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Comparison of Different Theoretical Models of Fancy Yarns

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A study deals with the analysis of the theoretical models of the fancy yarns. The investigated fancy yarns are of traditional structure, i.e., their effect intermediate product composed of two yarns as well as of complex structure – their effect intermediate product made of three yarns. The analysis is done using two theoretical methods for predicting the coil length of the binder yarn in the fancy yarn. Theoretical values of the coil length of the binder yarn of 29 types of investigated fancy yarns are compared with the experimental data. The experimental comparison was performed for various structure fancy yarns specially manufactured for this investigation and using data presented by the other authors. The comparison between the calculated coil length values and experimental data shows good agreement for 21 results (according to the 1st and 2nd method). Here the deviations not exceed 5 %. The developed analysis showed that the both theoretical methods could be used for the predicting of the geometrical indices of the fancy yarns, still the method satisfying the requirement of the precondition about the circle shaped cross-section of the effect intermediate product is more precise in many cases.

Keywords: coil length, fancy yarn, theoretical method, structure.

INTRODUCTION

Because of the significance in woven and knitted apparel, hand-knitted and upholstery fabrics, attempts are made to investigate fancy yarns structure and to study the effect of technological parameters of their manufacture process [1].

Traditionally, fancy yarn consists of core, effect, and binder component. An increasing interest in the structures of spun hybrid yarns, traditional fancy yarns, their complex structures as well as the new methods of manufacturing technologies of these yarns require analyses of geometrical models of yarns and reasons influencing choice of the model [1 – 6].

The modelling of snarl formation in the fancy yarns with snarl effects is based on the model of an elastic string. In paper [3] the modelling of specific kinds of the fancy yarn with loops and snarls is analysed. The theoretical analysis is based on the modelling of a fancy yarn as a linear elastic object with the assumptions about the geometry of the snarl's "leg" and without taking into the consideration the interaction between the contacting parts of the yarn. Such fancy yarn is produced using twist-lively yarns and the snarl formation occurs at a temporary decrease in tension or is due to a certain slack introduced into the yarn.

The most effective theoretical methods for the defining the important indices of the yarn are those that enable the various individual parameters for quantifying the fancy yarn effect to be considered separately [7]. A possible standardisation for the definition of the parameters of fancy yarns of very different types is discussed. The aim of such research is to optimise these parameters.

The structure of various kinds of fancy yarns is also investigated in [8 – 10].

As the theoretical background of the research presented in the current paper the geometrical models of complex structure yarns were used [4, 5, 11]. The structure of the fancy yarns was determined by the properties of the components of the fancy yarns and by the technological parameters of the manufacture: rotational speed of hollow spindle and delivery speed of fancy yarns. In the main, the proposed models differ in the accepted preconditions about the structure of effect intermediate product and its changes during the fancy yarn's manufacturing process.

The studies [5, 11] propose the theoretical method of predicting of the coil length of the binder component in the fancy yarn with the precondition that the cross-sections of yarns of effect intermediate product remain the circle shaped, and this shape does not change while manufacturing the fancy yarn. The effect intermediate product of these fancy yarns is composed of three or two yarns.

The research [4] deals with the proposed theoretical method of calculating of the coil length using the precondition about the circle shaped cross-section of the effect intermediate product that consists of three yarns – one core (effect) yarn and two effect (core) yarns or two yarns – one core yarn and one effect yarn.

The main purpose of this study is to develop the exhaustive comparable analysis of proposed theoretical methods using data of various variants of fancy yarns and to make the recommendations about the possibilities of their use.

RESULTS AND DISCUSSIONS

The 25 different samples of the fancy yarns were specially manufactured for this research. Additionally literature data [12, 13] of 4 types of fancy yarns were used also. The fancy yarns were made in one process by hollow spindle technology. Fig. 1 presents a detailed description of the object and the ways of theoretical investigations.

