№ 3C (317) TEXTILE INDUSTRY TECHNOLOGY 2009

UDK 677.06

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.

* This work was supported by the research project Textile Research Center LN00B090 and 1M4674788501 of Czech Ministry of Education.

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).

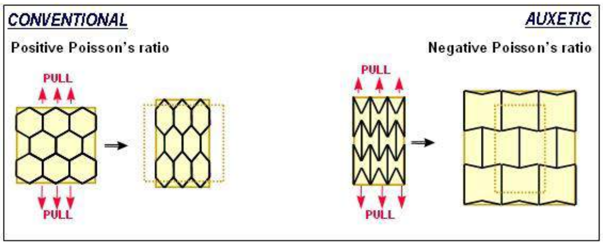


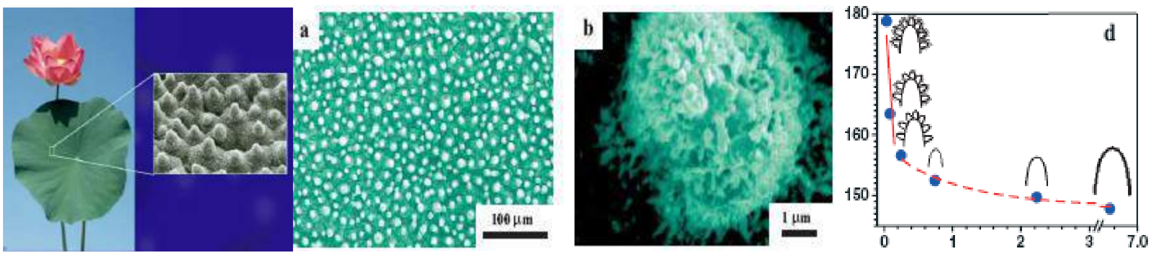
Fig. 1. Deformation behavior of auxetic structures

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).

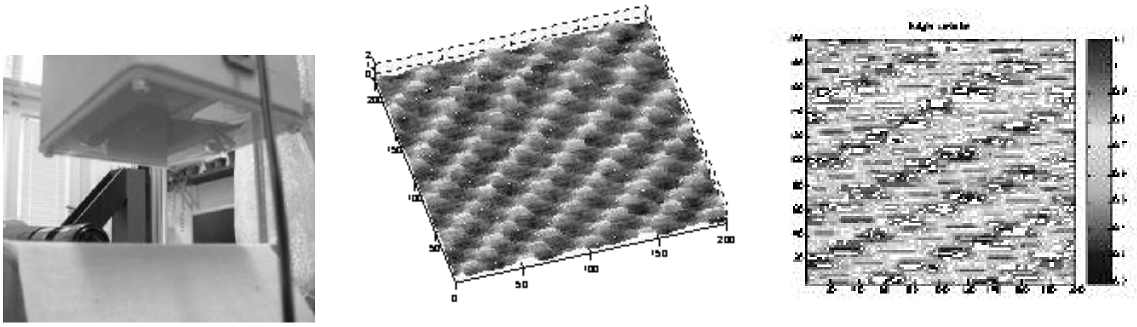


Fig.4. Details of RCM apparatus, reconstructed surface relief and local rough surface height variation

