ISSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA). Vol. 9, No. 1. 2003

Complex Structure Fancy Yarns: Theoretical and Experimental Analysis

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Received 05 September 2002; accepted 01 December 2002

A study is reported for geometrical model of complex structure fancy yarns. The investigated complex structure fancy yarns have a multithread structure composed of four components – one core, two effect, and one binder yarn. Due to the wrapping round the effect intermediate product that mostly has larger linear density the length of the binder component changes. In current research the precondition was accepted that the cross-sections of the all three yarns of the effect intermediate product in the complex structure fancy yarn remain the circles shaped, and this shape does not change while manufacturing the fancy yarn. The theoretical method for predicting the coil length of the binder yarn in the complex structure fancy yarn is developed. Theoretical values of the coil length are compared with experimental data. The developed method would help for further the set of information in designing of new assortment of the complex structure fancy yarns.

Keywords: coil length, complex structure, fancy yarn.

INTRODUCTION

Fancy yarns are special products of carding, drawing, Dref spinning, rotor spinning, twisting, texturing, etc. technologies with introduced visual irregular characteristics, in either diameter and unevenness or/and in colour. That is which clearly differentiate them from conventionally spun or twisted yarns.

Woven fabrics and knitted materials using fancy yarns find applications in normal and high-fashion clothing, curtains, carpets, upholstery, wallpaper manufacture and many more.

Analysis of the structural, geometrical, and mechanical properties of fancy yarns as well as usage possibilities are very actual questions of today.

Design of complex structure yarns requires especially great efforts and skills. The assortment of such yarns is very wide and their structure of last years becomes more and more complex [1 – 4].

Forecasting of the properties of complex structure yarns and designing them, it's very significant to choose properly and to co-ordinate parameters, which influence structural, geometrical, mechanical features. In [5] the computer simulation is used to show the distribution of fancy yarn effects in weft yarns and in which way it influences the appearance of the fabric. It is shown how pattern figures arise and what can be done to suppress them.

Effect of fancy yarns formation in one process using hollow spindles can be controlled by suitable choices of certain factors related to this process. Dependencies of the geometrical properties of fancy yarns upon the parameters of the manufacturing process of fancy yarns like the speed of hollow spindle, the delivery speed of fancy yarns, and the speed of supply of the effect component were investigated [6].

The dependencies of the geometrical and mechanical properties of complex structure fancy yarns upon the parameters of the manufacturing process of these yarns were investigated in [7].

In most cases fancy yarns have a multithread structure composed of such components – core, effect, and binder. The core yarn is the basis of the fancy yarn. The effects (twisted into knots, loops, etc.) are formed by effect yarn, which unites with the core yarn and it is supplied twisting field with higher speed. These two components form the effect intermediate product that is fastened by the binder yarn, which fixes effects. The continuous search for novelties turned into reality new fancy yarns structures like fancy yarn which effect intermediate product consists of one core yarn and two effect yarns or of two core yarns and one effect yarn. Very often all these three components are the single or plied spun yarns and twisted multifilament yarns.

Complex structure fancy yarn properties are influenced by changing the kind of raw material, the properties of the components, the number of the components, etc. as well as by changing machine parameters [8]. The connection between structure of fancy yarn produced by the combined ring-hollow spindle spinning system and manufacture parameters as well as the lengths of novelty yarn components are established in [9].

In [10] the research was carried out on influence of twist of slub yarn on its physical and mechanical indicators. There were obtained results about the influences: of dimension of twist on the length of slub; of value of twist on multiplicity of slub thickening as well as on the distances between slubs and on the breaking force of slub yarn.

Due to the importance of fancy yarns in knitted and woven materials the geometrical parameters of the yarns are studied. The correct forecasting of yarn structure, type, texture, etc. coupled with efficient control of production and yarn quality, can result an acceptable commercial standard. A model to predict the parameters of snarl formation in fancy yarns and to simulate the shape of the effect is discussed [11].

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The research [12] deals with fundamental parameters involved in the production of fancy yarns with the purpose to reproduce an existing fancy yarn without resorting to empirical methods as well as to create new yarns exhibiting special pre-selected effects.

This paper presents the geometrical model of the complex structure fancy yarns composed of four components (one core, two effects, and one binder) and the developed method for predicting the coil length of the binder yarn in the yarns of such sort.

Usually, the geometrical, structural, mechanical indices of fancy yarns, especially of complex structure are determinate in experimental or half-experimental ways that are not suitable for designing of new yarn qualities. The theoretical methods enable to eliminate the necessity of yarn samples manufacture and that is why they are very actual and needful.

