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# Forecasting of Structural Parameters of Hollow Spindle Yarns

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A study deals with hollow spindle yarns that are made by one process technology. Such yarns have the special structure of three components with deliberately introduced irregular characteristics in diameter. The effect intermediate product of investigated hollow spindle yarns consists of the two yarns or of the three yarns. Analysing geometrical model of hollow spindle yarns the main precondition about the circle shaped cross-section of effect intermediate product was done. The structural and geometrical parameters influencing geometrical model of hollow spindle yarns are identified. It is presented that the coil length of the binder yarn is determined by the structural and geometrical indices of the components and the manufacture parameters of hollow spindle yarn. Hollow spindle twisting machine was used to produce different types of yarn varying in manufacture parameters as well as in raw material and linear density of the components. The predicted results and experimental data of the binder component coil length are presented. The good agreement between the theoretical calculations and experimental results was obtained.
*Keywords:* geometrical model, fancy yarns, hollow spindle yarns, structure.

## INTRODUCTION

Projecting of new fancy yarns and examination of their properties are very actual questions of today's textile industry. Fancy yarns enjoy popularity because they enhance the appearance of textile products and thereby make them more attractive.

The structure and the properties of various fancy yarns suitable for use on equipment with electronic control in response to rapid fashion changes are examined in [1]. An especially pressing and important problem is to create various structures of yarns using hollow spindles [2]. One process technology is economically efficient and gives wide possibilities to enlarge the assortment of complex structure yarns [3 – 6]. Hollow spindles can work in tandem with ring spinning spindles if required.

The increasing interest in the structures of fancy yarns as well as new methods of their manufacture technologies requires the studies to analyse geometrical models of yarns and structural parameters influencing such models [7, 8] as well as to forecast the properties of hollow spindle yarns [9]. The [10] describes techniques applied to define the characteristics of hollow spindle fancy yarns and how these can be used to quantify changes that occur with processing speed. The authors have demonstrated that in the case of boucle production, the height of the effect component decreases as production speed increases. Besides that the variation in the height of the effect component increases as the production speed increases.

The most effective analytical methods for determining the significant characteristics of a yarn are those that enable the various individual parameters for quantifying the fancy effect to be considered separately [11]. The study proposes and discusses a possible standardisation for the determination of the fundamental parameters of various fancy yarns with the purpose to optimise them and to analyse their structures.

The main task of this research is to propose the theoretical method of predicting of the coil length of the binder component in hollow spindle yarn as well as to compare the theoretical and experimental results.

The object of the study is hollow spindle fancy yarn made by one process method.

## RESULTS AND DISCUSSIONS

Hollow spindle machines are built especially for yarn that differs from the normal construction of single or folded yarns by way of deliberately produced irregularities in its construction [12, 13]. The feed can be from cones for the core component as well as for other products of spinning process like slivers or rovings. Ordinary, hollow spindle fancy yarns are composed of such components: core, effect, and binder. The core component and the effect component are passed through the shaft of the hollow spindle that rotates at relatively high speed. Because of the technological originality of the hollow spindle twisting method, the preconceived condition can be made that the effect intermediate product in the fancy yarn has no twist or its twist is very small to compare with the twist in which the binder component wraps the effect intermediate product. It follows from this the core and effect components have no contraction in the effect intermediate product. Due to the wrapping round the effect intermediate product that mostly has larger linear density the length of the binder component changes.

The effect intermediate product of investigated hollow spindle yarns consists of:

a) three yarns - one core and two effect yarns,
b) three yarns - one effect and two core yarns,
c) two yarns - one core and one effect yarn.

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Analysing geometrical model and interaction of core, effect, binder component of hollow spindle yarns were made some preconditions:

- the cross-section of effect intermediate product, that consists of core and effect component is the circle shaped;
- the binder component winds the core and effect yarn at the place of their contact;
- the contraction of the binder yarn is not considered because it is negligible.