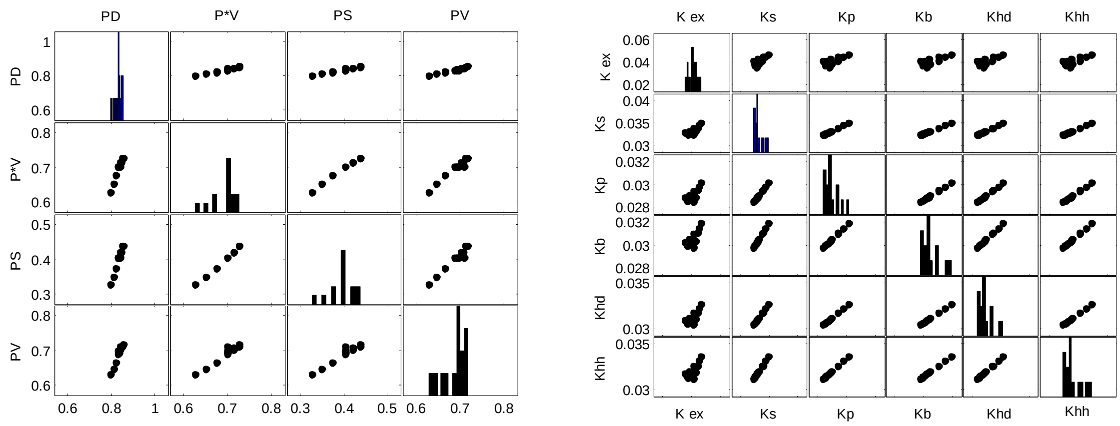
4. Specification of models of the twisted yarns and fabrics.

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.

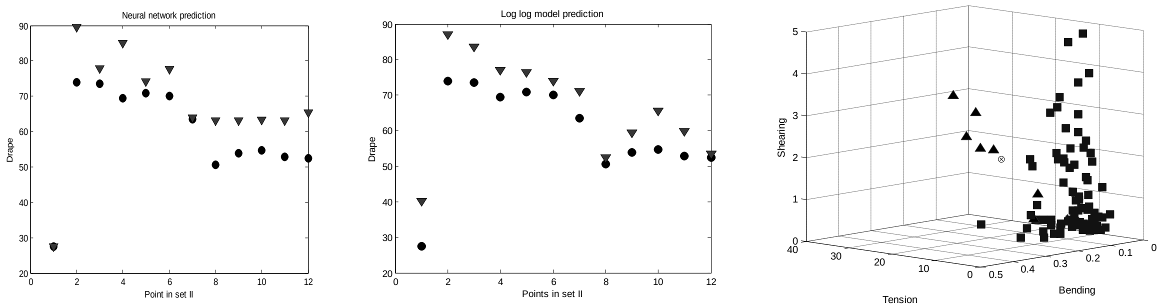


Fig. 6. Prediction ability of neural regression, nonlinear regression and results of K means clustering

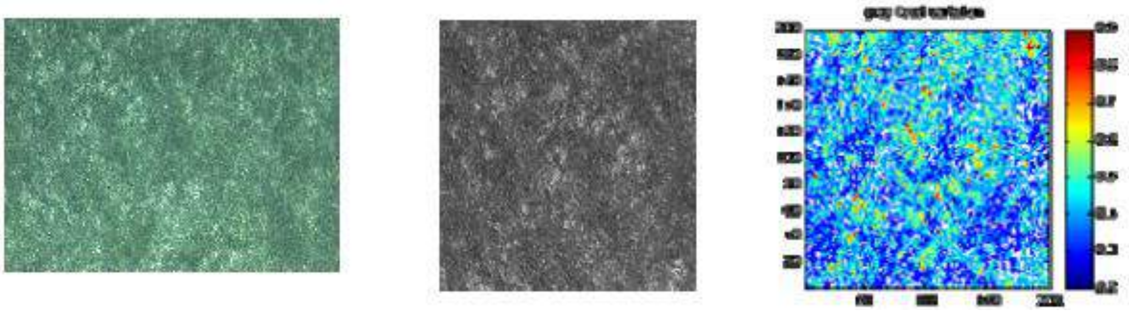
3. Yarn hairiness and unevenness characterization

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.