In this study the new approach to investigate the different kinds of the complex structure fancy yarns using the geometrical model of the components' interaction is described in details.

RESULTS AND DISCUSSIONS

Problem formulation

In present times hollow spindle wrapping became a standard method of fancy yarn production. The basic principle of this method is that the effect component is locked into position by the interaction of the core and the wrapping binder yarn. This is done by passing the components down the centre of a hollow spindle on which is placed a package containing the binder component. As the spindle rotates, the binder yarn is wrapped around the other materials.

The purpose of this study is to propose such theoretical method of predicting of the coil length of the binder component in the complex structure fancy yarn made using hollow spindle as well as to perform the comparison analysis between theoretical calculations and experimental tests.

The main idea of interpretation of complex structure fancy yarn model was that the following preconditions were made: firstly, the cross-sections of the yarns of core and effect components in fancy yarn remain the circle shaped, and this shape does not change while manufacturing the fancy yarn; secondly, the binder component winds the effect intermediate product at the place of core and effect component contact with screw winding; thirdly, the contraction of the binder yarn is not considered because of its insignificance. The first precondition is meaning especially in case when the yarns of core and/or effect component are spun yarns or twisted multifilament yarns that get less deformed in cross direction to compare with not twisted multifilament yarns or textured ones.

As the theoretical background of this study the geometrical model of fancy yarns is used. The structure of this model is definite by the geometrical properties of the core, effect, and binder components of complex structure fancy yarns as well as by the technological parameters of the manufacture.

Theoretical method

The fibres and filaments incorporated in the complex structure fancy yarn can be of different or same materials, colours, length, and thickness. Clearly, the fancy yarn can be produced in a variety of combinations. But depending on the end application of the textile material and the method of it manufacturing, the fancy yarn is produced accordingly. Spun slubs may be produced by an intermittent acceleration of the pair of rollers during spinning. Loop yarn is a compound yarn comprising a twisted core with an effect yarn wrapped around it so as to produce wavy projections, well-formed circular loops on its surface. This effect is achieved by different delivery speed of the effect component as to compare with the core component. Knot yarn contains prominent bunches along its length. Using two pairs of rollers capable of being operated independently can make such fancy yarn.

The mostly spread case of complex structure fancy yarns is that effect intermediate product consists of one core and two effect yarns or two core and one effect yarns. This structure especially is used trying to get expressive and combine effects of fancy yarn: slubs, knots, loops, spirals, snarls, waves, etc.

The structure of fancy yarn kind, when two effect (or core) yarns are uniform and their diameters are larger to compare with the binder yarn diameter is shown in Fig. 1 – 2. The coil length of the binder yarn l_{b1} is equal to hypotenuse of triangle, which one cathetus is equal to coil pitch of binder yarn h, and the second one is equal to the length of projection of involute p. The value h can be expressed in manufacture parameters of the fancy yarn: rotational speed of hollow spindle n_s and delivery speed of fancy yarn v_d. So, l_{b1} is calculated according to the equation:

