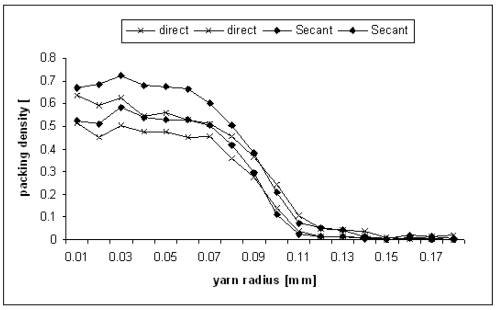


Fig. 2. Comparison of methods – 100% PET yarn

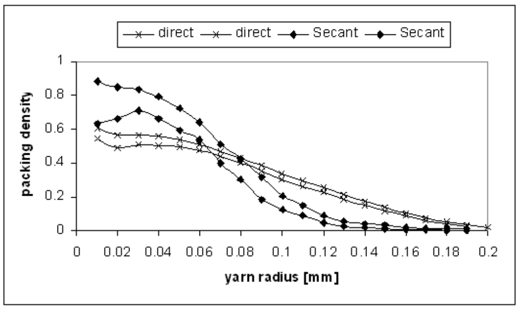
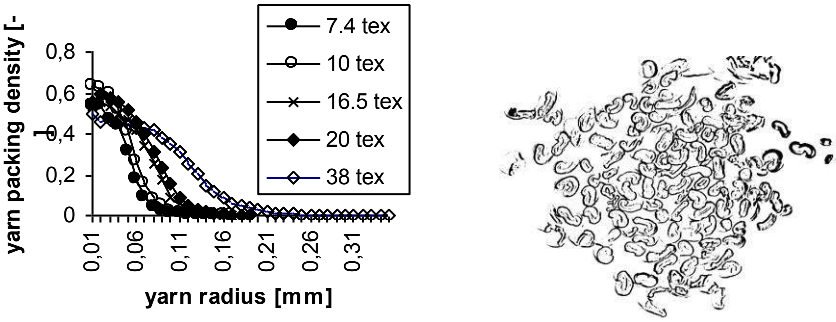


Fig. 3. Comparison of methods – 50%cotton/ 50%cottonized flax fibers

Typical courses of packing density for cotton ring yarns are on the Fig. 4.



a) packing density b) typical yarn cross-section

Fig. 4. Packing density of cotton yarns vs. yarn diameter

Yarn diameter is an intuitive expression. It is often defined by a diameter of imaginary cylinder where fibers are concentrated. Experimentally determined yarn diameter is denoted as effective yarn diameter. It can be estimated for example from a value corresponding to 0.15 of the mean radial packing density or from the value corresponding to 50% of the so-called blackness or hairiness function (explained below). It is useful to express the radial packing density by a single value known as effective packing density. It expresses the ratio between areas of fibers in a circle of effective diameter to the area of this circle. The relationship between yarn diameter and packing density μ has the form

$$d = \sqrt{4T/\pi\mu\rho}\,, \tag{1}$$

where T is yarn fineness and ρ is fiber mass density.

YARN HAIRINESS. Yarn hairiness can be evaluated from yarn longitudinal images (see Fig. 5). This method is based on the registration of light rays passing through yarn body and creation of so-called darkness density traces (Neckář and Voborová (2003)).

a) free yarn b) flattened yarn with loading 25 N

Fig. 5. Evaluation of yarn diameter and hairiness

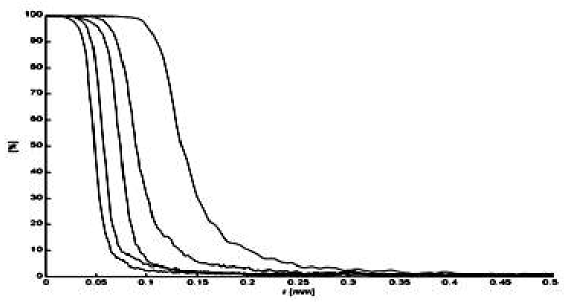


Fig. 6. Darkness intensity traces, ring yarns, fineness from left 7.4, 10, 16.5, 20, 38 tex

Roughness in various domains

Resulting traces for group of cotton ring yarns (see Table 1) are given in the Fig. 6. The main problem is exact definition of yarn diameter as dividing line between yarn body and hairiness area. According to our experiences yarn diameter is situated on 50% values of darkness intensity trace. The influence of spinning technology on the yarn structure and properties can be investigated as well. The description of the darkness density traces is

based on the model curve estimated by statistical analysis (Meloun, Militky and Forina

(1992)).

In the unevenness analysis it is common to aggregate raw data. This is equivalent to cutting the material to pieces and measuring variability between pieces only. In the case of roughness it is aggregation tool for smoothing of roughness profiles and avoiding local (small scale) roughness.

The principle of aggregation is joining of original data z(i) into nonoverlapping blocks or application of window of length L. Aggregated series $z^{(L)}(i)$ are created by the averaging of values z(i) into blocks having L values and characterization of block by mean value

$$z^{(L)}(i) = \frac{1}{L}(z(i*L-L-1+...z(i*L)) \quad L=1,\ 2,\ 3.. \tag{2}$$

For second order stationary of raw data aggregated series is still second order stationary with auto covariance function $c^{(L)}(d)$ and variance $v^{(L)}$. It is known that variance of aggregated series is connected to covariance function c(d) of original series

$$v^{(L)} = \frac{v}{L} + \frac{2}{L^2}\sum_{s=1}^{L-1}\sum_{h=1}^{s} c(d). \tag{3}$$

Here d is space lag used for computation of covariance function. The nature of original random series can be explained by using characteristics of aggregated series. There are three main groups of series:

1. Series of random independent identically distributed (i.i.d) variables. For this case all c(d) =0, for lags d = 1,2, and data are uncorrelated. This is ideal case for unevenness or random roughness analysis and it is implicitly assumed as valid in majority of methods used in practice.

2. The short-range dependent stationary processes. In this case the sum of all c(d) d = 1, 2, … is convergent.

3. The long-range dependent stationary processes. In this case the sum of all c(d) d = 1, 2, … is divergent.

For short-range dependent stationary processes the first order autocorrelation $R^{(L)}(1) = 0$ for $L \to \infty$. The same is valid for autocorrelation of all lags d. The aggregated series $y^{(L)}(i)$ therefore tends to the second order pure noise as $L \to \infty$. For large L variance $v^{(L)} = v/L$. The autocorrelation structure of aggregated series decreases until limit of no correlation. Typical model of short-range processes is autoregressive moving average processes of finite order. For the higher cut lengths are data is approaching to the i.i.d case.

For long-range dependent processes variance $L * v^{(L)} \to \infty$ as $L \to \infty$. The autocorrelation structure is then not vanishing. For these processes it is valid that for sufficiently large L

$$c(d) \approx d^{-\beta} \text{ and } v^{(L)} \approx L^{-\beta}, \tag{4}$$

where for stationary series $0 < \beta < 1$ is valid. For no stationary case β can be outside of this interval.

A strictly second order self-similar process has $R^{(L)}(d) = R(d)$ and $v^{(L)} = vL^{-\beta}$. Therefore for the long-range processes correlation structure is identical for original and aggregate series . For strictly second order self-similar processes are $c(d) \approx \frac{v}{2}(1-\beta)(2-\beta)d^{-\beta}$. For the higher cut lengths the correlation structure remains the same and assumption of i.i.d cannot be used. Instead of β the Hurst exponent $H = 1\text{-}0{,}5\beta$ is frequently used. When h = 0, this denotes a series of extreme irregularity and h = 1 denotes a smooth series. Exponent h is directly connected to fractal dimension df because in fact $D_F = 2 - H$ (zhang (1996)).

FABRIC ROUGHNESS. Roughness profile of textile surfaces at given position along machine direction can be obtained from the analysis of specially prepared fabric images. For good image creation it is necessary to select suitable lighting and fabric arrangement (Fig.1). The original RCM system designed for noncontact surface roughness evaluation uses the special arrangements of textile bend around sharp edge (Fig. 2) and laser lighting from the top (Mazal and Militky (2006)). Result after image treatment is so called “slice” which is the roughness profile in the cross direction at selected position in machine direction (the line transect of the fabric surface).

The RCM system allows reconstruction of surface roughness plane in two dimensions (Fig. 7). For this purpose, the sample holder is moved (step by step) in controlled manner. From set of these slices it is possible to reconstruct the roughness plane as well.

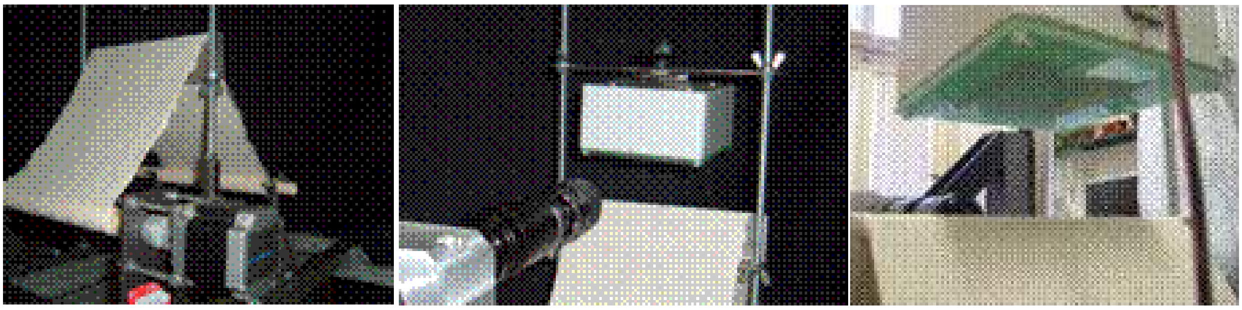
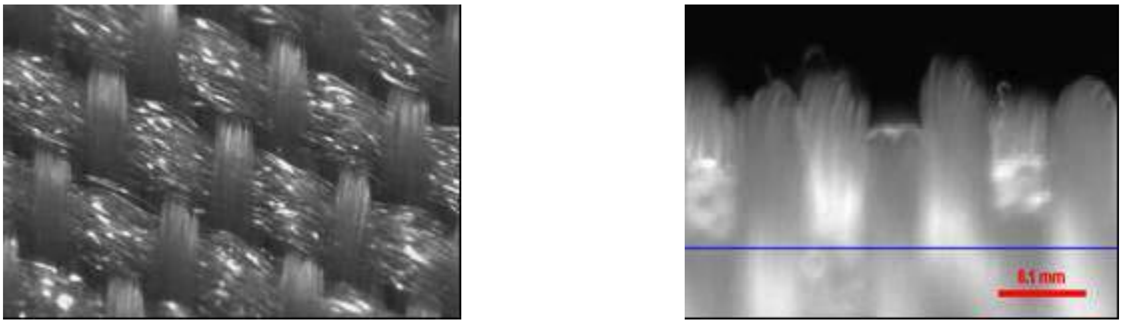


Fig. 7. Details of RCM apparatus

The maximal resolution in roughness slice is 2 μm and basic distance between slices is 76 μm

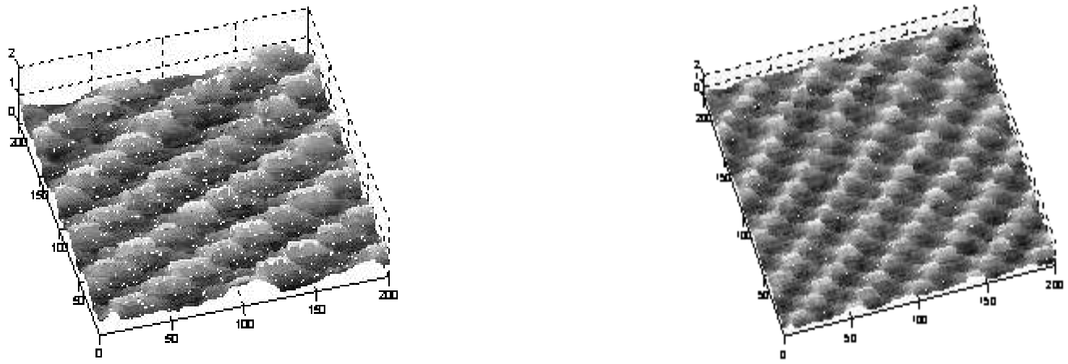
A multifilament filament fabric with relatively good structural homogeneity was selected for demonstration of RCM system capability. The fabric surface is shown on the Fig. 8-a.



a) b)

Fig. 8. Tested fabric: a) – surface view, b) – raw image of one slice

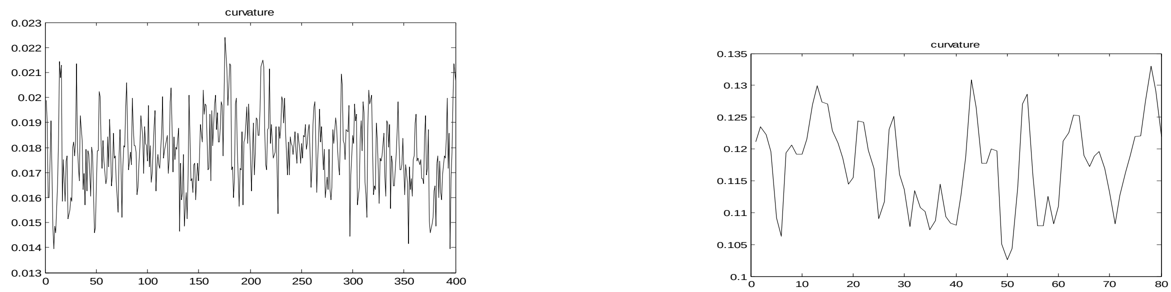
Individual slices roughness profiles were created by using threshold and set of morphological operations. Result of these operations is vector of surface contours in cross direction at specified machine direction. By using aggregation (see eqn(2)) the resolution is decreased and roughness profile is created without local roughness variation. This aggregation has the same function as cut length at unevenness measurement and therefore we use word “cut length X” for the case of aggregation of X subsequent values. After application of cut length principle the direct combination of slices leads to the creation of roughness surface (Fig. 9). The principle of aggregation can be used for smoothing in the machine direction as well (it is equal to the local averaging of slices).



a) b)

Fig. 9. Roughness surface: a) – cut length 1, b) – cut length 10

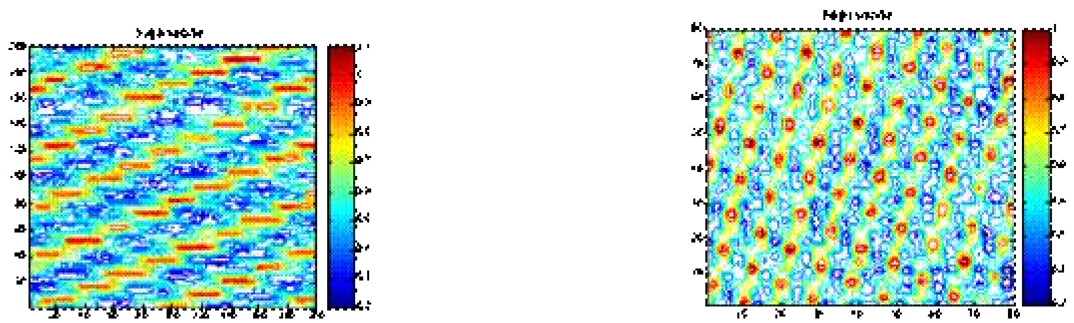
Output from data pretreatment phase is array of slices, i.e. array of vectors Rj(i) where index I corresponds to the position in jth slice. The simplest way to roughness characterization is to use characteristics for individual slices and averaging or plotting characteristics for all slices. For computation of these characteristics the ROSQ program in MATLAB has been created. Some special roughness characteristics are computed (Eke (2000)) also. For illustration of ROSQ capability, the standard deviation of profile curvature PC for cut length 1 and cut length 10 are shown in Fig. 10.



a) b)

Fig. 10. Standard deviation of profile curvature PC of individual slices:
a) – cut length 1, b) – cut length 10

The local rough surface height variation is shown in Fig. 11.



a) b)

Fig. 11. Local rough surface height variation: a) – cut length 1, b) – cut length 10.

CONCLUSIONS

The selected yarns' geometrical properties and fabric surface roughness were investigated by image analysis. The images were processed by the combination of statistical treatment and modeling based on idealized structural arrangement. Results of this analysis can be used for evaluation of textile production quality and for textile design purposes.

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PREDICTION OF THERMAL CONDUCTIVITY OF A COMPOSITE TEXTILE MATERIAL

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In conformity with standards НПБ 157-99 [1] the fire-fighter's clothing (FFC) possessing dehydrating, thermo-insulating and fireproof properties is manufactured from laminated composite materials supplied with detachable thermo-insulating linings. The linings are fabricated using 2 layers of a woollen needle-punched non-woven textile fabric and because of their bulky dimensions have limited applications. In order to increase the thermo-insulating properties of the basic FFC outfit it is suggested to introduce an internal stratum of a knitted material. In this case the best choice is the warp-knitted material made of flax yarns, as it is characterized by an equal extensibility in all directions and add some ergonomic properties to this outfit. In their turn the flax fibres possess high thermo-insulating and heat-resistant properties enhanced by the cellular porous structure of the knitted fabric. In the critical zones, i.e. in the places of contact with the heated objects (as a rule they are shoulder girdle, chest, thighs, knees), the knitted stratum can be fortified by tightening the structure or introducing the weft yarns. Apart from this the yarns produced from flax wastes are rather inexpensive.

In order to design such an outfit we must calculate thermal conductivity of the sandwich shell taking into consideration thermo-insulating properties of the fibres, structure of the knitted material, heat released by a man, external thermal field. Such problem can be solved using the equations of thermal conductivity employing the method of finite elements.

The shell being designed as well as a human figure can be regarded as axis-symmetric and the problem can be solved in a polar coordinate system (Fig. 1).

There is a well-known Laplace's equation [2] for determining the thermal conductivity

$$\Delta^2 T = \frac{\partial^2 T}{\partial r} + \frac{\partial^2 T}{\partial z} = 0, \qquad (1)$$

where Δ is the Laplacian; T – the temperature; r and z are the polar coordinates.

The problem is given for a variety of elements l consisting of the regions with boundaries S; Dirihle boundary conditions on a boundary segment will be:

$$T = 36.6°\ C,\ z = 0,$$
$$T = 200°\ C,\ z = H$$

and the Neuman conditions for the rest of the boundary will be:

$$\frac{\partial T}{\partial r} = 0,\ r = 0,$$
$$\frac{\partial T}{\partial r} = 0,\ r = L$$

36.6° C here is the temperature of a human body within the shell, 200°C – the most likely temperature of the radiant heat flux outside the shell.

The problem is solved with the help of the equivalent variation formulation whereby the solution T (r, z) coincide with certain function I (r, z) which is minimized with the help of the functional

$$I = \frac{1}{2}\iint_S \left[\left(\frac{\partial \widehat{T}}{\partial r}\right)^2 + \left(\frac{\partial \widehat{T}}{\partial z}\right)^2\right] drdz, \qquad (2)$$

where $\widehat{T}(r,z)$ is the function defined from the admissible variety of sampling functions specified for the surface *S*. The continuous functions having first piecewise continuous derivatives and satisfying the above said boundary conditions are considered as admissible. These conditions will comprise a set of control functions and dependences known from heat engineering:

$$I = \iint_S \frac{1}{2}\left[\lambda_r(S_\mu,T)\left(\frac{\partial T}{\partial r}\right)^2 + \lambda_z(S_\mu,T)\left(\frac{\partial T}{\partial z}\right)^2 + \lambda_r\lambda_z(S_\mu,T)\frac{\partial T}{\partial r}\frac{\partial T}{\partial z} - \right.$$
$$\left. -2Q(S_\mu)\Phi_Q(t)T + 2\rho_c(S_\mu,T)\frac{\partial T}{\partial t}T\right] rdS - \int_L q(L,)\Phi_q(t)TrdL +$$
$$+\frac{1}{2}\int_L \alpha(L)\Phi_\alpha(t)\left[T - 2T_b(L)\Phi_T(t)\right]TrdL + \frac{1}{2}\int_L \alpha(L_k,\sigma_k)\Phi_\alpha(t)\left[T - 2T_b(L)\Phi_T(t)\right]TrdL) +$$
$$+\int_L \varepsilon(L)\Phi_\varepsilon(t)\left\{\frac{T^5}{5} - \left[T_u(L)\Phi_u(t)\right]^4 T\right\} rdL, \qquad (3)$$

where λ_r, λ_z, λ_{rz} are the heat conductivity coefficients:

$$\lambda = \frac{q\delta}{(T_1 - T_2)St}$$

q is the intensity of the heat flow passing through the boundary; t – the time factor, δ – the thickness of the material; Q – the intensity of the internal sources of heat (heat released by a human body); ρ_c – the specific heat capacity of the material per a volume unit; αT_b – the heat transfer coefficient and the ambient temperature in the boundary region; ε, T_u – the radiant heat-transfer coefficient and the radiant temperature; $\Phi_Q(t)$, $\Phi_q(t)$, $\Phi_\alpha(t)$, $\Phi_T(t)$, $\Phi_\varepsilon(t)$, $\Phi_u(t)$ – the control functions**,** correlating with time variable and specified for boundary segments for changing the boundary conditions; S_μ - sub-regions of different materials of region S under consideration; σ_k - contact voltages in the region of contact L_k.

The thermal field is represented as a matrix indicating the temperature in the nodal locations around the shell under study in polar coordinates (Fig. 1). The control functions are also defined as matrices.

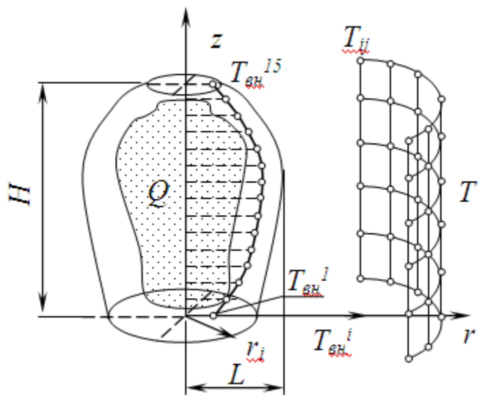

Fig 1. The calculated shell in the thermal field

The whole region is subdivided into finite elements l in a six-chain form, in their shape and size similar to the element of a looped structure of the warp knitted fabric [3]. The subdivision of the region and continuity conditions make it possible to write the functional (3) as:

$$I = \sum_{i=1}^{l} I^e , \qquad (4)$$

where I^e is the functional (3) for the finite element i with the number of nodes e.

The typical e-element is shown in Fig. 2.

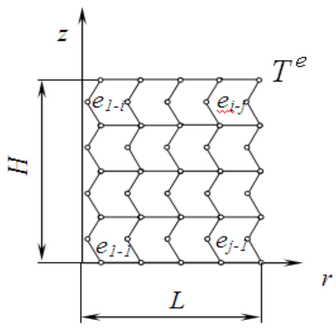

Fig 2. Subdivision of the region into finite element ℓ

The temperature within the shell under stationary heating conditions is determined by the ratio:

$$\frac{\partial I^e}{\partial T_{int}{}^e} = k^e T_{int}{}^e = 0 , \qquad (5)$$

where $T_{int}{}^e$ is the value of temperature in the mesh nodes (Fig. 2); k^e – the stiffness matrix of the element e comprised of the thermal conductivity coefficients [3], [4].

In line with the rules of the finite elements method, for the shell under study a global matrix can be assembled from rows i and columns j in compliance with the expressions (3), (4) and (5):

$$\begin{vmatrix} \dfrac{\partial I^1}{\partial T^{1-1}} \\ \dots \\ \dfrac{\partial I^l}{\partial T^{i-j}} \end{vmatrix} = \frac{1}{l\Delta} \begin{vmatrix} k_1^1 & \dots & k_i^l \\ \dots & \dots & \dots \\ k_j^1 & \dots & k_j^l \end{vmatrix} \cdot \begin{vmatrix} T_{BH}{}^1 \\ \dots \\ T_{BH}{}^l \end{vmatrix} . \qquad (6)$$

To calculate the thermal conductivity and design the distribution of the thermal fields within the shell a matrix mathematical system MatLab is employed. In programming of the design procedure the rows of matrix equation (6) corresponding to each node were successively calculated in accordance with expression (4).

Let us consider as our example a sample of the material with a number of nodes 15×15. The coefficient of thermal conductivity for flax yarn is 0.04, for cotton yarn – 0.05 for the protective layer of FFC – 0.3 W/(m·°C). Let us assume that the thermal field is homogeneous T=200°C and the control functions are constant, Q – 700 W/m², q – 350 MJ/m², ρ_c – specific heat capacity of the material – $9.18 \cdot 10^5$ J/m^3·°C. Then the matrix equation of the system can be written as:

$$
\left|\begin{matrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-4 & 0 & 0 & 10 & -2 & 0 & -4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -8 & 0 & -2 & 20 & -2 & 0 & -8 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & -4 & 0 & -2 & 10 & 0 & 0 & -4 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -4 & 0 & 0 & 10 & -2 & 0 & -4 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -8 & 0 & -2 & 20 & -2 & 0 & -8 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & -4 & 0 & -2 & 10 & 0 & 0 & -4 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & -4 & 0 & 0 & 10 & -2 & 0 & -4 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -8 & 0 & -2 & 20 & -2 & 0 & -8 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -4 & 0 & -2 & 10 & 0 & 0 & -4 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{matrix}\right|
\cdot
\left|\begin{matrix}
T_1 \\ T_2 \\ T_3 \\ T_4 \\ T_5 \\ T_6 \\ T_7 \\ T_8 \\ T_9 \\ T_{10} \\ T_{11} \\ T_{12} \\ T_{13} \\ T_{14} \\ T_{15}
\end{matrix}\right|
=
\left|\begin{matrix}
36,6 \\ 37,0 \\ 37,5 \\ 38,0 \\ 39,0 \\ 39,5 \\ 40,0 \\ 41,0 \\ 41,5 \\ 40,5 \\ 39,5 \\ 39,0 \\ 38,0 \\ 37,0 \\ 36,6
\end{matrix}\right|
\qquad (7)
$$

Temperature within the shell curve is shown in Fig. 1.

CONCLUSIONS

Methods are suggested to evaluate the thermal conductivity of the sandwich textile shell subject to the surface area of the upper layer, thermo-insulating properties of each layer, external temperature field, contact and no-contact (irradiation) method of heat transfer, the internal heat source.

The methods suggested can be implemented in designing the heat-proof properties of the fire-fighter's clothing supplied with lining made from warp knitted flax fabric.

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BED TICKING FABRICS COMFORT EVALUATION*

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It is well known that hand plays an important role as the first characteristic entering to contact with consumer. With the development of new types of technologies and textile products, the objective characterization of hand becomes more important. This leads to the finding of objective techniques for prediction of subjective hand based on the special regression models (multivariate calibration). For prediction of hand the KES (Kawabata Evaluation System) is routinely used. This system is tuned for specific kinds of fabrics only. The main aim of this contribution is utilization of KES properties for creation of regression type prediction model suitable for estimation of the median of bed ticking fabrics subjective hand. The subset of properties correlated strongly with subjective hand is used.

In this contribution the subjective hand evaluation of bed ticking fabrics is discussed. For representation of results the approach based on categorized variables is used. For the case of subjective hand the ordinal median is computed. Groups of 16 respondents are used for evaluation of hand and appearance of 61 finely selected bed ticking fabrics.

The data from KES measurements are analyzed by multivariate statistical methods for evaluation of potential sources of heterogeneity (clusters and outliers) and mutual dependencies. The clusters and PCA analysis are applied for grouping tendency estimation.

The complex system for prediction of bed ticking fabrics hand is presented. The subset of KES properties connected significantly with subjective hand is specified. The methodology of prediction of subjective hand based on the combination of psychophysical transformation and predictive regression model is described. This methodology is applied for creation of predictive equation with few numbers of measured properties (especially shear and roughness).

Hand evaluation. One of the basic contact properties of textiles is hand. The term "hand" is difficult to define precisely. It belongs to textile quality evaluation as one of the most important utility properties. It is possible to include hand among subjective feelings evoked by measurable textile characteristics.

Subjective hand. The subjectively evaluated hand is connected especially with surface, mechanical and thermal properties. The first attempts of hand evaluation of textiles were published by Binns (1926). Two basic procedures of subjective hand evaluation were proposed (Howorth (1964)):

a) Direct method is based on principle of sorting of individual textiles to defined subjective grade ordinal scale (e.g., 0 – very poor, 1 – sufficient, 5 – very good, 6 – excellent)

b) Comparative method is based on sorting of textiles according to subjective criterion of evaluation (e.g., ordering from textiles with the most pleasant hand to textiles with the worst hand).

For prediction of hand using any subjective method it is necessary to solve following problems (Militký (1998)):

– Choice of respondents;
– Choice of grade scale;
– Definition of semantic.

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Choice of respondents. The method of choice of respondents has very strong influence on obtained data and therefore also on results of hand evaluation. It is obvious, that subjective evaluation is based on quality of sensorial receptors of the individual respondents. Results of evaluation are also dependent on the psychical state of respondents and the state of environment. Different results are often obtained by experts and by consumers. It is given by different points of view on textile and used terminology. Above indicated problems show that it is very difficult to maintain reproducibility and choice of respondents has to be strongly defined. The significant differences exist between men and women, too. The men evaluate usually close to scale centre in comparison with women. The special problem is size of respondent group. The minimum size for expressing of consumer meaning is 25…30 people and for looking for relationships with objective characteristics more than 200 people.

Choice of grade scale. If the paired comparison is not applied it is possible to choose grade scale according to the actual criterion and needs. The size of grade scales varies from 5 to 99. The 99-grade scale is more suitable for experts handling with fabrics. For consumers grade scale from 5 to 11 is preferred as they have not so high sensitivity for judgment of very weak differences.

Definition of Semantic. Evaluation of total hand is not sufficient when more precise results are required. It is suitable to introduce primary hand values. Primary hand values are connected with surface, thermal and geometric properties. Paired comparison of several samples is often carried out and then the ranks are got together. This method is easy for statistical data processing but it is suitable for small sets of textiles only.

Statistical treatment of subjective judgments. Statistical analysis of subjective hand results is obviously based on the classical arithmetic mean. The more correct approach is based on the categorized variables (Militky (1993), Rehak (1986)). Generally, for categorized variable case the population of all events is divided to the categories $C_1,.....C_P$. Special case of categorized variable is ordinal variable (Rehak (1986)). For ordinal variable the categories $C_1,.....C_P$ are sorted according to external criterion (here hand). It is assumed that the first category is worst and last category is best. The category C_{i+1} is better that C_i for all $i = 1,...P-1$. Statistical treatment of ordinal variable is based on absolute frequencies $n_i, i = 1,....P$ corresponding to categories $C_1,.....C_P$. Total number of events is

$$n = \sum_{i=1}^{P} n_i .$$

Relative frequencies and cumulative relative frequencies are then

$$f_i = \frac{n_i}{n} \qquad F_j = \sum_{i=1}^{j} f_i \qquad j = 1,....P .$$

For characterization of location of ordinal variable the sample rating median can be computed. The median category *Me* is defined by inequalities $F_{Me-1} < 0.5$, $F_{Me} \geq 0.5$

The sample-rating median of ordinal variable has the form

$$X_{Me} = Me + 0.5 - \frac{F_{Me} - 0.5}{f_{Me}} .$$

For estimation of mean handle grade the sample rating median X_{Me} is suitable. Characteristic X_{Me} is estimator of population rating median Med. The simple method for constructing confidence interval for Med is described in works (Militky (1998)).

Objective methods for hand prediction. A lot of methods are used for indirect objective hand evaluation. These techniques can be divided to three groups according to used instruments:

a) Special instruments – the hand is result of the measurement. Drawing of textile through the nozzle of defined shape and evaluation of dependence "strength-displacement" course is usual principle (Alley (1980)).

b) Set of special instruments for measuring of properties corresponding to hand. Kawabata's evaluation system (KES) belongs here. It consists of four instruments for measuring tensile, shear, bending, surface and compressive properties under special conditions of measuring. Totally 16 mechanical characteristics are measured by using these instruments (Kawabata (1982)).

c) Standard instruments for evaluation of fabric properties connected with hand (Raheel (1991) Militky (1998)).

Techniques of objective hand evaluation can be divided to two groups according to data processing.

a) Result is one number characterizing hand - this number is very often obtained from conversion equation (e.g., regression model), where subjective hand is endogenous variable and measured properties are exogenous ones (Militky (1998)).

b) Result is the vector of numbers characterizing hand. Comparison of hand is then carried out on the basis of multivariate statistical methods (Pan (1988), Brand (1964)) (e.g., factor analysis, discrimination analysis and cluster analysis.

Applicability of various methods for objective hand prediction is connected with the choice of measured textiles properties.

Kawabata evaluation system (KES).

The KES systems of instrumentation for measuring the fundamental mechanical properties of fabric and regression type model for prediction of subjective hand are described in work (Kawabata (1982)).

The properties being measured are grouped into six blocks. Corresponding characteristics are collected in the Table 1.

Table 1. Characteristic values of basic properties

Properties	Symbols	Characteristic	unit
Tensile	LT x1	Linearity	-
	WT x2	Tensile energy	gf.cm/cm^2
	RT x3	Resilience	%
Bending	B x4	Bending rigidity	gf.cm^2/cm
	2HB x5	Hysteresis	gf.cm^2/cm
Shearing	G x6	Shear stiffness	gf/cm.degree
	2HG x7	Hysteresis at ∅ = 0,50	gf/cm
	2HG5 x8	Hysteresis at ∅ = 50	gf/cm
Compression	LC x9	Linearity	-
	WC x10	Compressional energy	gf.cm/cm^2
	RC x11	Resilience	%
Thickness	T x12	Thickness at 0,5 gf/cm2	mm
Surface	MIU x13	Coefficient Friction	-
	MMD x14	Mean deviation of MIU	-
	SMD x15	Geometrical roughness	micron
Areal weight*)	W x16	Weight per unit area	mg/cm^2

*) Denote that in our prediction equation is areal weight W expressed in g/m^2.

Details about measurement principles, sample preparation and prediction of subjective hand are collected in (Kawabata (1982)). The results of Kawabata procedure is so called THV value in the range [0, 5]. For computation of THV it is necessary to know special constants valid for specific types of fabrics.

Model construction for hand prediction. For many fabrics types constant required for THV computation are unavailable. Regression type model for subjective hand prediction based on the characteristics listed in the Table 1 can constructed by the following procedure (Militky (2001)):

I. Standardization of data $x_{ji}, j = 1, 2, ...16$, $i = 1, 2, ...$ by using relation $u_{ji} = \frac{x_{ji} - x_j^*}{s_j}$, where x_j^* is sample mean and s_j is corresponding standard deviation for $j-$th variable.

II. Non-linear transformation to the special psychophysical scale by using Harrington type function

$$H(u_{ji}) = w_{ji} = 1 - \exp(-\exp(-u_{ji})) .$$

III. Selection of statistically suitable regression sub-model from linear one

$$y_i = b_0 + \sum_{j=1}^{m} b_j w_{ji} + \varepsilon_i \,.$$

Predicted correlation coefficient R_p and mean quadratic error of prediction MEP are used for determination of regression models quality. For calculation of MEP and R_p the following equations are valid

$$MEP = \frac{1}{n}\sum_{(i)} \frac{e_i^2}{(1-H_{ii})^2},$$

$$R_p = \sqrt{\frac{1-n.MEP}{\sum_{(i)} y_i^2 - n.y^{*2}}},$$

where $e_i = y_i - y_{ipred}$, H_{ii} are diagonal elements of projection matrix $X(X^T X)^{-1} X^T$ and y^* is median of ordinal variable hand. Instead of MEP the relative error of prediction MEPR can be used. Both these characteristics use the special prediction from estimates where single points are left out when the prediction is calculated (prediction in $i-\text{th}$ point is calculated without information about this point) (Meloun Militký (1994)).

Experimental part. The 61 bed ticking fabrics types used frequently in Czech Republic or specially prepared in pilot scale plant have been collected. Material used is pure cotton, cotton/polyester blends and Lyocell. This set of fabric cover the range of areal weight 75...185 g/m2, yarn fineness 5,3…25 tex and sett 30…75 yarns/cm.

Subjective hand was carried out by means of group of 16 well-informed respondents. They had P = 12 order grade scale to disposal (1 – very bad, 12 – excellent). The estimations of median values from subjective evaluation results were treated by means of technique described in chap. 2.2. Median of ordinal variable was used as relative subjective hand $y_i = X_{Me}$.

The 16 characteristics (see Table 1) of all fabrics were evaluated by KES system. Individual x data are mean values computed from 3 repeated measurements in both major directions.

Results and discussion. Data from KES measurements were analyzed by multivariate statistical methods for evaluation of potential sources of heterogeneity (clusters and outliers). For prediction of subjective hand the methodology described in chap. 2.5 has been used.

Preliminary data analysis. In the Fig.1 are arranged data in the space of variables HB, HG, G as result of K means clustering (procedure is described in (Meloun Militky (1994)).

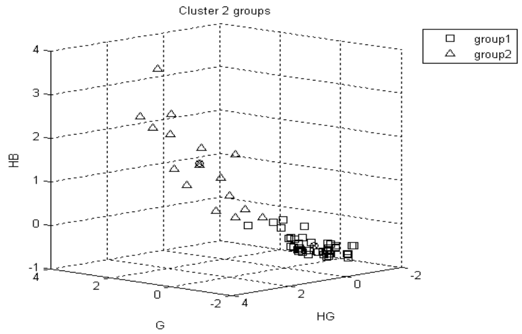

Fig. 1. Results of K means clustering for both sets I and II

There are two clusters visible. In the smaller cluster I (markers are triangles) fabrics are having higher values of shear stiffness G. In the bigger cluster II (markers are squares) there are fabrics with smaller nearly constant G. These two clusters were analyzed as separate groups. The paired dependencies between selected variables are given in Fig.2.

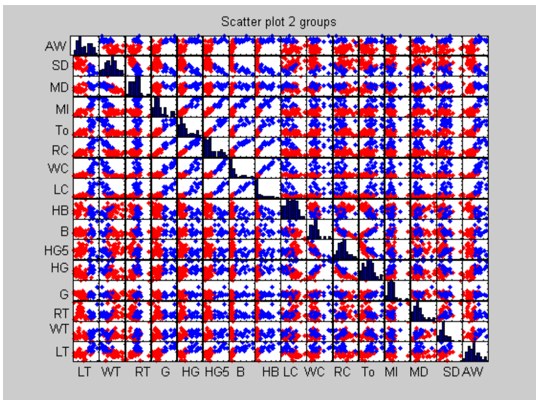

Fig. 2. Paired dependencies between variables

There are some strong correlations visible, especially between compressional characteristics and thickness and between shear characteristics.

It is visible that clusters I and II are separated for some characteristics. The distribution of some variables is skewed to the right but very probably unimodal.

The differences between individual fabrics in the cluster I and cluster II are visible from profile plot in the Fig. 3. Construction of this plot is described in (Meloun Militky (1994)).

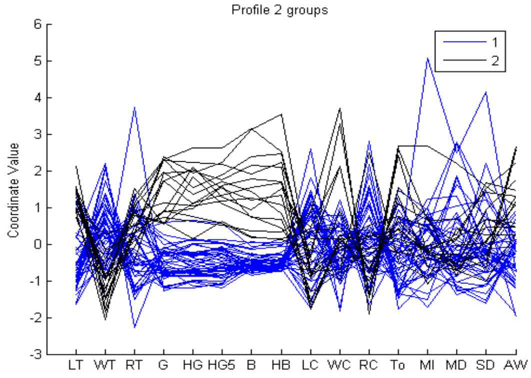

Fig.3. Profiles for all points in cluster I and cluster II

There are visible differences, especially due to shearing and bending characteristics. The profiles for individual clusters are in the Fig. 4.

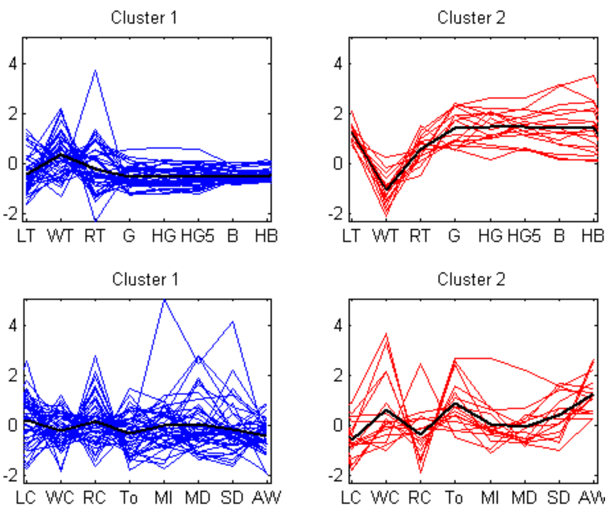

Fig. 4. Profiles for individual clusters

These plots are supporting the differences due to shearing and bending characteristics.