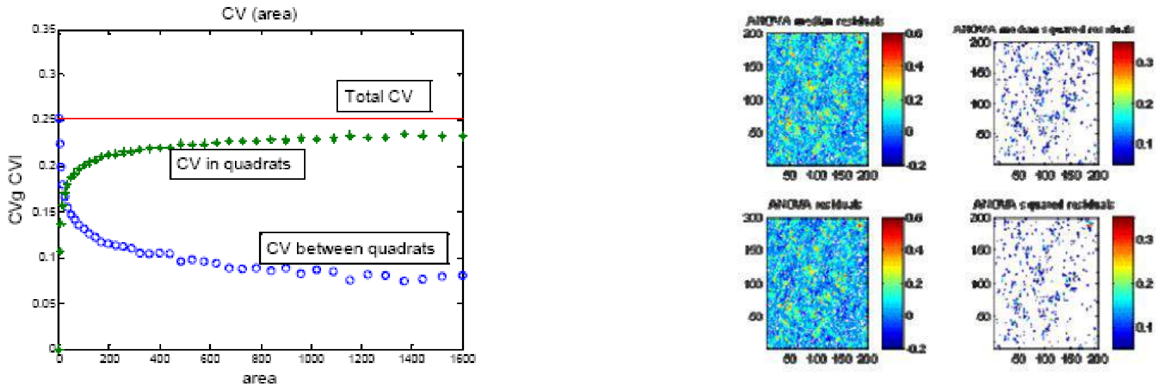


a) b) c)

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

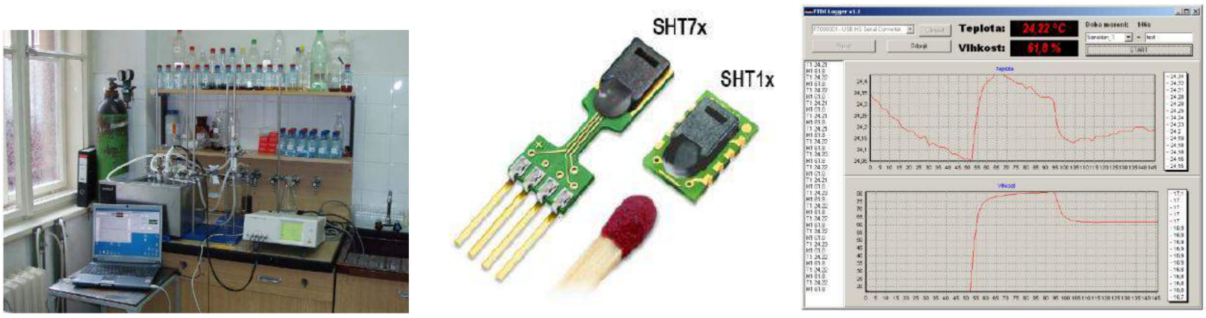
In frame of hard sensors for textile applications the humidity, temperature and special gas (fosgen and carbon dioxide) sensors were tested. The following tasks were solved:

– 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.



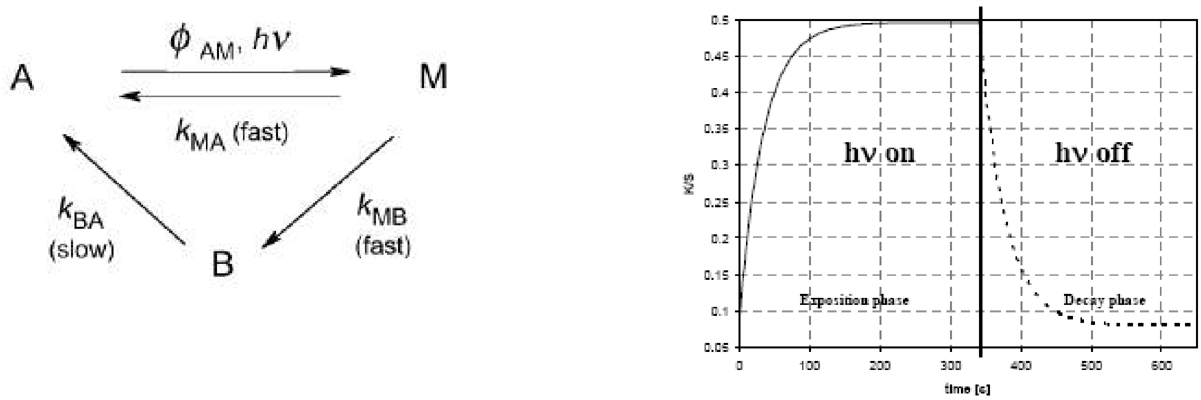
a) b) c)

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