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DESIGN OF A COMPLEX QUALITY INDICATOR OF THE APPEARANCE OF THE YARN

РАЗРАБОТКА КОМПЛЕКСНОГО ПОКАЗАТЕЛЯ КАЧЕСТВА ВНЕШНЕГО ВИДА ПРЯЖИ

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The questions of designing a complex quality index of yarn appearance are considered.

It has been established that the improvement of finished product quality in textile enterprises directly depends on systematic and effective quality control of semi-finished products and raw materials at all stages of textile production. When de-

termining the quality of the product obtained in spinning production, the appearance of the yarn is evaluated. The consumer properties of the finished product depend in many cases on the appearance of the yarn. The yarn purity class is determined by the composition of external defects in the yarn. The existing methods of determining the yarn purity class based on organoleptic and mechanical methods are not efficient enough. As a result of the conducted researches by methods of qualimetry, single indices characterizing the yarn appearance were determined. The attribution of this or that investigated image to a particular class of objects in accordance with the found values of signs is made according to the decisive rules formulated by the authors.

On the basis of the method of expert assessments, the dependencies between the values of single indicators and the point expert assessment, which are represented by linear functions, have been established. The value of the concordance coefficient of 0.86 was obtained for the survey carried out in the course of the work, which indicates good consistency of expert opinions. As an indicator of the desirability of each of the proposed single quality indicators, the average value of the scores on the indicator was used.

The weighting of single indices was determined, and expressions for the complex evaluation of the quality of appearance of the most widespread types of cotton yarns with linear densities of 50 and 20 tex were obtained.

Рассмотрены вопросы проектирования комплексного показателя качества внешнего вида пряжи.

Установлено, что повышение качества готовой продукции на текстильных предприятиях напрямую зависит от систематического и эффективного контроля качества полуфабрикатов и сырья на всех этапах текстильного производства. При определении качества продукта, полученного в прядильном производстве, оценивают внешний вид пряжи. Потребительские свойства готового изделия во многих случаях зависят от внешнего вида пряжи. Класс чистоты пряжи определяется составом внешних дефектов пряжи. Существующие методы определения класса чистоты пряжи, основанные на органолептических и механических методах, недостаточно эффективны. В результате проведенных исследований методами квалиметрии определены единичные показатели, характеризующие внешний вид пряжи. Отнесение того или иного исследуемого образца к конкретному классу объектов в соответствии с найденными значениями признаков производится по сформулированным авторами решающим правилам.

На основании метода экспертных оценок установлены зависимости между значениями единичных показателей и балльной экспертной оценкой, которые представлены линейными функциями. Для проведенного в процессе выполнения работы опроса получено значение коэффициента конкордации, равное 0,86, что говорит о хорошей согласованности мнений экспертов. В качестве показателя желательности каждого из предложенных единичных показателей качества использовалось среднее значение баллов по показателю.

Определена весомость единичных показателей и получены выражения для комплексной оценки качества внешнего вида наиболее распространенных типов хлопчатобумажной пряжи линейной плотностью 50 и 20 текс.

Keywords: yarn, single index, point assessment, quality, yarn purity, appearance.

Ключевые слова: пряжа, единичный показатель, балльная оценка, качество, чистота пряжи, внешний вид.

Introduction

The use of instruments makes it possible to determine the presence and count the number of defects of a certain type on the yarn, as well as to assign the yarn under examination to a certain purity class. The final result must be an assessment of the suitability of the examined yarn for the production of a particular fabric or knitted fabric. When using instruments and methods, such a judgment must be made by the technologist on the basis of his/her experience. The use of computer analysis with pattern recognition methods allows this task to be automated to a greater or lesser extent.

In [1], it is shown that the purity class of cotton yarn has a significant influence on the seam quality.

Such a task is solved in the Yarn Profiler [2] device by Lawson-Hemptill Company (USA), which is designed to measure the number of defects in air-textured threads. It is noted that the standard method of yarn and thread classification involves winding them on a cardboard plate and comparing them with reference samples. However, no such reference samples are available for air-textured threads. There are also no means of quantifying these threads to determine their grade.

The following EIB-S modification instrument from Lawson-Hemptill Company (USA) [3] can be used in the spinning mill and in the production of air-textured yarns. It detects the presence of defects in the yarn or filament and evaluates their influence on the fabric’s appearance. It is integrated with instruments for measuring hairiness and classifying defects. The EIB-E instrument is designed for optical measurement of the degree of plexus of chemical filaments and can be operated in three modes. It provides statistical data and a graphic image of the filaments, showing their influence on the appearance of the fabric. The device can be used in the production of smooth, partially oriented, and textured yarns.