This fact is supported by projection of both cluster I and II to the first three principal components Meloun Militky (1994)) shown in Fig. 5.

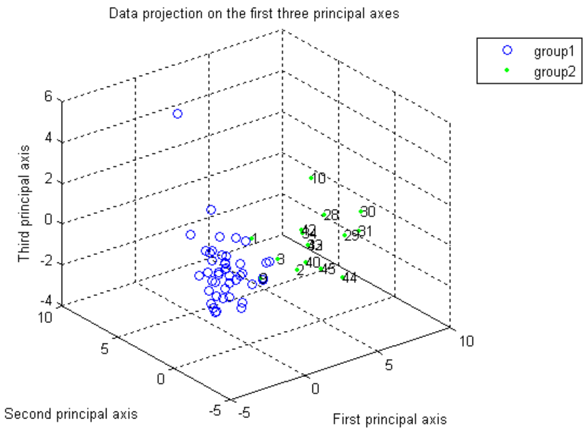

Fig. 5. Projection of both data sets to the principal components

The potentially outlying points are characterized by the high Mahalanobis distances (Meloun Militky (1994)). The plots of Mahalanobis distances for both clusters are shown in the Fig. 6

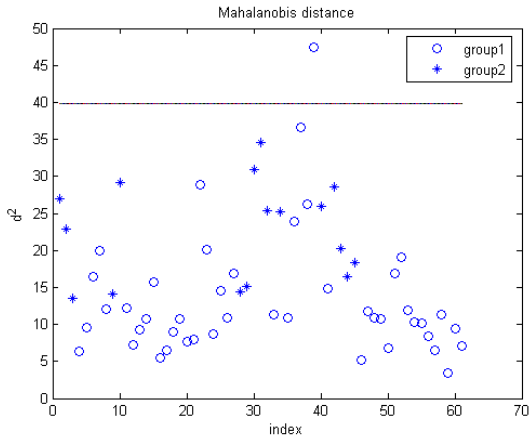

Fig. 6. Mahalanobis distances of fabrics

It is visible that one outlying point is above the limit but its importance is not very high. Both clusters are separated and there exists some outlying fabrics in some properties but differences are not so critical for subsequent analysis.

Predictive model creation. For creation of prediction type model the data were standardized and transformed by Harrington function. The linear regression models defined in chap. 2.5 was used. Results for full model (16 characteristics are given in the Table 2). The partial correlation coefficients characterize correlation between individual variables and subjective hand (other variables are statistically constant – see (Meloun Militky (1994)).

Table 2. Results for linear regression (all variables)

Variable	regression coefficient b_j	Standard deviation of regression coefficient	t- statistics	Partial Correlation
intercept	13,9	1,36	10,2	-
LT	0,104	0,852	0,122	0,095
WT	0,407	1,01	0,405	0,301
RT*)	-1,03	0,872	-1,18	0,697
G	-2,49	2,45	-1,02	0,44
HG	-2,87	2,78	-1,03	0,558
HG5*)	-4,15	3,10	-1,34	0,638
B	0,189	4,15	0,046	0,031
HB	0,226	4,61	0,049	0,027
LC	-0,027	0,79	-0,034	0,094
WC	-0,038	1,84	-0,021	0,007
RC	0,071	0,733	0,096	0,079
To	-0,50	2,52	-0,191	0,111
MI	0,071	0,549	0,129	0,114
MD*)	-0,808	0,629	-1,28	0,725
SD*)	-1,08	0,639	-1,69	0,571
AW	-0,975	1,03	-,0943	0,502

*)Gray color is used for highly significant variables.

Linear model was used for all variables (x1…x16) and also for the four (x3, x6, x14, x15) and three (x3, x6, x15) statistically most important variables. For all these models the characteristics of model quality RP and MEPR are shown in Table 3. The multiple correlation coefficients RD are shown here for comparison only (this characteristic is no decreasing function of number of variables)

Table 3. Characteristics of regression model quality for various models

Model variables	RD [%]	RP [%]	MREP [%]
All variables	95,32	88,81	16,68
3,6,14,15	94,11	92,75	15,78
3,6,15	93,76	92,52	15,32
3,6,15 raw data	91,47	89,93	20,24

It is evident that from the point of view of prediction ability the model with three variables (x3, x6, x15) is the best one. The model with all 16 characteristics is over-parameterised. The model with three variables without standardization and Harrington transformation has worse prediction ability (see Table 3). The estimates of parameters b_0, b_1 ,b_2, b_3 for optimal three variables model together with standard deviations are presented in the Table 4.

Table 4. Results for linear regression (three variables)

Variable	Beta	Standard deviation of beta	t- statistics
intercept	13,8e	0,317	43,6
RT	-1,68	0,398e	-4,23
HG5	-9,58	0,436	-22,0
SD	-1,56	0,437	-3,58

The relation between predicted and measured subjective hand for this model is shown in the Fig. 7.

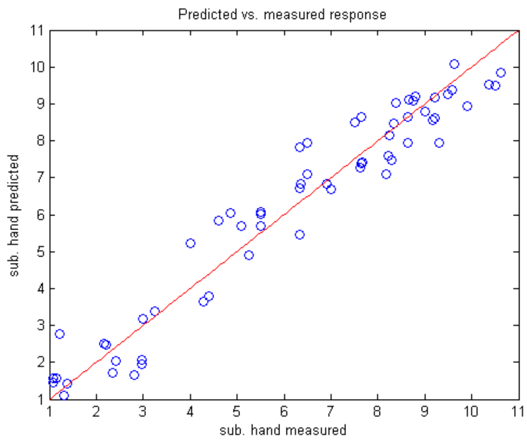

Fig. 7. Relation between measured and predicted subjective hand (from model with three variables)

The hand of bed ticking fabric is therefore dependent mainly on the tensile resiliency, shearing hysteresis and geometrical roughness. These characteristics can be in practice modified by using of special softening agents (finishing) or by proper design of raw fabric.

CONCLUSIONS

Prediction linear model with variables RT, HG5 and SD is very simple and suitable for prediction of the bed ticking fabrics subjective hand. Precision of the prediction is sufficiently high. The Kawabata testing system can be replaced for this purpose by tensile testing apparatus with adapter for shearing measurement and adapter for surface roughness evaluation.

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FORM AND YARN TENSION ON RING SPINNING MACHINES

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The issue regarding path-turning movement of yarn has always been and still is of profound interest for theory and application in the textile technology [1], [2]. Path or steady movement is a term for motion of yarn which maintains continuously its form of a certain unchanged or permanent line. Yarn moves along the line with a preset relative speed $v_r = v_r(t)$, and the line itself is motionless or moves with random order. This motion is implemented on the ring spinning machine with twisting and bobbin winding. Yarn with linear density μ moves with the constant speed v from the drawing mechanism through the thread guide A (fig. 1), then it passes through the traveller B which moves with a constant angular velocity ω along the ring K of radius $R_к$, and then it is wound on the bobbin of radius r.

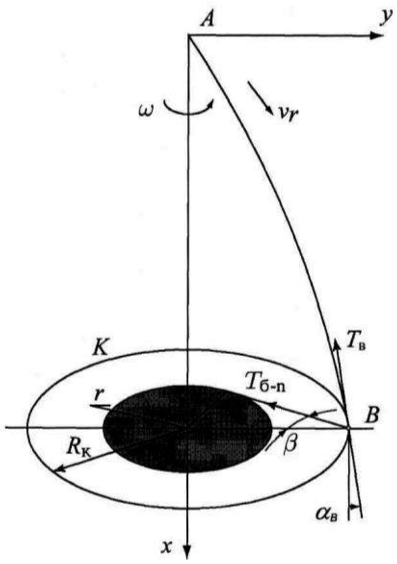

Fig. 1. Baloon on a ring spinning machine

In traditional ring spinning, rotational speed reaches 20000 min^{-1}. With such high angular velocities, yarn forms a visible surface, which is called balloon. Winding on ring spinning machines with participation of yarn, which rotates around its axle and simultaneously moves along a certain unchanged line, can be brought to path movement of yarn in its individual case – to the condition which "looks like standstill". Correct solutions to the problem of ballooning of yarn are given in [1]…[5], [8]. A relatively complete bibliography can be found in [3]. However, the papers of renowned or even prominent mechanic-engineers listed in the mentioned bibliography are restricted by investigation of movement or relative equilibrium of yarn at the yarn end of travelers, i.e. weight mass $m_в$ moving on the ring with friction. The mathematical model of balloon constructed in [6] considers quite complete conditions, but accepted assumptions, inaccuracies, as well as outdated modeling method restrict accurate information regarding winding by means of a ring spinning machine.

With uniform movement of yarn along the seems-to-be-standstill line, when outside forces are present, the seems-to-be-standstill line overlaps with the line of equilibrium of yarn with the same forces and with the same boundary conditions and linear dimensions. Tension of moving yarn increases in this case by value μv^2 [3]. Let us quote a numerical estimate of μv^2. With linear density 25 tex, rotation velocity of spindle 20,000 min^{-1}, 810 twists per meter and, consequently, path velocity 24.7 m/min μv^2 value is only $4.2 \cdot 10^{-3}$ mN. Then nonstretchable yarn with linear density μ, turning together with coordinate system Oxy with angular speed ω around the fixed axle x can be considered as being at rest without changing actual tension T for apparent tension $T^*=T-\mu v^2$.

Computation using mathematical balloon model, considering quite general conditions, indicates that the task can be significantly simplified. Usually the following is neglected: first, gravity, second, air resistance. During further simplification it is assumed to disregard Coriolis force (it is small in comparison to force of moving space because of $v_r \ll r\omega$). Calculations show that these assumptions do not add poor accuracy to computations.

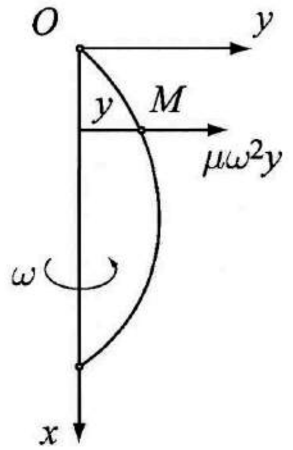

Fig. 2. Relative equilibrium of the ratating thread

One of variants reduces the mathematical model of balloon to the problem of turning yarn, which is attached with ends on the turning axle (Fig. 2). P. Appel, who considered the problem of finding the equilibrium position of weightless yarn, turning with a constant angular velocity around the axle (problem on "jumper") demonstrated that yarn form in this case is expressed in elliptic functions [4].

Let us project basic equation of path movement on axes of coordinates which are turning with yarn Oxy [3], [5]. We will get two equations of path movement of turning yarn

$$\frac{d}{ds}\left(T\frac{dx}{ds}\right)=0, \quad \frac{d}{ds}\left(T\frac{dy}{ds}\right)=-\mu\omega^2 y. \quad (1)$$

From the first equation of the system (1) it follows that projection of yarn tension on the direction of rotation axis is uniform along the whole length of yarn:

$$T\frac{dx}{ds}=C=\text{const}.$$

From here we will obtain tension T and place this value into the second equation:

$$\frac{d}{ds}\left(Cy'\right)=-\mu\omega^2 y.$$

Here $y'=\frac{dy}{dx}$. We enter designation

$$\frac{\mu\omega^2}{C}=\frac{2}{a^2},$$

considering that

$$ds=\sqrt{1+y'^2}\,dx=\frac{\sqrt{1+y'^2}}{y'}dy.$$

Then the previous equation will be written as

$$\frac{y'dy'}{\sqrt{1+y'^2}}=-\frac{2y}{a^2}dy.$$

After integration we will get

$$\sqrt{1+y'^2}=\frac{b^2}{a^2}-\frac{y^2}{a^2},$$

where b – new constant of integration. If we solve the equation for y', we will obtain

$$\frac{dy}{dx}=\pm\frac{1}{a^2}\sqrt{\left(b^2-a^2\right)^2-a^4}.$$

By dividing variables and integrating, we will get

$$x=\pm a^2\int\frac{dy}{\sqrt{\left(b^2-a^2-y^2\right)\left(b^2+a^2-y^2\right)}}. \quad (2)$$

Itegral is expressed by special functions which are called elliptic functions. Then all critical points are located in the class of elliptic sine [4]:

$$y=\sqrt{b^2-a^2}\,\mathrm{sn}\left(x\frac{\sqrt{2}}{ak'}\right),\quad k'=1-k^2,\quad k^2=\frac{b^2-a^2}{b^2+a^2}. \tag{3}$$

Value a with data l and h can take calculational set of values

$$a(n)=\frac{h\sqrt{2}}{2nKk'},\quad n=1,2,\ldots\quad K=\int_0^1\frac{dt}{\sqrt{(1-t^2)(1-k^2t^2)}},$$

i.e. there exist a countless number of forms (which consist from one, two, three etc. half-waves) of relative equilibrium of yarn. Stability theory methods on the basis of variational Lagrange equation indicate that there exist the only curve of length l, passing via points O, A which has no more than one half-wave at the section [O, h]. As a result, practically only one stable form of relative equilibrium is realized.

Let us define the unknown parameters a and b. Using equality (2), we will get the first equation

$$\frac{h}{2}=a^2\int_0^{\sqrt{b^2-a^2}}\frac{dy}{\sqrt{\varphi(y,a,b)}}, \tag{4}$$

where $\varphi(y,a,b)$ – polynomial, which stands under the radical sign in (2). Let us obtain linear element

$$ds=\sqrt{1+y'^2}\,dx=\frac{b^2-a^2}{\sqrt{\varphi(y,a,b)}}dy.$$

Now let us write the second equation

$$\frac{\ell}{2}=\int_0^{\sqrt{b^2-a^2}}\frac{b^2-a^2}{\sqrt{\varphi(y,a,b)}}dy. \tag{5}$$

Then from $\frac{\mu\omega^2}{C}=\frac{2}{a^2}$ we can obtain projection of yarn tension on the direction of rotation axis C. Taking into consideration

$$\frac{dx}{ds}=\frac{1}{\sqrt{1+y'^2}}=\frac{a^2}{b^2-y^2},$$

tension of turning yarn is determined by the formula

$$T=\frac{C}{a^2}\left(b^2-y^2\right). \tag{6}$$

With preset h and ℓ equations (4) and (5) are solved with a computer and unknown parameters a and b are obtained.

Solution can be obtained in analytical form, if yarn is considered quite sloping [1], [3], [8]. Let us assume that length of yarn l differs slightly from the distance h between the points of yarn's fixing. Then the angle α between the tangent to yarn and the rotation axis x is small and derivative $y'=\mathrm{tg}\alpha<<1$.

Let us use approximate relationship, which is obtained on the breakdown of radical with series expansion in powers of

$$y':\ ds=\sqrt{1+y'^2}\,dx\approx\left(1+\frac{1}{2}y'^2\right)dx.$$

General solution to the problem for the sloping turning yarn

$$y=\frac{1}{\omega}\sqrt{\frac{C_1C_2}{\mu}}\sin\left(\sqrt{\frac{\mu}{C_1}}\omega x\right) \tag{7}$$

and exact (3) solutions do not differ from each other in quality.

Tension T is determined by the formula

$$T = \frac{\mu\omega^2 h^2}{\pi^2}\left[1 + 2\frac{\ell - h}{h}\cos^2\left(\frac{\pi}{h}x\right)\right]. \quad (8)$$

For balloon between the thread guide and the traveller on the ring spinning machine (Fig. 1) differential equation system and general solution for the sloping turning yarn are valid, in form of (7):

$$y = \frac{1}{\omega}\sqrt{\frac{C_1 C_2}{\mu}}\sin\left(\sqrt{\frac{\mu}{C_1}}\omega x\right).$$

In all turning axes Axy thread carrier A and traveller B have constant coordinates: $x_A=0$, $y_A=0$, $x_B=h$, $y_B=R_к$. But in addition to boundary conditions, additional condition is to be added which will be fundamental; this condition determines significant difference of the balloon problem on the ring spinning machine from the ballooning without mass traveler m_B.

To obtain this condition, let us mentally consider the movement of one ring traveler without yarn, replacing it by a reaction. The following forces will effect the traveler:

– Tension of yarn at the entering point into traveler which is determined by the equation (9) with x=h:

$$T_B = C_1\left\{1 + \frac{1}{2}\left[\sqrt{C_2}\cos\left(\sqrt{\frac{\mu}{C_1}}\omega h\right)\right]^2\right\}. \quad (9)$$

Direction T_B is determined by the value of the derivative at the point B:

$$y' = tg\alpha_B = \sqrt{C_2}\cos\left(\sqrt{\frac{\mu}{C_1}}\omega h\right). \quad (10)$$

– Tension of yarn $T_{б\text{-}п}$ between the traveler and the bobbin. Between T_B and $T_{б\text{-}п}$ a certain functional connection exist which usually is presented in form of Euler formula. Conditions of utilization of this formula result from construction of this widely known formula which is mentioned almost in all courses of theoretical mechanics, and without which textbooks in mechanics of yarn and other fields adjacent to it, cannot go. First of all, it is assumed that yarn is located along the geodesic line, when directions of principal normal of yarn and normal to surface, on which yarn is located, are coincident. If contact of yarn with the traveler would have been along the screw line, finding of $T_{б\text{-}п}$ would not pose difficulties. However, form of the traveler on the contact line is, first, not cylindrical, second, section of traveler's bow is rectangular. Therefore, even if we employ relation between the tight and slack strands of yarn in form of Euler formula, there is no sense to complicate it, and we can restrict ourselves to the simple "flat" case. If branches (strands) of yarn form between each other an angle $\gamma = \alpha_B - \frac{\pi}{2}$, so arc of yarn contact with traveler will be $\pi - \gamma = \frac{\pi}{2} + \alpha_B$. Then we will write as follows:

$$T_B = T_{б\text{-}п} e^{-k_н\left(\frac{\pi}{2}+\alpha_B\right)}. \quad (11)$$

Take note of angle sign α_B. It was noticed earlier that the angle α represents a tangent tilt at the current point of balloon's curve to axle x. Using the right system of reference and calculating angle reference as positive counterclockwise, on Fig. 1 we see that at the origin of coordinates A the angle α_0 is maximal. If the curve of yarn form has extremum at the section between the thread guide and the traveler (between the points A and B), at the point corresponding to y_{max}, $\alpha = 0$, then inclination angle decreases, changing sign to negative one.

– The remaining forces influencing the traveler, as well as conditions of its relative equilibrium are mentioned in courses of manual [5], [6].

From [6] we will write an expression for tension of yarn between the thread guide and the cop:

$$T_{б\text{-}п} = \frac{m_B \omega^2 R_к}{\frac{\sin\beta}{k_к} + \cos\beta + (\sin\alpha_B - \cos\alpha_B) e^{-k_н\left(\frac{\pi}{2}+\alpha_B\right)}}. \quad (12)$$

Here $\beta = \arcsin\frac{r}{R_к}$, $k_к$ – coefficient of friction of traveler on the ring.

This way, we can write a system of three independent equations which are solved for C_1, C_2, α_B:

$$R_к = \frac{1}{\omega}\sqrt{\frac{C_1 C_2}{\mu}} \sin\left(\sqrt{\frac{\mu}{C_1}}\omega h\right),\ tg\alpha_B = \sqrt{C_2}\cos\left(\sqrt{\frac{\mu}{C_1}}\omega h\right),$$

$$\frac{m_B \omega^2 R_к}{\frac{\sin\beta}{k_к} + \cos\beta + (\sin\alpha_B - \cos\alpha_B) e^{-k_н\left(\frac{\pi}{2}+\alpha_B\right)}} e^{-k_н\left(\frac{\pi}{2}+\alpha_B\right)} = C_1\left\{1 + \frac{1}{2}\left[\sqrt{C_2}\cos\left(\sqrt{\frac{\mu}{C_1}}\omega h\right)\right]^2\right\}.$$

Let us calculate tension $T_{б\text{-}п}$ on the ring spinning machine P-76-5M4 under the following conditions: yarn of linear density μ=25 tex, balloon height h=240 mm, traveler's mass m_B=0.075 g, ring diameter $D_к=2R_к$=45 mm, chuck diameter d=2r=22 mm, rotational speed of spindle 11,000 min^{-1}. The mentioned values of balloon's height h, cop diameter r correspond to the maximum degree of tension between the traveler and the cop under concrete conditions of yarn formation. If we assume $k_к$=0.17, $k_н$=0.23, then we will get C_1=526.6, C_2=0.036, $\alpha_B = -0.062$. Maximum tension during winding on the spinning machine, i.e. tension between the traveler and the cop under the above mentioned conditions will be 74.65 cH. Minimum tension occurs with maximal radius of cop r=20 mm and minimal height of balloon h=112 mm. In this case parameters of balloon's form change notably: angle of yarn entering into traveler is $\alpha_B = 0.145$ radian, projection of yarn tension on the axle x equals to $T\frac{dx}{ds} = C_1 = 324.3$. Then minimum degree of tension between the traveler and the cop is 44.0 cH.

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BIMODALITY OF THE COTTON COMPACT YARN HAIRINESS INDEX*

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The yarn hairiness depends on the fibers on the outer layer of the yarn that do not directly adhere to the core. Some of them have an end in the core of the yarn gripped by other fibers, whereas others, because of the mechanical properties of the fiber (rigidity, shape, etc.) emerge to the surface. During the twisting of the yarn, other fibers are further displaced from their central position to the yarn surface.

Yarn hairiness is therefore a complex concept, which generally cannot be completely defined by a single figure. Hairiness can be considered as the fiber ends and loops standing out from the main compact yarn body. Beside other instruments, there are two major testing equipments available on the market used for evaluating the yarn hairiness. The most popular instrument is the Uster hairiness system, which characterizes the hairiness by H value, and is defined as the total length of all hairs within one centimeter of yarn. The hairiness H is an average value giving no indication of the distribution of the length of hairs. The H value suppresses information as all averages do. The spectrogram of hairiness is also available. The second major instrument used is the Zweigle hairiness tester. The numbers of hairs of different lengths are counted separately. In addition the S3 value is given as the sum of the number of hairs 3 mm and longer. The information obtained from both systems is limited, and the available methods either compress the data into a single vale H or S3 or convert the entire data set into a spectrogram deleting the important spatial information.

Modern USTER devices have possibility to give raw data about whole yarn hairiness. These data can be used for more complex evaluation of hairiness characteristics in the time and frequency domain. The yarn hairiness can be described according to the:

– periodic components;
– random variation;
– chaotic behavior.

For these goals, it is possible to use system based on the characterization of long term and short-term dependence of variance. The so-called Hurst exponent or fractal dimension can describe especially long-term dependence.

The yarn hairiness complex characterization can be divided to the two phases. The core of pretreatment phase is creation of power spectral density (PSD) curve. Rough PSD estimator is based on the FFT i.e. the squared spectral amplitudes abs $(Pk)^2$.

The hairiness complexity can be classified according to the slope S of log(PSD) on the log(frequency):

1. Fractional Gaussian noise f_G for range $1<S<0.38$. In this case the fractal dimension from power spectrum can be used but variogram is not suitable.

2. Fractional Brownian motion f_B for range $1.04<S<3$. In this case the variogram can be used for estimation of fractal dimension as well.

3. Transition case for range of S between 0.38 and 1.04. For this case the cumulative sum of SHV should be created (transformation to the case 2).

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4. No fractal behavior for cases when the power law model is invalid (in two decade range). For this case the chaotic models (broad bands) or ARIMA models (narrow peaks) have to be used.

Special techniques for estimation of Hurst exponent and fractal dimension for the above-mentioned cases can be used. The proposed approach is the core of HYARN program written in Matlab code. Application of this program for deeper characterization of selected cotton type yarns was shown in [1].

In this contribution HYARN program is used for creation of H values empirical probability density function (PDF) and fitting this PDF by mixture of Gaussian distributions.

PROBABILITY DENSITY FUNCTION OF H. As an estimator of the empirical probability density function histogram with constant or variable bins (number of bins is M) is often constructed. Smooth kernel type density estimator is natural generalization of histogram.

Histogram is piecewise constant estimator of sample probability density. Histogram height in jth class bounded by values (t_j-1, t_j) is calculated from the relationship

$$f_H(x) = \frac{C_N(t_{j-1}, t_j)}{N\, h_j},$$

where the function C_N(a, b) denotes the number of sample elements within interval <a, b> and $h_j = t_j - t_{j-1}$ is the length of the j-th interval. Now, the problem encountered is the choice of boundary values {t_j} j=1,...M, the number of class intervals M and their lengths h_j with respect to the histogram quality. In our programs the simple data based two-stage technique is used. In the first stage the number of class intervals

$$M = \mathrm{int}[2,46\ (N\text{-}1)^{0,4}]$$

is computed. Here int[x] is integer part of number x.

In the second stage the individual lengths h_j are determined. The estimation of h_j is based on the requirement of equal probability in all classes. For this purpose the empirical quantile function Q(P) based on the order statistics $x_{(i)}$ is used.

In practice the P-axis is divided into identical intervals having the size of 1/M. For these intervals the corresponding quantile estimates $t_j = x_{(j/M)}$ are constructed by using the relation

$$x_{(P)} = (N+1)\left(\frac{PN+P-i}{N+1}\right)(x_{(i+1)} - x_{(i)}) + x_{(i)},$$

where P = j/M. Practical experiences have hitherto proven that this construction is suitable even for strongly skewed sample distributions.

The kernel type nonparametric estimator of sample probability density f(x) can be constructed on the basis of Lejenne-Dodge-Kaelin procedure [1]. The final estimator has the form

$$f(x) = \frac{1}{N}\sum_{i=1}^{N} K\left[\frac{x - x_i}{h_i}\right].$$

Selection of kernel function K[x] and computation of bandwidths h_i is described in [1].

In the case of bimodal distribution the mixture of Gausians is often a good model. We used two Gaussian mixture model in the form

$$f_G(x_i) = A1\exp\left(-\frac{(x_i - B1)}{C1}\right)^2 + A2\exp\left(-\frac{(x_i - B2)}{C2}\right)^2,$$

where A1, A2 are proportions of smaller hairiness (first Gaussian having index 1) or higher hairiness (second Gaussian having index 2). Parameters B1 and B2 are mean H values for individual component and parameters C1, C2 correspond to standard deviations.

To obtain the coefficient estimates (A1, A2, B1, B2, C1 and C2), the least squares method minimizing the summed square of residuals is used. The residual for the ith data point r_i is defined as the difference between the observed response value and the fitted response value

$$r_i = f_H(x_i) - f_G(x_i).$$

The summed square of residuals is given by

$$S = \sum_{i=1}^{N} r_i^2 \ ,$$

where N is the number of data points included in the fit and S is the sum of squares error estimate. Assumption leading to the minimization of S is given in the book [1].

Model of two Gaussians mixture is nonlinear regression model.

Nonlinear models are more difficult to fit than linear models because the coefficients cannot be estimated using simple matrix techniques. Instead, an iterative approach is required.

The MATLAB toolbox used in HYARN provides these algorithms:

– Trust-region -- This is the default algorithm. It can solve difficult nonlinear problems more efficiently than the other algorithms and it represents an improvement over the well-known Levenberg-Marquardt algorithm.

– Levenberg-Marquardt -- This algorithm has been used for many years and has been proved to work most of the time in a wide range of nonlinear models and starting values. If the trust-region algorithm does not produce a reasonable fit, and there are no coefficient constraints, the Levenberg-Marquardt is good starting algorithm.

More information about these algorithms is given in the book [1]

EXPERIMENTAL PART AND METHOD OF EVALUATION. Experimental Part: Three cotton combed yarn of count 14.6 tex (Ne 41) were produced on Rieter com4, Sussen , and Zinser compact spinning machines. The in-feed roving and row material characteristics were constant for all yarn types. The main fiber properties are as follows: staple length 30.1 mm, fiber fineness 1.8 dtex (micronaire 4.6 μ/inch), fiber tenacity 30 cN/tex, and Short fiber index SFI 7.3. Furtheremore one open-end of tex 20, and a ring spun yarn of tex 15.2 were considered. All of these yarnes were tested on Uster tester 4 for yarn hairiness at 400 m/min for one minute. The results are as follows: Rieter yarn has mean hairiness H= 3.6, Suessen yarn has H=3.9, and Zinser yarn has H=3.41. The ring spun yarn has H= 5.05, and the OE –rotor yarn H=4.35.

METHOD OF EVALUATION. The individual readings of yarn hairiness were extracted from Uster 4 unevenness tester .The raw data of hair diagram were fed to a program (HYARN) written in MatLab for comlex evaluation of yarn hairiness.

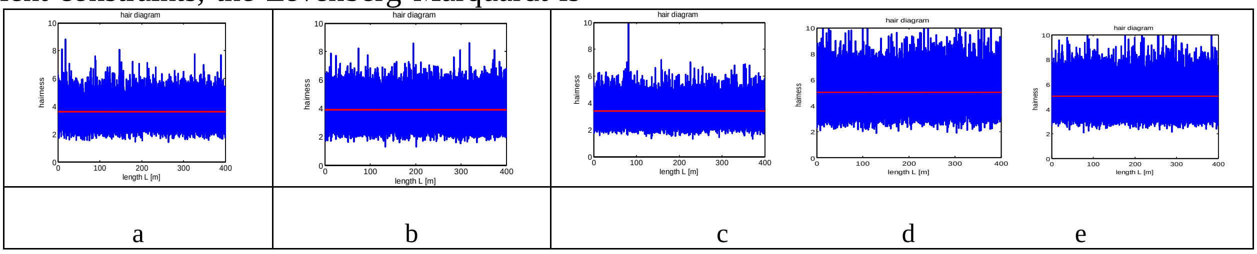


Fig. 1. Hairiness diagram a) Rieter, b) Suesen c) Zinser, d) Ring spun and e) OE-rotor yarns

RESULTS AND DISCUSSION. In the first part of our discussion we shall consider the distribution of hair for all types of yarns to find out if the distribution of the hairiness is a typically bi-modal distribution or only typically for some types of yarns. It was proven that parameter H comprise bimodal distribution for all yarns and this distribution can be well approximated by mixture of two Gaussians distributions. In the Fig. 2 the histograms for four sub samples (division of data for 400 meter yarn into 100 meter pieces) are given. It is clear that in all cases the bimodality is markedly appeared. The histograms of full samples are given in the Fig. 3.

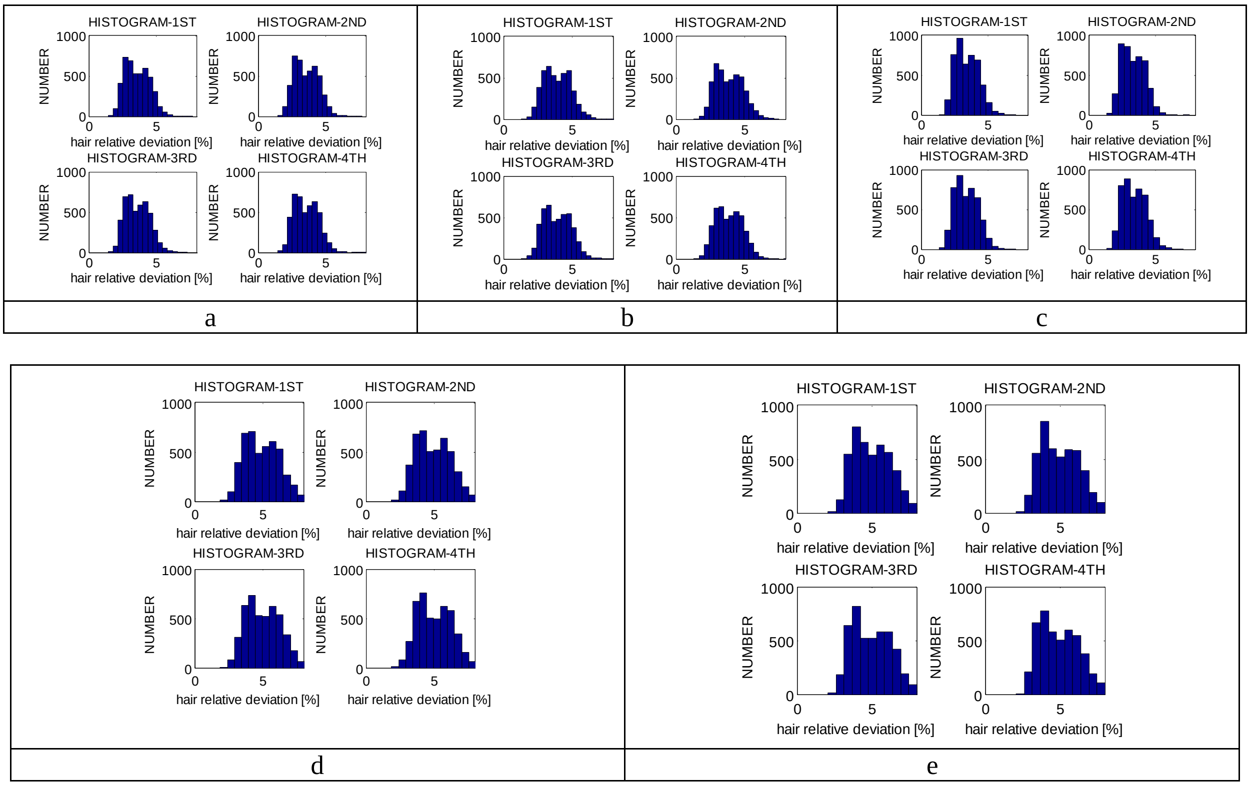


Fig. 2. Hairiness index H distribution for four subsamples
a) Rieter, b) Suesen c) Zinser, d)Ring Spun, and e) OE-Rotor yarn
b)

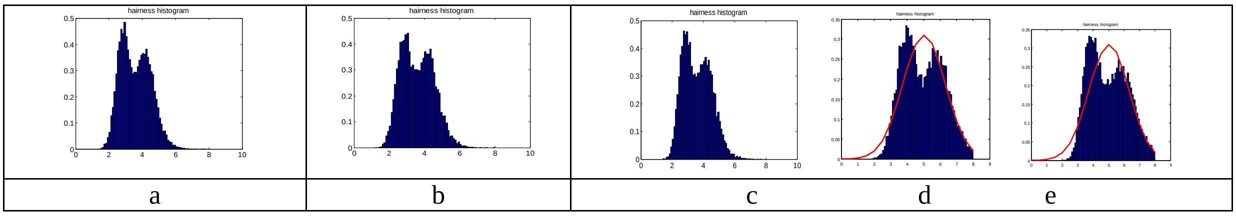


Fig. 3. Hairiness index H distribution for whole samples
a) Rieter, b) Suesen c) Zinser, d) Ring Spun and e) OE-Rotor yarn

At this point we shall limit our discussion to compare in details the fine differences between the compact yarns produced on different machines. The best fit by mixture of two Gaussians is in the Fig. 4.

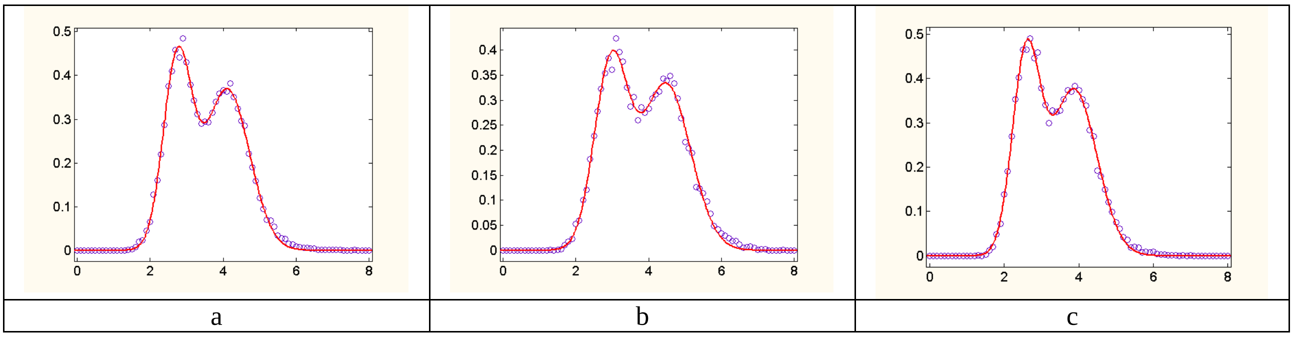


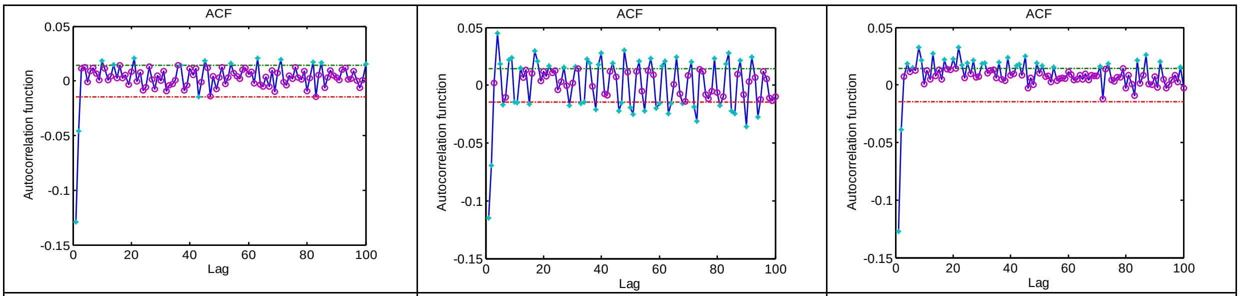
Fig. 4. Best fit of mixture of two Gaussians model a) Rieter, b) Suesen c) Zinser

The very good approximation for all cases is clearly visible. Parameter estimates of mixture of two Gaussians model obtained by nonlinear least squiares are given in the Table 1.

Table 1. Parameter estimates of mixture of two Gaussians model

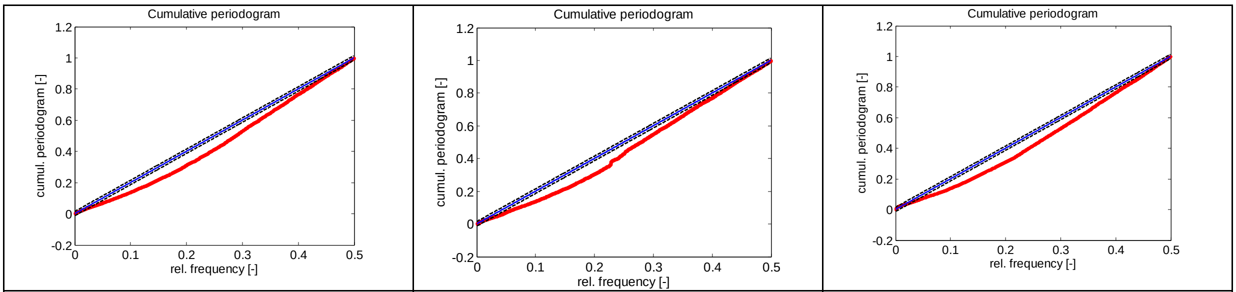
Yarn	A1	B1	C1	A2	B2	C2
Rieter	0,4335	2,752	0,5521	0,369	4,113	0,8643
Sussen	0,3696	2,973	0,6578	0,3323	4,479	0,948
Zinser	0,4406	2,589	0,5282	0,3754	3,87	0,8734

It is interesting that differences between individual yarns are small but the yarn Zinser has biggest portion of smaller H and smaller mean values. Therefore the presence of long hairs will be probably low. Bimodality of H distribution has influence on majority of parameters computed for spatial characterization of hairiness as well because standard assumption is unimodality or strict normality. Illustrations are in the Fig. 5 autocorrelation functions in the Fig. 6.



a b c

Fig. 5. Autocorrelation function a) Rieter, b) Suesen c) Zinser



a b c

Fig. 6. Cumulative periodogram a) Rieter, b) Suesen c) Zinser

The assumption of white noise (blue lines on cumulative periodogram cannot be naturally accepted. Bimodality of H parameter distribution has many practical consequences. First of all the mean value used in Uster outputs is bad estimator because it lies between two peaks on H parameter distribution. Proper way in this case is to evaluate parameters of mixture of two Gaussians and use two mean values for hairiness characterization. On the other hand, the modus will be better for description of bimodality. Appearance of two various H distributions can be connected to two types of hairiness, but this hypothesis needs practical verification.

CONCLUSION

The distribution of H parameter characterizing the overall hairiness for cotton yarns is bimodal. This event has huge influence on the majority of parameters characterizing spatial behavior of hairiness process. It will be necessary to prove bimodality for yarns having various fineness, compositions and systems of spinning before deciding about replacement of Uster mean value by more characteristics. This method facilitates complex characterization of yarn hairiness more deeply, differentiating hairiness distribution in two parts, short and long hairs.