The first precondition is especially acceptable if the one or both components of effect intermediate product are multifilament not twisted or textured yarns or yarns with low twist. Such yarns could be more deformed in the cross direction during manufacture process of hollow spindle fancy yarn.

The structure of hollow spindle yarn and the coil involute of the binder component are given in Fig. 1. The simplified cross-section of fancy yarn is shown in Fig. 2.

As it is visible from Fig. 1, the coil length of the binder yarn $l_{b1}$ is equal to hypotenuse of triangle, which one cathetus is equal to the coil pitch of the binder yarn $h$ and the second one is equal to the length of projection of involute $p$ (it is the length of curve, showed with dotted line in Fig. 2).

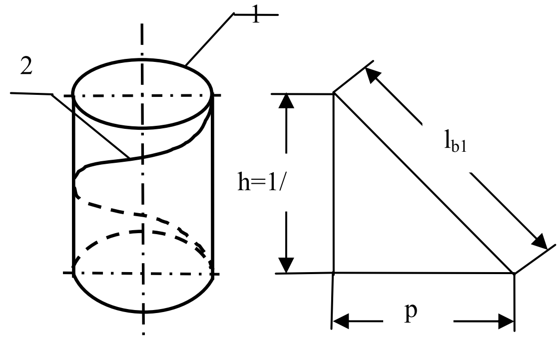


**Fig. 1.** The structure and geometrical indices of hollow spindle yarn and the coil involute of the binder yarn: 1 – effect intermediate product, 2 – binder component, $h$ – coil pitch of binder yarn, $p$ – length of projection of involute, $l_{b1}$ – coil length of the binder yarn, $K$ – twist of fancy yarn

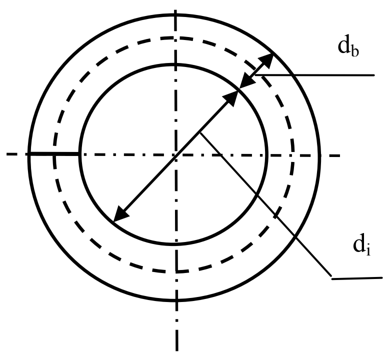


**Fig. 2.** Simplified cross-section of fancy yarn: $d_i$ – diameter of effect intermediate product, $d_b$ – diameter of binder yarn

The diameter of effect intermediate product $d_i$ and the diameter of binder yarn $d_b$ can be expressed by the linear density and the overall density of core, effect, and binder components.

The simplified model of cross-section of the fancy yarn was obtained from the real structures of the effect intermediate product made of the two yarns – one core yarn and one effect yarn or of the three yarns – two core (effect) yarns and one effect (core) yarn (see Fig. 3).

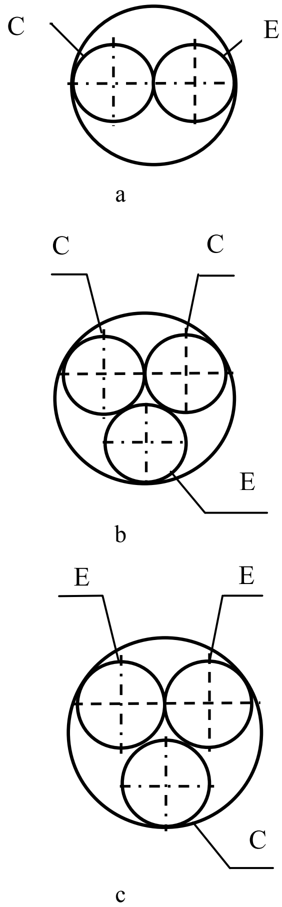


**Fig. 3.** The real structures of the effect intermediate product, when it consists of: a – two yarns; b, c – three yarns; C – core yarn; E – effect yarn