The same company has produced an electronic device called the Electronic Inspection Board [4], which sorts yarns by appearance. The device scans every millimeter of the surface of the moving yarn twice. The optical system of the device allows to obtain an image of the yarn profile with a resolution of 3.5 μm [5], data on diameter changes and to record yarn vices. The device provides the number of yarn blemishes and calculates the yarn grade based on the number of blemishes. Moisture, color, and composition of the fiber blend have no influence on yarn inspection results. The device allows the influence of twist on yarn diameter to be determined.

Instruments utilizing optical measurement methods are mainly being developed, gradually replacing competing methods for the control of external defects in yarn and raw materials. It should be noted that manufacturers are endeavoring to equip their developments not only with control means but also with means of improving the quality of raw material. For example, the yarn cleaner [6], through which yarn winding from one bundle (cob) to another bundle (bobbin) passes, is equipped with a measuring head that measures a number of yarn characteristics. These characteristics include yarn thickness, hairiness, yarn color, and yarn line density. For their determination, the measuring head is equipped with appropriate sensors. The signals generated by the sensors are sent to the calculation unit, where they are processed to obtain the numerical values of the respective characteristics.

The devices in question searched for and counted yarn defects in one way or another, providing numerical values for the person to analyze. The next step was the emergence of analyzing the collected data in a variety of graphic forms.

Equipping the USTER TESTER 4-SX [7] device from ZellwegerUster (Switzerland) Company with additional modules allows not only to record the obtained data but also to analyze them and to classify the yarn according to the results. The device allows to obtain a diagram of yarn quality indices in the form of colored sectors of a circle.

The Yarn Structure Tester G585 device [8] produced by Zweigle (Germany) Company us-ing the Oasys application software package can be used to build visual images of the yarn as it would appear in the fabric. The device uses optical sensors that register the location of thick and thin spots along its length, regardless of the mass distribution within the yarn.

The G 580 GYROS device, produced by Zweigle (Germany) Company [9] with an optical sensor registers thickened and thinned sections of the controlled yarn regardless of their weight. The system makes it possible to create a woven or knitted product from various yarn combinations on the computer in a few minutes. It also selects the optimal variant.

These devices have a high cost and are designed primarily for research laboratories. It is not possible to equip the quality control departments of textile plants with them. Digitized yarn images obtained by scanning can be used for the quantitative assessment of yarn quality under production conditions.

In this connection, it seems relevant to conduct a study aimed at designing a comprehensive quality indicator of yarn appearance.

Materials and methods

The qualimetric method of quality assessment on the basis of a complex indicator involves an analysis, the purpose of which is to identify single indicators significantly affecting the level of product quality, determine the weight of these indicators, and construct a complex quality indicator on their basis.

The most widespread, well-proven in practice is the differential evaluation method [10], which consists in comparing the values of the indicators of the evaluated products with the basic ones. Let's analyze and select single indicators for yarn grade evaluation by "machine vision" methods. Let's single out from the set of yarn defects those which presence is inadmissible in any class or limited according to GOST 15818-70. The results are summarized in Table 1.

Table 1

Yarn grade	Content of external defects in the yarn			
	Knots	Thinnings	Thickenings	Specks
A	small	not admissible	not admissible	not admissible
Б	more than in A	small	small	not admissible
B	more than in B	more than in B	more than in B	admissible

As can be seen in Table 1, the standard for the evaluation of the yarn grade provides four single indicators – these are "the number of knots", "the number of thin spots", "the number of thick spots", "the number of specks".

The attribution of this or that investigated image to a particular class of objects in accordance with the found values of attributes is made according to the decisive rules.

Let's form decisive rules on the selected features: thickening - has the color of thread, is longer than a centimeter, and is thicker than thread by more than 40%; Thinning: has the color of thread but is thinner than thread by 40%; knot - has the color of thread, the length is shorter than a centimeter, exceeds the cross-section of the thread by 140%; speck - darker than thread; length and width not more than one thread diameter.

Results and discussion of the study

The single indicators and the formulated decisive rules do not allow the yarn appearance quality to be assessed as a whole. As a matter of fact, their influence on yarn quality is not equal. In addition, there may be cases when some types of yarn have a low value for some indicators and a high value for others. In this case, it is difficult to compare their quality. To resolve this situation, it is necessary to design a generalized complex indicator. This will make it possible to consider the degree of influence of each single indicator on yarn quality. To assess the degree of influence of each of the above-mentioned single indicators, the method of expert assessment was used.

To implement the expert evaluation procedure, a group of experts was formed. The gen-eral requirement for the formation of a group of experts was the possibility of effective problem-solving. The validity of the group expert evaluation depends on the total number of experts in the group. It also depends on the proportion of different specialists in the group and the characteristics of the experts. The expert group for assessing the influence of the single yarn quality parameters defined above consisted of specialists in spinning and weaving. When forming the group of experts, the length of service in the specialty related to the area of expertise, conducting scientific work in the field of assessing the influence of semi-finished products quality on the warping and weaving processes and the ability of the experts to make independent judgments were taken into account. According to the classification of the types of tasks solved during expert interviews given in [11], the task solved refers to the quantitative assessment of given objects.