$$l_{b1} = \{p^2 + (v_d / n_s)^2\}^{1/2} \quad . \qquad (1)$$

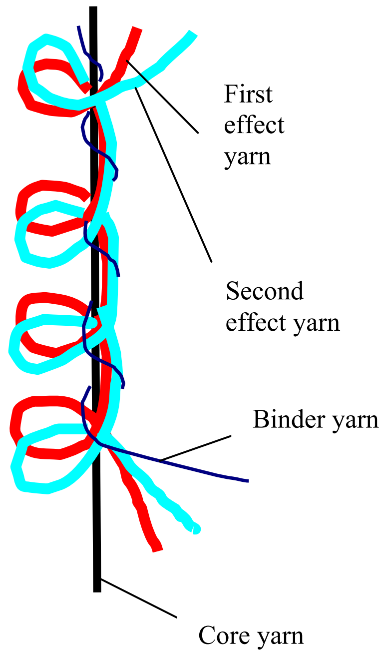

Fig. 1. Common view of complex structure fancy yarn with loop effects

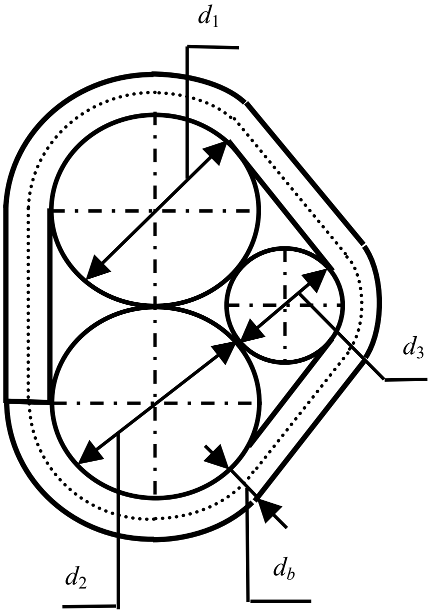

Fig. 2. Cross-section of complex structure fancy yarn: d_1, d_2, d_3 – diameters of yarns of effect intermediate product, $d_1 = d_2$, $d_1 > d_3$; d_b – binder yarn diameter

The index p (showed with dotted line in Fig. 2) is possible to determine from the equation suggested by the author:

$$p = d_1 + 2\sqrt{d_1 d_3} + \frac{\pi(d_3 + d_b)}{360^\circ}\left(180^\circ - 2x \times \arctan\frac{d_1 - d_3}{2\sqrt{d_1 d_3}} - \arccos\frac{d_3^2 + 2d_1 d_3 - d_1^2}{(d_1 + d_3)^2}\right) + \pi\frac{(d_1 + d_b)}{180^\circ}\left(270^\circ - \arctan\frac{2\sqrt{d_1 d_3}}{d_1 - d_3} - \arccos\frac{d_1}{d_1 + d_3}\right). \quad (2)$$

Other needed parameters are linear density of core, effect, binder yarns – T_1, T_3, T_b, respectively and overall density of core, effect, binder yarns – δ_1, δ_3, δ_b, respectively.

Experimental investigations and comparative analysis

The experimental verification was done with complex structure fancy yarns produced on fancy yarn twisting machine by one process method. The hollow spindles containing the package with the binder component were used.

The effect intermediate product of complex structure fancy yarns consists of three yarns: one core yarn and two effect yarns. These yarns are single or plied cotton spun yarns and linen spun yarns (1, 3, 4, 6, 7 variants) as well as multifilament PA yarn and linen spun yarns (2, 5 variants). Linen component chose not accidentally. Such yarns are stiff and get less deformed in cross direction while manufacturing fancy yarn.

Raw material and linear density of the components is given in the Table 1. Diameters of the two yarns of the effect intermediate product are equal. The diameter of the third yarn (core yarn in 1 – 4, 6, 7 variants of complex structure fancy yarns, second effect yarn in 5th variant of complex structure fancy yarns) is smaller. Technological parameters of manufacture were: $n_s = 253.3 - 400.0$ sec^{-1}, $v_d = 0.50 - 1.17$ m/sec. The most important point of investigations was the large interval of changing of the rotational speed of hollow spindle and the delivery speed of fancy yarn that enables to manufacture very different samples of complex structure fancy yarns.

The investigated complex structure fancy yarns are presented in Fig. 3. The appearance of these yarns shows that the main effects are waves and closed or opened loops. The size of the effects is very different.

Results of the theoretical and experimental investigations of the coil length of the binder yarn are presented in Fig. 4. The deviations are shown in the Table 2.

The comparison of the theoretical and experimental values showed that the deviation fluctuates in a range between –4.6 % (7 variant) and +14.7 % (1 variant). The smallest deviation (+0.9 %) is obtained for 6th variant of complex structure fancy yarns.

Table 1. Raw material and linear density of the components of complex structure fancy yarn

Var. of fancy yarn	Raw material of the components and linear density			
	core	effect		binder
		first	second	
1	Cotton spun yarn, 11.7 tex ×2	Linen spun yarn, 46 tex	Linen spun yarn, 46 tex	Multifilament PA yarn, 10 tex
2	Multifilament PA yarn, 10 tex	Linen spun yarn, 56 tex	Linen spun yarn, 56 tex	Multifilament PA yarn, 10 tex
3, 4	Cotton spun yarn, 11.7 tex × 2	Linen spun yarn, 56 tex	Linen spun yarn, 56 tex	Multifilament PA yarn, 5 tex
5	Linen spun yarn, 46 tex	Linen spun yarn, 46 tex	Multifilament PA yarn, 3.3 tex	Multifilament PA yarn, 3.3 tex
6, 7	Cotton spun yarn, 18.5 tex × 2	Linen spun yarn, 56 tex	Linen spun yarn, 56 tex	Multifilament PA yarn, 5 tex

Table 2. Deviations between theoretical and experimental values of the coil length of the binder yarn