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CALCULATION OF PARAMETERS OF BATTENING PROCESS

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Beating up of weft to the edge of fabric holds a special position. Correct course of this process ensures production of rational structure, high quality with minimal end, warp and weft breakage and with maximum possible productivity of labour and performance of equipment.

In the course of beating up of weft to the edge of fabric a new element of fabric is formed. Technological parameters of the battening process (primarily, warp and weft tension) should be such that they would ensure the assigned structure of the fabric element to be formed.

Formula for calculation of phase sequence of grey fabric's structureis:

$$F=\frac{9\varphi+1}{\varphi+1}, \qquad (1)$$

where φ – relation of wave heights of warp and weft bends.

Relationship of wave bend heights equals to:

$$\varphi=\frac{h_o}{h_y}=\frac{P_o^3 E_y I_y}{P_y^3 E_o I_o}, \qquad (2)$$

where h_o, h_y – wave heights of warp and weft bends correspondingly; P_o, P_y – warp and weft density of fabric correspondingly; E_o, E_y – elasticity moduli of warp and weft correspondingly; I_o, I_y – inertia moments of sections of warp and weft yarns correspondingly.

In the fabric, sections of yarns are represented as ellipses. Inertia moments of warp and weft sections of yarn can be determined by the following formulas:

$$I_o=0.05 d_{ов}^3 d_{ог}, \qquad I_y=0.05 d_{ов} d_{уг}, \qquad (3)$$

where $d_{ов} d_{ог}$ – vertical and horizontal warp diameters in fabric; $d_{ув}, d_{уг}$ – vertical and horizontal weft diameters in fabric.

Yarn diameters in fabric are determined from the following relations:

$$d_{ов}=d_o\eta_{ов}, \quad d_{ог}=d_o\eta_{го}, \qquad d_{ув}=d_o\eta_{ув} \quad d_{ог}=d_o\eta_{гв}, \qquad (4)$$

where d_o, d_y – round section diameters of warp and weft yarns prior to weaving, which are determined by the following formulas:

$$d_o=0.1c_o\sqrt{0.1T_o}, \; d_y=0.1c_y\sqrt{0.1T_y}, \qquad (5)$$

where c_o, c_y – coefficients which depend on the type of composition of yarn fiber; T_o, T_y – linear density of warp and weft yarns.

For all single-texture fabrics the following relation is true:

$$d_{ов}+d_{ув}=h_o+h_y, \qquad (6)$$

where h_o, h_y h_o and h_y – wave heights of warp and weft bend in the fabric element under formation.

Consequently,

$$h_o = \varphi h_y, \quad \varphi h_y + h_y = d_{ов} + d_{ог},$$
$$h_y = \frac{d_{ов} + d_{ув}}{\varphi + 1}, \quad h_o = \frac{\varphi(d_{ов} + d_{ув})}{\varphi + 1}. \qquad (7)$$

Since temples on a loom define the width of threading by beating up of weft to the edge of fabric, then absolute deformation of weft from battening equals to:

$$\lambda'' = \sqrt{h^2 + \left(\frac{100}{P_o}\right)^2} - \frac{100}{P_o}. \qquad (8)$$

Relative deformation of weft from battening process equals to:

$$\varepsilon'' = \frac{\lambda'' P_o}{100}. \qquad (9)$$

Tension of weft in the course of battening equals to:

$$\sigma_y = E_y \varepsilon_y, \qquad (10)$$

where ε_y – total deformation of weft in the course of battening.

$$\varepsilon = \varepsilon'_y + \varepsilon''_y,$$

where ε'_y – deformation of weft before the start of battening process.

Tension of weft before the process of battening equals to

$$\sigma_y = \frac{F'_y}{S_y}, \qquad (11)$$

where F'_y – weft tension before the battening process; S_y – cross-section area of weft yarn.

$$S_y = \frac{\pi d_{уг} d_{ув}}{4}. \qquad (12)$$

Interrelation of tension and deformation of weft before the battening process can be represented by the following expression

$$\sigma' = E_y \varepsilon'', \; \varepsilon' = \sigma' / E_y. \qquad (13)$$

Interrelation of stress, tension and deformation of weft from the battening process can be represented by the following relations:

$$\sigma'' = E_y \varepsilon'', \; F_y = \sigma'' S_y. \qquad (14)$$

For the purpose of preserving useful properties of fabric it is advisable, in order sequence of fabric construction phase (relation of wave peaks of warp and weft bend) in fabric, removed from the loom and in the element of fabric under formation, could be equal.

Wave heights of warp and weft bend of yarn on the loom can be determined by the following formulas:

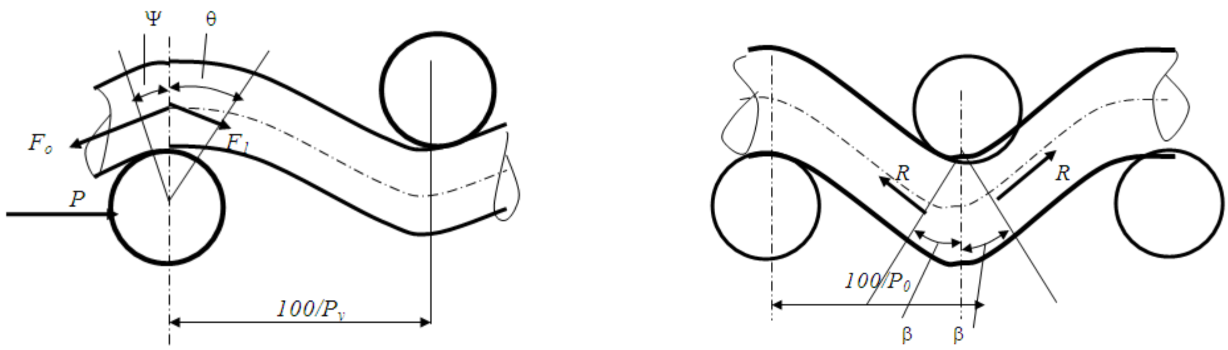
$$h_o = \frac{N}{2F_o}\left(\frac{100}{P_y} - \sqrt{\frac{E_o I_o}{F_o}}\right),$$
$$h_y = \frac{N}{2F_y}\left(\frac{100}{P_o} - \sqrt{\frac{E_y I_y}{F_y}}\right). \qquad (15)$$

Yarn strain in the course of battoning σ_y will be formed from tension of weft before the battoning process σ'_y and tension of weft from the battoning process to the edge of fabric σ'':

$$\sigma_y = \sigma'_y + \sigma''. \qquad (16)$$

We will cite methods of calculating forces, acting at the moment of battening, by means of equations, formally coinciding with equilibrium equation according to d'Alembert's principle. Battening process is considered as quasistatic.

Below are methods of calculating technological parameters of battening for production of plain weave fabrics. The following forces have been calculated: tension of warp at the fabric edge (F_o), tensions of warp inside of fabric element under formation (F_1), tension of weft yarn (R) inside of fabric element under formation (P), friction force ($F_{тр}$). Diagram of acting forces in the fabric element is given in Fig. 1.



a) b)

Fig. 1. Geometric models of construction of fabrics (a - along the warp, б - along the weft).

Calculation has been carried out with the aid of Microsoft Excel (Fig. 2).

Input data	
Linear warp density, To, tex	11,8
Linear weft density, To, tex	11,8
Warp density, Po, yars/10cm	421
Warp density, Po, yarns/10cm	472
Breaking force of warp yarn, Pp, cH	140,42
ange ψ, rad	0,0174
angle ψ, rad	1,566
Calculation of values	
d_o=d_y	0,135784756
φ	0,709610922
d_o+d_y	0,271569512
h_y	0,158848723
h_o	0,112720789
100/Po	0,237529691
100/Py	0,211864407
Angle θ	0,488951521
Angle β	0,589445684
Fthread	14,042
Ffor battoning	21,063
Ffor beating at the edge	37,9134
Ffor beating at the edge	25,2756
Output parameters	
B at the start of beating	
Tension of warp yarn inside the fabric, F1, cH	34,26191226
Beating force, P,cH	7,660360199
Tension of weft yarn, R,cH	15,067897
Friction force, Tтр,cH	3,65148774
At the end of beating	
Tension of warp yarn	
inside of fabric, F1, cH	27,62233298
Friction force, Tтр,cH	10,29106702
Beating force, P,cH	37,77517559
Tension of weft yarn, R,cH	25,43772095
Post-battening period	
Tension of warp yarn inside the fabric, F1, cH	27,9693651
Friction force, Tтр,cH	2,6937651
Tension of weft yarn, R,cH	12,48912859

Fig. 2. View of program on display

Angles β и θ, according to Fig. 1, are determined by the formulas:

$$\begin{aligned} tg\theta &= h_o/(100/P_y), \\ tg\beta &= h_y/(100/P_o). \end{aligned} \quad (17)$$

Calculation of tension of warp edge of fabric is carried out in the following order.

Tension of warp threading in the area of "backrest - drop-wires" or tension of warp before the start of battening process is taken to be equal to 10% of the breaking strain of yarn P_p:

$$F_з = 0.1P_p, \quad P_p = pT_o. \qquad (18)$$

where p – relative breaking strain of warp yarn; T_o – linear density of warp.

Warp tension with weft in the area of "backrest–drop–wires" is taken approximately 1.5 times higher than threading tension of warp:

$$F_{appr} = 1.5\ F_з. \qquad (19)$$

Warp tension with weft in the area of "backrest – drop – wires" is taken equal to:

$$F_{пр} = 1.8F_з. \qquad (20)$$

Warp tension with weft at the edge of fabric is equal to:

$$F_o = 1.8F_{пр}. \qquad (21)$$

Calculation of forces acting in the fabric at the initial moment of battening is the following.

Tension of warp yarn in fabric F_1:

$$F_1 = F_o e^{-f(\psi+\theta)}. \qquad (22)$$

Force of beating up P:

$$P = F_1(\cos\psi - e^{-f(\psi+\theta)}\cos\theta). \qquad (23)$$

Weft yarn tension R:

$$R = [(\sin\psi + e^{-f(\psi+\theta)})F_1 / 2\sin\beta. \qquad (24)$$

Friction force between the warp and weft T_{fr}:

$$T_{тр} = F_o - F_1 = F_o[1 - e^{-f(\psi+\theta)}]. \qquad (25)$$

Calculation of forces, which act in fabric, at the final moment of beating up is carried out by similar formulas, but in this case the angle is $\theta = 90°$.

Calculation of forces acting in the fabric in the post-beating up period is the following.

Tension of warp yarn in fabric F_1:

$$F_1 = F_o e^{f(\psi+\theta)}. \qquad (26)$$

Tension of weft yarn R:

$$R = F_1 \sin(\psi+\theta) / 2\sin\beta\sin\theta. \qquad (27)$$

Friction force, acting during sliding of weft on the warp T_{fr}:

$$T_{тр} = F_1 - F_0 = F_o[1 - e^{f(\psi+\theta)}]. \qquad (28)$$

This program appears on the computer's display in the following way (Fig. 2).

Analysis of obtained results allows to define conclusions as follows:

– tension of warp at the edge of fabric reaches its maximum value at the end of the beating up process;

– tension of warp inside the fabric element under formation decreases in the course of beating up; in the post-beating up period it changes insignificantly;

– tension of weft in the course of beating up increases sharply up to the values, which are commensurable with the tension of warp; in the post-battoning period it decreases by more than 2 times;

– beating up force increases sharply and reaches its maximum value at the end of the beating up process;

– friction force between the warp and weft yarns in the course of the beating up increases for the majority of fabrics by more than 3 times; in the post-beating up period it is slightly less than at the start of beating up process.

CONCLUSIONS

1. In the course of frontal beating up of weft yarn to the edge of fabric with consideration of tension in depth of threading, structure

parameters of the produced fabrics and properties of yarn used method for calculation of technological parameters has been proposed.

2. The proposed method of calculating parameters of tensioned-deformed state of yarns in the course of frontal beating up can be used as a basis for development of the automated system for designing technological process of weaving as one of blocks.

Recommended by the department of weaving. Received 05.06.09.

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GRAFT COPOLYMERS AS BASIS FOR FABRICATION OF ENVIRONMENTALLY FRIENDLY FIBROUS CHEMOSORBENTS

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Creation of a new generation of technical textile materials, in particular, sorption-active materials, application of which allows to solve urgent environmental and social issues - based on implementation of high-end technologies - is one of important and promising directions for the development of textile industry. Utilization of such materials for monitoring and protection of the environment, when producing protective clothing for workers of different industry branches (chemical industry, health care facilities, construction industry, and service providers), creates conditions for human health protection, and for more efficient and safe work.

Technogenous environmental effects have resulted in deterioration of ecological situation. Development and application of sorption materials (among which chemo-sorption fibers hold a special place) plays important role in the integral solution of environmental protection and human health protection problems. Developed specific surface, which surpasses the surface of granulated sorbents up by an order of magnitude, significantly higher sorbtion speed, mechanical strength, a great variety of forms of fiber materials provide a basis for development of efficient sorption processes with utilization of different instrumentation.

One of the promising methods for obtaining new types of chemo-sorption fiber materials is graft polymerization of ionogen monomers and monomers which contain reactive nonionic groups, with their subsequent chemical transformations, for which chemical fibers of different types as polymer matrix are used [1], [2].

On the basis of the conducted studies of the behavior of graft polymerization of monomers, which incorporate functional-active groups, a number of extremely efficient reduction-oxidation initiating systems has been developed, containing fluctuating-valence metals, one component of which was fixed on the fiber [3], [4].

The established relationship of composition of fluctuating-valence metal complexes and their activity in initialization of graft polymerization made it possible to select as a component - which provides the highest efficiency of olefinic block copolymers (OBC) - copper complex compound. When employing OBC Cu^{+1} – H_2O_2 , conversion of amino-alkyl esters of α, β- unsaturated acids, 2-methyl-5-vinypyridine and glycidyl methacrylate made up 70 and 98…100% accordingly with 90…100% degree of conversion into graft copolymer [2], [5], [6].

Graft polymerization, proceeding at the boundary of solid and liquid phases, is characterized by certain peculiarities, such as effect of crystallinity degree, degree of orientation and molecular dynamics of polymers on dynamics of the polymerization process and interaction of functional groups of graft polymers with low-molecular nucleophilic reagents [6], [7], [8].

On the basis of quantum-chemical calculations, records of infrared spectroscopy and electron microscopy, ideas have been developed regarding a place of bonding of graft chains of polymethyl aminoethyl methacrylate and polyglycidyl methacrylate to macromolecyles of polymer-matrix, regarding the mechanism of graft polymerization of appropriate monomers and dependency of the character of distribution of the graft components in the structure of the modified fibres from their chemical nature and structural peculiarities [9]. Data obtained by means of mathematical simulation of chemical reaction kinetics, which proceed during obtaining of chemosorbent fibers, have been used for determining the optimum characteristic of the process (durability, concentration of reagents, type of solvent) [10], [11], [12].

As modified reagents, which provide for incorporation of ionogen and complexing groupings into composition of graft copolymers, compounds of different structure have been used (Table 1) [13…18].

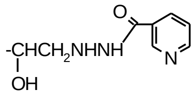
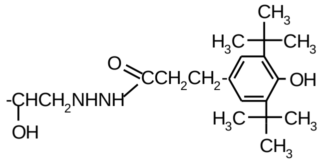
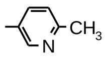
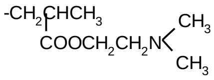
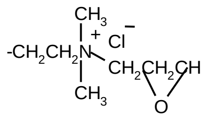
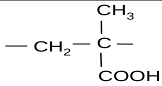
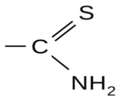
Change of the structure of functional groups makes it possible to produce fibrous chemosorbents, selective in relation to different cations; in return, it makes their employment a promising technique in technological processes of sorption and separation of platinum group metals, catchment of gold from exhausted citric gold-plating electrolytes, radionuclides from water solutions and emulsions, conducting monitoring of environment [19…21].

High degree of withdrawal of heavy metal ions from different solutions (including low concentration solutions) by means of fibrous chemosorbents makes their use advisable at the stage of final treatment of waste water and for development of closed-circuit water circulation systems. Employment of nonwoven fabrics made of polycaproamide fibers, modified by grafting with dimethylaminoethylmethacrylate, can be advisable as sorption-filtering media of individual protection equipment, such as respiratory protective devices, as well as filters for gas analyzers.

T a b l e 1. Characteristics of modifying compounds and properties of chemosorbent fibers

№	Modifying compound	Constitution of functional-active groups	COE, mmol/g	Sorbing compounds
1	Dimethylamine	$-CH(OH)CH_2N(CH_3)_2$	3,0-3,5	HCl, SO_2
2	Hydroxy ethylamine	$-CH(OH)CH_2NC_2H_4OH$	1,7-2,0	HCl, SO_2
3	Ethylendiamine	$-CH(OH)CH_2NHC_2H_4NH_2$; $-CH(OH)CH_2NHC_2H_4NHCH_2CH(OH)-$	3,5-4,3	Zn, Cu, Ni, Cr ions
4	Triethylene tetramine	$H_2N-(CH_2CH_2NH)_2-CH_2CH_2NHCH_2CH(OH)-$	2,5-3,5	Cu ions
5	Hydrazine hydrate	$-CH(OH)CH_2NHNH_2$; $-CH(OH)CH_2NHNHCH_2CH(OH)-$	1,7-2,0	Zn, Cu, Ni, Cr ions
6	Polyethylenepolyamine	$-CH(OH)CH_2NH-[(CH_2)_2-NH]_n-(CH_2)_2NH_2$ $-CH(OH)CH_2NH-[(CH_2)_2-NH]_n-(CH_2)_2NHCH_2CH(OH)-$	3,5-4,5	Chlorine complexes Pt, Pd, Ru, Rh, Os, Ir, and Cu, Cd, Pb ions
7	Guanidine	$-CH(OH)CH_2NHC(=NH)NH_2$; $-CH(OH)CH_2NHC(=NH)NHCH_2CH(OH)-$	1,5	HCl
8	Potassium sulphocyanate Thiocarbamide	$-CH(SH)CH_2R$	2-3*	Cu, Cr, Pb, V ions
9	Glycolic acid phenyl ether hydrazide	$-CH(OH)CH_2NHNHC(=O)CH_2O-C_6H_5$	0,36	HCl, Cu ions

Table 1, continued

10	Nicotinic acid hydrazide		0,44	HCl, Cu ions
11	Propanoic acid hydrazide p-(4-hydroxy-3,5-ditert-bytyl phenyl)		0,36	HCl, Cu ions
12	2-methyl-5-vinyl pyridine		2,0-2,7	HCl, HF
13	Dimethylamino-ethyl methacrylate		1,5**	Pb, Cu ions
14	Epichlorohydrin		2,5-2,8	HCl, SO_3, $Au(CN)^-$
15	Methyl-acrylic acid		3,0-4,0	NH_3, Cu ions
16	$K_4[Fe(CN)_6]$	–	35 mg Fe/g	Radionuclides, ^{137}Cs
17	$(NH_4)_2S$		3,0-3,5***	Hg, Ag, Au, Pt, Pd, Rh ions, radionuclides

* OBE for Fe^{3+} ** COE for NaCl *** OBE for Ag^+

C O N C L U S I O N

1. Possibility of employment of graft polymerization in relation to chemical fibers and chemical transformations of functional-active groups of graft chains as a method of incorporation of ionogen groups was examined.

2. Structural features and distinctive properties of fibrous sorbents, providing high efficiency of their use in the environmental monitoring and water purification systems, were demonstrated on the basis of experiments.

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UTILIZATION OF CHITOSAN FOR DYEING TEXTILE MATERIALS OF DIFFERENT NATURE USING ACTIVE DYES

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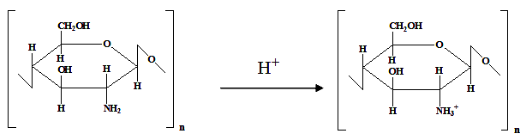
Chitosan is the most well known soluble chitin derivative – product of chitin's deacylation [1]. Chitosan (basic form) is water-insoluble, but is good soluble in diluted solutions of some acids [2], [3], as a result of obtaining a positive charge (salt form):



Presence of ionogen amino groups in chitosan determines many properties of it, including consumer ones. Diversity of unique consumer properties of chitosan ensures its wide utilization. There are more than 100 fields of chitosan's application, preparations and medical compositions on the basis of it. Natural polymer chitosan can be used in finishing manufacture to improve the quality of textile materials as indelible finishing, which helps to improve dyeing of fabrics subject to give finish [4…11].

It has been established in this paper that treatment in chitosan solution prior to dyeing with reactive dyes results in increase of intensity of dyeing of cotton, linen, woolen and blended fabric (wool/polyacrylonitrile and wool/kapron). This is illustrated in Fig. 1. Uniform bright dying can be reached on blended fabrics using one class of dyes.

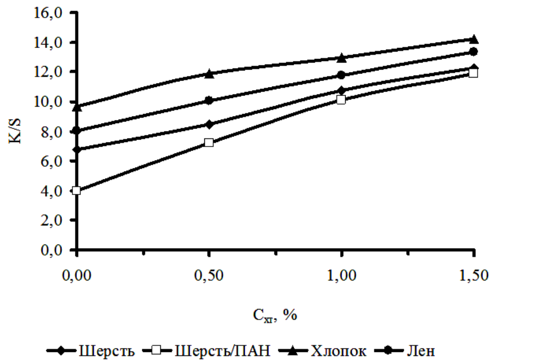


Fig. 1. Dependence of colour intensity of fabrics from chitosan concentration

The conducted tests testify that chitosan treatment enables to increase resistance to different physical and chemical effects when dyeing with reactive dyes is carried out. The obtained results are given in Table 1.

Table 1. Resistance of dyed textile materials

Testing methods	Cotton and linen fabrics		Woolen and blended wool/polyacrylonitrile fabrics	
	without chitosan treatment	with chitosan treatment	without chitosan treatment	with chitosan treatment
Washing fastness				
40°C	5/5/5	5/5/5	4/4/4	5/4/5
90°C	5/4/5	5/4/5	-	-
Resistance to distilled water	5/5/5	5/5/5	5/4/4	5/4/5
Sweat resistance	5/4/5	5/5/5	4/4/4	5/4/4
Resistance to rubbing				
dry	5/4/4	5/5/5	5/4/5	5/4/5
wet	4/4/4	5/4/4	4/4/3	4/4/4

Increase of intensity and dyeing fastness of textile materials may be attributed to the fact that chitosan forms on textile fabrics a stabile film which changes the essence of colouring textile materials. Investigation of chitosan's film structure by means of X-ray structural analysis revealed that chitosan - regenerated as films in salt form - has a structure which is typical for amorphous substances (Fig. 2). Basic form of chitosan has a more ordered structure.

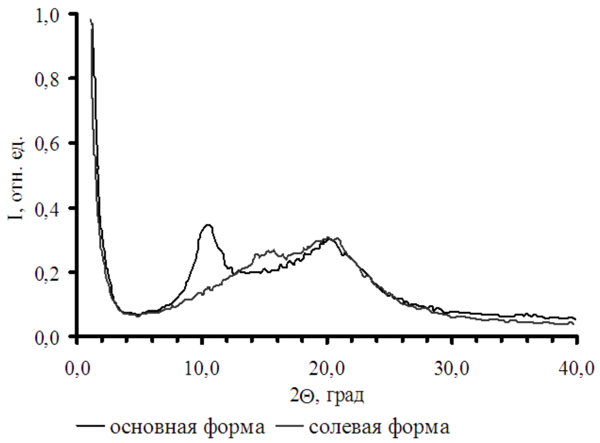


Fig. 2. X-rays of chitosan films

Amorphous film of chitosan is able to adsorb dyes from solutions quicker; and high degree of film's swelling allows to adsorb bigger quantity of dyes. It was found that film of chitosan has a high degree of swelling, both in water, as well in the medium of water steam. Swelling kinetics of chitosan films is given in Fig. 3.

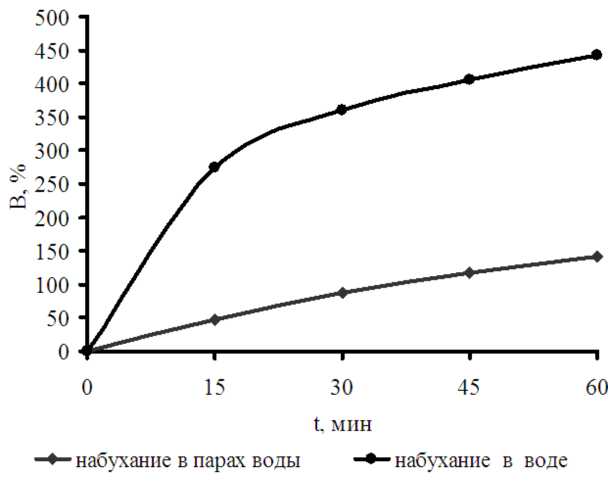


Fig. 3. Kinetics of swelling of chitosan films

By means of infrared spectroscopy, bonds of chitosan with dye and fiber have been determined. The study of IR spectra of chitosan-treated cellulose films revealed that main interactions proceed in the range of oscillations 3600…3100 cm^{-1}, which are typical for oscillations of hydroxyl groups. No frequency drifts or redistribution of band intensity has been found within the range 1800…1300 cm^{-1}. From the aforesaid it follows that chitosan is fixed on the surface of cellulose fiber by force of adhesion and molecular interactions.

Investigation of strength value of adhesion bond of chitosan film with the fiber, as well as effect of thermal processing on the strength of adhesion bond, revealed that temperature increase of thermal processing results in deterioration of adhesion bond between chitosan film and fiber. Optimal temperature range for processing is 60…80°C.

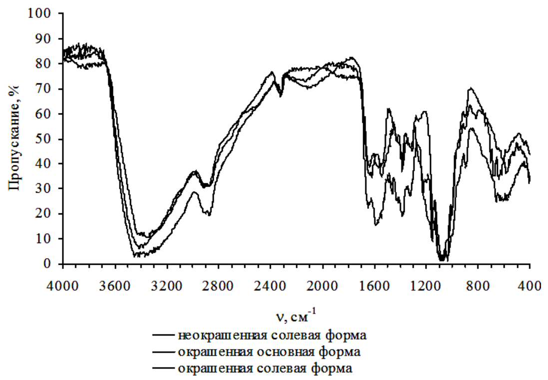


Fig. 4. IR-spectra of dyed and undyed chitosan films

Analysis of IR spectra (Figure 4) of films dyed in salt and basic forms revealed that when dyeing chitosan film in salt form with reactive dye, it forms covalent, hydrogen and ionic bonds. Dyeing of basic form of chitosan results in formation of covalent and hydrogen bonds. Consequently, it is advisable to carry out dyeing of the salt form of chitosan.

It has been established in this paper that chitosan treatment results in change of properties of textile materials. As a result of treatment, positive charge of chitosan leads to change of electrokinetic potential of fibers: surface charge of cellulose fibers in water medium changes from the negative to positive charge, thus improving approach of dye anions to fiber; in protein fibers positive charge increases. Effect of chitosan on electrokinetic potential of fibers of different nature is illustrated in Fig. 5.

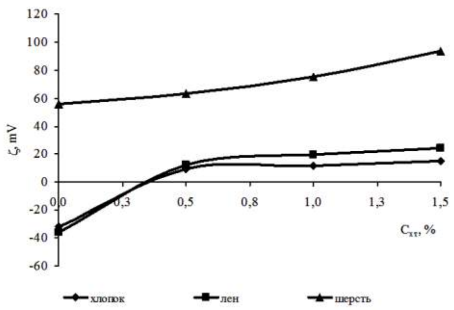


Fig. 5. Impact of chitosan treatment on electrokinetic potential of fibers of different nature

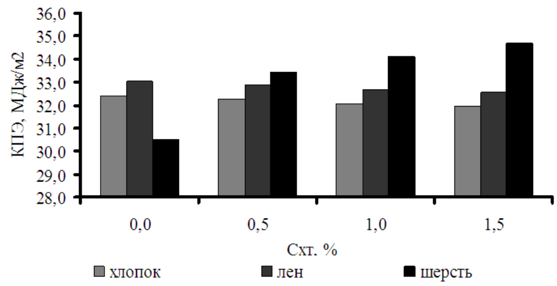


Fig. 6. Impact of chitosan treatment on indices of critical surface energy of fibers of different nature

In addition, change of surface energy with increase of chitosan concentration in protein fibers is observed (Fig. 6), which results in improvement of capillary properties. Impact of chitosan concentration on change of critical surface energy of cellulose fibers is less marked.

It has been established in the paper that finishing of fibers with chitosan solutions results in deterioration of air permeability and resistance to abrasion, rupture and repeated folding. In Table 2 physical-mechanical indices of textile materials during treatment with different chitosan concentrates are given.

T a b l e 2. Physical-mechanical indices of textile materials during treatment with different chitosan concentrates

Raw material mixture of fabric	C_{XT}, % In finishing mixture	Breaking load, N		Resistance to repeated folding, cycles		Resistance to abrasion by cotton system, cycles
		warp	weft	warp	weft	
Cotton	0,0	264	178	1521	1382	2663
	0,5	298	247	2830	2303	3109
	1,5	332	238	3570	3338	3589
Linen	0,0	364	366	1174	1052	1586
	0,5	438	460	1910	1620	2101
	1,5	609	623	2430	2220	2568
Wool	0,0	258	386	8214	8474	2345
	0,5	285	410	9750	10300	2954
	1,5	324	440	11563	258	3267
Wool/ polyacrylonitrile	0,0	284	301	7247	7512	2860
	0,5	346	342	8653	8970	3202
	1,5	214	363	10442	10752	3689

The data presented in Table 2 indicate that increase of chitosan concentration in finishing mixture leads to improvement of physical-mechanical properties of all fibers under consideration.

CONCLUSION

1. Chitosan treatment of textile materials made of fibers of different nature results in improvement of quality of finished products due to increase of intensity and colour fastness of textile materials.

2. Chitosan treatment of textile materials made of natural and synthetic fibers leads to increase of their physical-mechanical indices, which improves utilization properties of textile materials.

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SOME WAYS OF INCREASING EFFICIENCY IN UTILIZATION OF DYES PRODUCED FROM RENEWABLE PLANT RAW MATERIALS FOR COLOURING OF TEXTILE MATERIALS

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(The Moscow State Textile University named after A.N. Kosygin)

Approximately until the middle of the 19th century only natural dyes have been used for colouring of textile materials, which were extracted from plant-based raw materials, minerals and insects. In spite of the fact that they were poetically called "dyes presented by nature", natural dyes can hardly be considered as "presents" since their price had always been high.

Experience with the use of dyes, extracted from plant raw materials, has also revealed a number of drawbacks, inherent to them; these are, first of all, the following: as usual, low percentage of coloured compounds in raw materials, undetermined composition of admixtures extracted from natural raw materials during extraction of coloured compounds, alternate composition of extracts, and as consequence bad repeatability of colour characteristics of dying materials, difficulties to obtain mixed dyes. In addition to the above said, in order to fix dyes on fibres, there is a need to use, in most cases, salts of heavy metals (mordants) which have negative effect on ecological characteristics both of dying process, as well as dying materials, etc.

Therefore, it is not surprising that with advance of industrial fabrication of synthetic dyes, natural dyes became insignificant and they were practically of no interest in 19th century.

At the same time, a number of advantages of natural dyes over synthetic ones, for instance, extraction (sometimes several times within the year) from the renewable plant raw materials, safe use, quite a wide range of colours, as well as environmental situation that worsened over the past decades, aroused interest of chemists for research aimed to overcome the drawbacks mentioned above. Let us dwell on some of these studies.

To increase the percentage of coloured compounds in plant-based raw materials, it has been suggested to employ, in particular, methods of genetic engineering [1].

Another approach to increase percentage of coloured compounds in extracts has been suggested in paper [2]. With this aim in mind, crops of Saint-John's wort (Hypericum perforatum L) were treated 10…15 days prior to harvesting with plant growth stimulant– gibberellin.

The obtained benzine and ethanolic extracts from the treated and untreated raw materials were tested for content of coloured compounds. It has been established that about 14% of coloured compounds are extracted from the untreated raw materials (from total mass of dry raw materials). When treated with plant growth stimulant, quantity of extracted coloured compounds increased up to 8…19%, with unchanged extraction conditions.

Electronic adsorption spectra (EAS) of extracts obtained from the treated and untreated raw materials are identical and have 2 pronounced maxima by 400 and 670 nm. Significantly higher optical density of absorption spectra indicates bigger quantity of coloured compounds in the extract of the treated raw materials.

Evaluation of the relative quantitative amount of coloured compounds in the obtained extracts has been made also by colour characteristic of samples of cloth coloured with these extracts, calculated by means of uniform contrast system SIE Lab. The obtained results confirmed high content of coloured compounds in the treated raw materials.

Moreover, colour shade of obtained coloured samples practically does not change. This fact may serve as prove that as a result of treatment with plant grouth stimulant, probably, accumulation of coloured compounds takes place and no any other substances are formed.

Though influence of pH medium on the extraction process of coloured compounds had long been known, no systematic research had been conducted. In the study [3] effect of acidity of the extraction medium on the quantity of extracted coloured compounds was examined.

Extraction from Saint-John's wort plant raw material has been carried out by means of water-bath during 60 min with pH ranging from 5 to 10. We were able to reach maximum extraction of coloured compounds in acid medium. Yield of dry residual averaged 23%, whereas dry residual in the neutral and acid media made up 13 and 18% correspondingly.

It has been shown in the study of Mongolian scientists [4] that utilization of ultrasound during extraction of coloured compounds from plant raw materials enables to considerably increase the yield. Investigations were conducted in the temperature range from 50 to 70°C and with ultrasound exposure (22 kHz power) during 3, 5, 10, 15, 20 and 25 min. Optimal conditions for the process appeared to be the following: time – 20 min and temperature – 70°C. Under these conditions, depending on the type of raw materials, amount of extracted coloured compounds accounts for 30…70%. Process procedures for preparation of dye solutions has been suggested and process scheme has been developed on the basis of the worked out laboratory methods.

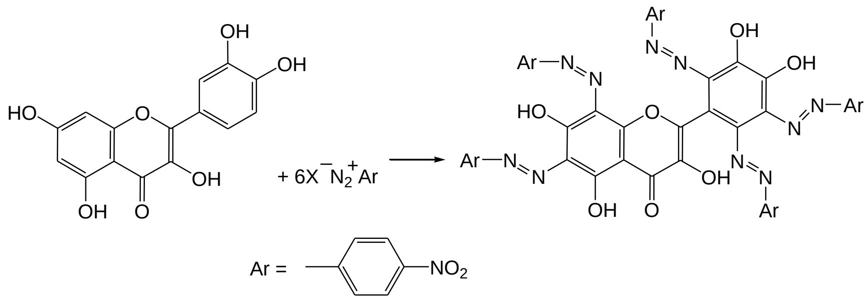
A conceptually new approach to solve problems with the use of coloured compounds of plant origin for colouring textile materials has been suggested by authors of this paper. The approach under development is based on the concept that derivatives of phenolic nature, such as flavonoids, antraquinone compounds, etc. are part of coloured compounds;

in principle, this enables them to be involved into reaction of electrophilic substitution.

To confirm the possibility for implementation of the above mentioned approach, azo coupling reaction of quercetin (1), being part of extracts of Saint-John's wort with p-nitrophenyl diazonium chloride, has been investigated as a model reaction, which was not described so far.

Azo coupling was carried out during 30 minutes in aqueous-alcohol medium (30:70), pH = 9÷10 and at temperature 10°C, with quercetin ratio: diazonium salt equaling to 1:1, 1:4, 1:6.

Reaction has been carried out until diazo compound was completely consumed (it was determined by means of testing with acid solution of R-salt). Sediment formed in the reaction was filtered in a drying kiln and in an exsiccator over P_2O_5



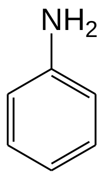
1 2

Analysis of products isolated by means of ^{1}H NMR spectroscopy revealed that with quercetin:diazonium salt ratio, equaling to 1:1 and 1:4, reaction proceeds non-selective – resultant represents a mixture of compounds of different degree of substitution. In the spectrum of the product (2) isolated from the reaction mixtures with reagent ratio 1:6 signals of protons of the original quercetin in the range of 6,0…7,6 m.d. are missing; there are only signals of aromatic protons of p-nitro-phenyl radicals available, with chemical shifts in the range 7.65-8.36; this enables to make a conclusion on the fact of complete substitution of all aromatic protons in the molecule of quercetin.

Comparison of electronic adsoption spectrum (EAS) of original quercetin and coupling product (2) testifies the appearance of new chromophoric systems. In the EAS of quercetin there are three intensive absorption bands (AB): λ_{max} = 204 nm, λ_{max} = 256 nm and λ_{max} = 374 nm, curve with λ_{max} = 222 nm. In the EAS of the product (2) band with λ_{max} = 256 nm is bathochromically displaced for 5 nm and new ABs appear with λ_{max} = 390 nm and λ_{max} = 480 nm.

Taking into account the obtained results, possibility for chemical modification of extracts of Saint-John's wort has been investigated.

Reaction has been carried out according to the following method: a certain amount of dry extract obtained during extraction of a whole plant was dissolved in the alkaline solution (pH 9-10) and cooled down to 0-5°C. While constantly mixing, diazonium salt solution was added to the liquid for 3…4 hours. Diazonium salts have been used as diazo compounds obtained from the following amines: aniline (3), p-nitro aniline (4), p-amino azobenzide (5), 4-nitro-2-amino phenol (6), 5-nitro-2-amino phenols (7)



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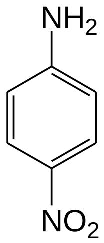

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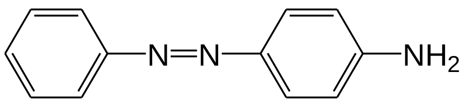

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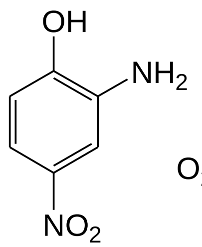

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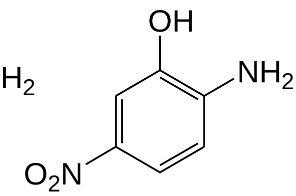

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Reaction was considered to be completed, when after adding next portion of diazonium salt outflow test with R-salt was positive, and test with diazonium salt solution was negative. Sediment was filtered, washed with water and dried in an exsiccator under vacuum over P_2O_5. Since extract of Saint-John's wort has multicomponent composition, we were able to obtain mixtures of azo compounds of similar structure as a result of azo-coupling reaction.

Analysis of EAS of obtained products revealed that all of them have changes, compared to EAS of original extract of Saint-John's wort, similar to those for above mentioned EAS of quercetin and the product of its modification. These changes (appearance of new AB which are notably displaced into the long-wave region) testify to the appearance of new chromophoric systems.

We turned then our attention to the study of the possibility to employ coloured extracts of Saint-Jon's wort and products of their chemical modification for colouring of textile materials.

Since separation of individual compounds both from extracts, as well as from a mixture of azo derivatives from the point of view of practical use is not advisable, we have employed them without separation.

The conducted investigation revealed the following. When extract of Saint-John's wort is employed for colouring, wool fabric changes colour to beige. Colour fastness to washing at 40°C equals to 3/3/4 degree. Utilization of mordants ($CuSO_4$, $K_2Cr_2O_7$, $SnCl_2$) with 2% concentration from fiber results in significant saddening, as well as in increase of colour fastness to wet treatment – 4-5/4-5/5 degree. However, we failed to dye polyester fabric with extract of Saint-John's wort.

Dying with products obtained as a result of modifying Saint-John's wort according to disperse dyeing technology revealed that polyamide fabric is dyed with synthesized compounds into yellow, yellow-brown, brown and red-brown colours, and polyester fabric - into pink-beige, yellow and light-brown colours. It has been established that colour fastness for these types of fabric is: to washing at 40°C: 4…5 degree; to dry and wet rubbing: 4…5 degree. The obtained "azo dyes" are also able to dye wool according dyeing technology with acid dyes with good colour fastness index (to washing at 40°C: 4/4/5 degree; to dry and wet rubbing: 5 and 4 degree correspondingly).

This way, utilization of modified coloured compounds of plant origin enables to discontinue to use mordants – heavy metal salts, and at the same time to ensure high indices of colour fastness to physical-chemical actions.

In conclusion, it should be noted that in countries with developed textile and chemical industries there is a process of assessment of economic, technological and environmental advisability of utilizing natural dyes for colouring textile materials currently under way.

World production of natural dyes accounts for 10,000 tons, i.e. ~1% from production output of synthetic dyes. World market in monetary terms reaches 100 million US dollars. Consequently, price of dye averages 10-20 US dollars per kilogram, which is comparable to the value of synthetic dyes and therefore is not a limiting factor for their utilization.