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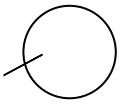
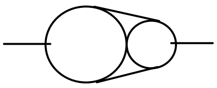
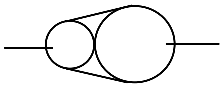
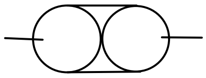
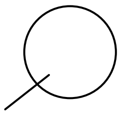
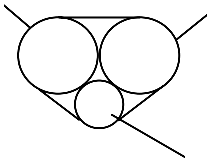
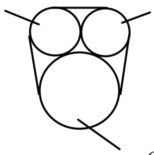
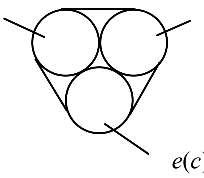
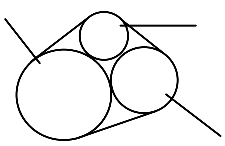
Fancy yarns comprise three or four component yarns of natural and/or man-made fibres. The fibres are of staple length or continuous filaments. The fibres incorporated in the fancy yarn construction are of different or same material, length, and thickness. So, the investigated fancy yarns were manufactured in a big variety of combinations.

The two theoretical methods are used for each type. The types differ in the diameter and the number of the yarns of effect intermediate product. These types also the number of samples is presented in the Table 1.

One process technology and hollow spindle method were used in manufacture of all fancy yarns. According to this technology the effect component is locked into position by the interaction of the core and the binder

Table 1. Possible types of fancy yarns' structure (effect intermediate product consists of two or three yarns)

Type	Graphic pictures of the structure of effect intermediate product*		Condition for diameters of initial components	Number of investigated fancy yarns' samples
	1st method	2nd method		
Two yarns (one core yarn and one effect yarn) form effect intermediate product of the fancy yarns:				
1	 c+e	 c e	$d_c > d_e$	–
2	”	 c e	$d_c < d_e$	13
3	”	 c e	$d_c = d_e$	3
Three yarns (one core/effect yarn and two effect/core yarns form effect intermediate product of the fancy yarns:				
4	 $c_1(e_1)$+$c_2(e_2)$+$e(c)$	 $c_1(e_1)$ $c_2(e_2)$ $e(c)$	$d_{c1} = d_{c2} > d_e$	3 (individual cases when d_e=d_{c1}>d_{c2})
5			$d_{e1} = d_{e2} > d_c$	6 (and 1 individual case when d_c=d_{e1}>d_{e2})
6	”	 $c_1(e_1)$ $c_2(e_2)$ $e(c)$	$d_{c1} = d_{c2} < d_e$	–
7			$d_{e1} = d_{e2} < d_c$	–
8	”	 $c_1(e_1)$ $c_2(e_2)$ $e(c)$	$d_{c1} = d_{c2} = d_e$	3
9			$d_{e1} = d_{e2} = d_c$	–
10	”	 $c_1(e_1)$ $e(c)$ $c_2(e_2)$	$d_{c1} > d_{c2} > d_e$	–
11			$d_{e1} > d_{e2} > d_c$	–

* yarns of effect intermediate product: c_1 and c_2 – first and second core yarn; e_1 and e_2 – first and second effect yarn; c and e – core and effect yarn; d_c, d_{c1}, d_{c2} – diameters of core yarn, first core yarn, second core yarn; d_e, d_{e1}, d_{e2} – diameters of effect yarn, first effect yarn, second effect yarn; binder yarn is shown by continuous line.

yarn. This is done by passing the core and effect yarns down the centre of the hollow spindle that contains the package with the yarn of the binder component. As the hollow spindle rotates the binder component balloons of the package and wraps the effect intermediate product made of core and effect component. The technological parameters were following: the rotational speed of hollow spindle – 233.33 – 466.67 sec^{-1} (14000 – 28000 min^{-1}), the delivery speed of the fancy yarns – 0.50 – 1.17 m/sec (30 – 70 m/min). Raw material, linear density of the components are presented in the Table 2 (these samples own fancy yarn's structure according to the Table 1).