Of the types of surveys used in collective expertise the survey in the form of questionnaires without feedback was chosen, i.e., the survey was conducted in one stage and the experts were not informed about the survey results. The choice of such a variant of the survey is explained by the fact that the questionnaire survey is the most effective and widespread type of survey. This is because it allows the best combination of information provision of experts with their independent creativity. When conducting the survey, the experts were offered a questionnaire as shown in Table 2.

Table 2

Sequence number	Indicate on a nine-point scale the degree of negative influence of each of the named yarn defects on the suitability of the yarn for further processing in warping or as weft in weaving.			
	The defect's name	Score		
1	Number of thickenings per 100 meters of yarn	50	125	200
2	Number of thinnings per 100 meters of yarn	10	30	50
3	Number of knots per 100 meters of yarn	50	125	200
4	Number of specks per 100 meters of yarn	5	10	20

The information obtained from the individual expert survey [12] for 20 tex cotton yarns is summarized in Table 3 and for 50 tex cotton yarns in Table 4.

Table 3

Expert	Number of thickenings per 100 meters of yarn			Number of thinnings per 100 meters of yarn			Number of knots per 100 meters of yarn			Number of specks per 100 meters of yarn		
	50	125	200	10	30	50	50	125	200	5	10	20
1	1	5	9	1	3	6	1	2	3	3	5	8
2	2	8	9	4	9	9	2	4	7	5	9	9
3	1	3	7	1	5	7	1	4	7	5	7	9
4	2	4	9	1	2	5	1	2	3	2	4	8
5	1	7	9	2	9	9	1	3	7	3	9	9
6	1	4	8	4	5	6	2	4	8	9	9	9
7	2	7	9	7	8	9	1	2	3	9	9	9
8	1	5	7	2	6	8	1	2	4	7	8	9
9	2	6	8	1	4	9	3	6	9	5	7	9
10	1	5	8	1	6	9	1	3	5	3	7	9
11	2	6	9	3	7	9	2	4	7	3	6	8
12	2	4	7	2	5	9	1	3	6	3	8	9
13	2	6	9	1	3	8	2	4	6	5	7	8
14	1	5	9	2	5	8	1	3	6	6	7	9
15	1	4	7	1	6	9	1	2	5	4	7	9
16	2	5	9	3	7	8	3	5	7	5	8	8
17	2	5	8	3	7	9	1	3	5	6	8	9
18	1	6	9	2	5	9	1	4	6	7	8	9

Table 4

Expert	Number of thickenings per 100 meters of yarn			Number of thinnings per 100 meters of yarn			Number of knots per 100 meters of yarn			Number of specks per 100 meters of yarn		
	50	125	200	10	30	50	50	125	200	5	10	20
1	3	7	9	3	7	8	4	6	8	2	5	7
2	3	6	9	4	5	9	2	6	9	1	5	6
3	4	7	9	2	5	7	3	4	8	2	4	7
4	2	7	9	3	7	8	2	5	6	2	4	8
5	4	8	9	2	8	9	3	5	9	1	5	7
6	3	7	8	4	5	7	2	7	9	4	5	9
7	2	7	9	5	8	9	4	6	8	3	5	7
8	3	6	9	3	6	8	3	6	8	4	7	8
9	2	6	8	2	7	9	3	6	9	3	5	6
10	4	7	8	2	6	8	2	5	7	2	4	7
11	3	6	8	3	7	9	2	6	9	3	5	6
12	4	7	9	2	5	9	3	5	7	3	6	9
13	3	6	9	4	6	8	2	4	6	3	5	7
14	4	5	9	2	7	9	4	6	8	2	4	7
15	3	7	8	4	6	9	3	7	9	3	6	7
16	2	5	9	3	7	8	3	6	7	2	6	7
17	2	8	9	4	7	9	2	5	9	4	6	8
18	4	6	9	2	7	9	3	5	7	2	4	7

When compiling the questionnaire, four parameters (criteria) were selected to assess yarn quality in terms of the presence of appearance defects. For each criterion, three fixed values of a single indicator were set. The expert had to rank each of these criteria according to a nine-point system. This is due to the fact that criteria influencing yarn quality may not only be absent or present but may also take a quantitative expression subject to a certain functional dependence, which in turn influences yarn quality assessment. Therefore, to construct a generalized index of the package's quality according to its shape, it is necessary to have as much complete information as possible for each criterion. For this purpose, the average rank values for each fixed value were calculated. These values were paired with the corresponding values of the criteria used for interpolation by a straight-line equation based on the least squares method. The functions obtained as a result of interpolation performed using the built-in MS Excel function are shown in Table 5.