According to estimates of some experts, utilization volume of natural dyes in the first half of 21st century should make up about 10% of the total volume of consumed dyes.

Modern history of development of natural dyes can be characterized in short as follows.

Industry of natural dyes is apparently related to social issues. For many remote regions of our planet cultivation of plants, serving as raw materials for dyes, and their processing are sources of income and means of subsistence for whole settlements. Besides, primitive manual multi-stage methods of textile colouring are a part of natural crafts and belong to cultural heritage of nations.

In the developed countries natural dyes are utilized as auxiliary materials for different hobbies, especially in the USA, where numerous hobby groups, workshops are organized; there are even courses for art of batic painting, discharge printing, moire dyeing, etc.

Ecological standards, which become more and more strict, force us to pay attention to the nature as a source of harmless, harmonious and user-friendly products. A category of consumers appeared in the West who are ready to pay any possible amount of money for natural goods, including garments, produced from plants which are not treated with pesticides and artificial fertilizers, and which are dyed with dyes produced from natural raw materials.

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CHEMICAL DEGRADATION OF BASALT FIBERS*

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INTRODUCTION. Basalt materials are attractive for creation of composites with polymeric and inorganic matrices. The main advantages are low price of raw materials, cheap production of filaments and possibilities of creation of textile structures (weaves, knitted forms etc.). Basalts are more stable in strong alkalis than glasses. Stability in strong acids is slightly lower. Basalt products can be used from very low temperatures (about -200°C) up to the comparative by high temperatures, 700…800°C. At higher temperatures the structural changes occur. It is possible to use some dopes for increasing or enhancing of basalt properties as well. This contribution is devoted to investigation of degradation kinetics in hydrochloride acid HCl and sodium NaOH or calcium $Ca(OH)_2$ hydroxides. The process of degradation is characterized qualitatively by scanning electron microscopy.

This work was supported by the project LN 00 B090 of Czech Ministry of Education

BASALTS. Basalt is generic name for solidified lava, which poured out the volcanoes. The name is often applied to the solid rock, lava and magma, which on the eruption become lava. Basalt rocks are melted approximately in the range 1500…1700°C. Quickly quenched melt solidificated to glass like nearly amorphous solid. Slow cooling leads to more or less complete crystallization, to an assembly of minerals. Two essential minerals, plagiocene and pyroxene, make up perhaps 80% of many types of basalt. Classification on basaltic rocks based on the contents of main basic minerals is described in the book [1]. From the point of view of chemical composition the silicon oxide dominates, $Al_2 O_3$ is next in abundance and CaO, MgO and FeO are closely similar, a little less then 10%. Other oxides are almost always below 5% level.

The color of basalt is from brown to the dully green in dependence on the ferrous oxides content. Basalts are more stable in strong alkalis that glasses. Stability in strong acids is lower [2]. Basalt products can be used from very low temperatures (about 200°C) up to the comparative high temperatures, 700…800°C [3]. At higher temperatures the structural changes occur. The basic physical properties of basalt fibers are presented in Table 1.

Table 1. Basic physical properties of glass and basalt fibers

Property	E-glass	Basalt
Diameter [μm]	9…13	8,63
Density [kgm^{-3}]	2540	2733
Softening temperature [°C]	840	960

EXPERIMENTAL PART. The roving from Ukraine was used for degradation experiments. Mean fineness of filaments was 2.44 dtex. Samples were firstly treated one day in acetone for removing of sizing agent. The degradation was realized at room temperature in 10 % solution of HCl, NaOH and $Ca(OH)_2$. After selected times samples were removed, rinsed three times in hot water, dryed and weighted. The rest weight after degradation was computed from relation

$$R_Z = \frac{M_K}{M_P} \cdot 100 \text{ [\%]}, \qquad (1)$$

where M_K [g] is weight after degradation and M_P [g] is sample weight after acetone cleaning. For comparison of degradation in various times it is better to use relative rate of degradation defined by relation

$$K_P = \frac{M_P - M_K}{t_P M_P} = \frac{100 - R_Z}{t_P} \text{ [\%.hour}^{-1}\text{]}, \quad (2)$$

where t_P is degradation time [hours]. Higher relative degradation rate corresponds to more severe action of degradation agents. The values R_Z and K_p for HCl are in the Table 2 and for alkalis in the Table 3.

Table 2. Rest weights and relative degradation rates for acid

t [hour]	R_Z [%] 10% HCl	K_P [%.hour^{-1}] 10% HCl
0	100,000	0,000
2	94,713	2,640
5	90,436	1,913
10	80,936	1,906
15	67,080	2,195
24	66,982	1,376

Table 3. Rest weights and relative degradation rates for alkalis

t [hour]	R_Z [%] 10% NaOH	K_P [%.hour^{-1}] 10% NaOH	R_Z [%] 10% $Ca(OH)_2$	K_P [%.hour^{-1}] 10% $Ca(OH)_2$
0	100,000	0,000	100,000	0,000
2	96,889	1,556	100,000	0,000
5	95,845	0,831	99,888	0,022
24	94,968	0,2097	99,278	0,030

DEGRADATION KINETICS. During the degradation process the chemical solution attacks the surface and subsurface layers. Direct investigation of fibers diameter after long-term degradation has shown that the predominant mechanism is opening of crazes and degradation in the volume of fibers. Step by step removal of surface layers was negligible. Therefore the reason of degradation is the reaction of chemical solution with some cations (in the case of acids) or anions (in the case of alkalis) from basalt fiber body. The kinetic model is therefore based on the assumption of first order reaction. The instantaneous rate of degradation is dependent on the difference between actual weight and weight in equilibrium

$$\frac{dM_t}{dt} = -K\left(M_t - M_\infty\right). \qquad (3)$$

Solving of this differential equation in the intervals $[M_0, M_t]$ and $[0, t]$ results in the following equation

$$M_t = M_\infty + \left(M_0 - M_\infty\right)\exp\left(-Kt\right). \qquad (4)$$

After introducing the rest weight the final relation is obtained

$$R_Z = R_\infty + \left(100 - R_\infty\right)\exp\left(-Kt\right), \qquad (5)$$

where R_∞ [%] is equilibrium rest weight and K [$hour^{-1}$] is degradation rate constant.

DEGRADATION IN HCl. The parameters characterizing weight loss for degradation in 10% HCl are given in the Table 2. The parameters of degradation model $R_\infty = 54.883$ [%] and K = 0.063 [$hour^{-1}$] were obtained by using nonlinear least squares criterion. Experimental points and model curve are shown in the Fig. 1

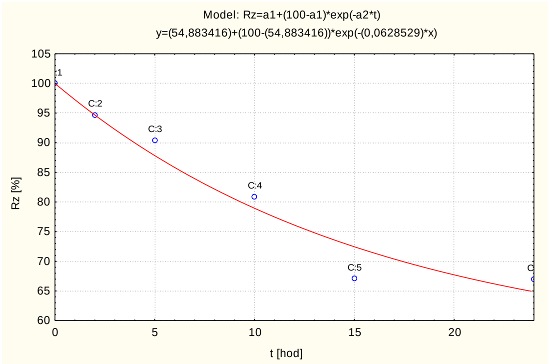
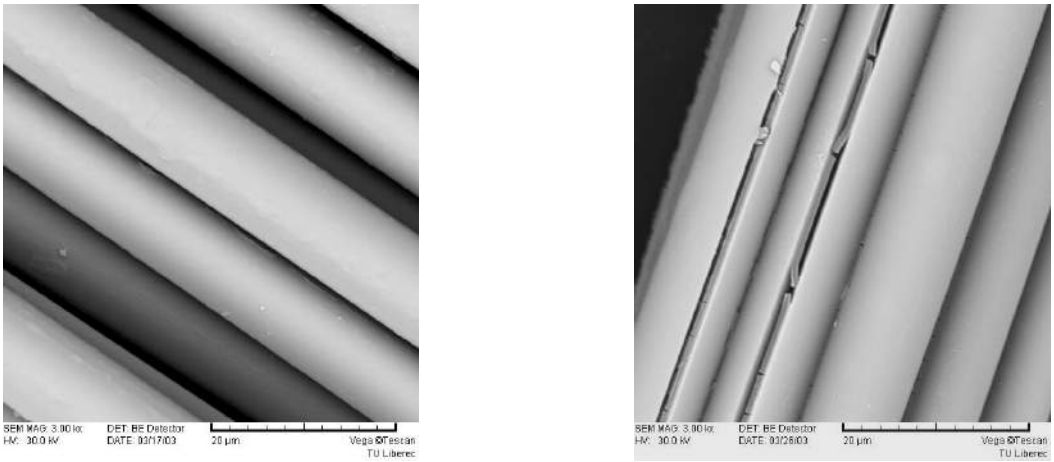


Fig. 1. Kinetics of weight loss in 10% HCl described by eqn. (5)

The surface of degraded fibers is shown in the Figs. 2, 3. It is very interesting that degradation is mainly due to opening and creation of long crazes in the fiber axis. After long-term exposure the crazes in direction perpendicular to fiber axis appeared.



a) b)

Fig. 2 Basalt fiber after degradation in 10% HCl for 2 hours (a) and 5 hours (b)

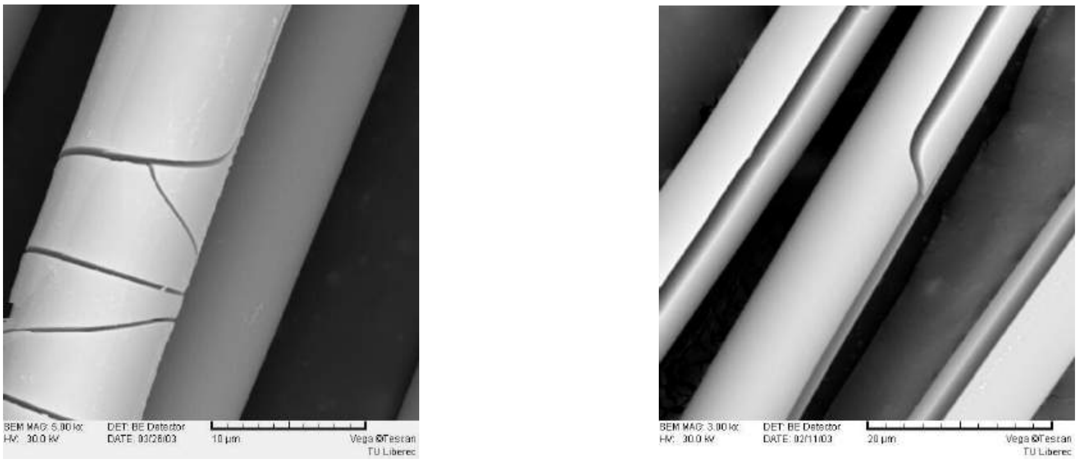


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Fig. 3 Basalt fiber after degradation in 10% HCl for 15 hours (a) and 24 hours (b)

Result is great loss of durability and disintegration of fibers in long degradation times. The degradation is accompaigned by the great loss of mechanical properties, especially tensile strength [6]. The volumetric density computed from diameter and weight of treated basalt is for 2 hours of acid action, 2511 kgm^{-3}. This value is slightly lower than volumetric density, 2572 kgm^{-3}, for untreated basalt fiber.

The increasing of pH acid solution after degradation is in accordance with assumption of reaction of HCl with cations and destroying the glass-like network. The chloride salts replace the intermediate oxides as MnO_2, Fe_2O_3 and Al_2O_3. These salts are typically well soluble in water and these phenomena supported the basalt degradation due to action of acid.

DEGRADATION IN AKALIS. It is known that alkali attacks the silica network directly. The hydroxyl ion of the alkali breaks the Si-O-Si linkage. The presence of intermediate oxides like MnO_2, Fe_2O_3 and Al_2O_3 should always improve the alkaline durability [8]. Degradation in 10% alkaline solutions is relatively small. The durability in 10% $Ca(OH)_2$ is excellent. Action of 10% NaOH is more severe but in comparison wit acid the weight loss is very low.

The parameters characterizing weight loss for degradation in 10% alkalis are given in the Table 3. The degradation kinetics was modeled for the case of 10% NaOH only. The parameters of degradation model R_∞ =95.009 [%] and K = 0.440 [$hour^{-1}$] were obtained by using nonlinear least squares criterion. Experimental points and model curve are shown in the Fig. 4. The very high rest weight equilibrium and high rate constant in comparison to the same values for acid degradation indicate that the degradation processes are mainly on surface of fibers. The glass-like network breaking increases number of free hydroxyl group.

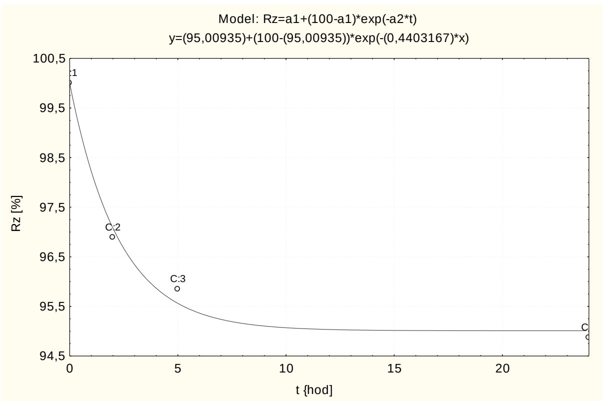
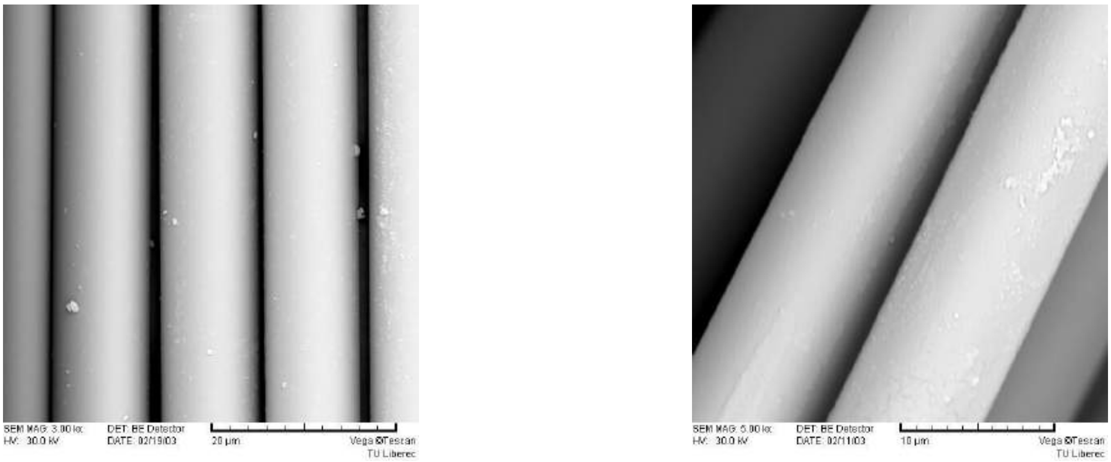


Fig. 4. Kinetics of weight loss in 10% NaOH described by eqn. (5)

The surface of degraded fibers is shown in the Figs. 5, 6. It is very interesting that the surface is now without crazes and the precipitation of insoluble materials on the fiber surface is visible.

The very small weight loss indicates good stability of basalt in strong alkalis. The small loss of mechanical properties, especially tensile strength was found [6]. The volumetric density computed from diameter and weight of treated basalt is for 2 hours of NaOH action equal to 2308 $kg{\cdot}m^{-3}$. This relatively low value supports assumption about surface ablation in alkaline conditions.



a) b)

Fig. 5 Basalt fiber after degradation in 10% $Ca(OH)_2$ for 24 hours (A) and in 10% NaOH for 24 hours (B)

C O N C L U S I O N

According to the previous finding it was proved that the stability of basalt in alkalis is generally very good. The stability in acids is comparatively small. Prolonged acids action leads to the full disintegration of fibers.

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SETTING OF POLYESTER FIBERS*

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INTRODUCTION. Thermal setting of synthetic fibers is mainly used for dimensional stabilization, improving some properties and removing internal stresses evolved during spinning and drawing.. The main mechanism of setting is establishment of new conformation balances of polymeric chains in fibers deformed during their formation. In semicrystalline polymers this process is accompanied by re-crystallization leading to more perfect crystallites with higher melting temperatures. In the loose state the chains retraction and disorientation in amorphous regions occurs. These processes are macroscopically visible as shrinkage. The structural changes during setting are dependent on the state of fibers (pre stress) and setting conditions (humidity, temperature and time of treatment). In this work the dependence of selected polyester fibers on the setting temperature is investigated.

This work was supported by the research project 1M4674788501 - “Textile Center” of Czech Ministry of Education.

PET FIBERS. The polyethylene terephtalate (PET) fibers represent polyesters having rigid benzene ring in its backbone. These fibers were patented by Whinfeld and Dickson in 1941. The consumption of polyester fibers is presently about 46 % of world fibers production.

PET exhibit glass transition Tg (about 77…80°C), crystallization temperature (180…190°C) and melting point (256°C). The elastic modulus of crystalline regions of PET in direction parallel with chain axis is 108 GPa. PET fibers are well known for their high performance properties, resistance and good tensile properties. The geometrical structure of the terephtalate unit is in the Fig. 1.

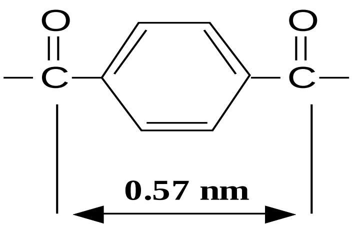
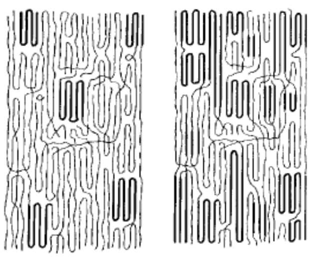


Fig. 1. Dimensions of terephtalate unit

The molar volume of PET V_{PET} = 144 cm^3/mol. The amorphous density of PET ρ_{aPET} = 1333 kg/m^3. The crystalline density of PET ρ_{cPET} = 1440 kg/m^3. Total energy of secondary bonds is 1.37 kJ/mol. Undrawn fibers are practically amorphous. The semi-crystalline structure appears mainly during thermal setting in isometric or isotonic state. Changes of PET structure after setting are schematically shown in Fig. 2.



a) b)

Fig. 2. Structure of PET before (a) and after (b) setting

Fibers after setting have degree of crystallinity about 0.4, orientation factor of crystalline phase is fc > 0.95 and orientation factor of amorphous phase is fa =0.6. Basic structural units are relatively strong micro fibrils having diameter 10…15 nm and length 103 nm. These units are assembled into fibrils having diameter 30…45 nm.

Very important role is played by oriented non crystalline phase (TTM) – „taut tie molecules“. Portion of TTM is around 0.1…0.05. This phase is responsible for mechanical properties of PET fibers.

EXPERIMENTAL PART. The staple unmodified dull polyester fibers with fineness 3.3 dtex were used. Dry thermal setting in oven (loose state) at three temperatures 140, 170 and 200 °C during 15 min. was realized. The changes of mechanical thermal and surface characteristics were investigated. The thermal behavior was measured on the DSC 6 (Perkin Elmer) under nitrogen atmosphere at rate of heating 20 K/min. Ultimate mechanical properties were measured on the dynamometer Vibrodyn 400 (Lenzing Instruments). Dynamical mechanical measurements were realized on the apparatus DMA DX04T (RMI Ltd.). Fiber surfaces were investigated by using electron raster microscope VEGA TS 5130 (Tescan) having resolution 3.5 nm. Fiber images have resolution 512 x 512 pixels.

RESULTS AND DISCUSSION. The typical DSC thermogram of polyester fibers after setting is shown in the Fig. 3.

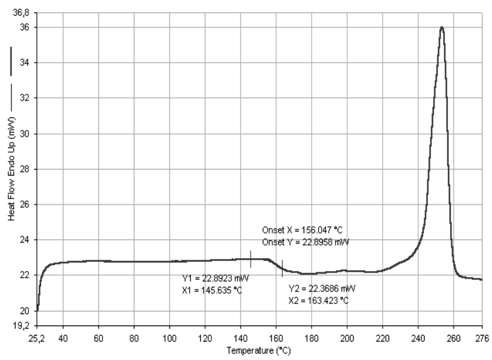


Fig. 3. Thermogram of polyester fiber (DSC)

Typical bend in the exothermic direction is indicator of setting temperature. Location of this bend is called effective setting temperature or start of recrystallization (T_{rc}). The location of maxima on melting peak corresponds to the melting temperature (T_m). Both these characteristics are given in the Table 1.

It is visible that values T_{rc} are about 15K higher that selected setting temperature. The setting temperature of original fibers (setting during fiber production) was about 134°C. The melting temperature is practically independent on the setting temperature. The temperatures corresponding to the maximum of loss tangents $T_{\tan\delta}$ measured at frequency 0.1 Hz on the DMA apparatus are presented in the Table 1. The evaluation of $T_{\tan\delta}$ is shown in the Fig. 4.

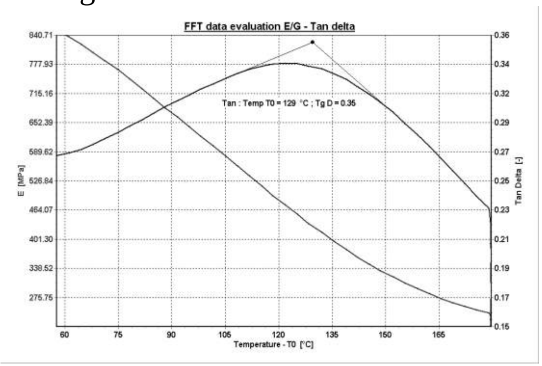


Fig. 4. Evaluation of $T_{\tan\delta}$ from dynamic mechanical measurements (DMA)

The increase of setting temperature leads to the decrease of $T_{\tan\delta}$ due to the increase of mobility in the amorphous regions. Mean values of tenacity and break elongation are given in the Table 1 as well. The tenacity slightly decreases and deformation at break increases with setting temperature increasing. The distribution of tenacity can be approximated by the two parameter Weibull distribution. Parameters of the Weibull distributions were practically unchanged by setting temperature. The statistical nature of fibers break is therefore not dependent on the setting temperature. The deformation energy to break is characterized by factor $SF = \sigma\sqrt{\varepsilon}$, where σ is tenacity and ε is fiber breaking elongation. It is visible that SF factor increases with the increasing of setting temperature.

Table 1. Thermal and mechanical characteristics of fibers after setting

Setting temperature	T_{rc} [°C]	T_m [°C]	$T_{\tan\delta}$ [°C]	Tenacity [mN]	Break elongation [%]	Factor SF
Original sample	148,8	255,7	112	153,9	34,5	903
140°C	156,3	254,5	110	153,9	35,7	917
170°C	185,1	255,4	90	152,7	37,7	937
200°C	215,8	255,4	81	145,9	42,3	948

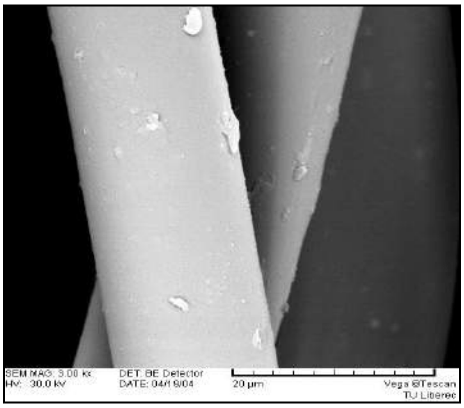


Fig. 5. Original fiber

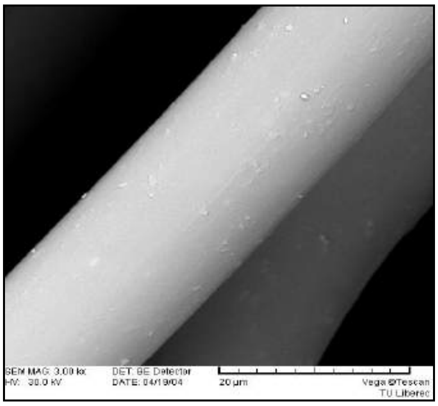


Fig. 6. Cleaned fiber

The surface of fibers was characterized by electron scanning microscopy. Surface of original fiber is shown in the Fig. 5. The oligomers on the surface of original fibers were firstly removed by repeated extraction in boiled ethanol at temperature 78.3°C.

Surface of cleaned fibers is shown in the Fig. 6. These cleaned fibers were then treated at above mentioned setting conditions. The effective setting temperatures T_{rc} from DSC thermograms were unaffected by setting temperature. Surfaces of cleaned fibers after setting are presented in the Figs. 7, 8 and 9. It is clear that oligomers creation is equilibrium reaction. After their removing from surface and setting the oligomers are reappear on the surface due to diffusion.

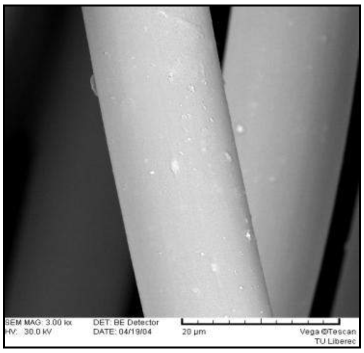


Fig. 7. Setting at 140°C

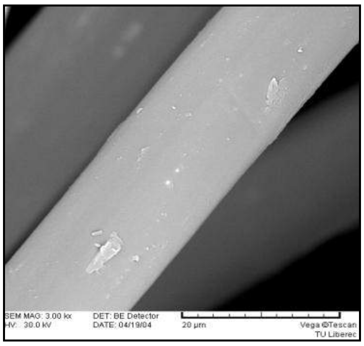


Fig. 8. Setting at 170°C

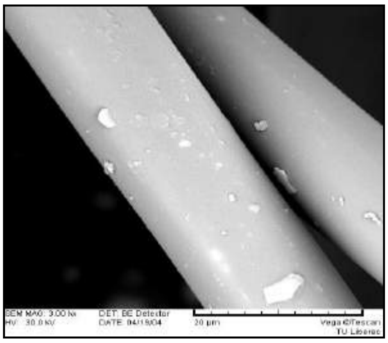


Fig. 9. Setting at 200°C

The breaking zone of fibers before and after setting is shown in the Figs. 10 up to 13. Increase of setting temperature leads to the increase of plastic flow portion at fiber break and corresponds to the increase of breaking elongation or deformation work to break.

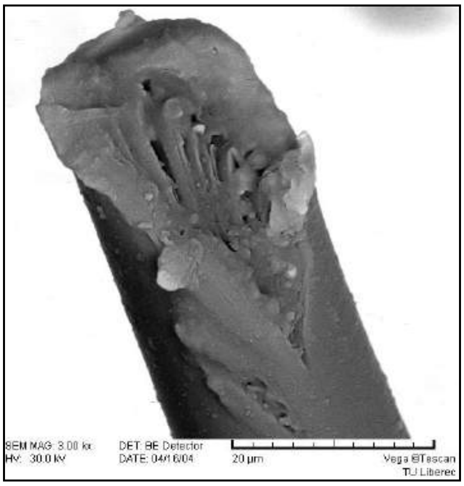


Fig. 10. Breaking zone of original fiber

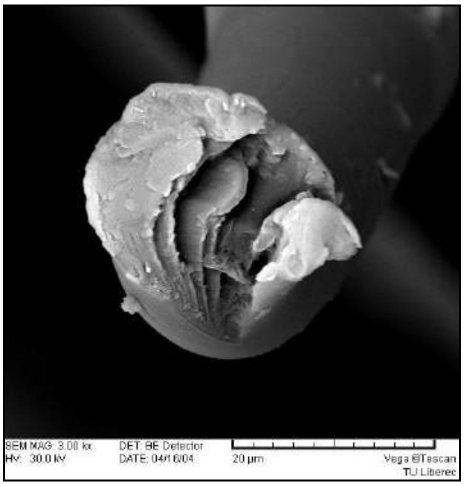


Fig. 11. Breaking zone (setting at 140°C)

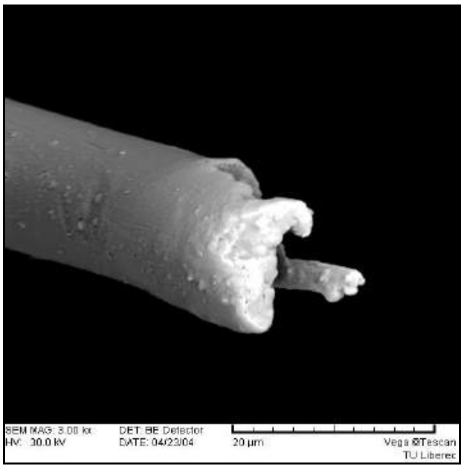


Fig. 12. Breaking zone (setting at 170°C)

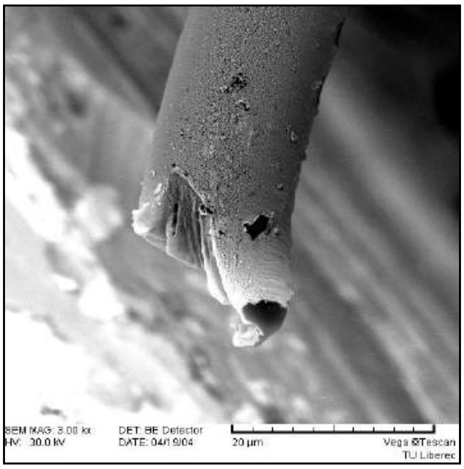


Fig. 13. Breaking zone (setting at 200°C)

C O N C L U S I O N

The influence of setting temperature on the behavior of polyester fibers was investigated. Results of measurements are in accordance with assumption that increase of setting temperature leads to the increase of amount and quality of crystalline phase and its separation from amorphous phase. Direct consequence of these structural changes is increase of chains mobility in amorphous phase and increase of plastic deformation portion at fiber deformation. The oligomers are appeared on the surface of fibers after setting.

Recommended by Scientific and Technical Counsil of Moscow State Textile University named aftert A.N. Kosygin. Received 05.06.09.

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UTILISATION OF NANOSCALE ORGANOSYLOXAN COATINGS TO IMPART SPECIFIC PROPERTIES TO NONWOVEN MATERIALS

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(The Moscow State Textile University named after A.N. Kosygin)

Over the last ten years we have been carrying research work with the aim of developing nonwoven textile materials with a package of tailor-made properties; the areas of research are as follows:

– processes of fixation of functional-active organic, inorganic and elementorganic compounds on the surface of fibrous materials are studied;

– methods of immobilisation of nanoscale organosiloxan polymer coatings (covalently bound to the surface of fibrous material) of tailor-made composition and structure to the surface of fibrous materials, consisting of functional oligomers which are soluble or self-dispersing in water, are developed;

– methods of designing of nanoscale laminated templated siloxan-organo-inorganic polymer coatings of tailor-made structure, composition and texture on the surface of flexible fibrous materials are developed;

– methods of adjusting and controlling properties of such laminated coatings and their performance specifications are developed.

Through the use of such laminated coatings nonwoven materials are endowed with hydrophobic, bactericidal, aromatic, strengthening and other special properties. Very small quantity of silicone is used to obtain such coatings. This fraction accounts for millimols (10^{-3} g/mol) and micromols (10^{-6} g/mol) of silicone per 1 square meter of specific surface of fibrous material. Nanoscale organosiloxane polymer coatings demonstrate dimensional effects. In particular, high chemical activity of functional groups manifest itself, both directly bound with silicon atoms, as well with the ones which are in carbofunctional radicals, which are covalently bound to silicon atoms.

Nanocoatings are fixed very strong on the surface of fibrous materials, so that they can be removed only with hydrofuoric acid or by boiling for extended time in a concentrated alcaline solution.

Organosiloxane polymer coatings are steam and gas-permeable. Therefore, fibrous material "breathes" even under a thick layer of siloxane film, retaining its comfort properties during usage.

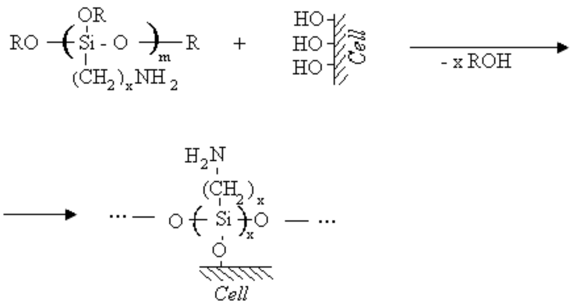
Silicon atoms of such coatings possess carbofunctional radicals, covalently bound to them, which are capable of further chemical transformations. Therefore, by using methods of nanochemistry and nanotechnology, we have developed a method of molecular design on the surface of organosiloxane polymer coatings of the second, third and forth generation. Coatings can be organic, inorganic or elemento-organic.

Such methods enable to obtain conceptually new generation of flexible laminated composite materials on the surface of which nanoscale laminated templated siloxane-organo-inorganic polymer coatings are located (positioned coaxially in relation one to another) of tailor-made structure, composition and texture .

Let us consider as an example a formation of complexing laminated nanoscale siloxane-organo-inorganic polymer coatings on the surface of fibres having on the surface highly active and high-selective complexing ligands.

1. Immobilization of complexing ligands onto the surface of fibres. Fixation of complexing ligands is carried out by method of molecular design on the surface in two stages. During the first stage aminoalkyl sylil ($\equiv Si(CH_2)_xNH_2$) groups are fixed covalently on the surface of fiber by means of treatment of fibers with oligoalcoxy(aminoalkyl)-siloxane (Diagram 1).

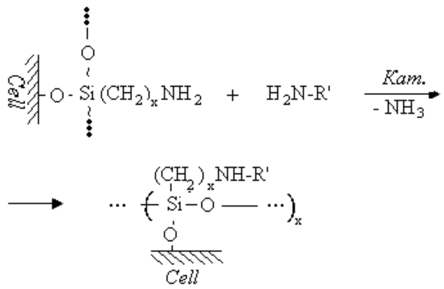
Diagram 1

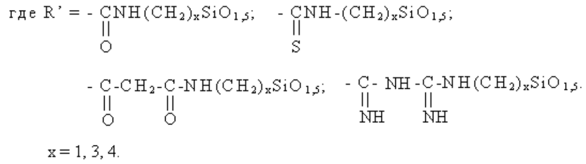


где R = Me, Et, Bu; x = 1, 3, 4; m = 5, 10, 15.

During the second stage condensation of aminialkyl groups with carbamide, dicyandiamide is carried out (Diagram 2).

Diagram 2





As a result complexing carbamide, thiocarbamide, malonodiamide, biguanidine ligands are fixed.

Content of complexing ligands is varied from 5 to 30 mol %.

Thermal and chemical stability of sorbents on the basis of acetate, acetate-cellulose and viscose fibers is determined by nature of the fibrous carrier.

All sorbents are distinguished by a wide range of sorption activity. They withdraw efficiently toxic, precious metals and a large group of heavy metals from liquids, thus forming nanoscale metal-containing coating of the third generation. Such coatings are of interest in terms of application:

2. Adsorption of toxic elements. Toxic elements Hg(II), As (V), Bi (III), Cd (II), Sb (III), Pb (II) are active complexing agents, and consequently can form stable ion-coordinating ligands with the above mentioned complexing groups in more acidic environments. The highest degree of adsoption for Hg(II), As (V) and Bi (III) is found in 1-3M solutions of mineral acids and is characterized by quite high values of sorption capacities (Table 1). The investigated materials with thiocarbamide ligands manifest the highest activity with regard to Hg(II) ions, for which the value of capacity reaches 400 mg/g.

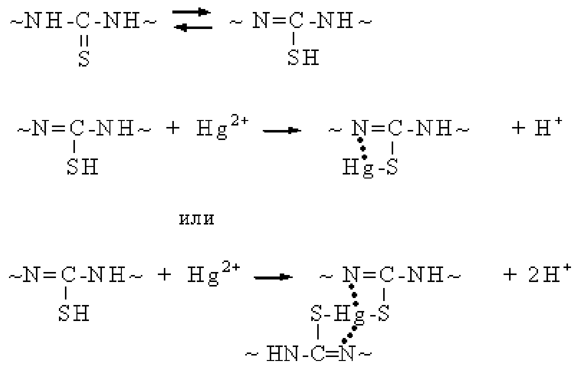
Table 1. Values of static sorption capacities (CCE) of fibers for toxic elements

CCE, mg/g					
Hg(II)	Bi (III)	Cd (II)	As (V)	Sb (III)	Pb (II)
179 (1m HNO_3)	40 (1m HNO_3)	40 (pH=1)	145 (3m HNO_3)	110 (pH=1)	131 (pH=1)
128 (1m HCl)	134 (pH=6)	127 (pH=6)	-	-	-
210 (3m HNO_3)	-	-	-	-	-
400 (1m H_2SO_4)	-	-	-	-	-

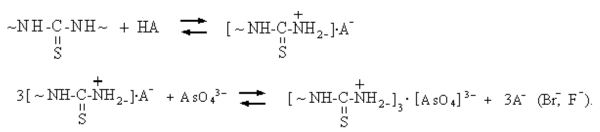
Such values of capacities for Hg(II) for known sorption materials are found extremely rare.

High efficiency of these materials in relation to Hg(II) ions and other toxic metals is a result of forming strong complexes in the sorbent phase.

With due consideration of thion-thiol tautomerism which is inherent to thioamides, and especially to thiocarbamides, one can assume that sorption of cations of toxic metals proceeds according to mechanism of ion coordination:



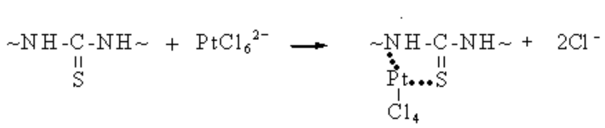
Anion metabolic activity of the thiocarbamide with regard to oxo complexes AsO^{3-} and SbO^{-}_2 is related to the known capability of thiocarbamides to form iso-thyronine salts in acidic solutions. The discovered ability of sorbents containing thiocarbamide groups to extract anions of bromine and fluorine from solutions can also be attributed to the above said.



Solutions of 6M HCl serve as all-purpose desorbents for regeneration of sorbents saturated with toxic metals; effect of excessive acid on metal-saturated sorbents causes complete outwashing of them from the surface of the sorption material.

3. Sorption of precious metals. Highly selective recovery of precious metals Ag (I), Au (III), Pt (IV), Pd (II), Rh (III), Jr (IV), Ru (III), Os (IV) by new sorbents can proceed in concentrated solutions of hydrochloric and sulphuric acids in the presence of dominant amount of diverse non-ferrous and heavy metals. Sorbents with thiocarbamide groups manifest maximum efficiency and selectivity.

Process of complex formation with ions of precious metals proceeds according to the following scheme:



and is accompanied by displacement of two to four chlorine atoms from the coordination sphere of metal-acido complex.

Statistical sorptive capacity (SSC) of sorbents on the basis of fibrous glass in sulphate solutions at 100°C is the following:

Ir (IV) – 48 mg/g (4.5m H_2SO_4),

Ru (III) – 31 mg/g (6.0m H_2SO_4),

Os (IV) – 46 mg/g (7.5m H_2SO_4).

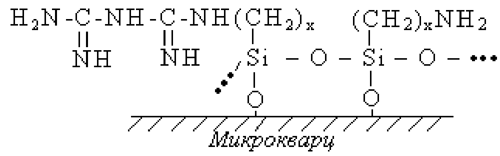
It should be noted that, in case of extraction of Au (III) by a sorbent on the basis of glass"microquartz" fiber, insignificant portion (up to 20%) of gold (III) passes to the zero-valent state, i.e. is regenerated to Au (0).

4. Sorption materials with biguanidine ligands. Most of organic biguanidine derivatives are biologically active substances. For instance, biguadine grouping is part of palaumine and styloguadine alkaloids (which have citotoxic, antibiotic, antifungal and immunomodulatory action) of the antibiotic glyformin preparation.

Besides, organic compounds containing polydentate biguadine grouping are known as selective complexing agents. Until now there was no information in technical literature regarding biguanidine derivatives.

We have developed zol-gel method for designing organosiloxane polymer coatings on the surface of fibers of different nature which possess high sorption activity, especially with regard to silver (statistical sorption capacity of coating (I) amounts as to Ag (I) 544 mg/g). It is determined by high tendency of Ag (I) ions to complex formation with nitrogen-containing ligands.

(I)



Change of sorption activity of coatings (I) in the range of the examined metals Au (III), Pt (IV), Pd (II) is related to the higher stability of coordination compounds Ag (I) with amines in comparison with Au (III), Pt (IV), Pd (II).