In the case when the fancy yarn consists of one core yarn, two effect yarns, and the binder yarn with linear density – $T_c$, $T_{e1}$, $T_{e2}$, $T_b$, respectively and overall density - $\delta_c$, $\delta_{e1}$, $\delta_{e2}$, $\delta_b$, respectively, the value $l_{b1}$ is obtainable by the formula:

$$l_{b1}=\left\{\begin{matrix}4\pi\left(\dfrac{T_c+T_{e1}+T_{e2}}{\sqrt{T_c\delta_c+T_{e1}\delta_{e1}+T_{e2}\delta_{e2}}}+\sqrt{\dfrac{T_b}{\delta_b}}\right)^2+\\+\left(\dfrac{v_d}{n_s}\right)^2\end{matrix}\right\}^{\frac{1}{2}}. \qquad (1)$$

Similarly it is possible to calculate the $l_{b1}$ in other cases of fancy yarn structures: when the fancy yarn consists of one effect yarn, two core yarns, and the binder yarn or when effect intermediate product consists of two yarns: one core yarn and one effect yarn. For example, when the effect intermediate product consists of one effect yarn and two core yarns with linear density – $T_e$, $T_{c1}$, $T_{c2}$, respectively

**Table.** Raw material and linear density of core, effect, binder component of hollow spindle yarns

| Variant of hollow spindle yarn | Raw material and linear density of the components of hollow spindle yarns | | |
|---|---|---|---|
| | core | effect | binder |
| 1, 2, 3 | Multifilament PES yarn, 11 tex | Linen spun yarn, 33 tex | Multifilament PES yarn, 11 tex |
| 4, 5 | Cotton spun yarn, 18.5 tex × 2 | Linen spun yarn, 56 tex | Multifilament PA yarn, 5 tex |
| 6, 7, 8 | Cotton spun yarn, 18.5 tex × 2 | Linen spun yarn, 46 tex | Multifilament PA yarn, 5 tex |
| 9 | Cotton spun yarn, 11.7 tex × 2 | Linen spun yarn, 46 tex | Multifilament PA yarn, 10 tex |
| 10 | Cotton spun yarn, 18.5 tex × 2 | Linen spun yarn, 46 tex | Multifilament PES yarn, 5 tex |

and overall density - $\delta_e$, $\delta_{c1}$, $\delta_{c2}$, respectively, the length of projection of involute $p$ can be expressed as follows:

$$p = 2\sqrt{\pi}\left(\frac{T_{c1}+T_{c2}+T_e}{\sqrt{T_{c1}\delta_{c1}+T_{c2}\delta_{c2}+T_e\delta_e}}+\sqrt{\frac{T_b}{\delta_b}}\right). \quad (2)$$

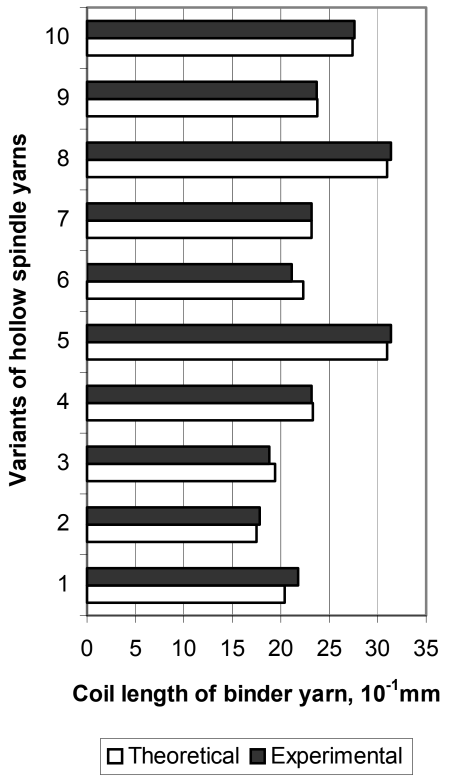


**Fig. 4.** Theoretical and experimental results of the coil length

Very often the linear densities and the raw material of core and effect yarns are equal. If the effect intermediate product consists of two yarns: one core yarn and one effect yarn with linear density - $T_c = T_e = T$ and overall density - $\delta_c = \delta_e = \delta$, the index $p$ is calculated from the formula:

$$p = 2\sqrt{\pi}\left(\sqrt{\frac{2T}{\delta}}+\sqrt{\frac{T_b}{\delta_b}}\right). \quad (3)$$