Variant of fancy yarns; deviation, %						
1	2	3	4	5	6	7
+14.7	+13.1	+13.8	+13.8	+14.1	+0.9	-4.6

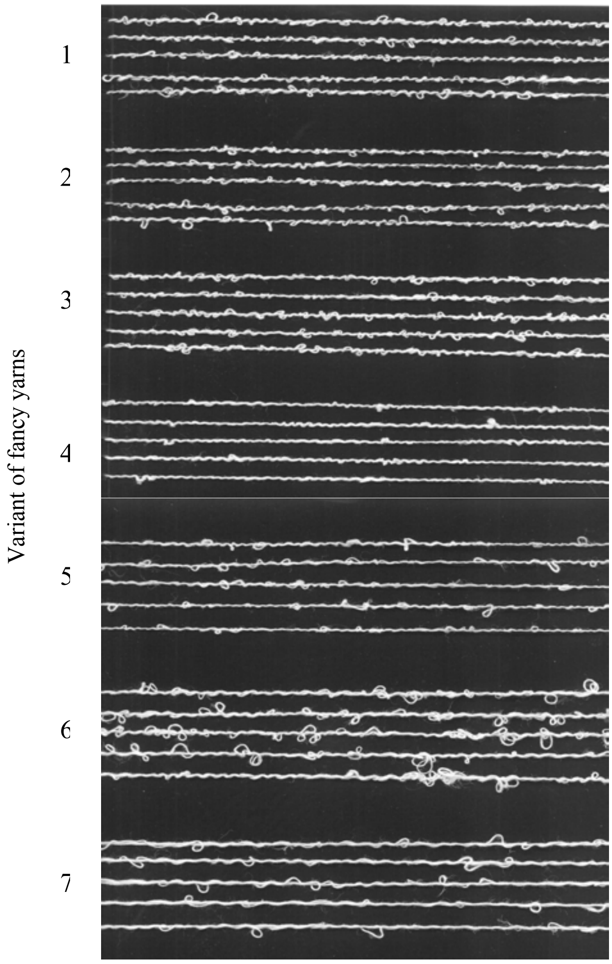

Fig. 3. Appearance of investigated complex structure fancy yarns

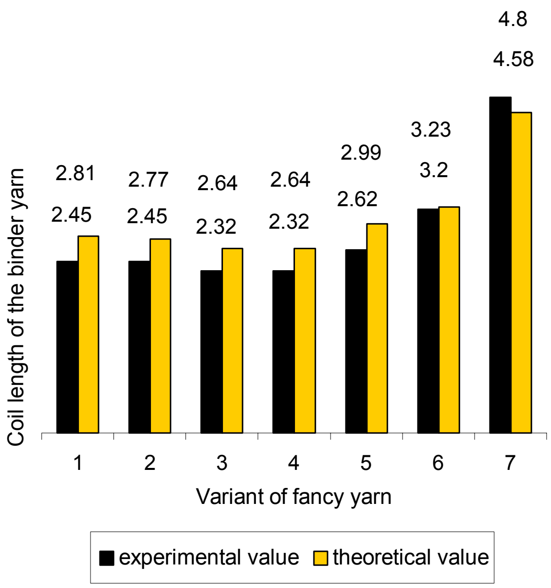

Fig. 4. Theoretical and experimental results of the coil length of the binder yarn

CONCLUSIONS

As the result of the theoretical analysis carried out, the method for the calculation of the coil length of the binder yarn of complex structure fancy yarns, which effect intermediate product consists of three yarns, was obtained. In current research the precondition was accepted that the cross-sections of the all three yarns of the effect intermediate product in complex structure fancy yarn remain the circle shaped, and this shape does not change while manufacturing the fancy yarn.

The examinations presented allow us to determine that necessary indices conditioned the coil length of binder yarn: linear density and overall density of fancy yarn components, rotational speed of hollow spindle, delivery speed of fancy yarn.

7 variants of fancy yarn samples for the experimental tests were produced on fancy yarn twisting machine by one process method using hollow spindles. The manufacturing parameters were: $n_s = 253.3 - 400.0$ sec^{-1}, $v_d = 0.5 - 1.17$ m/sec. The effect intermediate product consists of 3 yarns: one core and two effect yarns.

The results of experimental investigations and comparison analysis indicate that deviation between theoretical and experimental values fluctuates in a range between –4.6 and +14.7 %. The smallest deviation made +0.9 %.

The presented results made it possible to collect for further the set of information in designing of new assortment of complex structure fancy yarns.

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