Coating (I) has been examined as adsorbent of precious metals Ag (I), Au (III), Pd (II) и Pt (IV). Sorption has been carried out in acidic medium 0.5-0.6M HNO_3 for Ag (I), 3M HCl for Au (III), Pd (II) and Pt (IV) in static mode. Results of determining statistical sorptive capacity (SSC) of the coating with regard to the examined metals (elements) are given in Table 2.

Table 2. Results of determing SSC of coating with regard to examined metals (elements)

Sorbate	SSC, mg/g
Ag (I)	544
Au (III)	6,6-22
Pt (IV)	30
Pd (II)	30,8

C O N C L U S I O N

In summary, the examined sorption-active complexing laminated nanoscale templated siloxane-organo-inorganic polymer coatings on the surface of fibers of different nature, which contain carbamide, thiocarbamide, malonodiamide biguanidine ligands, represent promising sorption materials for extraction of toxic metals – As (V), Cd (II), Sb (III), Hg(II),Pb (II), Bi (III), precious metals - Ag (I), Au (III), Pt (IV), Pd (II), Rh (III), Ir (IV), Ru (III), Os (IV); and some rare elements – V (V), Mo (VI), W (VI), Th (IV), U (VII) from natural objects and technological facilities (liquids, gas media, fume, suspensions, emulsions, etc.).

In terms of application aspects, it is of some interest to utilize coatings of the 1st, 2nd, 3rd generation both separately and in different combinations to solve different technical tasks, such as:

– to impart predefined electrophysical (nonlinear optical and luminescent, electrochromic, magnetic, conducting and other) properties (rare earth elements) to fibers,

– to impart resistance to radioactive exposure and other high-energy rays (^{10}B, ^{113}Cd, ^{149}Sm, ^{151}Eu, ^{155}Gd, ^{157}Gd),

– to impart fire-resistance (P, N, Si),

– to impart antimicrobial properties, biocide (Ag (I), Cu (II), Zn (II), Fe (III)),

– acaricide properties, i.e ability to repel encephalitic ticks,

– to impart hydrophobic, hydrophilic, antistatic and other properties,

– metal-organic paintable coatings made of conjugate of rare metals for nonwoven new-generation materials under the accepted "Intelligent Textile" program,

– development of optical sensors to determine metal cations (Cu (II), Zn (II), Cd (II), Fe (III) and others) in aqueous solutions.

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UDK 677.025

THE INSTRUMENT OF FORMALIZATION AND SYNTHESIS OF NEW STRUCTURES OF KNITTED FABRICS

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In development of the work [1] we want to show efficiency of the instrument of the formalized description developed by us and synthesis of new interlacings. Thus we shall emphasize a special urgency of productive thinking presently, meaning that 2009 in ES is declared "the Year of innovations and inventions".

Formation of properties and providing of quality of knitted production, creation of new "product line" of assortment of products is carried out in system whose basic elements are a textile fiber, a thread (yarn), a knitted material (fabric) and a design of a product. The account of all factors in the complex (system) approach to design of products essentially expands opportunities updating of production and maintenance of much wider spectrum of technical requirements to production or meeting consumer’s demands. A special place takes decorating-pattern color design of products for harmonization of decisions because it depends not only on characteristics of the applied material, creativity of the artist and the designer, but also possibility of application of various kinds of furnish of the knitted fabrics.

At the same time, the main tool of innovative development in technology of knitted manufacture is, first of all, creation of new structures of materials. And it is a question not of updating structures of knitting fabrics on the basis of existing processes and the equipment, but of creation of essentially new designs and consequence of new materials with new properties, and also technical decisions which initiate creation of new machines and mechanisms. On development of mechanical engineering it is possible to track those technological breaks which were born by an engineering technological idea. Updating of production also went on the basis of modernization of the process equipment.

There are enough facts to affirm that the majority of physical mechanical properties of knitted materials and products is defined by its structure and new structural properties. It concerns practically all objects of textile manufacture. The structure is base for creation of any production, processes and mechanisms for their realization.

Thus, ability to create new structures including knowledge in educational process matters for reproduction of an intellectual resource and the solution of practical problems. Main principles of the solution of such problems are concluded in methodology of structural synthesis and the system approach.

Historically many problems of structural synthesis were solved within the limits of inventive activity on the basis of experience, intuition and rational thinking. As a result, the attributes used for the characteristic of various objects (inventions) have been certain and necessary conditions of carrying out the information analysis of environment are certain to define a level of techniques and a reference point of the further development. However to perform such work presently it is rather uneasy.

It is possible to ascertain as the fact, that in a science, education (owing to information "explosion") and practical activities there was a dialectic contradiction and a crisis situation between growth of quantity of the information and an opportunity of operative data processing in real time. Development of traditional verbal sources of knowledge even in a narrow subject domain represents a real problem "to keep up to science level". The solution of this contradiction lays in a sphere of the formalized description of technological knowledge, their structurization, compact representation and construction on this basis of effective systems of gathering, storage and transfer of the information, and also machining of data and information search. As a whole it is a question of creation of new information culture [2], [3].

It is also essential that creation of new innovative decisions lays in sphere of the new ideas, fundamental knowledge and structural synthesis. The world of engineering creativity, inventions, the copyright is not a result of numerical and mathematical calculations but search of the structural decisions concerning creation of new kinds of products.

Thus consider that the problem of any complexity can be reduced to a problem of search of decisions in discrete space of conditions (alternatives), if it is formalized in terms of an initial condition (S_0), final (S_e) and formulas (F) (rules) of transition in space of events [4]. Formalization of representation of objects is a basis of creation of databases and knowledge bases when transiting to algorithmization and computer processing, including expert systems.

The most universal form of data presentation (and "knowledge, skills are data and rules of work with them" (Dijkstra)), reflecting the law of the form of various objects and their properties, the matrix of data is. The matrix cell of data, its coding (figures, signs, color, an image and etc) gives the most informative meaning of essence of discrete object, deepening processes of perception of knowledge and efficiency of thinking.

The matrixes' theory of data leads to uniform technology of the analysis and structural synthesis (as attitudes of variables), reflects psychological aspects of creativity, connected with purchase, structurization and processing of the information, figurative representation of object [5].

In textile technology, in particular in knitted manufacture, matrix and sign forms of display structure materials traditionally remained the basic compact and clear forms of technological knowledge. In fact, all textile objects have discrete structure, including fibers, yarn (threads), knitted cloths and products. Processes of their manufacture are also discrete. Therefore models of such systems can be considered as algebraic at a design stage, and processes as complex (time) event systems [6], [7], connected with change of states of "processed objects".

The problem of creation of new structures and expert systems ("soft algorithms") [7], [8] being based on the theory of discrete mathematics should be constructed not on an intuitive basis (in the certain sense as unsystematic primitive search and "blind" search of variants which leads to deadlock decisions, when the top of "a tree of decisions" appears trailing [7]), and as a problem of a logic conclusion of new attitudes of structural elements of initial base set with use of the certain generating rules and technological knowledge.

It is known, that any object of discrete system should be presented only by one essence which should be is unique identified. The name of essence should reflect a category, type or a class (concept) of object, instead of its concrete copy. Generation of new objects is dependent essence or new concept [9]. Presence of unequivocal identifiers of concepts allows to form the dictionary of base elements of a subject domain, to use computer processing knowledge (in particular to pass from structure fabric to technology of their manufacturing and creation of new technological machines). Identification of production in the market of sales is a basis of recognition of properties of materials, decrease in risks of losses and safety of production.

It is possible to consider that some set of M with the set of attitudes R can be a model of discrete system (object), i.e. a design of a kind $\psi = \langle M, R \rangle$ [8].

For knitted structure fabrics it is possible to generate base set E of structural elements from known $\{e_i\} \in E$ supposing that all these elements form orthogonal space of attributes[1], and have the certain length (i.e. are parametrically set) and can be certain at the analysis in a numerical kind. To this set the following can be carried: known loops of a various kind – plain loops (face, back), rib loops (face, back), terry, tuck and futter loops; floats, including weft threads, jacquard and etc.

Let's use a matrix method of formation (synthesis) of interlacings (structure of jersey) on model $\psi = \langle M, R \rangle$ in the form of the bi-dimentional table, each line (column) of which we shall biuniquely compare to elements of set of M. Set of M we shall consider as some final set E of base elements of structure of jersey, i.e. we shall put $M = E = \{e_u | u = 1, 2, \ldots, U\}$, where U – some number of elements (units) which with a high probability can be used at formation of structures of knitted interlacings and fabrics and can extend. At the task of binary attitudes in the form of a matrix which fragment is presented on Fig. 2 each line (column) we shall compare biuniquely to element of set of E. Therefore each cell (i, j) matrixes (which can be realized technologically) can be presented in the form of logic crossing elements $e_i \cap e_j \left(e_i e_j\right)$ corresponding to the binary attitude $R_e^{(s=2)}$. Theoretical capacity of such set $E \times E = E^2$. I.e. the binary attitude $R_e^{(s)}$ on set E is the subset of its square: $R \subset E^2$. In this case the matrix E^2 will represent attitudes at display of set to, and its attitudes to represent set of the ordered pairs $\left(e_i e_j\right)$ or trains of two-componental interlacings, such that $\left\{e_i\ e_j\right\} \in E^2$.

In a matrix of base elements E on which algebraic binary operation is certain, we shall add an individual element e_0 [7], such that $å_0 \cdot e_i = å_i$, $å_0 \cdot e_j = å_j$ which gives identical (monadic) display of elements (often designate at additive record in zero). It allows to form unicomponent (one threads) structures of interlacings in coordinates of knitting field (in each point to add on one element), and also attitudes any "measure size", both even and odd. In view of it, theoretical capacity of set of binary attitudes increases up to values $M = E^2 + E$, and capacity of all decisions is practically unlimited.

In each point of coordinates (crossing loop course and wale) fields of knitting $k = \langle k_w, k_c \rangle$[2] in a direction of axes w and c within the limits of chosen rapport R_B and R_H interlacings $k_w = \{1, 2, \ldots, R_B\}$ also $k_c = \{1, 2, \ldots, R_H\}$ can be formed unary, binary, including n-ary attitudes of elements, i.e. individual, double, threefold, etc. sets or groups $R_e^{(s)}$ are formed at transition from one coordinate to another. As result, within the limits of the chosen size coordinates we have set M_S of interlacings in the form of associations $R_e^{(s)}$ of elements in structural complexes - cells SKC (Structural Knitted Cell)[3] of the interlacings belonging to certain properties R_e^*, i.e. $R_e^{(s)} \subset R_e^*$ of which elements are formed.

The methodology of synthesis of interlacings of regular structures on a matrix of binary attitudes has been realized in the form of the computer version (Fig. 1) at work in a mode of expert system. The program allows to carry out "assembly" of structural elements in complexes (cells) SKC, to realize visualization of the fabric (Fig. 1) and to display results of synthesis in the form of formalization of structure and a semantic design of an interlacing (Fig. 1). The result of designing is: the size repeat interlacings R_B and R_H, quantity and a kind of applied threads t_h[4], graphic record of an interlacing and quantity of elements n in structural cell SKC of a cloth.

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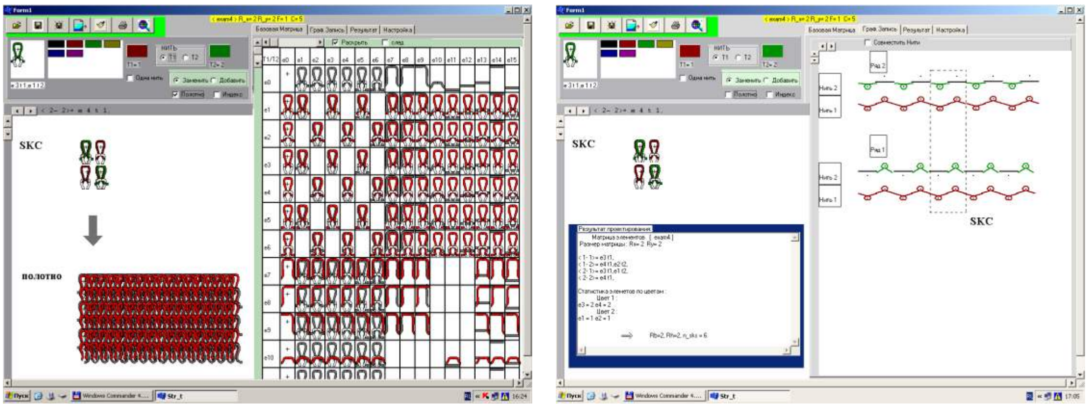
[1] Orthogonality of space means that change of any component does not entail automatic change of another.

[2] Abbreviation *w* and *c* from English *wale* – a loop column, *course* – a loop number.

[3] The concept of a structural cell (unlike раппорта) is a basis of the description and designing of properties of jersey and is base concept of a structure of jersey of a foreign science and an expert. For the first time has entered J.J. Knapton.

[4] From English *thread* – the yarn.



a) b)

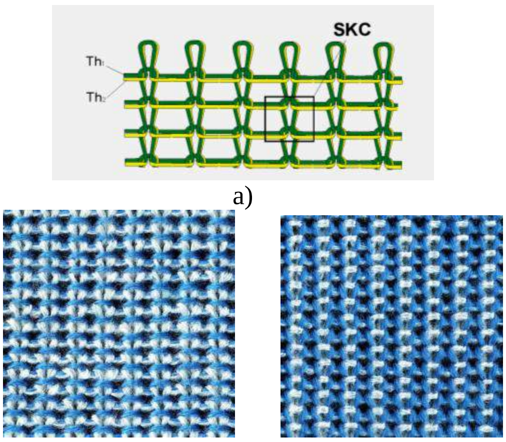
Fig. 1

The final decision as information model can be presented in the form of the formalized semantic design (train) of defining attributes

$$\langle \text{interlacing } m_S \in M_S \rangle ::= \langle \text{name of elements, } e_i \in E \rangle \langle \text{type of thread, } t_h \in T_H \rangle$$
$$\langle \text{type and size of logical attitudes, } R_e^{(s)} \rangle \langle \text{coordinates } K_w \in R_B, K_c \in R_H \rangle,$$

which uniquely identify an interlacing[5], including creation of databases in the software.

The received data, firstly, is enough for designing technological process of knitting of the fabrics and drawing up of operating technological programs of the automatic knitting machines, secondly, for the solution of problems of parametrical synthesis of the developed interlacings.



a)

b)

Fig. 2. Structure of a new interlacing (*a*) and a general view of samples of the face and the back sides (*b*) $m_s = \langle T_{h1}e_1; T_{h2}e_2 \rangle$. The variant 1

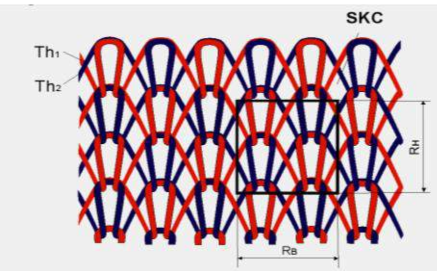
Except for the description of interlacings matrix M_S works as the tool of synthesis of new interlacings by consecutive search of decisions on the basis of "crossings and summation of cells" matrixes. As an example, on Fig. 2, 3 unknown to us before are shown interlacings: crossing in one coordinate face and back loops[6] (Fig. 2) – a variant 1 or crossing in each of coordinates of a loop and a tuck stitch, formed from various yarns (Fig. 3) – a variant 2. Experiment shows, that such interlacings (Fig. 2, 3) possess new structural properties, and their realization underlies creation of new processes and functional mechanisms of knitted machines, i.e. initiates development of new technologies and creation of knitted materials with new structural and physic mechanical properties.

The developed tool of computer design (synthesis) transforms a problem of creation of new interlacings into simple engineering procedure, raises efficiency of innovative works, meets new requirements of construction of educational process, perception and processing of the information at higher (cognitive) levels, promotes development of productive creative thinking.

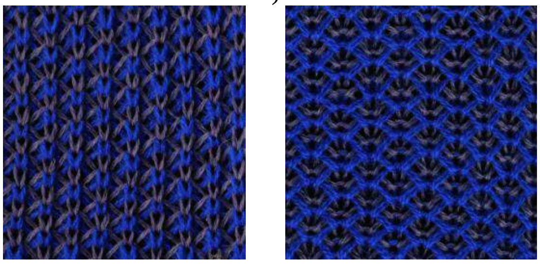
Our position is that the productive creative component of activity should be based on synthesis of new objects, as opposed to the concept search of decisions on the basis of the analysis of opportunities of existing technological processes and textile machines.

[5] Regular structures without transformation of structural elements mean. Their synthesis demands construction of an additional matrix of binary attitudes.

[6] Authors recognize the level of incompetence if such interlacings are known.



a)



b)

Fig. 3. Structure of a new interlacing (a) and a general view of samples of the face and the back sides (b) $m_s = \langle T_{h1}e_1 \cap T_{h2}e_7 \cup T_{h1}e_7 \cap T_{h2}e_1 \rangle$. The variant 2

Synthesis of new textile designs allows to create new processes and the new process equipment, initiating development of textile technology and mechanical engineering.

Analyzing the developed methodology of structural synthesis of interlacings we come logically to creation of knitted machines of the future as the robot systems simulating manual knitting. Such machine should be equipped by an individual independent drive loop knitting parts and yarn finger and forming programs of knitting process on base synthesis of new structure fabrics. It is already possible to find in the world practice realization of such constructive decisions (f. Shima Seiki (Japan), f. Karl Mayer (Germany), etc.).

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IMAGE, TEXTILE AND PERFORMANCE

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There exists an open sphere of images in mass consciousness at each historic moment of time. Let us consider in the sphere of images such a qualitative phenomenon like textile performance. In this interdisciplinary sphere of activity synthesis of different fields of knowledge takes place: textile forms and plastique of human body, music and choreography. At the end of 20th century new synthetic works of art of tapissary emerged, plastique forms of which fulfill semiotic functions, similar to functions of a suit. Similarity of functions and of such significant characteristics, as configuration and interplay with plastique of human body, allow us to identify - with any degree of relativity - similar forms of tapissary presented on a human body as an avant-garde, to some degree theatricalized suit.

Textile performance is a striking example of complex interplay and interlacing of different types of art in a unified culture complex, being so typical for modern avant-garde art. Special role in the origin and dynamic development of performance played kinetic art (kinetism). From time immemorial people noticed that the word "movement" is used with such attribute like astonishing, unexpected, comic, amazing, fantastic and impossible. Just as design of a car, kinetism also comprises hypnotic action, as well as an irrational factor, and nervous excitement. Kinetism includes also such categories like time and changeability, freedom and limitation, development and stagnation, spiritual energy and synthesis.

Kinetism as a style in art was formed in the 50's of 20th century and actively developed during the next decades. However, interest of artists to mobile, changing form has its own prehistory. Roots of kinetism can be found in the history of world culture: in making fire works, in medieval mysteries, in folk art (various moving toys, musical boxes, kaleidoscopes, and puppet theatre). At the beginning of 20th century, representatives of such art styles, like rayism, futurism, expressionism, have used methods of kinetism in their works of art. With development of scientific-technical progress, object-space environment, surrounding man, became extremely filled-up with mobile and transforming objects. Therefore, movement and light became an integral part of modern art. Ideas of object's temporary transformation have been actively developed in Bauhaus. So, Oskar Schlemmer, creator of "Mechanical ballet" has paid considerable attention to problems of moving space and light forms. In the sphere of sculpture, space dynamics, then light dynamics appeared first. By forcing a sculpture to move, artists obtained a plenty of expressive effects: stops, starts, accelerations, slowing-downs. This way, a "temporary dynamism" appeared, which produced visual and audio-visual effects on spectators, created new unity of space, time and light. In 1920 - 1930's tests in the field of movement of space compositions have been carried out by renowned European masters Maurice Duchan, Laszlo Moholy-Nagy, Alexander Calder.

Certain insights of apologists of constructivism, as well as ideas of a changing form along with kinematic models of A. Calder have paved the way for flourishing of kinematism as a trend of world art in 50 - 60's of the 20th century. During this period a great practical experience was collected in the field of kinematic generation of forms, especially by Nicolas Schoffer, who made an attempt to analyse and to generalize long-term experience of art activity.

French artist N. Schoffer - one of outstanding representatives of kinematism - has conducted an interesting experiment on utilizing his moving sculptures "Kyldex" and "Chronos" as parts of a theatrical performance with participation of artists from Hamburg opera. Synthesis of kinetic objects of N. Schoffer, music by Pierre Henry and choreography by Alwin Nikolais resulted in excellent performance. This play was recorded by German TV and broadcasted like a kind of present at Christmas time. The idea to use kinematic art in theater was supported by English and American tapissiers, who were first to incorporate textile into happenings and performances.

Origination of performance is related to music, theater, cinema, poetry, dance, but first of all with issues of new art. Overcoming illusiveness of picture space and transfer to three-dimensional constructions is a main trend of artistic avant-garde at the beginning of 20th century that provoked emergence of performance. The following modifications of external image of works of art in the development of world art process can be mentioned: collage — assemblage — environment — happening and performance.

Happening is usually a collective action, organized by an artist-author, but provoking freedom of action for each of its participants and manipulation with objects. Great deal of space is allocated to improvisation that stimulates different unconscious inducements (not rarely in form of hysteria), when each participant of the event feels himself like a creator.

Performance is a conceptualized play with participation of the artist himself and a group of people. Usually it is related to revelation of biological and psychic energy of performers and takes a form of a modern ritual. Moreover, in contrast to happening with its improvisation and spontaneity, it is created by a group of people under a certain agreement; performance reflects deep personal aesthetic and physiological feelings of spectators and co-partners. Performance is characterized by the fact that it is free from spontaneous associations and those which are closely related to everyday life, as well as demonstrative elementary plot and art devices.

Art language emerged from the abundance of eccentric gestures of body-art, action art aimed at destruction of dominating styles in the art. From street performances and home plays - staged in presence of "its own" exclusive audience - performance moved to artistic spaces, specially allocated for demonstration purposes, into a tailor-made environment. Such environment was often created by many foreign tapissiers, who understood that textile-environment is most suitable for arranging actions of this kind. They appeal, like other artists, to art of ideas, which will spread all over the consumer market, will find a philosophy, behavioural moral code, to the art which is based on personal communication.

Approach to creating textile performances, based on philosophy and worldview, paved the way for experiments of different kind, allowed a free hand to select methods and devices for incarnation, good illustration of which is a performance put on the stage in London by the Hungarian artist Chilla Kelechen. Transparent curtain from synthetic film separates audience hall from the stage, completely hidden behind the black cloth. Spotlight highlights from the darkness figures of women (a brunette in trousers and brown pullover and an blonde in white dress), who dip gauze bandages - with ritual greatness - into a bucket with liquid gypsum and cover with them a beautiful figure of a completely naked young guy. Alive naked body turns into a statue before spectators' eyes. During the play the artist puts liquid gypsum on the curtain, and by the end of performance spectators see in front of them a nontransparent gypsum wall. Artistic effect of the performance was that much strong that one exalted lady run to the stage and began to tear the curtain, trying to see, what is actually happening behind it.

Special attention, from the point of view of image studies, deserves the research works of Hungarian tapissiers of art interplay between landscape and textiles materials, which are introduced into the landscape. Textile actions have been carried out by Anico Baiko, Ilona Lovash and Zhuzha Senesh at the site of archeological excavation in Velem and on the surrounding hills. The artists have covered an area of land with canvas and wrapped into them also a woman sitting on her hunkers. This vehicle is already well known in the style of art, which is called land art (or earth art). However, artistic image, created in this case by interplay of landscape and textile, promoted setting of a bright poetic mood. We have the right to assert that as a result of talented use of textile materials, a completely new art of tapissary emerged, not just a living picture.

In performances with curtains, Judith Kele is dyeing fabrics which have different surface finish, into a green color with a certain shade and capes made of them are put on all participants of performance. Capes during movement of dancers, because of the capability of fabrics with different texture to drape in different ways, untwist and fly in the air, forming all possible folds. The performance takes a symbolic form of initialization, which can be traced back to rites of primitive society. Freedom from direct associations and simplicity of dramaturgic tools and artistic devices are characteristic for this textile performance.

Attempt was made to make synthesis of demonstration of suit models and theatrical action, music and plastique of human movement, space and time. Performance was considered and interpreted from the point of view of a couturier; its task was to determine, how artists-modellers could express themselves, to convey their personal vision of authors, how they could emphasize and accentuate plastique idea, inherent to suits. Performance as a relatively new style of art, possessing great possibilities for creation, offered a wide range of various variants to solve these problems. Having selected suit as unit of measure and made attempt to synthesize types of arts being different in nature, we have investigated and offered different forms of behavior of suits in space by combining music, entourage, dancing movements and plotline of narration. Our prime interest was to find out how a form, understood from inside, relates to human body. The body has its own language and topics, its own technique to express energy hidden inside it. Energy flows from Outer Space and from the Earth run through the body; and we tried to work with these energies.

Performance enables to look at the process of fashion show from a new prospective. Professional fashion designer should not only create a suit, but also find a form of show which is adequate to his idea, select music and think over the character of fashion model's movements.

Using induction principle, i.e. deductive reasoning - from the general to the special, we will try to highlight those positive moments, which have introduced ideas of plastique into design of suits, image concepts and techniques of experimental tapissary. This is, first of all approach to the suit as a semiotic product, visual message of which is characterized by artistic interpretation of philosophical-aesthetic conceptions of the world order. In terms of spatial configuration, new was the fact that abstract language of forms resulted in emergence of new model paradigms of suits and costumes.

Use of non-traditional textile and non-textile materials for creation of new sensation of space and expression of philosophical and metaphysical conceptions has inspired unbelievable diversity of ideas regarding suits and plastique.

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MODEL OF ABSTRACT SYSTEM OF SUIT-DESIGN LANGUAGE

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At the present stage of investigation, theory and model of the suit-design language system are hypotheses of different levels. A hypothesis, formulated in form of a theory, has more general character and cannot adequately be more detailed, with the best will to reach it [3]. Therefore, theory should be accompanied by a hypothesis – a model. Model of the suit-design language system has a more exact character, it is more detailed. The model is relatively independent, compatible with the theory, developed on its basis and is capable to prove hypothesis by facts from experience. In Table 1, a schematic model of an abstract system of a suit-design language is given, which consists of divisions (vertically) in two aspects: concrete – visible and abstract – distracted.

T a b l e 1. Theoretical model of the system and structure of suit-design language

Levels of system of CA	Concrete aspect. Units of expression plan.	Theoretical aspect. Units of contents
0	Integral-distinguishing attributes of explication element.	Integral-distinguishing attributes of pre-image (seme)
1	Explication integral of pre-image	Pre-image
2	Integral of explication of morphs	Morpheme
3	Integral of explication of icons	Icon
Speech level units		
4	Mapping explication integral	Proposition
5	Explication text integral	Presupposition

Table 2 represents a complicated character of the system and structure of suit-design language which includes five classes of the linguistic form, interacting in reality simultaneously, and being also perceived simultaneously by a viewer, i.e. all explication of suit-design signs is perceived integral, as an integral unity.

T a b l e 2. Overlapping units of suit-design language structure with the structure of parts of suit-design speech

<table>
<tr><th rowspan="2">Levels CA</th><th rowspan="2">Units of expression plan</th><th colspan="5">Parts of suit-design speech - with independent meaning - in the structure of suit-design language</th><th rowspan="2">Abstract aspect. Units of contents plan CA</th></tr>
<tr><th>N class</th><th>P class</th><th>A class</th><th>N-A class</th><th>D class</th></tr>
<tr><td>0</td><td>Integral-distinguishing attributes of explication element.</td><td rowspan="2">Objectivity of body.
Minimal element of body.
Silhouette of body (pictorial image).</td><td rowspan="2">Process of body movements.
Minimal element of body movement.
Beck.</td><td rowspan="2">Attributeness of natural objectivity of covering.
Minimal element of natural covering.
Skin, hair.</td><td rowspan="2">Objectivity and attributeness of artificial covering.
Minimal element of artificial covering.
Material.</td><td rowspan="2">Attributeness of nonsubject membership.
Minimal element of action.
Act.</td><td>Integral-distinguishing attributes of of pre-image (seme)</td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Element of pre-image explication (matter and light)</td><td rowspan="2">Pre-image</td></tr>
<tr><td colspan="5">Explication integral of pre-image</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Morph (matter and light)</td><td>Part of body-build's form.</td><td>Gesture (small).</td><td>Part (area) of natural covering.</td><td>Construction part of artificial covering.</td><td>Action.</td><td rowspan="2">Morpheme</td></tr>
<tr><td colspan="5">Integral of explication of morphs</td></tr>
</table>

Table 2, continued

3	Icon (matter and light)	Belt of body-build's form	Posture, gesture (dynamic)	Belt of of natural cov-ering	Item of artificial covering	Conduct	Icon
		Integral of explication of icons					
Speech level							
4	Mapping (matter and light)	Figure of individual	Manner of walking of individual	Face of individual	Set of items of individual's artificial cov-ering	Behavior of individual	Proposition
		External look of individual					
		Mapping explication integral					
5	Text (matter and light)	Personality (internal conceptual unity)			Suit-covering of a personali-ty	Behavior of a person	Presuppositi on
		Explication text integral					

Conception of "integral of explication of a pre-image" is minimal, but very complicated unit of the suit-design language system, expressed in two essentialities: material (perceptive) and abstract (ideal). Physical aspect of base unit is given to perception in two types of substances: matter and light substances. This way, splitting into matter and light pre-image takes place.

Analog of the conception of "pre-image of the system of suit-design language" is the "phoneme" conception of the natural language. There is much in common between them. So, comparison of the substance of phoneme sound and of the substance of light of pre-image indicates that they have wave nature. Human ear perceives sound at a certain distance from the source of sound, also human eye does not touch the surface of a thing, but perceives only the light reflected from it. Precisely that way, visual communication in suit-design language takes place. In ordinary life, people do not separate initial visual impressions (which are a light reflection of a subject) from reality itself. Subjectively, visual image for normal perception acts not as reflection, but as reality itself. Virtually, creative activity of an art designer is based upon the substance of light. By processing, he transforms the thing, mostly for the sake of a visual effect and light impression from it. That's why it is easy to verify visual impression on a drawing, since contour of a form, color, etc. are adequately mapped on paper with colours. However, it is better to implement the technological idea in a natural model.

Modeling of light beam is opposed by meaning of light flux. This meaningful light is denoted by explication of light. The same happens with matter pre-image. Modeling of matter substrate is opposed by the meaning of substrate, which is called meaningful substrate, or explication of substrate. Both explications intersect in the consciousness: material value of a thing and its visual image. It will be recalled: "substrate" is material basis of different properties of an individual object, thing. "Meaning" is implication, i.e. that what this particular subject denotes. "Matter pre-image" is element of a perception unit of suit-design language, being material basis of uniformity of properties, forming a suit, including a person, reflected in the consciousness in form of semantic uniformity of sensations. "Light pre-image" is element of a perception unit of suit-design language, being material basis of uniformity of properties of things, forming a suit, reflected on the retina of organ of vision in the consciousness as semantic uniformity of light beams. "Explication integral of pre-image of suit-design language system" is a complex structural phenomenon, analysis of which is stated in our paper [1]. It should be noted that pre-image is a minimal unit of suit-design language (for instance, atom is also the smallest particle of a chemical element) has a complex structure.

In our paper [2] investigation considers as main element class of N-A units, i.e. pre-image of material, from which all consequent units of this class originate: morphs, i.e. strips of designing elements; small items (collars, fastenings, etc.), clothing items (blouses, skirts, etc.); representations – sets of suit items. Finally, all these items form artificial covering of a suit.

Let us consider another class of linguistic form of suit-design language system – N class – bearer of a suit – human. In contrast to material, human bearer remains always an integral physical body at all levels of suit-design language system. With a great degree of conditionality, properties and features of bearer's body can be separated from each other, relating them with one or another level of the suit-design language system. Nevertheless, at each level of suit-design language system not all, but only individual features, properties and qualities of a bearer are highlighted and used in different combinations. It can be said, in some cases with more confidence, in other cases – with less confidence that at the level of the suit-design language system certain role will play such attributes, like body-build, certain belt of body-build's form and even a part of body-build (leg, hand, neck, etc.) an of course silhouette of body, as minimal object of bearer's body. In fact, minimal size of an individual, which does not destruct his integrity as a physical body, is element of body expressed with the conception "silhouette" meaning external contour of the body-build's form. Silhouette is element of integral's explication of pre-image, in other word, is a minimal unit of the suit-design language system, "element of explication of pre-image" (seeTable 2). By comparing interplay between N class and N-A class, we can understand which attributes, properties and qualities of an individual, as a physical body, influence the attributes, properties and qualities of N-A class units.

So, N class, representing a body of an individual-bearer of suit, as an unit of suit-design language system, can be subjected to "segmentation" both in smaller, as well as in bigger units of suit's language system.

Relations between levels of a concrete class of suit-design language units are based on hierarchy. A concrete unit is separated, for instance in N-A class; set of items of artificial covering, item of artificial covering, part of a construction of artificial covering, material, minimal element of material, integral-distinctive features of an element of artificial covering. Units of higher level include units of lower level.

Relations between levels of N unit classes are also based on the hierarchic interplay: figure (body) of an individual, belt of the body-build form, silhouette of body-build as a minimal element of pre-image, integral-distinctive features of of an element of pre-image of the individual-bearer's body-build. All units are classified on the basis of the objectivity attributes of body as a physical object.

However, we should mention an important restriction: all above mentioned relations exist within the specified object, i.e. in the suit-design language system.

Units of not only artificial covering, but also units of natural covering are used in the suit-design language, with great degree of conditionality, selected on the basis of relevance phenomenon and meanings, related also to the level of suit-design language system. Artificial and natural covering of the bearer is in close interplay and mutual influence, replacing each other. The relevance phenomenon does express the degree of reaction of two coverings to certain meanings.

Let us shortly consider and compare with each other another two classes: Class P and class D. These suit-design language units are based on the substrate of physical movements of body, caused by reflection of large, medium and small muscles of human. However, difference lies in the fact that P class is related to an individual, while D class is related to a human personality. Difference between anthropological and social aspect of human development can be clearly traced in the difference of conceptions of individual and personality. "Individual" is a concrete person or individual, independently existing organism. "Personality" is an adult person, completely involved into the sphere of labour and into the system of public relations. Individual becomes personality, but does not discontinue to be an individual. Culture of utilization and wearing suits is a part of social relations; to a great degree, it is related more to personality, rather than to individual; however, it is based on physical attributes and qualities of individual.

Suit-design language units of these classes are correlated in the suit-design language system (see Table 2).

The conducted investigation is based on the linguistic-semiotic approach. As a result, we have segregated units of suit-design language, determined their place in the suit-design language. Each unit is located at a certain level of the system. As a level of language is that part of its system called, which has the appropriate unit. There is a level of "speech units" (text), having in mind dress; this was assigned to the sphere of composition; level of "mapping" units is assigned to syntax; level of "icons" and "morphs" is assigned to morphology (see Table 2). More detailed description of suit-design language, as well as description of morphology and stylistics of suit, is presented in our papers.

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BASIC THEORETICAL PRINCIPLES OF THE ELECTRIC ANALOGY METHOD

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A task is set to develop electrical analogy method for analyzing and designing electromechanical systems of technological equipment with consideration for properties of fibrous products and dynamics of its movement during formation and transportation process.

Specific of the developed procedure is its physical orientation on the basis of the electrical analogy method, i.e. representation of electrochemical systems in form of equivalent electric circuits. Analog modeling of electrical networks is the most convenient means for analysis and designing of technological and dynamic modes of operation of complicated textile equipment and for implementation models on a PC.

Direct analogy mathematical model for electromechanical systems is an electrical network. It is easy to convince oneself in identity of mathematical descriptions by comparing equations of electrical networks with equations of the prototype mechanical system.

The model under consideration is based on the electric analogy principle, where elements of mechanical systems are represented and regulated.

Comparison of the model of direct analogy of electromechanical system in form of electric network and structural model demonstrate that the first one distinguishes itself by a significantly greater visualization, since each mechanical element has its electrical image.

It is shown below that electrical network–analogue appears to be convenient also for pure circuit analysis of complex electromechanical systems, their transformation and simplification.

At present, structural models are implemented with the aid of modern computers and with the appropriate software.

Advantage of direct implementation of simulative model electric circuits becomes apparent when prototype systems have a great number of linear passive elements (inductances, L; capacitances, C; resistive elements, R), i.e. they have a branched electrical network and complex mechanics.

Electrical network remains a visual and generalized image of a prototype system also with indirect method of its implementation thanks to advantages of electrical analogy. With indirect methods, electrical network model is implemented completely as a circuit design, directly according to the diagram of this circuit, enabling each element to change its parameters independently. In this case, a special "four-terminal network method" was used.

In this article, based on the above said, along with well-proved principles of structural modeling of electromechanical systems of technological equipment, possibilities of direct and indirect use of electrical analogies of mechanical systems, as well as issues of generalization of experimental data and development of engineering and designing methods for solving problems of controlling process of formation, winding-up and transportation of materials are considered.

It should be stressed that method of generative electrical modeling provides a better visualization of physical process, which enables to go into the heart of the matter, and sometimes to discover some logic and regularities in the system, which are difficult to identify when solving problems with regard to separate individual cases.

Characteristic feature of correct statement of modeling problems consists in physical approach to investigations carried out on models [1]. A model is analyzed and revised part by part by means of conducting additional experiments in individual systems, which can be analyzed separately, for instance, by introducing disturbances, carrying out linearization, etc.

It should be stressed that issues of employment of electrical modeling of dynamic systems did not receive sufficient attention in technical literature.

For a wide class of nonlinear problems of dynamics of electomechanical systems with forwarding and twisting mechanisms, namely, for cases when electromagnetic inertia of drivers should be taken into consideration, family of nonlinear mechanical characteristics, deformation properties of products of spinning and other factors, to investigate dynamics of systems considering flexible and elastic couplings in power transmissions, employment of structural modeling method, especially direct analogy method, requires development of special procedures, which are beyond of the scope of standard methods of modeling with differential equations.

Formation of equivalent electrical circuits of models for mechanical systems is carried out in accordance with the electromechanical analogy theory [2].

Let us consider electromechanical analogy theory with regard to modeling of elastic systems consisting of finite number of lumped mass, which is connected with elastic couplings. Elastic system, position of which is determined with the aid of n independent coordinates, is a system with n degrees of freedom.

A distinction is made between mechanical systems with linear and angular movements, which are expressed with similar equations. For the purpose of analysis of deformation properties of fibrous product during its transportation, let us define fundamental quantities of longitudinal displacement of the mechanical system: linear displacement y, m; force F, N; mass m, kg; rigidity $c_п$, N/mm; compliance $e_c=1/c_п$, mm/N; frictional resistance $S_{f.r}$, N·s/mm.

Electric models in form of circuits and passive elements can be built according to two electromechanical analogy systems [3].

A real mechanical structure during modeling, as well as during analytical study is represented in form of a dynamic system consisting of idealized elements.

One-dimensional linear mechanical systems contain elements (components) of three types: elastic, inertial and friction ones.

Elastic elements are marked by the fact that in them there is a restoring force (proportional to the extent of element's deformation), which counteracts the relative displacement of ends (deformation). Elastic element is represented in form of an idealized spring, which is deprived of friction and mass.

Inertial elements are represented in form of "material points" - absolutely rigid bodies and are described with the aid of absolute displacements.

Elements of (linear) viscous friction are those in which a force counteracts relative displacement of ends, being proportional to the speed of relative flow. Similar to the fact that idealized elastic elements are deprived of friction, friction elements are deprived of elasticity and mass. It is common practice to designate elements of (linear) viscous friction as $S_т$, N·s/mm.

Mechanic elements m, e, $S_т$ are simulated accordingly by passive elements of electrical network L, C, R. External elements effect the elastic system, which, in general case, can be time variant according to any law. External force is simulated by voltage source U(t), internal resistance of which is low. Values of external forces, assigned in the simulator (model), will not depend on the load, i.e. from the network which simulates the elastic system.

It is assumed that with application of loading of the prototype system values of external sources also do not change.

According to analogy system, circuit of electric model copies the representation of the mechanical system.

Mechanical elements and their electrical analogues are presented in Fig.1.

It is advisable to employ method of four-terminal network to construct electrical models of complex dynamic systems consisting of elastic, inertial and friction elements connected in form of chains of these elements or containing several branches from such chains [4]. Method of four-terminal network enables to use a unified approach to solve problems with lengthwise and twisting movements.