Table 5

Sequence number	Name of a single indicator	Equations of dependence of the score assessment Yi on a single indicator Xi	
		20 tex yarns	50 tex yarns
1	Number of thickenings per 100 meters of yarn	Y1=0,05x1-0,66	Y1=0,04x1+1,4
2	Number of thinnings per 100 meters of yarn	Y2=0,15x2+0,98	Y2=0,14x2+1,88
3	Number of knots per 100 meters of yarn	Y3=0,03x3-0,1	Y3=0,03x3+1,13
4	Number of specks per 100 meters of yarn	Y4=0,2x4+4,56	Y4=0,3x4+1,48

For this purpose, the coefficient of concordance or agreement of experts is calculated [11].

As a result of the calculation for the conducted survey, the value of the coefficient of concordance was obtained: W=0.86, which allows us to consider the experts' opinions as co-consistent.

In order to construct a comprehensive indicator characterizing yarn quality by appearance defects, it is necessary to establish the desirability of taking into account each of the single indicators. Since the desirability of each indicator is not specified by experts, the average value of the indicator scores can be used as such a characteristic. Table 6 summarizes these values. Then the weighting coefficients of indicators were calculated according to the methodology given in [11].

Table 6

Sequence number	The name of a single indicator	Scoring of the accounting of the indicator	
		20 tex yarns	50 tex yarns
1	Number of thickenings per 100 meters of yarn	5,04	6,11
2	Number of thinnings per 100 meters of yarn	5,35	5,96
3	Number of knots per 100 meters of yarn	3,52	5,43
4	Number of specks per 100 meters of yarn	6,89	4,48

The weighting coefficient of the indicator is equal to:

$$m_i = \frac{a_i}{\sum_{i=1}^{n} a_i}, \qquad (1)$$

where m_i – weighting coefficient of the i-th indicator; a_i – score assessment of the i-th indicator; n – the number of indicators that can be taken into account when assessing product quality.

The obtained weighting coefficients are presented in Table 7.

Table 7

№	The name of a single indicator	Weighting coefficient	
		20 tex yarns	50 tex yarns
1	Number of thickenings per 100 meters of yarn	0,24	0,28
2	Number of thinnings per 100 meters of yarn	0,26	0,27
3	Number of knots per 100 meters of yarn	0,17	0,25
4	Number of specks per 100 meters of yarn	0,33	0,20

A comprehensive assessment of product quality can be obtained by the weighted average method [11]. The weighted average indicator is constructed as a dependence, the arguments of which are quality indicators and their weighting parameters:

$$Q = F(m_i, q_i), \qquad (2)$$

where m_i – weighting coefficient of the i-th indicator; q_i – relative value.

The relative value q_i is chosen based on the meaning of the indicator. If the indicator is positive, i.e. quality improves with its growth, then

$$q_i = X_i / X_б, \qquad (3)$$

where X_i – value of the i-th quality indicator of the evaluated product; $X_б$ – is the value of the i-th basic indicator; and if the indicator is negative, then by the inverse relationship.

Based on the data in Tables 5, and 7, it is possible to express a complex quality indicator. It will be equal to the sum of indicators, because each of the indicators affects the quality of the product regardless of the value of the other indicator. The value of the basic indicator is set as the lower limit of the scale on which the parameters were measured.

For yarns of 20 tex

$$Q = \frac{0,24 \cdot 50}{0,05X_1 - 0,66} + \frac{0,26 \cdot 10}{0,15X_2 + 0,98} + \frac{0,17 \cdot 50}{0,03X_3 - 0,1} + \frac{0,33 \cdot 5}{0,2X_4 + 4,56}. \qquad (4)$$

For yarns of 50 tex

$$Q = \frac{0,28 \cdot 50}{0,04X_1 + 1,4} + \frac{0,27 \cdot 10}{0,14X_2 + 1,88} + \frac{0,25 \cdot 50}{0,03X_3 + 1,13} + \frac{0,2 \cdot 5}{0,3X_4 + 1,48}. \qquad (5)$$

The greater the value of this indicator, the higher the quality of the controlled pack. It should be noted that the criteria values are always greater than zero. The stated methodology for determining the complex indicator is an algorithm for its calculation, which was implemented in software.

C O N C L U S I O N S

1. It has been found that the yarn appearance quality assessment instruments available on the market are expensive, complex and not suitable for use in production conditions.

2. The use of a yarn image digitized by scanning on a black board together with application software allows to obtain a simple and affordable instrumental method of yarn appearance evaluation.

3. Equations of dependence of the score evaluation on the corresponding unit indicators are obtained by the method of expert evaluations.

4. On the basis of the qualimetric method of quality assessment an algorithm for calculation of the complex index characterizing the yarn appearance was developed.

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