Such way of calculating, suggested by the authors of this paper, is very good for forecasting the yarns' qualities and designing the new assortment, because doesn't appear a need to produce the samples of yarns.

The experimental comparison was done with 10 variants of hollow spindle fancy yarns. Raw material and linear density of core, effect, binder components are shown in the Table.

The yarns having been produced by the method of one process twisting using hollow spindles of FAG type (Germany). The technological parameters of manufacture are the following: rotational speed of hollow spindle – 233.3 – 433.3 $sec^{-1}$ (14000 – 26000 $min^{-1}$), delivery speed of fancy yarns – 0.50 – 0.73 m/sec (30 – 44 m/min).

The results of the theoretical calculations and experimental tests of the coil length of the binder yarn are given in Fig. 4. The deviations between these results are presented in Fig. 5.

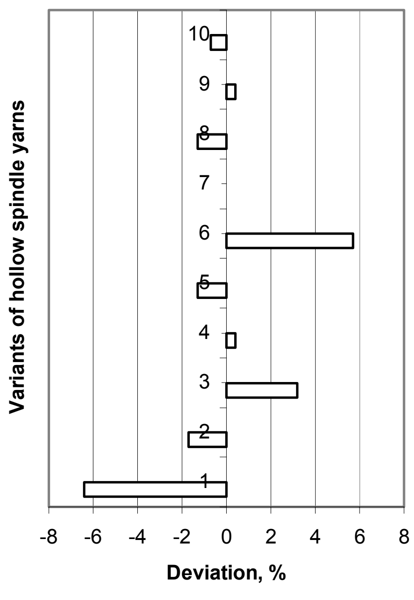


**Fig. 5.** Deviations between theoretical and experimental values of the coil length

It was found that for the 7th variant of hollow spindle yarns the calculated value of the coil length of the binder yarn is equal to the experimental value. Very good agreement between the theoretical and experimental values

– up to 1.0 % was also obtained for 4, 9, 10 variants of tested yarns.

The deviation between theoretical and experimental results of the coil length varies between – 6.4 (1st variant) and +5.7 % (6th variant).

## CONCLUSIONS

As the result of the theoretical investigation carried out, the method for calculating of the coil length of the binder yarn in hollow spindle yarns which effect intermediate product consists of the three yarns – one core yarn and two effect yarns or two core yarns and one effect yarn or of the two yarns – one core yarn and one effect yarn, was obtained. Analysing the geometrical model of hollow spindle yarns the main precondition about the circle shaped cross-section of effect intermediate product was done.

It is presented that the coil length of the binder yarn is determined by the indices of core, effect, and binder yarn like linear density and overall density as well as by the manufacture parameters of hollow spindle yarns like rotational speed of hollow spindle and delivery speed of fancy yarns.

Hollow spindle machine was used to produce different types of yarn varying in manufacture parameters – rotational speed of hollow spindle (233.3 – 433.3 $sec^{-1}$ and delivery speed of fancy yarns (0.50 – 0.73 m/sec) as well as in raw material and linear density of the components.

Good agreement between theoretical calculations and experimental results confirms the applicability of proposed research. Very good agreement between the theoretical and experimental values – up to 1.0 % was obtained for 4 variants of tested yarns.

It is worth to note that approximately half of the calculated values of the coil length (3, 4, 6, 9 variants) exceeded the experimental results and other part of calculated values (1, 2, 5, 8, 10 variants) are smaller to compare with experimental data.

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