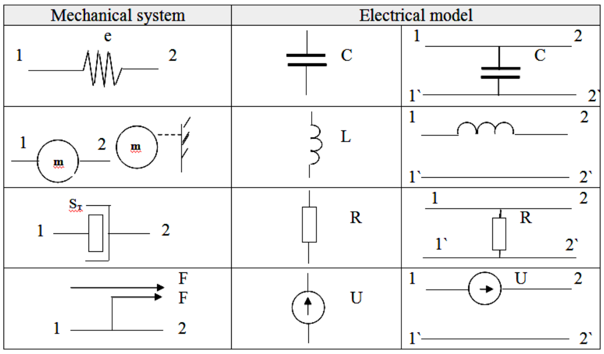

Fig. 1. Mechanical elements and their electrical analogs

A model is constructed from separate elements of four-terminal networks the same way, like prototype system is composed from elements-components. Each element of the prototype mechanical system is replaced by an element of electrical model – by a four-terminal network representing relations between forces and dynamic displacements at the ends.

Fig. 1 displays equivalent networks (four-terminal networks) for elements of elastic system under tension and twisting. Lumped mass has a equivalent network in form of inductance. Models of friction element are four-terminal networks, which have ohmic resistance.

In coupling points of passive four-terminal networks (replacing elements of the mechanical system) voltage sources are included, which correspond to application of external forces.

Open-circuit terminations of four-terminal networks correspond to a rigid fixation of end of the mechanical element. Short-circuited outputs of the four-terminal network correspond to free points.

The direct analogy method being used provides physically a clearer idea of systems under consideration, possesses certain advantages in simulating systems with reversible transducers of energy. On the basis of direct analogy method, controlled four-terminal networks can be created, which represent elements of electromechanical systems and areas of movement of fibrous products, with the aid of which different operational modes can be investigated (including high-speed mode).

Important advantage of this method is the fact that models offer the possibility to increase reliability and accuracy of simulation results. This can be explained by the fact that this method enables to construct models not on the basis of formal display of initial equations of the system under investigation, and according to the equivalence principle of equations of object and model with regard to results to be obtained, i.e. to make correction on the basis of simulation of real characteristics of electromechanical systems.

On the basis of the above said, employment of direct analogy methods for some problems of elecromechanics is quite justified, especially when utilization of methods of the automatic control theory and computers raises the capabilities of passive electrical networks with R, L, C.

On the basis of electromechanical analogy method the authors have studied dynamics of fibrous material in the controlled area of the card; in addition, they have studied process of formation of the lay at the outfeed of the card's measuring hopper. Drafting and forming zones are represented as systems of automatic control [4].

CONCLUSION

Along with well-proved principles of structural modeling of electromechanical systems of technological equipment, possibilities of direct and indirect use of electrical analogies of mechanical systems, as well as issues of generalization of experimental data and development of engineering and designing methods for solving problems of controlling process of formation, winding-up and transportation of fibrous materials are considered.

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DRYING AND MOISTENING OF THIN MATERIALS IN HUMID AIR

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This study is a survey devoted to research of heat-and-mass transfer between thin wet materials and humid air conducted at the department "Industrial thermal engineering" of MSTU named after A.N. Kosygin. Conception of thin material contemplates small values compared to the unit of heat and mass transfer Biot numbers. The first value of two is determined in a traditional manner, determination of the second one is given in [1]. Under these conditions, temperature fields and humidity content fields are uniform by thickness, which enables to neglect regularities of heat and humidity transfer inside the material.

Equations of energy and mass transfer, describing change of temperature and humidity content of wet materials, are formulated on the basis of balance relations:

$$M_с c_с \left(1 + W\frac{c_с}{c_ж}\right)\frac{dt}{d\tau} = \left(\alpha_к + \alpha_р\right)\left(t_в - t\right)F + rM_с\frac{dW}{d\tau}, \tag{1}$$

$$M_с\frac{dW}{d\tau} = \mu\beta\frac{\chi_в - \chi}{1-\chi}F, \tag{2}$$

where M – mass; c – specific heat per unit mass; r – specific heat of phase transfer; μ – molar mass of water; τ – time; α and β – heat and mass-transfer coefficients; F – surface area of heat-and-mass-transfer; $\chi_в$ and χ – molar fractions of water steam in air and on the material surface. Indices "s, zh, v, k, r" belong to dry material, liquid, air, convection and heat-transfer factors. There are no special emitters, only radiation of environment is taken into consideration, with temperature that is equal to air temperature.

Denominator in the right part of the equation (1) takes into account correction for Stefan's flow in the course of masstransfer.

These equations are transformed as follows. Mass of dry material is determined using specific density m (mass of 1m^2) and surface area. Convection heat-exchange coefficient is expressed through its value for low intensity of mass transfer and correction for final velocity of mass transfer according to film theory [2]. Mass-transfer coefficient is transformed in a similar way, moreover, value of the last one for low intensity mass transfer is expressed by heat-exchange coefficient for the same conditions $\tilde{\alpha}$ using the heat-and-mass transfer analogy. Besides, nondimensional time (nondimensional coordinate for a material moving with a constant velocity) X is entered.

As a result, equation system is transformed as follows:

$$\left(1 + \frac{c_ж}{c_с}W\right)\frac{dt}{dX} = B\left[\left(\frac{\ln(1+\psi)}{(1+\psi)^B} + \frac{\alpha_р}{\tilde{\alpha}B}\right)\left(t_в - t\right) - \frac{r}{c_п}\ln(1+\psi)\right], \tag{3}$$

$$\frac{dW}{dx} = -\frac{c_c}{c_п} B\ln(1+\psi), \qquad (4)$$

where

$$B = \frac{c_п \mu_п}{c\mu} Le^{1-n}; \quad X = \frac{\tilde{\alpha} x}{2c_c m_c w} = \frac{\tilde{\alpha}}{2c_c m_c \tau}; \quad \psi = \frac{\chi - \chi_в}{1-\chi}; \qquad (5)$$

Le =a/D – Lewis-Semenov number that is determined using temperature conductivity of air a and diffusion coefficient of vapor in air D.

Value of molar fraction on the surface of the material has been determined using atmospheric pressure p_{at}, saturated-vapor pressure at temperature of the material $p_s(t)$ and equivalent relative humidity φ on the surface of the material and it corresponds to $\varphi p_s(t)/p_{at}$. Value φ in the range of capillary-bound moisture corresponds to $\varphi \equiv 1$, and in the absorbing area, by $W < W_{md}$, is calculated based on the equations (3):

$$\ln\varphi = \frac{\varsigma}{\rho T^2} - \left(\frac{\nu}{W} - \frac{\rho\gamma}{W^2}\right)\exp\left(\frac{\alpha}{T}\right), \qquad 0{,}07 \le \varphi < 1, \qquad (6)$$

$$W = b\varphi/(a + \varphi), \quad 0 \le \varphi \le 0.07, \qquad (7)$$

where

$$a = \frac{b - W_*}{W_*} \exp\left[\frac{\zeta}{\rho T^2} - \left(\frac{\nu}{W_*} - \frac{\rho\gamma}{W_*^2}\right)\exp\left(\frac{\alpha}{T}\right)\right], \qquad (8)$$

$$b = W_*\left[1 - \frac{1}{1-\left(\frac{\nu}{W_*} - \frac{2\rho\gamma}{W_*^2}\right)\exp\left(\frac{\alpha}{T}\right)}\right], \qquad (9)$$

with W_{md} calculated according to equation (6) by φ = 1. Values of material and energy constants in equations (6) ÷ (9) are given in Table 1 [3] for desorption cases that are characteristic for drying process, and sorption that is characteristic for moistening process.

Table 1

Types of fibers	α,K	Sorption ς·10⁻⁷, Pa·K	Sorption ν·10³	Sorption γ·10⁹ v³/kg	Desorption ς·10⁻⁷, Pa·K	Desorption ν·10³	Desorption γ·10⁹ m³/kg
Raw cotton	1050	4,29	2,37	5,46	4,29	3,07	7,41
Ginned cotton	1050	4,29	2,29	7,00	4,29	3,00	9,56
Mercerized cotton	1050	4,29	2,73	7,88	4,29	3,58	12,20
Raw silk	1230	6,28	2,27	2,48	6,28	2,78	5,36
Degummed silk	1230	5,24	1,81	7,60	5,24	2,18	5,54
Fine wool	1080	5,15	4,14	1,75	6,67	5,91	1,75
Harsh wool	1080	5,15	4,24	1,75	6,67	5,23	1,75
Viscose rayon fiber	740	4,74	13,7	55,8	4,74	10,5	17,3
Acetate cellulose fiber	640	2,42	5,32	7,60	2,42	7,45	21,1
Cupraammonium fiber	960	5,07	5,52	20,3	5,07	6,88	27,6

Reduced equation system was solved numerically at given values of temperature and pressure and relative air humidity and initial parameters of fiber t_0 and W_0. In Fig. 1 the following is given: change in parameters of fiber – moisture content W, temperature t, rate of drying, determined as $R_d = -dW/dX$, as well as air temperature $t_в$ in the process of drying, which continues until equilibration state is reached, during which rate of drying is transformed into zero, values of air and fabric temperature become equal, rate of drying is transformed into zero. The diagram demonstrates three characteristic stages of drying – initial period, periods of constant and decreasing rate of drying. During the initial period temperature of fabric can rise or drop depending on the relation between the initial temperature t_0 and temperature of wet-bulb thermometer $t_М$. With $t_0 < t_m$ temperature of fiber rises, in addition, if it is lower as dew-point temperature, i.e. rise of temperature, to a considerable degree, is caused by steam condensation from air. With $t_0 > t_М$ temperature of fabric decreases. During the period of constant rate of drying, temperature of the material is coincident with t_m. Period of decreasing rate of drying is caused by removal of hygroscopically bound moisture.

Comparison conducted with results of the experiment for a fine cotton fabric revealed satisfactory agreement at air temperatures up to 100°C.

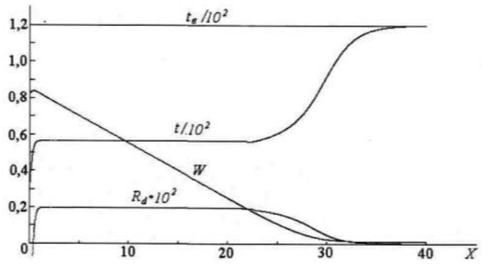

Fig. 1

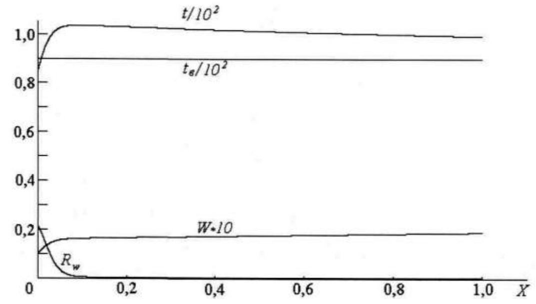

Fig. 2

The same equation system was used for description of fabric moistening processes at constant air parameters. In Fig. 2 initial stage of the moistening process and the same curves are given as in Fig. 1, except that the curve of rate of drying is replaced by a curve of rate of moistening determined as $R_w = dW/dX$. In this case, temperature of fabric can exceed air temperature due to heat emission of phase change, which includes also heat of sorption. This fact is known from technical literature and was established experimentally in earlier studies of other authors.

In order to describe processes of heat-and mass transfer at variable air parameters, the mentioned system should be accompanied by equations which determine the change of temperature of air and its moisture content. These equations take the following form [4]:

$$\pm g_в \frac{c_в}{c_т}\left(1+\frac{c_п}{c_в}D\right)\frac{dt_в}{dX} = B\left[\left(\frac{\ln(1+\psi)}{(1+\psi)^B}+\frac{\alpha_р}{\tilde{\alpha}B}\right)(t-t_в)\right] \mp \frac{c_п(t-t_в)}{c_f}\frac{dW}{dX}, \qquad (10)$$

$$g_в dD = \mp dW, \qquad (11)$$

in this case $g_в = G_в/G_т$. Indices "п, т" relate to vapor and fabric; D – moisture content of air.

In the equations (10), (11) in the terms with double sign, the upper one belongs to the case of direct flow, the lower one – to the case of counter flow.

System of differential equation system was solved numerically. In case of direct flow we obtain Cauchy problem – initial parameters of fabric t_0 and W_0 and air $t_{в0}$ and D_0 are set at the inlet to the dryer and give no rise to fundamental difficulties. With counter flow, initial parameters of fabric are set from one side of dryer, and those of air – from the opposite side, and during resolving the system we had to resort to iterative procedure according to secant method.

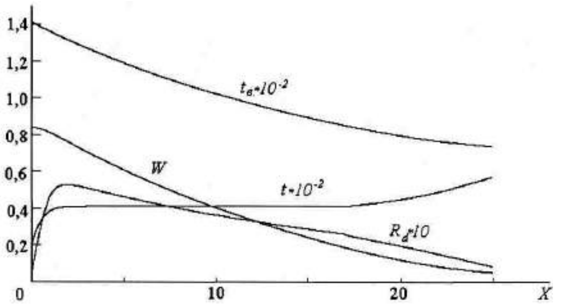

Fig. 3

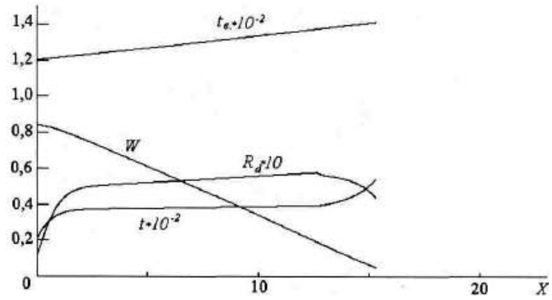

Fig. 4

Computing results are given in Fig. 3 for the case of direct flow, and in Fig. 4 for the case of counter flow. Designation of curves is the same as in Table 1. As we can see in both cases, sections of constant rate of drying are missing, though temperature of fabric changes insignificantly at the section of removal of capillary moisture (excluding initial period). The analysis revealed that this change is determined by dependence of thermal capacity on temperature. Removal of hygroscopically-bound moisture is followed by decrease of rate of drying and notable increase of temperature in the material.

Comparison of drying efficiency in the modes of direct and counter flow revealed that process duration and specific heat consumption in the last case are less. This difference is significantly bigger in case of relatively small air consumption.

Method for rating of a multisection dryer has been suggested. First of all, approximate method of rating [5] of distribution of suction devices along the length of the machine depending on the location of the point of release of waste air has been developed that enabled us to calculate air escape from one section into another one. On the basis of these data, equations of material balance on dry air and vapor, as well as heat balances have been formulated for a certain generalized section containing a section of fabric, section of safeguarding barrier, blower as a flow mixing unit and a heater [6], [7]. On the basis of such equations for separate sections, the whole drying machine was designed [8]. Design data are in satisfactory agreement with the data of industrial experiment which has been carried out by other authors.

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PROBLEMS OF DRYING DISPERSE MATERIALS AND ACTIVIATION OF HYDRODYNAMIC REGIMES

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More than 85% of materials to be dried undergo drying in disperse and dispersgated conditions in all industry branches, including fuel and energy and agricultural as well as industrial complexes [1], [2]. Since drying is the most power-consuming process from all technological processes, special attention during a selection of a drying device is to be paid to energy factors of the machine [3]. The most efficient tool is exergy analysis which enables, in addition to all the rest, to expose the weakness of execution of the hardware and technological process and available reserves for saving energy costs, including pressure losses [4], [5]. Development of optimal technical solutions and technological drying modes should be related to maximum efficiency of the process which for a long period of time had been related only to intensity. At the present stage of development of science and engineering with consideration for economy and market demand, the following four major factors are to be included into the concept of efficiency: intensity, economical efficiency, quality of final products and safety (including environmental and industrial safety) [6].

Selection strategy of optimal execution of the hardware and technological process of drying of a specific material should comprise the following six major stages: 1) integral analysis of materials as drying object; 2) determination of a type of the dryer on the basis of integral analysis and available classification of drying apparatus; 3) determination of optimal drying conditions with consideration for technological requirements to quality of the dried final product; 4) design of the apparatus with consideration for the required performance; 5) environmental and industrial safety of technological process; 6) value engineering.

With integrated analysis of disperse materials as drying object, the following five groups of characteristics are distinguished: thermal (heat conductivity, temperature conductivity, heat capacity, etc.), hygrothermal and kinetic (types of bond of moisture with materials, thermographs and energographs, drying graphs, etc.); sorption-structural (isothermal curves of sorbtion-desorbtion, amorphism and crystallinity, curves of pore distribution by sizes, etc.); technological (desired residual moisture, permissible temperatures, fire and explosion safety properties and others) [6], [7] as well as hydromechanical (size, form of particles, fluidizing and terminal velocity, angle of natural slip, adhesive-autoadhesive properties and others).

At present, express methods and efficient devices for determination of all characteristics of wet materials (for instance, determination of thermal characteristics by means of two temperature-time points method, determination of isotherms of sorbtion-desorbtion using vacuum Mach-Ben's scales and others) have been developed [2], [8].

One of the most important problems during drying of disperse materials is classification of materials as drying objects. When there are many thousands of materials to be dried, it is impossible for each material to develop an individual dryer. Therefore there is a need for standard dryers suitable for processing of materials which are similar in properties and belong to one class of the appropriate classification. Classification by sorption characteristics with consideration for adhesion-autoadhesion properties of dryable materials can be recommended [2], [7]. This classification by the critical size of pores, which determines the measure of diffusion resistance (and therefore time of the drying process) during drying of this material, as well as by value of adhesive-autoadhesive coefficient, which determines degree of clotting and adhesion of wet particles on the walls of the apparatus, enables to determine place of this material in the classification table and the efficient standard apparatus in accordance with this place (Table 1).

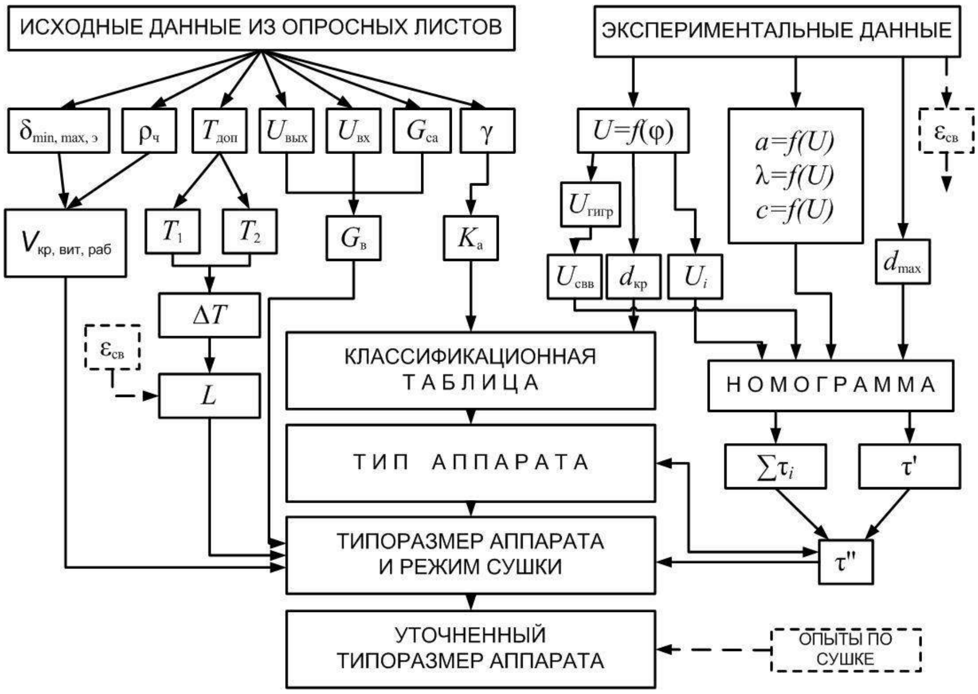


Fig. 1. Procedure of selecting drying apparatus on the basis of complex analysis of material as an object of drying

Nomenclature: $d_{ч_{экв}}, d_{ч_{max}}$ – equivalent and maximum diameters of particles; $\rho_ч$ – density of material particles; $\theta_{доп}$ – permissible temperature of material's heating; $\upsilon_{кр}, \upsilon_{вит}, \upsilon_р$ – gas velocities, correspondingly: critical, soaring working; $U_н, U_к, U_i, U_{мг}$ – content of liquid in material: initial, final, corresponding to filling of the i-group of pores, maximal hygroscopic; G, G_w – dry product and evaporated liquid-handling capacity; β – angle of natural slip; K_a – rank of adhesive-autoadhesive coefficient; L – consumption of drying agent; $d_{кр}$ – critical radius of pores; $Э_{св}$ – bond energy of water with material; $U = f(\varphi)$ – sorbtion and desorbtion isotherms; $a = f(U)$, $\lambda = f(U)$, $c = f(U)$ – dependences of temperature conductivity a, thermal conductivity λ, heat capacity c of material from content of fluid; $\tau, \tau', \sum\tau_i$ – total drying time, time of removal of free moisture and total removal of liquid from i group of pores.

Concept of active hydrodynamic regimes relates not only to drying of disperse materials: AHR – this is when by means of hydrodynamics significant intensification of drying process is reached (or another technological process) with good technical and economic indicators and quality of dried product.

We have developed a comparative assessment method of activity of hydrodynamic regimes using exergy analysis by the degree of exergy performance index. This method enables to select a hydrodynamic drying regime in a correct way. Useful effect obtained as a result of using active hydrodynamic regimes should be compared with the costs for their implementation.

As an index, characterizing thermodynamic efficiency of employed methods of activation of hydrodynamic conditions in the apparatus, it is advisable to use relation of exergy coefficient prior to and after employment of the above mentioned methods for alternative technical solutions. In this case hydrodynamic regime is to be considered as active (with regard to a specific material and utilization of instrumentation) for which the above mentioned index is bigger.

Expression for exergy performance coefficient can be obtained based upon the balanced heat to mass relations (1), (2). Using additivity law (relation 3), we can get from (1)…(3) equation (4), and inserting dimensionless groups (5) related to kinetic coefficient α and β, from relation (4) we will get (6) and then the expression (7) for exergetic coefficient of performance.

$$G_м \Delta h_м + Wz_n = \alpha F \Delta t_{cp}, \qquad (1)$$

$$G_м \Delta U_м = \beta F \Delta x_{cp}, \qquad (2)$$

$$\Delta h_c = c\Delta t_c + h_м \Delta x_c, \qquad (3)$$

$$\Delta h_c = G_м \Delta h_м \frac{c}{\delta\alpha F} + \frac{c\beta}{\delta\alpha}\Delta x_{cp} h_n + \Delta x_{cp} h_n, \qquad (4)$$

$$L_e = \frac{c\beta}{\alpha}, \quad g = \frac{G_c}{G_м}, \quad n = \frac{\beta F}{G_c}, \qquad (5)$$

$$\Delta h_c = \frac{L_e}{gn}\Delta h_м + (1 + \frac{L_e}{\delta})\Delta x_{cp} h_n, \qquad (6)$$

where Δx_{cp} – mean driving force of the process; $\delta = \frac{\Delta t_{cp}}{\Delta t_c}$:

$$\eta_e = \frac{\Delta e_n}{\Delta e_c} = \frac{\frac{1 - L_e \Delta e_м}{gn \Delta e_c}}{\frac{1 + L_e}{\delta}\Delta x_{cp.}}. \qquad (7)$$

Useful effect obtained as a result of using active hydrodynamic regimes should be compared with the costs for their implementation.

Exergy coefficient of performance can also serve as a complex indicator for evaluation of the hydrodynamic regime and degree of pollution of environment by thermal pollutants, which characterize ecological cleanness of industrial equipment. For instance, in the drying machine with active hydrodynamic regime, thermal component of exergy of interacting flows is subjected to the maximum change, therefore thermal exergy function could be used for transfer from thermal characteristics of these flows to exergetic ones.

For a more complete characteristics of the drying machine, a component is to be inserted in the exergetic coefficient of performance η_e, which takes into account hydraulic resistance of the machine and energy costs, caused by extraction of dried product from the vaporized state or costs for dust cleaning, regardless whether this process proceeds direct in the dryer or outside (8)…(10):

$$\eta_э = \frac{k_1 \eta_e + k_2 \eta_{сеп}}{2}, \qquad (8)$$

$$\eta_{сеп} = \frac{\eta_г + \eta_{ул}}{2}, \qquad (9)$$

$$\eta_г = \frac{\ln(P^{вх} - \Delta P) - \ln P_o}{\ln P^{вх} - \ln P_o}, \qquad (10)$$

where k_1, k_2 – relative level of damage from thermal and dust pollutants; $P^{вх}, P_o, \Delta P$ – pressure correspondingly: at intake into apparatus, environment and hydraulic resistance of equipment.

Results of exergy analysis demonstrate that active hydrodynamic regimes are resource-saving not only with regard to metal and production areas (due to small dimensions of equipment), but also with regard to specific energy consumption.

For disperse materials, which are processed in active hydrodynamic regimes, problem of calculating drying time without carrying out drying has been solved on the basis of simulation materials. Real materials have a complex structure and contain pores of different sizes, therefore drying time will depend on the quantitative relation of pores of different diameters. Emptying time of i-group of pores:

$$\tau_i = \frac{1}{\overline{N_i}} \frac{\rho_æ}{\rho_ì} \int_{d_i}^{d_{i+1}} f_V(d) d(d) = K_i \Delta U_i, \qquad (11)$$

where $\rho_æ$, $\rho_ì$ – density of absolutely dry material and liquid being removed during drying; f_V – function of distributing volumes of pores by diameter; K_i – coefficient, which is inversely related to mean speed $\overline{N_i}$ of removing fluid from i-group of pores; ΔU_i – content of liquid in the material, which corresponds to filling of pores with diameter ranging from d_i to d_{i+1}.

Total time τ'' of removal of liquid from pores of material, which has a structure of different pores, can be defined from the relation:

$$\tau'' = \sum_{i=1}^{i=n} \tau_i = \sum_{i=1}^{i=n} K_i \Delta U_i \,. \qquad (12)$$

Total drying time of porous material (with consideration for removal of free moisture):

$$\tau = \tau' + \tau'' = \tau' + \sum_{i=1}^{i=n} K_i \Delta U_i \,, \qquad (13)$$

where τ' – time of removal of free moisture, which usually ranges with active hydrodynamic regimes from fractions of a second to 2…3 seconds.

Average speed of removing moisture from each group of pores is determined by kinetics of drying of simulated materials with structure of different sizes in real apparatus with different temperatures of the drying medium. The obtained data in the aggregate with values τ', which we have defined with consideration for thermal characteristics according to a developed technique, enabled us to chart a nomogram for calculating kinetics of drying any material without conducting the tests on drying this material in real dryers. Comparison of kinetics of a computational experiment with a real one for 15 different materials has confirmed the efficiency of this method.

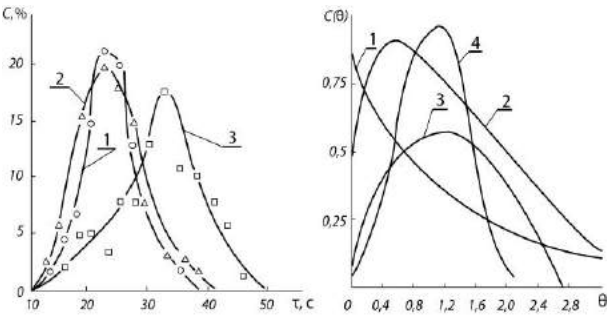
The procedure of selecting drying machines for disperse materials on the basis of a complex analysis of material as object of drying, using classification table of the calculating nomogram, is illustrated in Table. 1.

Table 1. Classification table for disperse materials

Index of technological task Bi'	Class of materials	Code (class, group, разряд)	$d_{кр}$, nm	Pores group	K_a	Index of dispersivety according to the dusty fraction		Characteristics of porous structure of material and type of moisture bonding	Drying time in active hydrodynamic mode
						Coarse	Fine		
Bi'<0.1 $\delta \le 3$ mm	First	1.1.1.	> 100	0	2	1		Nonporous materials with free moisture	0.5-2.0 s
		1.1.2.					2		
		1.2.1.			3	1			
		1.2.2.					2		
Bi' < 1 $\delta \le 3$ mm	Second	2.1.1.	100-8	1	2	1		Materials with wide pores and weakly bonded moisture (evaporation of liquid from liquid film)	3.0-5.0 s
		2.1.2.					2		
		2.2.1.			3	1			
		2.2.2.					2		
		2.3.1.			4	1			
		2.3.2.					2		
Bi'< 10 $\delta \le 3$ mm	Third	3.1.1.	8-6	2	2	1		Highly wet materials with transitional pores and bonded moisture (Knudsen diffusion)	10-40 s
		3.1.2.					2		
		3.2.1.			3	1			
		3.2.2.					2		
Bi' < 20 $\delta \le 3$ mm	Fourth	4.1.1.	6-4	3	2	1		Thin pores with free and bonded moisture (Knudsen and surface diffusion)	0.5-2.0 min
		4.1.2.					2		
		4.2.1.			3	1			
		4.2.2.					2		
Bi' > 20 $\delta \le 3$ mm	Fifth	5.1.1.	4-2	4	2	1		Micropores with bonded moisture (surface diffusion)	2-20 min
		5.1.2.					2		
20< Bi' <<30 $\delta \le 1$ mm	Sixth	6.1.1.	< 2	5	1			Ultramicropores comparable to size of molecules (solid state diffusion)	2-20 min

For each class of the developed classification table (mentioned above) of disperse materials as drying objects, standard machines are recommended which implement those hydrodynamic regimes being active during drying materials of this class.

In connection with the problem of dust cleaning, multi-purpose non-entrainment apparatus with counter-vortex flows and controllable hydrodynamics [7…12] hase been developed in recent years, which can be recommended as a new generation of standard apparatus for materials with critical diameter of pores up to 6 nanometers. Capabilities of dryers with counter-vortex flows are restricted by a short dwelling time, nevertheless, the authors [2] managed due to the new hydrodynamic regime – annular circulating bed - to increase dwelling time of dryable material by 5…6 times, which has enabled to use devices with counter-vortex flows for drying products of the third and partially of the fourth class according to a variant of classification of materials as drying objects which we have suggested, i.e. to expand the range of materials by several thousands of types, which are dried in dryers with counter-vortex flows.



a) b)

Fig. 2. Curves of response to impulse disturbance of input signal with different consumptions (a) (1 – L= 0.08 m^3/c; 2 – L= 0.09 m^3/c; 3 – L= 0.10 m^3/c) and C-curves (b): for ideal mixing apparatus (1), KS (2), with counter-vortex flows (3), with counter-vortex flows in the annular bed regime (L – □ – 0. 12 m^3/c; Δ – 0.10 m^3/c.

Taking into consideration dependence of quality of the dried product both from average dwelling time, as well as from the range of dwelling time of particles forming the bed, one of the tasks of experimental study of regime of annular bed was to record the curves of response to disturbance of input signal, which allow to obtain a curve of distributing disperse particles by dwelling time in the annular bed (Fig. 2).

Analysis and processing of experimental response curves given in Fig. 2-a have been carried out by means of the statistical method. Moments of the first and second order were defined which characterize dwell time and dispersion according to the following formulas:

$$\bar{\tau} = \frac{\sum_{i=1}^{n} \tau C_i}{\sum_{i=1}^{n} C_i}, \qquad (14)$$

$$\delta^2 = \frac{\sum_{i=1}^{n} \tau^2 C_i}{\sum_{i=1}^{n} C_i} - (\bar{\tau})^2. \qquad (15)$$

Nondimensional dispersion was calculated by the following formula:

$$\delta_\theta^2 = \frac{\delta^2}{\bar{\tau}^2}. \qquad (16)$$

Number of cells of hydrodynamic model of the device was evaluated by the value δ_θ^2:

$$n_{\ddot{y}} = \frac{1}{\delta_\theta^2}. \qquad (17)$$

The data presented in Fig. 2-a indicate that the dwell time reached is 5…6 times longer than with standard regimes.

Evaluation of range for dwell time can be obtained on the basis of C-curves response recorded during the experiments. In Fig. 2-b C-curve of response for device with counter-vortex flow in the regime of annular bed with different consumptions L in nondimensional coordinates in comparison with response curves of the device with counter-vortex flow operating in standard regime is presented (without forming an annular bed), fluidized bed apparatus and ideal mixing apparatus. The presented data indicate that the quantity of conditional cells, which characterize hydrodynamic conditions in the apparatus, equals for fluidized bed to 1.5…2, for the apparatus with counter-vortex flow in standard regime $n_{\ddot{y}} = 3 \div 4$, and for the apparatus with counter-vortex flow in the annular bed regime $n_{\ddot{y}} = 6 \div 8$. The obtained parameter evaluations $n_{\ddot{y}}$ of the hydrodynamic structure of flows in the apparatus are an indication of a possibility to achieve more uniform drying of disperse materials in the annular circulating bed in contrast to standard regime of the apparatus with the counter-vortex flow, and even more so, in contrast to fluidized bed apparatus, since with the increased number of cells more uniform drying is reached.

To facilitate selection and design of standard fluidized bed devices, which correspond in the best way to the assigned task, generalized codes are developed: technological tasks and their implementation, which contain information regarding difficulties of the technological task on drying of this material (regarding diffusion resistance during this material, its adhesion-autohesion properties, availability and absence of dust fraction), as well as information regarding optimal solution to this problem (efficient type of dryer, type of feeder of the drying apparatus, availability and type of special dust separator as a component of the drying apparatus, availability or absence of closed cycle of heat medium).

Recording polydispersity of dryable materials is a serious problem. Calculation is usually made based on big fraction (thus ensuring drying of finer fractions) or by using fractional drying. Reducing polydispersity index of dryable material allows this process to become significantly more efficient. One of the methods to solve this problem is establishing identical conditions for formation of disperse particles in the course of obtaining them (for instance, in annular reactors with mixers) [2].

In a number of technological processes it is possible to influence the capillary-porous structure in the course of production of disperse materials, for instance, during polymerization processes, which makes it possible to obtain easy dryable wide-pored materials instead of microporous ones, removal of water from which is related to significant heat and time waste to reach the required residual moisture of the dryable material (for instance, during polymerization when producing polyolefines) [2]. The same seems to be true also with regard to controlling adhesive-autoadhesive properties in the course of production of disperse materials to be dried, which has impact on associated equipment of dryers (feeders, measuring hoppers, discharging machines).

When drying disperse materials (but not only disperse materials), important problem is providing environmental and industrial safety of drying equipment [11], [13]. One of the core issues is providing dust cleaning and development of non-entrainment dryers. Significant progress has been reached in recent years in this direction, especially with regard to employment of non-entrainment dryers with counter-vortex flows and highly efficient dust separators with counter-vortex flow [11], [12]. At present, more than ten thousand of apparatus with counter-vortex flow of different design and versions (including group and multi apparatus) have been introduced into production, which make it possible to carry out non-entrainment drying, as well as dust arresting, containing extra-fine nano-size particles (up to 50…100 nanometers).

In addition, considerable advances have been made in creating methods and designs which allow to sharply decrease noise level and harmful impact of vibrations from operating drying machines, thus ensuring the required industrial safety [14…16].

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COMPUTER MODELING OF STRAND ELONGATION

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Computer models are considered, which allow to forecast dependence between the elongation of a strand of homogeneous threads and the strength of their strain (so called strain – strength (S-S) curves), if this dependence is known for individual threads of a strand and with consideration for statistical dispersion of breaking load and breaking elongation load of threads.

In the case, when deformation of threads is described by Hooke's law, and all threads have an identical elasticity module k, dependence of strain strength of a strand P(S) from its elongation S can be found analytically [1]. With elongation of the strand S, load on each not ruptured fiber will equal to kS. Number of ruptured fibers in a strand equals to

$$n_b = N\int_0^{kS} f(p_{max})dp_{max} = NF(kS), \quad (1)$$

where $f(p_{max})$, $F(p_{max})$ – density and function of breaking load distribution p_{max} of threads, N – initial number of threads in a strand, and dependence of strain strength of a strand from its elongation

$$P(S) = \left(N - n_b(S)\right)kS = NkS\left(1 - F(kS)\right). \quad (2)$$

Elongation value S_{max}, at which strength of strand resistance to elongation is maximal, can be obtained from the equation

$$dP(S)/dS\big|_{S=S_{max}} = Nk\left(1 - F(kS_{max})\right) - Nk^2 f(kS_{max}) = 0. \quad (3)$$

By substituting the obtained value S_{max} in (2), we will get maximum resistance strength $P_{max} = P_s(S_{max})$, generated by a strand during its stretching. The determined value P_{max} allows to evaluate yarn strength factor $\eta_{max}=P_{max}/(Np_{sr})$ by their average strength p_{sr}.

Below is a list of directions of model complexification: 1) difference of elastic deformation from Hooke's law; 2) inhomogeneity of yarn in a strand; 3) correlation between breaking elongation and yarn load; 4) statistical dispersion of parameters and characteristics of yarn deformation and its manifestation in strand's properties; 5) modeling of different conditions of strand stretching; 6) considering inelastic components of deformation and dynamic, for instance, pulsating loads.

Any complexification of a model should be justified from the point of view of its manifestation in the results with consideration for statistical dispersion of parameters. In order to ensure continuity between models and possibilities of endless complexification, it is advisable to switch over from analytical models to computer modeling of behavior of a strand during stretching [2]. For this purpose, modeling algorithm has been developed implemented in software, in which first four directions of the above mentioned list have been implemented.

In most of natural and chemical yarns, dependence p = φ(S) differs from a linear one, corresponding to Hooke's law [1]. In case of computer modeling, it is more suitable, as a rule, to approximate this dependence (obtained in a real experiment) by spline functions. In Fig. 2 this dependence is given for orlon fibers [3] and its approximation by polynomials of the 3rd, 4th and 5th order and cubic spline. Approximation by spline function appears to be more exact and is naturally incorporated into the modeling program. Let us indicate dependence being typical for a concrete type of fibers as $p_c = \varphi_c(S_c)$. Then with consideration for a real range of change of p and S from zero to p_{max} and S_{max} dependence for a concrete thread can be represented as follows:

$$p = \varphi(s) = p_{max}\varphi_c\left(S/S_{max}\right). \qquad (4)$$

In the simplest case of modeling, values p_{max} and S_{max} for a concrete thread are considered as independent and are random values with certain distribution laws. There is interest to define the effect of these random variations S_{max} and p_{max}, as well as deviations of dependence (4) from the linear Hooke's law on S-S – curves of yarn strand. To compare results of modeling, it is more convenient, instead of absolute values of strain P of a strand, to use relative specific tension of the thread η(S) and a portion of ruptured threads from their initial quantity a_b:

$$\eta(S) = P(S)/Np_{sr}\,;\ a_b = n_b/N. \qquad (5)$$

In model p_{max} ~ Norm(m = 5; CV = 20%); S_{max} ~ Norm(m = 4%; CV =25%); N = 200.

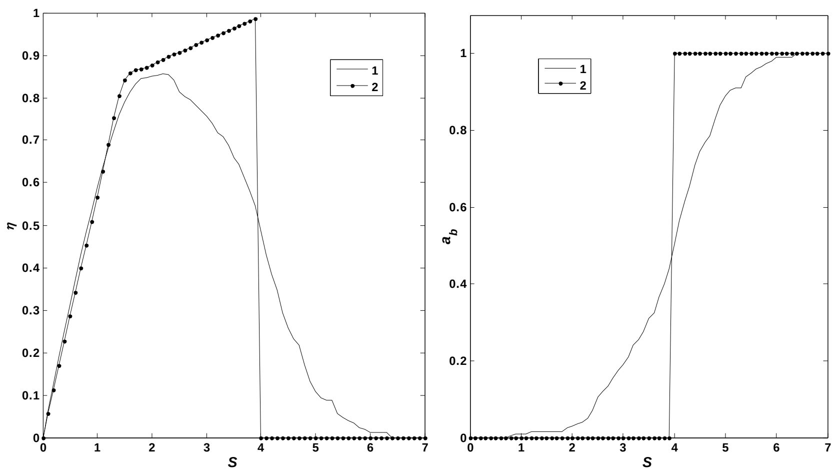

Fig. 1

The curves in Fig.1 demonstrate results of operation of the model. The curves 2 show results with CV S_{max} = 0. In this case dependence η (S) represents exactly the S-S – curve of yarn (Fig. 2). Threads rupture simultaneously, reaching breaking elongation mS_{max}=4%.

Scattering of values of yarn breaking strain with the coefficient of variation CVp_{max}=20% has practically no impact on the form of the curve, which is manifestation of the law of averages for large numbers (N = 200) of threads per strand. In fact, if N will be reduced to 10, then each new simulating of model will generate a curve of dependence η(S), which differs from the remaining ones.

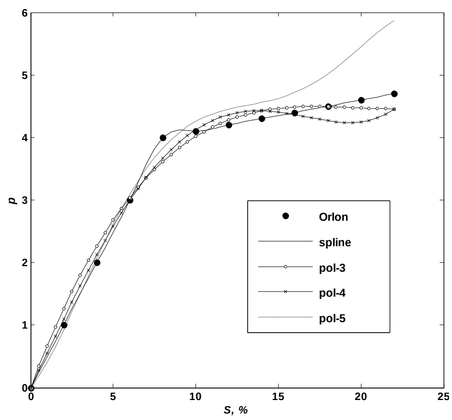

Fig. 2

Nevertheless, all these curves overlap with the accuracy up to the scale multiplier. In Fig. 3

curve 2 for N = 200 and curves 3…7 on five independent runs of simulating of a model with N = 10 are shown, which confirm the conclusion made.

On the contrary, scattering of values of breaking elongation of threads influences significantly the character of dependence η (S). Fig. 4 shows dependences η (S) and a_b(S) with different values of variation coefficient CVS_{max}: 0%, 5%, 10% and 25%. Increase of scattering in values of breking elongation of threads of a strand extends the curve η(S) along the X-axis, simultaneously decreasing coefficient of utilization of yarn strength η_{max}.

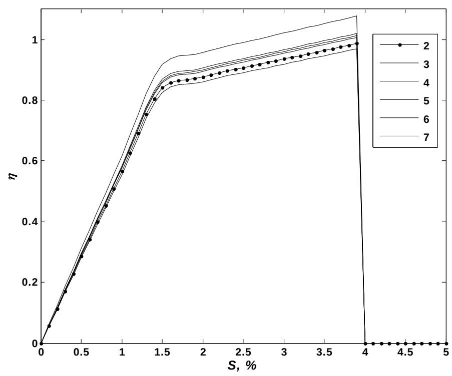

Fig. 3

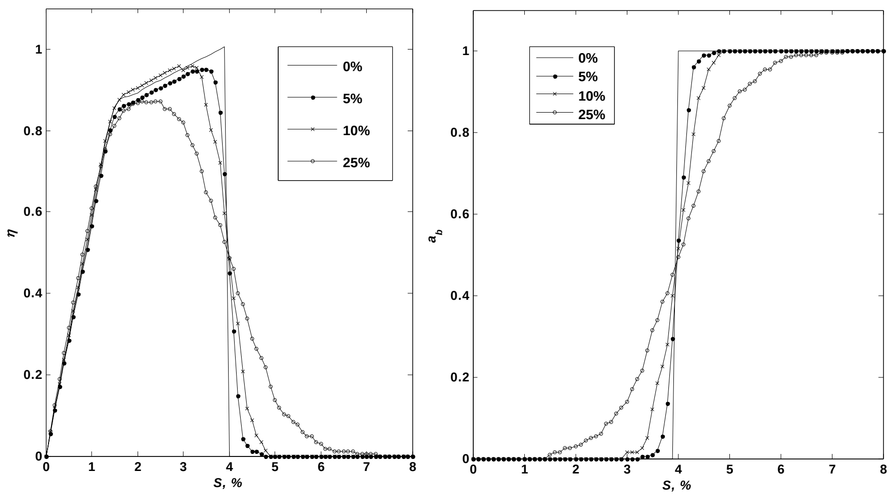

Fig. 4

Rupture of threads happens not simultaneously, but with different values of stretching of a strand, thus transforming from a single event into a process of gradual destruction, extended in time. Similar situation is observed for all homogeneous types of yarn, independently from specific of their S-S – curves.

With a small number of threads in a strand, for instance, N = 10, random scattering of values p_{max} and S_{max} will take place as a result of modeling. In Fig. 5-a assemblage of dependences, obtained with CVp_{max} = 0% and CVS_{max} = 25% with different realizations of random values p_{max} and S_{max} is shown. Results in Fig. 5-b differ only in the fact that they are obtained with CVp_{max} = 20%. Increase of scattering of yarn breaking load resulted in big difference in dependences with preservation of their general view.

By comparing dependences in Fig. 4 and 5, one can see that decrease of number of threads in a strand leads to appearance of characteristic step-like signals, which are related to break of concrete threads. With big number of threads in the stand, these areas are smoothed, since the number of "steps" increases, and their relative height decreases, and they become practically invisible on the graph. In order to confirm the aforesaid, in Fig.5-c graphs of dependence η (S) are given, obtained with fixed values CVp_{max} = 20% and CVS_{max} = 25% and different values n = 10; 20; 50; 100; 200. The curves are obtained in different realizations of values of random values p_{max} and S_{max}.

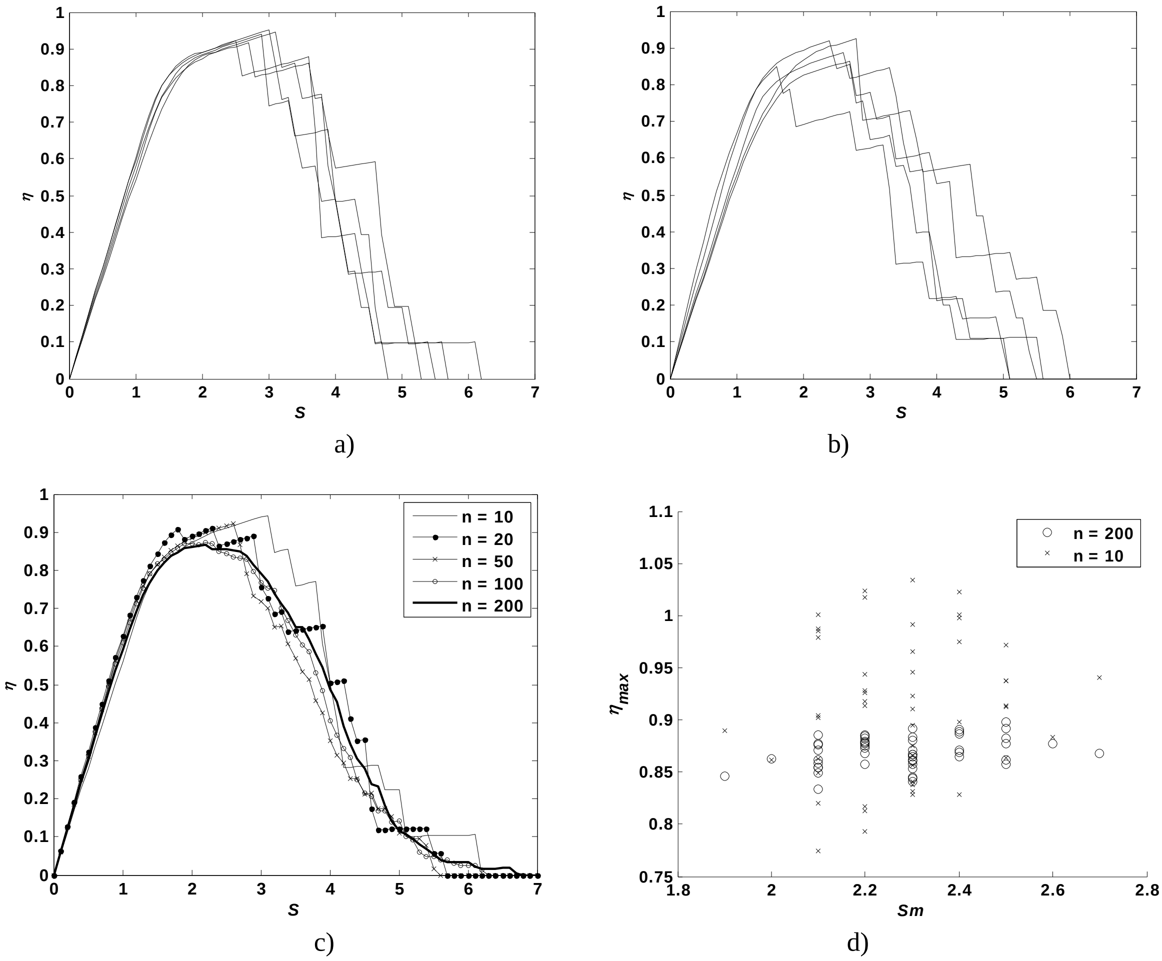

Fig.5

Probability scattering of values p_{max} and S_{max} leads to scattering of values of utilization coefficient of yarn strength in the strand η_{max} and the appropriate elongation of the strand, which we will denote with S_m. These values are determined by formulas

$$\eta_{max} = \max_{S>0} \eta(S),$$
$$S_m = \arg\max_{S>0} \eta(S). \qquad (6)$$

Fig. 5-d shows scattering graphs (S_m; η_{max}) obtained from 50 repeated simulating models with N = 10 and N = 200. With increase of quantity of threads in the strand, scattering η_{max} decreases significantly. Practically, there is no dependence of scattering of elongation values, when the maximum value η_{max} is observed, from the number of threads per strand. Portion of sample values η_{max}, being accounted for a certain value S_m, remains practically the same, irrespective of N.

Real yarn has correlation between breaking elongation S_{max} and breaking strain P_{max}, and one-dimensional distributions of these characteristics differ from a normal distribution.

When modeling is carried out, considering peculiarities of these yarns presents no problems. It is found that presence or absence of correlation of both signs between the breaking elongation and breaking strain will lead to differences only within the statistical dispersion of results, i.e. it does not influence the S-S – curves of the strand. Yarn deformation law along with the distribution law S_{max} and p_{max} significantly influences S-S – curve of yarn strand deformation. Difference not only in extremum values P_{max} and S_{max} are observed, but also in the shape of a curve. This way, during modeling of elongation of the strand of threads it is extremely important to correctly set up the law of deformation of individual threads both by a shape of a deformation curve, as well as by values of statistical dispersion of values.

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COMPUTER-AIDED EVALUATION OF MIGRATION DEGREE OF HETEROGENIC FIBERS AT CROSS-SECTION OF YARN

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There are known methods of evaluating migration suggested by J. Hamilton, M. Coplan, W. Klein, L. Rudolph, W. Onions, R. Toshnival, P. Townend, M. Kirshner. Mathematical analysis of these methods under condition of absolute random distribution of fibers across section has been carried out by authors of this paper. The analysis revealed that the examined indices have one or more drawbacks: impossibility to evaluate the statistical accuracy of the migration index, low level of statistical accuracy, bias of estimator.

Possibility to use computers lifts restrictions (related to labour intensity of computations) on designing migration index. The suggested method is based on section view of yarn, which becomes available for computer analysis with the aid of scanner. Operator marks with a mouse click the center positions of fibers of the 1st component, then of the 2nd component, etc. Computer processing of fiber center coordinates proceeds in 2 stages:

1. Reduction of yarn section to a circle (approximately) without distortion of the sequence order of heterogenic fibers in tangent direction, which also enables to evaluate in future the tangental unevenness.

2. Calculation of migration index and its statistical accuracy.

Several variants of determining migration index have been developed. Selection of the best variant with the aid of generating coordinates of fibers according to a law of accidental errors with different migration degrees of the 1st component followed by determination of discrimination and statistical accuracy. Discrimination is understood as the relation of absolute difference of values of the index for 2 different migration degrees to mean-square deviation of this difference.

Below is description of the suggested algorithm for calculation of index with the maximum discrimination for a sample of yarn section.

At first, position of center of gravity of the section is calculated. For this purpose:

– section is reduced to the circle (reduction algorithm is not given for reasons of space);

– distance to the center of each of N fibers is determined;

– the obtained distances are arranged in order of magnitude. Let us assume that the fiber, being the nearest to the center, takes the 1st place;

– arithmetic mean K_1 is determined from places, which are taken by fibers of the 1st component. With absolute random distribution of fibers across the section of yarn, place number, taken by any fiber, is random variable taking values 1, 2, ... N with equal probabilities 1/ N , where N – total number of all fibers in this section.

Mathematical expectation of this valueis:

$$T = \frac{(N+1)}{2}. \quad (1)$$

For this reason the value

$$S_1 = \frac{(K_1 - T)}{T} \quad (2)$$

may serve as a migration measure in a two-component mixture. In order for this measure to take values ±1 with full migration of the component outwards or inwards, the value S_1 is to be normalized to its value in case when fibers of the first component take first places (complete internal migration):

$$S_{1,min} = \frac{(n_1 - N)}{(N+1)}, \quad (3)$$

where n_1 – number of fibers of the 1st component in the section of yarn.

Having divided the right part (2) by the right part (3), we obtain migration index M_1 of the first component

$$M_1 = \frac{(2S_1 - N - 1)}{(N - n_1)} \cdot 100\%. \quad (4)$$

Migration index possesses the following properties.

1. With complete migration of fibers of first component its value corresponds to 100%.

2. With complete migration of fibers of first component outwards its value corresponds to 100%.

Migration indices of remaining components are determined by the formula (4) with the corresponding replacement of indices. For instance, migration index for second component equals to:

$$M_2 = \frac{(2S_2 - N - 1)}{(N - n_2)} \cdot 100\%. \quad (5)$$

Migration index for two-component yarn possesses the following property: Migration index of first component equals to zero and is opposite in sign to migration index of second component.

The above stated migration indices characterize only one section of yarn. Overall evaluation is made on the basis of arithmetic mean from indices for each section. Since process of obtaining the view of yarn section is quite labour intensive, it is important to be able to predict the required number of sections to reach the predetermined statistical accuracy. In case of absolute random distribution of fiber components across the section of yarn (i.e. with no migration) the stated accuracy can be predicted. It is important to do this since statistical error with zero value of migration index, of course, will be smaller (imagine yarn with 100% migration). It is sufficient to determine root-mean-square deviation for the two-component yarn. With absolute random distribution of fiber components across the section of yarn, place number of fiber (when moving away from the center), as has been said before, is an evenly distributed value with dispertion

$$D_0 = \frac{(N^2 - 1)}{12}. \quad (6)$$

In accordance with the sampling theory method, dispertion of arithmetic mean of place number for final assembly equals to

$$\frac{D_0 (N - n_1)(N - 1)}{n_1}. \quad (7)$$

Taking into consideration the fact that multiplying by a constant results in changing dispertion by the square of this constant, we get dispertion of migration index:

$$D[M_1] = \frac{(N+1)(N - n_1)}{3n_1} \cdot 10000. \quad (8)$$

Mean square deviation (MSD) of the migration index σ is

$$\sigma \approx 100 / \sqrt{3pq}, \quad (9)$$

where $p = n_1/N$ – portion of fibers of the 1st component in section; $q = 1 – p$ – portion of fibers of the 2nd component in section.

Using (9), it is easy to determine how many sections should be examined in order to obtain a predetermined statistical accuracy. It follows from (9) that the more composition of mixture differs from 50%/50%, the more sections of yarn are to be examined.

On the basis of the proposed algorithm a computer program has been developed which enables automation of process of entering initial data and calculation of migration index.

C O N C L U S I O N S

1. On the basis of the analysis of the available migration indices and computer modeling of results of employing possible migration indices, algorithm of determination of the unbiased migration index with a minimal statistical error (from the examined ones) has been developed.

2. Maximum possible dispertion of the suggested index has been determined, which reaches minimum value for 50%/50% composition of mixture (that is true for all "correct" indices of blending).

3. A computer-assisted program for determination of migration index has been developed.

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STUDY OF ALGORITHMS FOR RECOGNITION OF PIXEL IMAGE RAPPORTS

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Extensive use of information technologies in practical work of decorative design of dobby weave fabric resulted in the fact that original pixel images of woven fabric patterns are most commonly developed by designers in the graphics editor environment or are produced as a result of scanning of hard copies of pictures. These images are to be converted into a type which meets the requirements of the appropriate textile technology [1]. One of the tasks of the above mentioned conversion is recognition of repeatable rectangular fragments (rapports) in pixel images. It is assumed that rapports can apply to the original pattern entirely and have no common areas (overlapping).

Terms and algorithms used in this study are presented as pseudocodes with utilization of C programming language elements. Let us assume that pixel image is presented by means of bidimensional integer array A[m][n]. Furthermore, it is assumed that the width of the original pattern equals to n, and the height to m. Let us consider the integer array R[mr][nr] as a rapport which is a part of the array A[m][n] or is created from a part of the array A[m][n] as a result of processing: for(i=0; i<mr; i++) for(j=0; j<nr; j++) {ia=(id+i)/%m; ja =(jd+j)/%n; R[i][j] = F(A[ia][ja]);}, where F() − processing function, (id, jd) − coordinates of the left upper corner of the area A[m][n], from which rapport R[mr][nr] is formed, "%" − here and further it represents a division operator to obtain the remainder. The width nr can vary from 2 to n/2, and the height mr − from 2 to m/2. The limits of changes of rapport size are based upon the assumption that the pixel images under consideration are not monochrome (rapport is not degenerated into a pixel) and contain, at least, two rapports horizontally and two rapports vertically, one of which can be presented in A[m][n] only partially. The array V[m][n] is called overlapping of the image A[m][n] by rapport pixels R[mr][nr] which is obtained from R[mr][nr] as a result of the fol-

lowing calculations: for(i=0; i<m; i++) for(j=0; j<n; j ++) {if(i>id) ir=(i-id)%mr; else ir=mr-(id-i)%mr; if(j>jd) jr=(j-jd)%nr; else jr=nr-(jd-j)%nr; V[i][j]=R[ir][jr]}.

Let us evaluate the possible rapports by their overlappings of original images by means of W mismatch function: int W(A [m][n], V[m][n]) {int s=0; for(int i=0;i<m;i++) for(int j=0;j<n;j++) {if(A[i][j]<V[i][j]) s+= V[i][j] - A[i][j]; else s+= A[i][j] - V[i][j];} return s;}. Now the task of recognition of a rapport consists in determining the preset original image A[m][n] of the rapport of minimum size R[mr][nr], of such one that W(A[m][n],V[m][n]) → min. Images, for which R[mr][nr] is available are such that W(A[m][n],V[m][n])=0, will be called class 1 images. The second class of images is characterized by the fact that with any variant of R[mr][nr] the value of mismatch function exceeds zero: W(A [m][n],V[m][n])>0. Images of both classes are used in textile design. So, class 1 images are usually obtained as a result of repeat of a certain rapport in the graphics editor environment and are distributed on different storage media or by means of network technologies. The class 1 images are obtained as a result of scanning or by means of digital photographing. In this case, change of color of separate image pixels has a random nature and can be considered as just noise, laid over the true image.

Let us consider possibilities for utilization of full constructive enumeration for determining of class 1 image rapports. For each preset array A[m][n] we will enumerate variants of rapports R[mr][nr] in the order of increasing of their sizes considering the upper left corners A[m][n] and R[mr][nr] as matching ones, and calculating W(A[m][n],V[m][n]) of each R[mr][nr]. The purpose of such enumeration is to define R[mr][nr] for which W(A[m][n],V[m][n]) =0. To speed up the above described constructive enumeration, it is advisable to modify the mismatch functions: int W1(mr, nr, A [m][n]) { int ir, jr; for(int i=0; i<m; i++) for(int j=0; j<n; j++) {ir = i%mr; jr = j%nr; if (A[i][j] ≠ A[ir][jr]) { return 1;} }return 0;}. To enumerate R[mr][nr] in the order of increasing of their sizes, let us apply the variable pr, value of which is equal to the "semiperimeter of the array R[mr][nr]": pr=mr+nr. The pseudocode of the algorithm for determing of class 1 image rapports will then take the form of Rpt1 function: int mr=0, nr=0; /* variables mr, nr − global */ void Rpt1(A[m][n]) {int pr=0, prmax=m/2+n/2; for(pr=4; pr≤prmax; pr++) {mr=2, nr=pr-mr; if(nr>n/2){nr=n/2; mr=pr-nr;} while(mr≤m/2&&nr≥2) { if(W1(mr, nr, A [m][n]) == 0) return; mr++; nr--;}} mr=nr=0; return;}. When after completing Rpt1 the values mr of variables nr are not equal to zero, then R[mr][nr] = A[mr][nr]. With values of mr variables being equal to zero, nr for this A [m][n] does not provide rapport, exact repetition of which is overlapping this image. Without restricting generality of analysis results of time complexity of algorithms under consideration, it can be considered that m = n = K. Then, in worst case, calculation of the mismatch function W1(mr, nr, A [m][n]) will require execution of K^2 cycles, and, correspondingly, time complexity of function evaluation will be equal to: $T1(K)=K^2 \approx O(K^2)$. Call of the mismatch function W1(mr, nr, A [m][n]) is executed in cycle while((mr≤m/2)&&(nr≥2)). It is easy to verify that the mentioned cycle, depending upon the values of pr variable, is repeated the following way: 1, 2, …, K-3. Total number of repetitions of this cycle (recycling) determines its time complexity: $T2(K) = ((K-3)\times(K-2))/2 = (K^2 - 5\times K + 6)/2 \approx O(K^2)$. Consequently, asymptotic estimate of time complexity of Rpt1 algorithm, in the worst case, appears to be equal to $T3(K)= T1(K)\times T2(K) = O(K^4)$. Then, by K=1000, extraction of rapport by means of Rpt1 algorithm, in the worst case, will require about 1 hour time of computation with 10 GHz clock frequency.

Assume that now class 2 image array 2 A[m][n] is defined. As before, we will consider variants of R[mr][nr] rapports in the order of increasing of their sizes (mr, nr). For each variant of combining of values of mr and nr parameters we will consider all possible matches between the upper left corner of rapport and all A[m][n] points computing the value of mismatch function for each such match. The purpose of such enumeration is to define such combination of R[mr][nr] and coordinate values of its upper left corner (id, jd) for which the value of mismatch function appears to be minimum. We will compute the value of V[m][n] array by the following algorithm: for(i=0; i<m; i++) for(j=0; j<n; j ++) {if(i>id) ir=(i-id)%mr; else ir=mr-(id-i)%mr; if(j>jd) jr=(j-jd)%nr; else jr=nr-(jd-j)%nr; V[i][j]=R[ir][jr]}. In order to speed up the above mentioned enumeration of variants, it is advisable to modify the mismatch function as follows below: /*variables int mr, nr id, jd, − global */ long int W2(A [m][n]) {long int s=0; int ir, jr; for(int i=0; i<m; i++) for(int j=0; j<n; j++) {if(i>id) ir=(i-id)%mr; else ir=mr-(id-i)%mr; if(j>jd) jr=(j-jd)%nr; else jr=nr-(jd-j)%nr; if(A[i][j] < A[ir][jr]) s+=(A[ir][jr] - A[i][j]); if(A[i][j] > A[ir][jr]) s+=(A[i][j] - A[ir][jr]);} return s;}.

Taking into consideration the above stated remarks, Rpt2 function will execute extraction of rapport in class 2 images: long int Rpt2(A [m][n]) {int pr=0; int prmax= =m/2+n/2; long int wmin=255×n×m; long int ww =0; int mrmin=0, nrmin=0, idmin=0, jdmin=0; for(pr=4; pr≤prmax; pr++) {mr=2, nr=pr-mr; if(nr>n/2){nr=n/2; mr=pr-nr;} while((mr≤m/2)&&(nr≥2)) {for(int id=0; id<m; id++) for(int jd=0; jd<n; jd++) {ww= W2(A[m][n]); if(ww < wmin) { mrmin=mr; nrmin=nr; idmin=id; jdmin=jd; wmin=ww; } mr++; nr--; } } if(wmin==255×n×m) {mr=0, nr=0, id=0, jd=0;} else { mr=mrmin; nr=nrmin; id=idmin; jd=jdmin;} return wmin;}

The Rpt2 algorithm contains additionally, in comparison with Rpt1 algorithm, two nested loops for(int id=0; id<m; id++)for(int jd=0; jd<n; jd++), time complexity of which (taking into consideration the accepted assumption K=m=n) is equal T4= $O(K^2)$. Then, time complexity of the Rpt2 algorithm, in the worst case, can be evaluated using assessment for the Rpt1 algorithm: $T5=T3\times T4\approx O(K^6)$. This way, in the worst case by K=100, extraction of the optimum rapport in the class 2 image by the above specified method (Rpt2) will require about 1 hour of computation with clock frequency of 10 GHz.

C O N C L U S I O N S

1. The theoretical analysis of elementary algorithms reveals that these algorithms make it possible to extract rapports in the class 1 images, dimensionality of which does not exceed the dimensionality 1000×1000, or in class 2 images, provided that their dimensionality does not exceed the dimensionality 100×100.

2. To extract rapport in the images, dimensionality of which exceeds the mentioned limits, more faster algorithms are needed which will be discussed in the next paper.

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DEVELOPMENTS OF TECHNICAL TEXTILES AND CZECH NATIONAL TEXTILE CENTER*

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INTRODUCTION. The application of textile fibers and fibrous structures for technical purposes has long tradition. In medieval time textile based structures were used for buildings enforcement as assemblies (nets). One of first protective clothing was silk structures used by Mongolian tribes for protection against enemy's arrows. The ropes were used for transportation and anchoring purposes. Technical textiles were used for packing, protection or consolidation. Advent of composites extended application of technical textiles into industrial sphere. In this time sector of technical textiles is very important for many industrial branches: transport, medicine, agriculture, etc. Textile structures are now one of very special light construction materials with some extraordinary properties (as flexibility, shape changeability, viscoelasticity) and simple process ability.

In the first part of this paper the main branches of technical textiles and their development are discussed.

Second part is devoted to the description of National Textile Research Centre II (NTRC) activities in the fields connected with technical textiles.

TECHNICAL TEXTILES. Majority of textile fibers and fibrous structures can be used without problems for creation of technical textiles. For special applications as barrier textiles it is possible to obtain required effects by finishing techniques as coating, curing, lamination, grafting and top finishing combined with proper construction of fabrics. Especially for achieving of high tenacity and modulus or extra thermal stability the specialty fibers are necessary. These fibers have majority of required properties (mechanical, thermal, electrical, biological, chemical etc.) as intrinsic. On the other hand, there are problems with creation of textile structures (due to brittleness, low deformation to break) and finishing or dyeing. The prices of specialty fibers are generally high as well. More than 90% of technical textiles are still based on classical fibers.

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Technical textiles are classically defined by theirs special properties (electrically conductive, heat resistive, antimicrobial, antistatic, super absorbents etc.). The definition of technical textiles is not simple and therefore the classification based on the main areas of application is widely accepted (Table 1).

Table 1. Technical textiles and their development

Type	Application examples	Increase by year [%]	
		2000…2005	2005…2010
Geotech	geotextiles, civil engineering	4,6	5,3
Buildtech	buildings, constructions	4,3	5,0
Medtech	Hygienic and medical sector	4,6	4,3
Indutech	filtration, cleaning	3,5	4,4
Protech	Protection of humans and machines	3,3	4,0
Agrotech	Agriculture, horticulture, forestry	3,2	3,9
Pactech	Packing materials	3,2	3,8
Sporttech	sport, leisure	3,1	3,7
Mobiltech	cars, boats, ,trains, airplanes	2,7	3,4
Clothech	Trimmings, accessories	2,7	3,2
Hometech	Furniture coverings, carpets	2,7	2,7
Total		3,3	3,8

Prevailing technology of technical textiles creation is weaving. Weaved structures are widely applicable in all branches where the relative strength, shape stability and directional orientation are required. An example are geotextiles, composites and protective clothing. Knitted structures are due to their high shape instability traditionally used in medical sector. Now these materials are used for creation of 3D structures, braiding and special coverings (e.g. car seats). Knitted structures are covering about 3…5% of all technical textiles. In many cases weaved and knitted structure are replaced by nonwovens, especially for products where it is not necessary to have high strength and dimensional stability. The highest increase of consumption is for nonwovens and composites (5.6% yearly). All kind of technical textiles consumption increase is about 3.7% per year.

SOME WAYS OF TECHNICAL TEXTILE DEVELOPMENT. Development in the technical textiles branch is in close connection with technical level of civilization. Developed countries are not only using advanced technologies but are oriented to protecting human health, increasing quality of life and offering new way of relaxing or leisure activities. New textile structures are reflecting these needs and main innovative activities are focused into these products:

– “Intelligent” body adaptive response apparel textiles having improved comfort controlled by the state of microclimate and wearers needs.

– “Intelligent”-knowledge based technical textiles with specified properties (e.g. locally compressive behaviour) and complex actions (comfort type mattresses for disabled persons, intelligent car seats etc.)

– Hybrid multifunctional textiles for protective clothing combining improved protection (a barrier against the selected types of radiation and particles) with improved comfort.

Especially in the technical textiles branch improvement is influenced by:

– development of new materials and technological principles;

– simulation of the nature (biominetics);

– progress in new technologies of fabric creation ;

– transfer of materials and technologies from another branches.

The common doubt is that development is based on the new materials, new patents and new technologies, which is very expensive and time consuming.

It is true that new complex solutions are often results of long term intensive activities of multidisciplinary teams. On the other hand there exist many of surprisingly simple and elegant solution without huge investments. For example hollow yarns produced by Japanese companies are hybrid yarns containing in core water soluble fibers (PVA).

Very simple application of new materials appeared already on the market. For example, aero gels developed in frame of NASA research can be used for textiles with enhanced temperature insulation.

There exist companies in Europe focused to the application of cosmic research results for textile branch. Usually these applications are very simple and straightforward.

Examples of utilization of new materials requiring some research are auxetic textiles, which have negative Poisson ratio. During extension/compression in one direction these textiles are extended/compressed in perpendicular direction as well (Fig. 1).

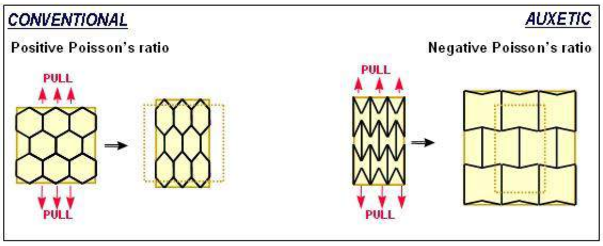


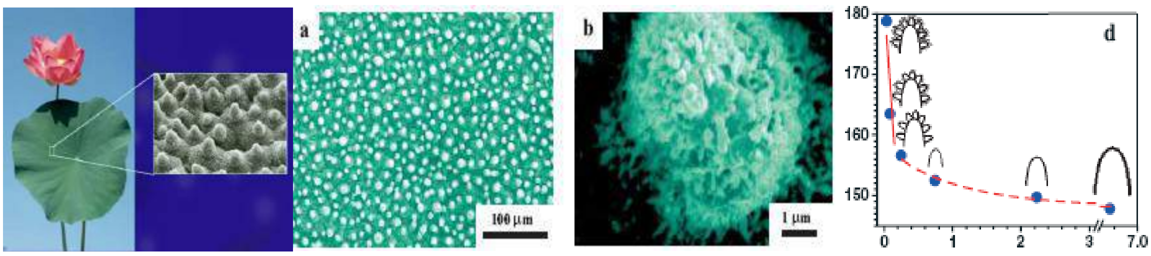
Fig. 1. Deformation behavior of auxetic structures

Auxetic behavior can be achieved by special construction of yarns and fabric. At Bolton University (England) the auxetic fibers (Polypropylene) and auxetic hybrid yarns were developed (Fig. 2).

Fig. 2. Auxetic yarns, polyamide/cotton

Auxetic structures are applicable e.g. for composites, textiles with improved cutting resistance, energy absorbers and for controlled dosing of medicals according to the volume changes of healed part of body.

Example of biominetic solution is well known lotus effect. Structure of Lotus leaf is in the Fig. 3. There are visible local apices with diameter 5…9 μm having branched caps of diameter 124 nm. On this surface layer only 20% are occupied by matter and rest is air. Contact angle for water drop is around 161°.



Diameter [nm]

Fig. 3. Lotus leaf surface and dependence of contact angle on surface roughness

By simulation of lotus surface on the textiles surface it is possible to obtain super hydrophobic materials, materials with improved cleaning efficiency and anti bacterial activity. It is possible to obtain directionally variable lotus effect as on the rice leaf.

Very popular tools for innovations of higher order are nano technologies and nano materials. Materials are usually defined as materials having one dimension fewer than 100…500 nm. There are three possibilities of nanomaterials preparation:

– top down approach (from bigger to smaller objects – Freymam “There is a plenty of room at the bottom”). Etching by laser, electron or ion beam;

– bottom up approach (molecular machines – molecular biology and molecular chemistry). Self organization – the spontaneous transition from chaos to order ;

– molecular manufacturing (scanning probe microscopes).Carving out nano parts from appropriate surfaces.

Nano particles (less 100 nm) contain 1 million atoms or less (1 nm radius has approx. 25 atoms) and majority of atoms are on the surface. It is well known that many properties of matter depend on the size range. In nano scale there are in some cases extra effects not following the bulk materials because the particle/wave nature of matter appears (quantum effects, tunneling, self-assembling).

Selected properties of nano materials are:

– extreme specific surface area;

– similarity of dimensions with UV and visible rays. Color and scattering depends on nano particle size;

– critical length (mean free path, scattering length) of materials properties (conductivity, diffusion) is comparable or higher than nano particles dimension;

– toxicity of particles increases with decreasing particles size.

In the textile branch the following nano materials are used: nano fibers (electrospinning), nano particles (powders), nano porous materials, nano composites, quantum dots and carbon nanotubes. One example of nano particles application is nano TiO_2 (anatase). This material obeys at illumination (mainly in UV region) strong catalytic activity (leading in the presence of moisture to local oxidization). Practical effects are destroying bacteria, super hydrophility and self cleaning. Common approach is fixing of active substances on the surface of fabrics by encapsulation, coating or by using molecular cages in cyclodextrines or dendrimers [7]. Dendrimers are branched macromolecular structures with central cage. Active substances can be in central cage or on the individual branches. Polypropylenimin dendrimer having on the surface 16 quartery ammonium groups (dimetyldodecylamonium) is very effective antibacterial agent.

These examples illustrate the huge varieties of innovation possibilities in technical textiles sector.

ACTIVITIES OF CZECH NATIONAL TEXTILE RESEARCH CENTRE. The National Textile Research Centre II (NTRC) is five-year project administrated by Czech ministry as a continuation of the project of the TEXTIL Centre solved in 2000-2004. The Technical University of Liberec and Research Institute of Textile Machines, Plc Liberec are the founders. The researchers from cooperating research institutions, namely INOTEX Ltd. Dvůr Králové, Resesach Institute of Cotton Ústí n. Orlicí and SPOLSIN Česká Třebová, are integrated into the particular groups according to their specialization.

Long-term research program of NTRC II are oriented above all to conceptual and application research in areas of design and optimization of textile structures, designs of textile machines including use of mechatronics and related technologies, product innovations of higher order for special protective fabrics and use of new materials for design of special sensors and sensors on clothing. In the sequel the selected projects connected with technical textiles or textile technologies are described. Full spectrum of projects and results obtained during first two years are presented in the reports of section II for year 2005 and 2006 (see www.centrum.tul.cz)

Extension of system of the fabric projection. Aim of project is upgrading of complex system of fabric design starting from system of prediction structure and properties of textile fibrous formations (result of Centrum TEXTIL I).

1. Prediction of the fiber properties from their chemical composition and basic structural parameters.

The molecular modeling software was adopted for modeling textile fibers chemical topology. The various methods based on the sum of individual atoms or groups contribution were used for prediction of optical and electrical properties of fibrous polymers.

2. New yarn technology –NOVASPIN.

The design software LIBTEX also contains the properties of yarns produced on a new developed spinning system named as Novaspin (Cotton Research Institute VÚB Ústí nad Orlicí – CZ). Yarn properties from this spinning system are comparable with yarns produced on classical ring spinning machines, and Open End machines. The LIBTEX is able to predict yarn parameters, fabric cover factor, mass per sq. meter, permeability, surface roughness and many other selected mechanical properties.

3. Prediction of selected organoleptic properties (touch, appearance).

The subjective hand evaluation of bed ticking fabrics was analyzed and the complex system for prediction of bed ticking fabrics was created.

The system for contact less evaluation of fabrics surface roughness (RCM) was developed (Fig. 4).

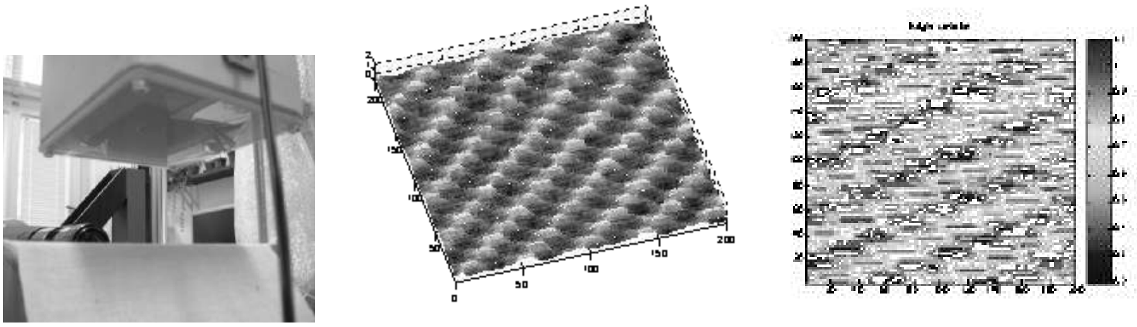


Fig.4. Details of RCM apparatus, reconstructed surface relief and local rough surface height variation

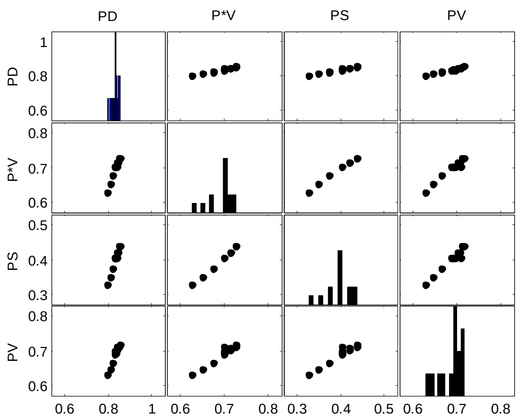
4. Specification of models of the twisted yarns and fabrics.

The prediction of yarns and fabrics properties is based on developed theoretical models as well as experimental methods and regression analysis. The regression models are mainly used for estimation of cotton fiber strength measured on common testing instruments. Furthermore, the system deals with prediction of yarn packing density, yarn diameter, hairiness and yarn strength using the basic parameters of fibers, yarns, and technology applied. The system is able to predict fabric cover factor, mass per sq. meter, permeability, surface roughness and many other selected mechanical properties. The system enables visualization of yarns, and fabrics in 2D projections.

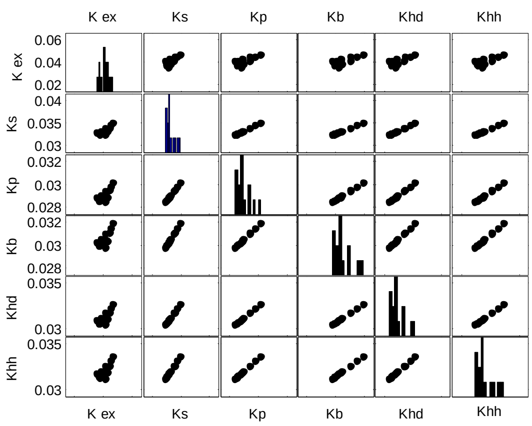
Optimum designs of textile products. In frame of this project the huge amounts of methods and model were created. Majority of these models were based on the stochastic modeling or computer intensive methods. For description of textile structures homogeneity (yarns, fabrics nonwovens) the standard tools combined with nonlinear stochastic models, self affine models and chaos dynamic models were proposed. Programs in MATLAB for complex characterization of homogeneity in line or plane were created.

1. Modeling the special properties of textiles

The transport behavior and interactions with gases or liquids were described on the base of models composed from porous system (pore volume fraction and material volume fraction). The scatter plot map for porosities of 14 different kinds of the cotton fabrics for the summer clothing is given in the Fig. 5-a. The scatter plot map for thermal conductivities computed from semi empirical models (surface porosity PS) is given in the Fig. 5-b. The strong correlation between experimental Kex values and predicted thermal conductivities are visible. The predicted thermal conductivities correlated strongly with each other as well.



a)



b)

Fig. 5. Scatter plot map for porosities and thermal conductivities (case PO = PS)

2. Creation of stochastic models.

The stochastic models on the basis of neural networks and non-linear methods for dimensional reduction were used for describing textile fabrics thermal conductivity, air permeability, drape ability and comfort. For example fabric drape can be assumed as complex buckling and shearing of an original planar configuration. The drape behavior is mechanically very complex phenomena connected with fabric weight and various characteristics as bending rigidity and shear resistance. The set I of 79 fabrics was used for creation of nonlinear regression model (see Fig. 6) and neural network regression model and set II of 12 fabrics was used as check of model prediction ability. The quality of data set I was checked by K means clustering.

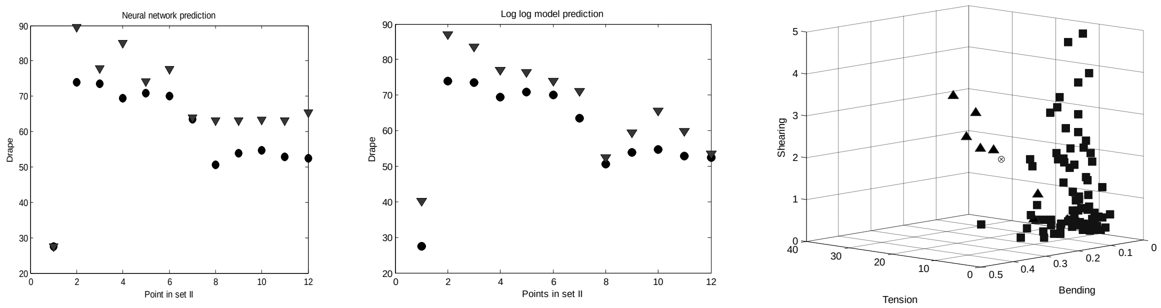


Fig. 6. Prediction ability of neural regression, nonlinear regression and results of K means clustering

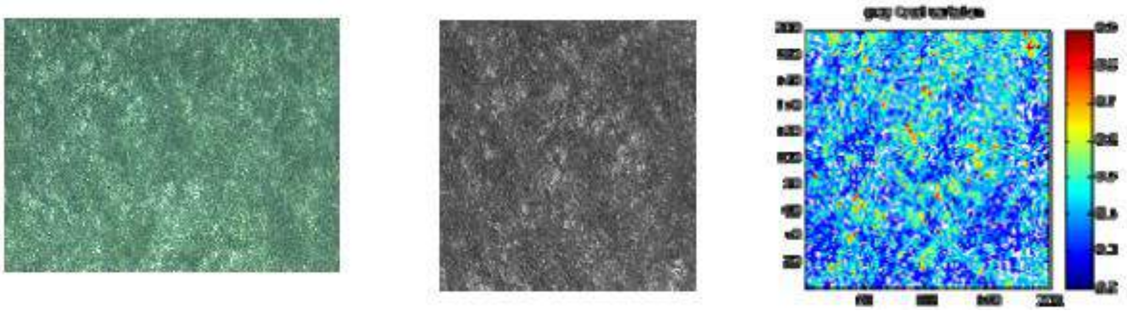
3. Yarn hairiness and unevenness characterization

Hairiness can be considered as the fiber ends and loops standing out from the main compact yarn body. Uster hairiness system characterizes the hairiness by H value, i.e. the mean value of the total length of all hairs within one centimeter of yarn. The raw data H_i are in fact realization of spatial process (hairiness spatial process - HSP) and can be used for more complex evaluation of hairiness characteristics in the space and frequency domain. The same approach can be used for yarn unevenness data characterization. Four approaches are mainly applied: first based on random linear stationary processes, second based on the self affine processes, third based on the long range dependences, fourth based on the theory of chaotic dynamics on nonlinear time series. Before choosing the approach, some preliminary analysis is needed mainly to test the stationarity and linearity. For complex characterization of these signals' statistical behavior the techniques based on the embedding dimension and correlation integral or long-range dependences evaluation were used. The selected methods and techniques for basic assumptions checking (stationarity, independence, linearity etc.) are core of HYARN and UNYARN program in MATLAB.

4. Surface unevenness prediction

The 2D spectral analysis, autocorrelation function and variogram were used for prediction of surface unevenness of woven fabrics and nonwovens.

The spun bonded nonwoven image (see Fig. 7-a) was used for uniformity evaluation. The starting square of 2x2 pixels size was selected. Corresponding modified image is in the Fig. 7-b and mean grey levels in squares are in the Fig. 7-c.

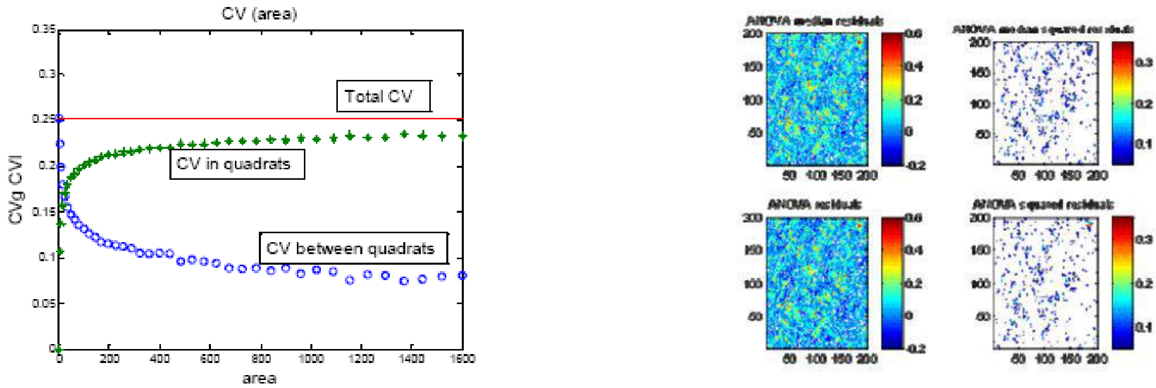


a) b) c)

Fig. 7. Raw image (a), quadrats 2x2 image (b) and mean grey levels in quadrats (c)

These data were used for characterization of uniformity. The influence of square size on the corresponding areal CV was investigated by using NONWCV program (see Fig. 8-a). Deeper analysis of local anomalies is based on the investigation of residuals. Simple parametric model is based on the ANOVA model without interaction $z_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij}$. The residuals and squared residuals for this model are in the Fig. 8-b. The residuals were computed from total mean m, row means m_{io} and column means m_{oj} or by replacing of means by medians. The local "hot spots" (anomalies) are here clearly visible.

The division of total variance and index of dispersion can be used for surface uniformity characterization as well. The system of data analysis based on the above mentioned methods can be used for identification of spatial dependence for regular lattice data or planar unevenness evaluation.



a) b)

Fig. 8. Dependence of CV on quadrat size (a) and residuals and squared residuals for ANOVA model (b)

Textile sensors and sensors for textiles. The project is focused on the testing of special sensors (temperature, humidity and chemicals) considering their installation and functioning in textile structures. The application possibilities of special dyestuffs for UV radiation dosimeter or detection of bacteria and toxic substances are investigated as well.

1. Hard sensors

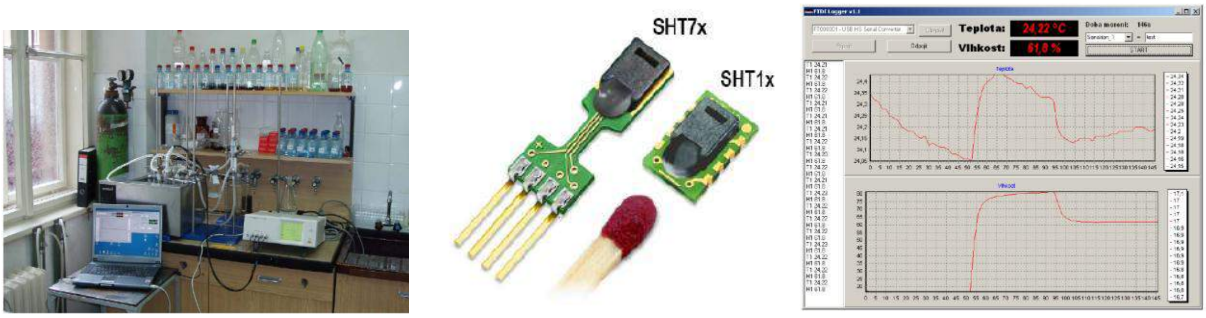
In frame of hard sensors for textile applications the humidity, temperature and special gas (fosgen and carbon dioxide) sensors were tested. The following tasks were solved:

– studying the basic properties of sensors and theirs sensitivity or selectivity;

– the incorporation of sensors into textile structures;

– testing the applicability of sensors considering the wear and maintenance of textiles.

The stand for testing of sensors sensitivity is shown in the Fig. 9-a and humidity sensor Sensirion is in the Fig. 9-b.



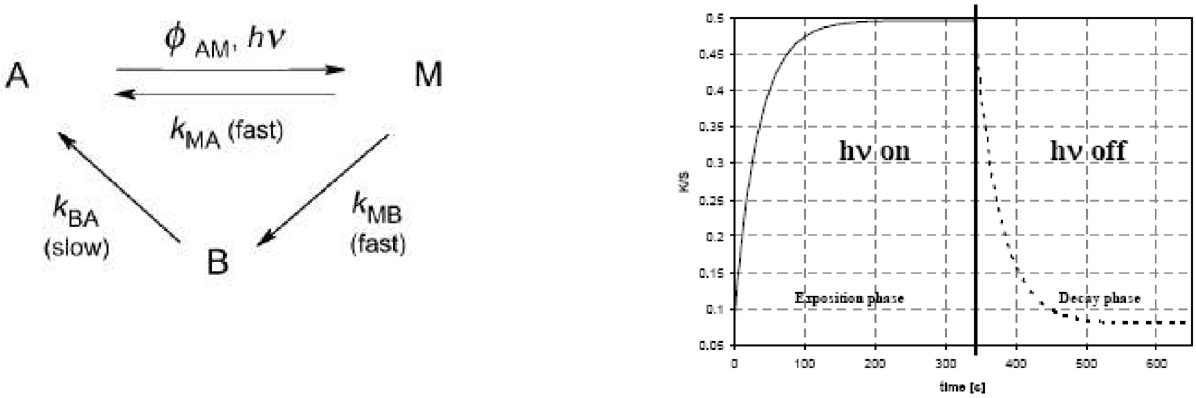
a) b) c)

Fig. 9. Testing stand (a) , humidity sensor (b) , combined humidity temperature testing output

Digital output from combined humidity temperature sensor is given in the Fig. 9-c. The wireless transfer of signal from sensors to the computer or personal computer was created.

2. Soft sensors

The textile soft sensors are based on the special environmentally responsible dyestuffs. First step was selection, verification and testing of chosen dyestuffs and filters for the design of textile UV radiation dosimeters (Fig. 10).



a) b)

Fig. 10. Photochromic compound (A-noncolored, B-transient excited C-colored) kinetics (a) and evolution of reflectance under continuous irradiation or decay (b) .

In the second step the dyestuffs for indication of chosen bacteria and toxic substances were selected and tested.

Principles of stabilizing active substances on textile substrates. Most of new textiles with special effects are implemented with the aid of special active substances which are to be suitably stabilized on the surface of textiles or into undersurface layers with securing the controlled release as the case may be. For those substances, suitable technologies of stabilization or encapsulation are to be chosen. Attractive is the use of special energy resources (plasma, microwaves, and laser) which can also act independently on the surface of textile substrates.

1. Stabilization of active substances on textiles surface.

Main aim was testing of new procedures and processes of stabilizing active substances on the surface of textile substrates ensuring their special properties, controlled release or reactivity considering the achievement of new effects. The techniques for creation of microcapsules were compared.

2. New principles and new energetic resources.

Research was oriented on the use of new principles or new energetic resources such as plasma, lasers, microwaves and electropolymerization for the implementation of multifunctional and barrier effects on textile substrates or facilitation of stabilization of active substances. The intensification of wet processes by ultrasound was tested as well.

Textiles for special applications. The project is focused on the product-oriented research and development of textile structures for three basic fields:

1. Smart – intelligent textiles adaptively reacting and structures with controlled release of active substance in use in food-processing, chemical pharmaceutical, electronic industry and agriculture.
2. Development of textiles from non-traditional or recycled raw materials for special applications.
3. Development of designs of barrier textiles for packing materials and working clothing protecting against the effects of static electricity, chemical substances, radiation, thermal and flame effects, cutting through, weather and against guns.

C O N C L U S I O N

The innovations in the technical textiles branch are dependent on the many factors and in some cases the interdisciplinary cooperation is necessary. Some solutions are simple and depend on the skills and knowledge. The National Textile Research Center II is oriented to the long term research in the major fields influencing of textile technology and production of new fabrics. In all projects, complex research and development from the selection of fibers via yarn constructions up to final and special treatments is used.

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SOME WAYS OF TECHNICAL TEXTILES DEVELOPMENT*

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Introduction. The application of textile fibers and fibrous structures for technical purposes has long tradition. In medieval time were textile based structures used for buildings enforcement as assemblies (nets). One of first protective clothing was silk structures used by Mongolian tribes for protection against enemy's arrows. The ropes were used for transportation and anchoring purposes.

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Technical textiles were used for packing, protection or consolidation. Advent of composites extended application of technical textiles into industrial sphere.

In this time sector of technical textiles is very important for many industrial branches, transport, medicine, agriculture etc. Textile structures are now one of very special light construction materials with some extraordinary properties (as flexibility, shape changeability, viscoelasticity) and simple process ability.

In the first part of this paper the main branches of technical textiles and their development are discussed.

Second part is devoted to the description of National Textile Research Centre II (NTRC) main activities connected partially with technical textiles.

Technical textiles. Majority of textile fibers and fibrous structures can be used without problems for creation of technical textiles. For special applications as barrier textiles it is possible to obtain required effects by finishing techniques as coating, curing, lamination, grafting and top finishing combined with proper construction of fabrics. Especially for achieving of high tenacity and modulus or extra thermal stability the specialty fibers are necessary.

These fibers have majority of required properties (mechanical, thermal, electrical, biological, chemical etc.) as intrinsic. On the other hand there are problems with creation of textile structures (due to brittleness, low deformation to break) and finishing or dyeing. The prices of specialty fibers are generally high as well. More than 90 % of technical textiles are still based on classical fibers.

Technical textiles are classically defined by theirs special properties (electrically conductive, heat resistive, antimicrobial, antistatic, super absorbents etc.). The definition of technical textiles is not simple and therefore the classification based on the main areas of application is widely accepted.

Prevailing technology of technical textiles creation is weaving. Weaved structures are widely applicable in all branches where the relative strength; shape stability and directional orientation are required. Examples are geotextiles, composites and protective clothing. Knitted structures due to their high shape instability are used traditionally in medical sector. Now these materials are used for creation of 3D structures, braiding and special coverings (e.g. car seats). Knitted structures are covering about 3…5% of all technical textiles. In many cases weaved and knitted structure are replaced by nonwovens, especially for products where it is not necessary to have high strength and dimensional stability.

The highest increase of consumption is for nonwovens and composites (5.6% yearly). All kind of technical textiles consumption increase is about 3.7% per year.

Some ways of technical textile development. Development in the technical textiles branch is in close connection with technical level of civilization. Developed countries are not only using advanced technologies but are oriented to protecting human health, increasing quality of life and offering new way of relaxing or leisure activities. New textile structures are reflecting these needs and main innovative activities are focused into these products:

– "Intelligent" body adaptive response apparel textiles having improved comfort controlled by the state of microclimate and wearers needs.

– "Intelligent"-knowledge based technical textiles with specified properties (e.g. locally compressive behaviour) and complex actions (comfort type mattresses for disabled persons, intelligent car seats etc.)

– Hybrid multifunctional textiles for protective clothing combining improved protection (a barrier against the selected types of radiation and particles) with improved comfort.

Especially in the technical textiles branch improvement is influenced by:

– development (computer assisted) of new materials and technological principles

– simulation of the nature (biomimetics)

– non standard combination of fabric creation technologies

– transfer of materials and technologies from another branches

The common doubt is that development is based on the new materials, new patents and new technologies, which is very expensive and time consuming.

It is true that new complex solutions are often results of long term intensive activities of multidisciplinary teams. On the other hand there exist many of surprisingly simple and elegant solution without huge investments.

Very simple is application of new materials appeared already on the market. For example aero gels developed in frame of NASA research can be used for textiles with enhanced temperature insulation. There exist companies in Europe focused to the application of cosmic research results for textile branch. Usually these applications are very simple and straightforward.

Examples of utilization of new materials requiring some research are auxetic textiles, which have negative Poisson ratio. During extension/compression in one direction are these textiles extended/compressed in perpendicular direction as well (Fig. 1).

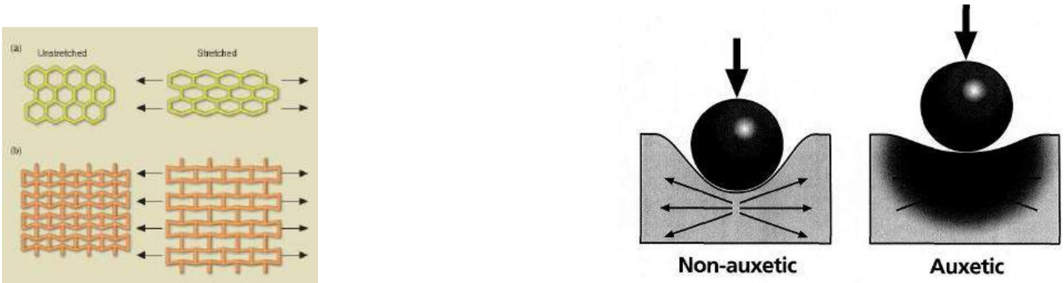


Fig. 1. Non auxetic and auxetic behavior

Poisson ratio of fiber with original cross area S_o and cross section area S changed due to tensile deformation ε is defined as

$$\nu = \frac{\text{lateral deformatin}}{\text{longitudinal extension}} = -\frac{\varepsilon_T}{\varepsilon} \quad \text{where} \quad \varepsilon_T = \frac{S - S_o}{S_o}.$$

Poisson ratio is connected with some mechanical characteristics of solid materials. Initial tensile modulus E for isotropic materials is connected with shear modulus G and volume compression modulus K by these relations:

$$K = \frac{E}{3(1-2\nu)},\; G = \frac{E}{2(1+\nu)},\; \nu = \frac{E}{2G} - 1.$$

Condition G > 0 leads to lower limit of Poisson ratio $\nu > -1$ and condition K > 0 leads to the upper limit of Poisson ratio $\nu < =1/2$. Most of polymeric fibers obey Poisson ratio in the interval $0.2 \le \nu \le 0.45$. Poisson ratio of auxetic materials is negative, i.e. the shear modulus is high and volume compression modulus is low. Solids with negative Poisson ratio are compressible but resistant to shearing and then tough. Material hardness expressed as indentation resistance H:

$$H \approx \frac{1}{(1-\nu^2)^{2/3}}$$

for auxetic materials is very high as well. The sorting of materials into groups according to relation between shear modulus and volume compression modulus is shown in the Fig. 2. Auxetic materials are in the group of anti rubber (dilatation materials).

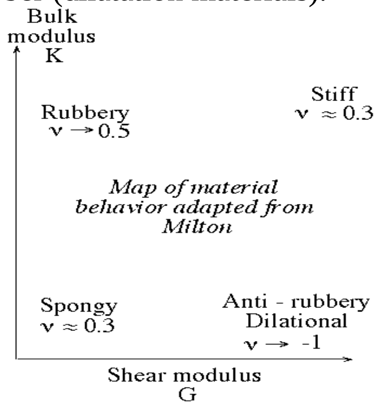


Fig. 2. Sorting of materials according to their behavior

Auxetic behavior can be achieved by special construction of yarns and fabric (Fig. 3).

Fig. 3. Auxetic behavior of cords

Auxetic structures are applicable for composites, textiles with improved cutting resistance, energy absorbers and for controlled dosing of medicals according to the volume changes of healed part of body. Another possibility to improve impact resistance of textiles is to use the special shear thickening fluids (STF) which are able to dramatically increase viscosity during shearing. Simple example of STF is colloid dispersion of silica particles (500 nm) in polyethyleneglycole (molecular weight 200) [7]. Final content of STF on textiles is up to 20%. The improvement of puncture resistance due to STF presence is shown in Fig. 4.

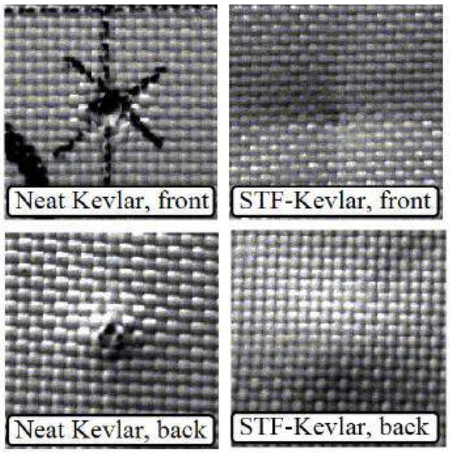


Fig. 4. Influence of STF on puncture resistance [7]

The "active protection" system presented by Dow Chemical company at the last Techtextil exhibition in Frankfurt combines distance fabric with special silicone STF (Fig. 5)

Fig. 5. The "active protection" system of Dow Chemical Co.

The silicone composition consists of polymers which show transient bonding to a cross-linking component. Under normal conditions, the polymers are bonded to the cross-linker in such a way that the bonds become open when subjected to a long period deformation force, which allows the material to flow. When this force is removed, the bonds easily reform again, returning the silicone to its original lightly cross-linked soft solid state. If the silicone is subjected to a sudden deformation force, the cross-linking bonds do not have time to open; the material resists the deformation force, and appears as a solid. This dilatant nature of the silicone means that when it is being impacted it instantly transforms from a soft flexible material to a rigid solid, but only for the duration of the impacting force. After the force has been dissipated through the dilatant/fabric construction, the silicone is again soft and flexible.

Choice of fabric used as the carrier plays an important role in performance. The typical carrier has a diamond surface configuration made from multifilament polyester yarns, with the spacer yarns formed from monofilament polyester to create the three dimensional structure, that is just 4.5mm thick. When this fabric is impregnated with the silicone, it is particularly important to present the silicone in such a way that it can readily absorb the impacting force through the spacer yarns in the direction of the force. By careful design of the dimensions of the spacer textile, this orientation is assured; allowing the silicone to absorb maximum force, yet leaving the fabric completely breathable (Fig. 6).

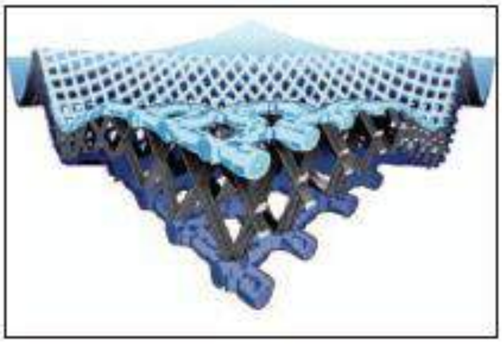


Fig. 6. The three dimensional spacer textile support of Dow Chemical Co

Relatively new example of biomimetic solution are shape memory membranes. For temperatures below activation point the structure of membranes is in glassy state, molecular structure is rigid, permeability is low and body heat is retained. For temperature above activation point structure is in the rubbery state. Micro-Brownian movement creates gaps between molecules, permeability is increasing and moisture or body heat can escape.

Very popular tools for innovations of higher order are nano technologies and nano materials. Materials are usually defined as materials having one dimension fewer than 100…500 nm. There are three possibilities of nano materials preparation:

– Top down approach (from bigger to smaller objects – Freymam "There is a plenty of room at the bottom"). Etching by laser, electron or ion beam.

– Bottom up approach (molecular machines – molecular biology and molecular chemistry). Self organization – the spontaneous transition from chaos to order.

– Molecular manufacturing (scanning probe microscopes).Carving out nano parts from appropriate surfaces.

Nano particles (less 100 nm) contain 1 million atoms or less (1 nm radius has approx. 25 atoms) and majority of atoms are on the surface. It is well known that many properties of matter depend on the size range. In nano scale there are in some cases extra effects not following the bulk materials because the particle/wave nature of matter appears (quantum effects, tunneling, self-assembling). Selected properties of nano materials are:

– Extreme specific surface area

– Similarity of dimensions with UV and visible rays. Color and scattering depends on nano particle size.

– Critical length (mean free path, scattering length) of materials properties (conductivity, diffusion) is comparable or higher than mano particles dimension.

– Toxicity of particles increases with decreasing particles size.

Very common mistake is assumption that nano particles have better mechanical properties in comparison with more voluminous particles. In facts cohesion energy per atom (diameter d) is dependent on the diameter of particles (D) by relation

$$E = E_b\left(1-\frac{d}{D}\right) = E_b\left(1-\frac{1}{L}\right),$$

where E_b is cohesive energy for bulk material. For nano particles ratio d/D is 0.1…0.01 and cohesive energy is increasing with particle diameter. It is interesting that starting from diameter of nano particles around 100 nm E is practically constant. This is one natural definition of nano range. Typical length ratio L = D/d can be simply used for computation of:

- Number of atoms in particle $n = L^3$
- Particle mass $M_c = M_h L^3/6.022\cdot10^{23}$,

M_h is molecular mass of material.

- Particle volume $V_c = \pi d^2 L^3 / 4$.

In the textile branch the following nano materials are used: nano fibers (electrospinning), nano particles (powders), nano porous materials, nano composites, quantum dots and carbon nanotubes.

All these examples illustrate the huge varieties of innovation possibilities in technical textiles sector.

Activities of Czech National Textile Research Centre. The National Textile Research Centre II (NTRC) is five-year project administrated by Czech ministry as a continuation of the project of the TEXTIL Centre solved in 2000…2004. The Technical University of Liberec and Research Institute of Textile Machines, Plc Liberec are the founders. The researchers from cooperating research institutions, namely INOTEX Ltd. Dvůr Králové, Resesach Institute of Cotton Ústí n. Orlicí and SPOLSIN Česká Třebová are integrated into the particular groups according to their specialization.

Long-term research program of NTRC II is oriented above all to conceptual and application research in areas of design and optimization of textile structures, designs of textile machines including use of mechatronics and related technologies, product innovations of higher order for special protective fabrics and use of new materials for design of special sensors and sensors on clothing. The following projects connected with technical textiles or textile technologies are solved:

Extension of system of the fabric projection. Aim of project is completion of complex system of fabric design starting from system of creation – structure – and properties of separate textile fibrous formations (result of preceding Centrum TEXTIL) by following parts.

1. Prediction of the fiber properties from their chemical composition and basic structural parameters. The basic fiber forming polymers polyethylene, polypropylene, polyehtylenterephtalate, polyamide 6, Kevlar (Fig. 7) and polyacrylonitrile were investigated. The tables containing molecular descriptors, properties and models were created.

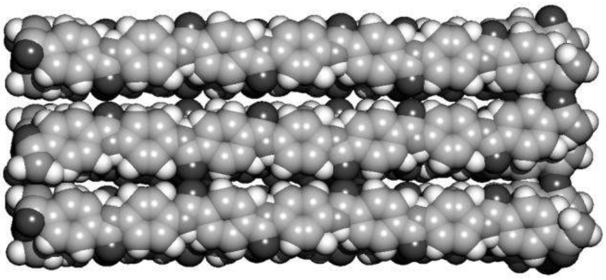


Fig. 7. Molecular model image of Kevlar (3x3 chains, optimizing with Chem3D – Cambridge Soft software) [12]

2. New types of yarns. The complex quality QI of typical cotton fibers varieties was used for prediction of rotor yarn strength YS (Fig. 8). The image analysis was used for description of structural parameters of compact, Sirospun and Vortex yarns. The structure and properties of yarns from blends of cotton and polypropylene were investigated.

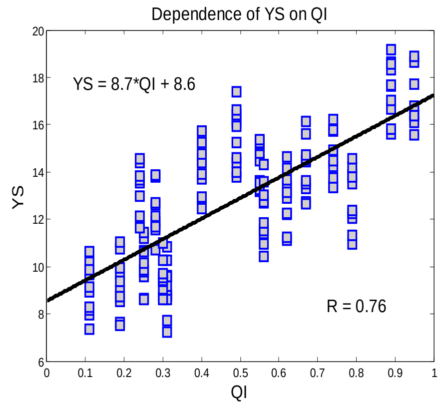


Fig. 8. Regression line for dependence of *YS* on *QI*

3. Prediction of selected organoleptic properties. The contactless method for evaluation of surface roughness was created. The roughness was separated into micro and macro roughness (Fig. 9). The evaluation of bed linen fabric hand was standardized.

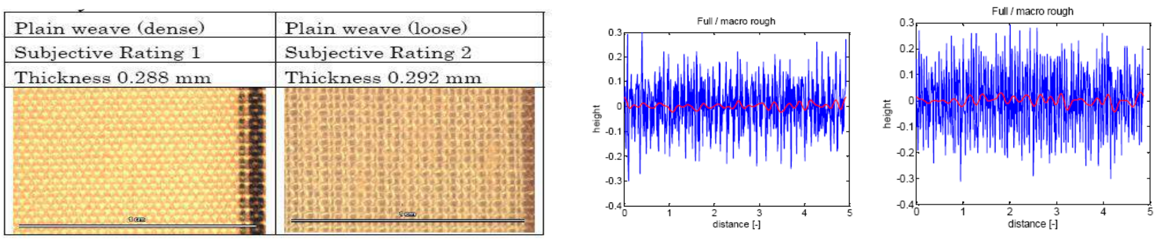


Fig. 9. Full and macro roughness for two plain weaves

4. Specification of models of the twisted yarns and fabrics. The unevenness and hairiness of yarns was described by using stochastic models (see Fig. 10). The program HYARN in MATLAB for complex analysis of mass and geometric unevenness of linear structures was created. The models for prediction of mechanical properties of woven structures were modified. The anisotropy of mechanical properties of woven structures was investigated.

5. The blending optimization. The prediction of blended yarns from cotton and polypropylene is investigated.

6. Influence of type finishing technologies on change of properties. The basic properties of finished cotton type fabrics were evaluated by using laboratory simulation. The operation of cotton pretreatment, hydrophobic finishing and pigment printing were described.

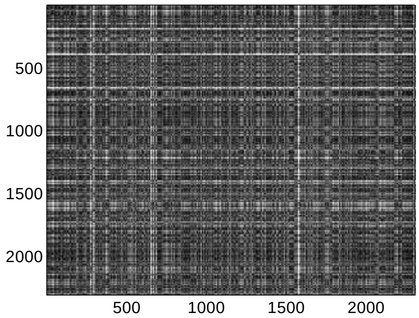


Fig. 10. Real yarn recurrence plot for D=2

Optimum designs of textile products. In frame of this project the following tasks are performed.

1. Modeling the special properties of textiles, transport behavior and interactions with gases or liquids. Fabrics thermal conductivity was predicted. The best model is based on the parallel arrangements of fiber mass and air (Fig. 11).

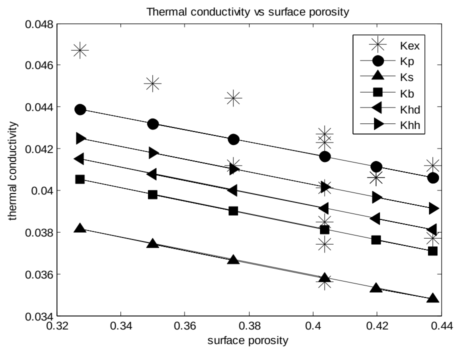


Fig. 11. Prediction of cotton fabrics thermal conductivity (optimal is $K_P = P_O K_y + (1 - P_O) K_a$)

2. Databases of type products and their properties. The database of type products was updated and extended.

3. Creating stochastic models on the basis of neuron nets and non-linear methods for dimensional reduction. The selected techniques of dimension reduction were compared. The Matlab programs for multivariate data treatment were created (Fig. 12).

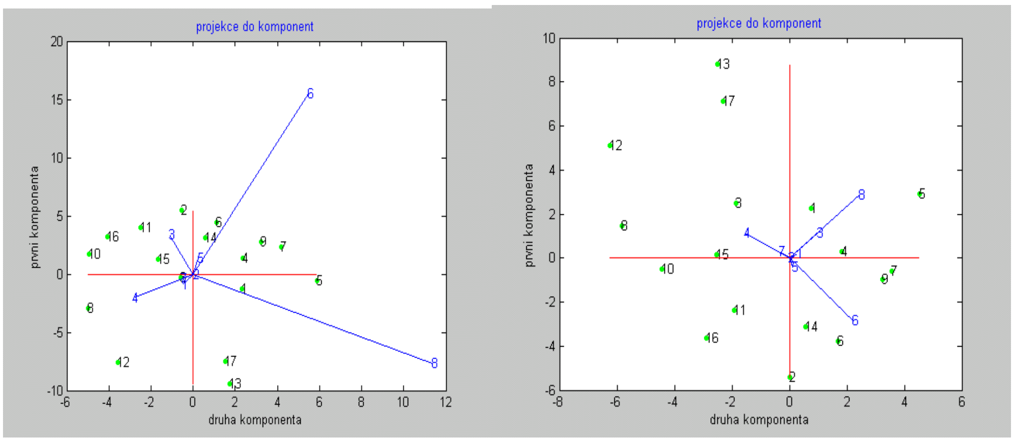
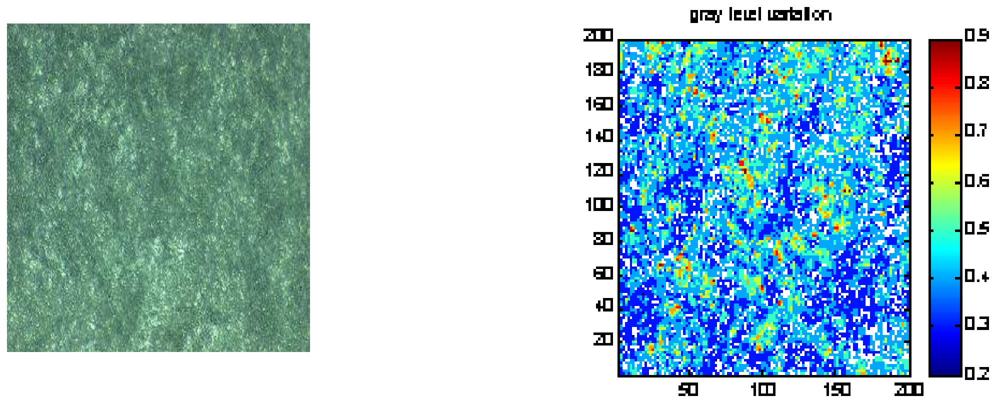


Fig. 12. PCA BiPlot for raw and standardized data

5. Unevenness prediction in the surface. The 2D spectral analysis, autocorrelation function and variogram were used for planar unevenness characterization. The planar unevenness of nonwovens was characterized by using spatial statistical tools (Fig. 13).



a) b)

Fig. 13. Raw image (a) and mean grey levels in squares (b)

The project is focused on the testing of special sensors (temperature, humidity and chemicals) considering their installation and functioning in textile structures. The application possibilities of special dyestuffs for UV radiation dosimeter or detection of bacteria and toxic substances are investigated. In frame of this project the following tasks are performed:

1. Studying the properties of sensors and their selectivity or humidity.

2. The ways of installation of sensors into textile structures.

3. Testing the usability of sensors considering the wear and maintenance of textiles.

4. Selection, verification and testing of chosen dyestuffs and filters for the design of textile UV radiation dosimeters.

5. Selection, verifying and testing of chosen dyestuffs or means for indication of chosen bacteria and toxic substances.

The Sensirion SHT15/75 relative humidity and temperature sensors were embedded into various places in ski suits. One extra sensor measures ambient condition on a surface of measuring unit box which is further equipped with 2-axis digital acceleration and inclination sensor. The testing stand for hard sensors and sensor of temperature was developed (Fig. 14).

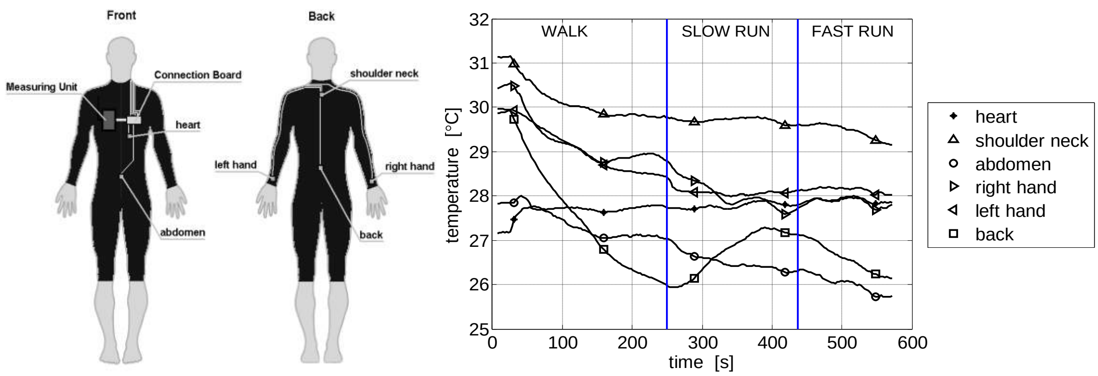


Fig. 14. Temperature during motion [13]

Principles of stabilizing active substances on textile substrates. In frame of this project the following tasks are performed:

1. New procedures. The in situ creation of silver nano particles on the surface of cotton fibers by two phase method was investigated (Fig. 15).

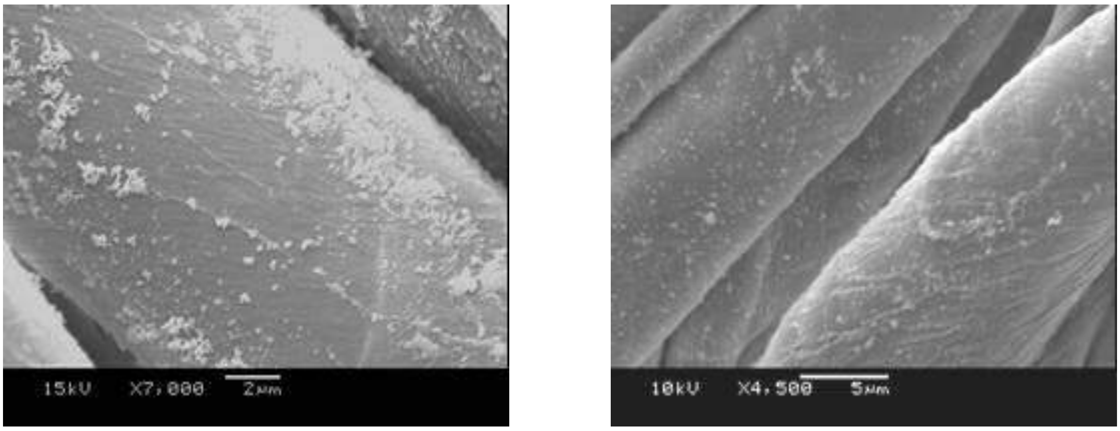


Fig. 15. Cotton fibres with silver nanoparticles [14]

2. New energetic resources. The application of atmospheric plasma for surface modification of selected materials (cotton, wool, Kevlar) and for realization of surface finishing was described. Utilization of the atmospheric plasma pretreatment and enzyme surface degradation (by esterase) was used for hydrophilization of polyester fabric. The microwave radiation was used for drying special textile structures. Research of the use of IR laser was used for surface ablation and local dyestuff removal.

Textiles for special applications. The project is focused on product-oriented research and development of textile structures for designs of special types of nonwovens and cryogenic drying as part of waste textiles treatment. Very effective ways for consolidation of fibrous assemblies or joining of nonwoven structures are so called quasi yarns created by simultaneous rotating and moving of cylindrical or conical - shaped body on the nonwovens surface. By suitable adjustment of the rotating body and the textile fabric surface it is possible to bond textile fabrics together by "surface-broad" lamination.

Czech patent CZ 192693 (European patent 0 648 877 A1) was used for quasi-yarn creation. A scheme of line enabling the production of 3D nonwovens textiles is shown on Fig. 16.

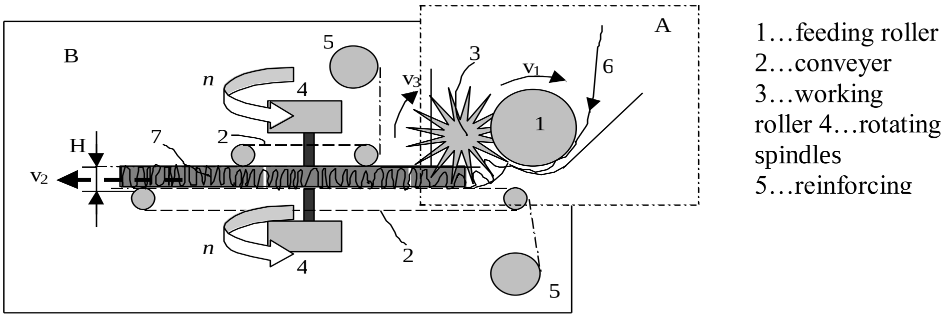


Fig. 16. System for 3D nonwovens processing fixed by quasi-yarns and by two reinforcing nets [16]

CONCLUSION

The innovations in the technical textiles branch are dependent on the many factors and in some cases the interdisciplinary cooperation is necessary. Some solutions are simple and depend on the skills and knowledge. The National Textile Research Center II is oriented to the long term research in the major fields influencing of textile technology and production of new fabrics. In all projects, complex research and development from the selection of fibers via yarn constructions up to final and special treatments is used.

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СОДЕРЖАНИЕ

Автоматизация технологических процессов

Экология и промэнергетика

Информационные технологии

Обмен опытом, критика и библиография, краткие сообщения

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Textile Materials

Spinning

Weaving

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