Table 2. Raw material and linear density of fancy yarn components

Fancy yarn component	Raw material* and linear density
Core yarn (c)	Cotton spun yarn, 11.7 tex × 2; 18.5 tex × 2; PES multifilament yarn, 11 tex; linen spun yarn, 33 tex; 46 tex; PA multifilament yarn, 10 tex; PES textured yarn, 16.7 tex; 25 tex; PAN and CV spun yarn, 28 tex; 50 tex.
First core yarn ($c1$)	Linen spun yarn, 33 tex; 46 tex; cotton spun yarn, 11.7 tex × 2.
Second core yarn ($c2$)	PES multifilament yarn, 11 tex; linen spun yarn, 46 tex; 56 tex.
Effect yarn (e)	Linen spun yarn, 33 tex; 46 tex; 56 tex; wool spun yarn, 22 tex × 2; PAN and CV spun yarn, 28 tex; 28 tex × 2; 50 tex.
First effect yarn ($e1$)	Linen spun yarn, 46 tex; 56 tex.
Second effect yarn ($e2$)	Linen spun yarn, 46 tex; 56 tex; PA multifilament yarn, 3.3 tex.
Binder yarn	PA multifilament yarn, 3.3 tex; 4.4 tex; 5 tex; 10 tex; PES multifilament yarn, 5 tex; 11 tex.

* PES – polyester, PA – polyamide, PAN – acrylic, CV – viscose

Theoretical and experimental results of the coil length of the binder yarn are presented in Tables 3 and 4. The types differ in fancy yarn's structure, in technological parameters, in raw material and linear density of components. There were obtained three kinds of distribution of theoretical and experimental results of the coil length of the binder yarn l_T and l_E, respectively:

- kind I: $l_E \leq l_T$ (1st method) < l_T (2nd method),
- kind II: l_T (1st method) < l_E < l_T (2nd method),
- kind III: l_T (1st method) < l_T (2nd method) < l_E.

The kind I (17 types of investigated fancy yarns) of the distribution of the results is more frequently if to compare with the kinds II (7 variants of fancy yarns) and III (5 types of fancy yarns). As we can see from the Table 3, the deviations between the theoretical and experimental values fluctuate in a range of zero and +9.9 % when l_T was calculated according to the 1st method and in a range between +5.6 % and +21.9 % when l_T was calculated according to the 2nd method. This kind of distribution shows the theoretical values calculated according to the 1st method is more precisely correspond the experimental values. There are about a half of such deviations with the

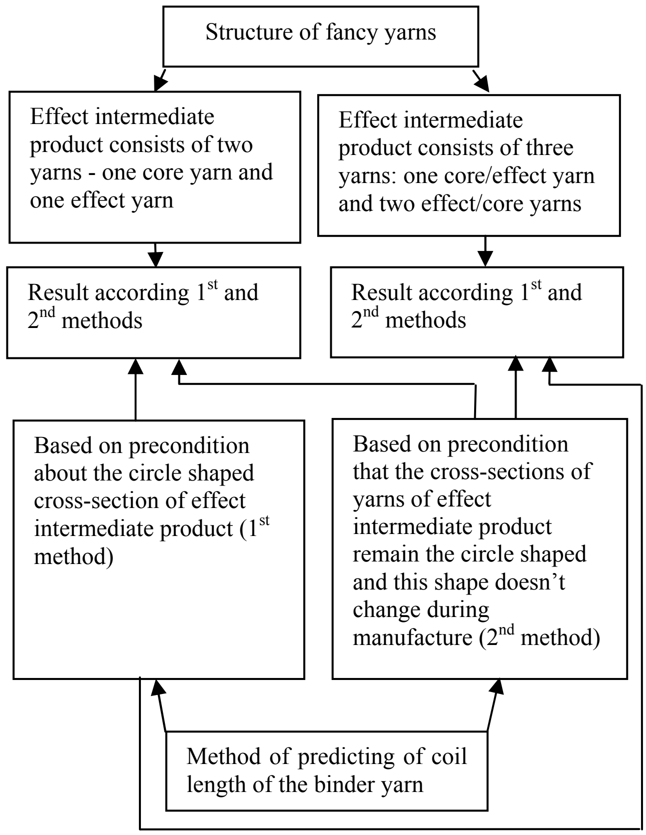


Fig. 1. The object and the ways of theoretical investigations

Table 3. Theoretical and experimental results of the coil length of binder yarn (distribution of kind I)

Type (see Tab. 1)	Experi-mental value l_E, mm	Theoretical value l_T, mm, according to		Deviation, %, according to	
		1st method	2nd method	1st method	2nd method
2	2.32	2.33	2.53	+0.4	+9.1
2	2.11	2.23	2.37	+5.7	+12.3
2	3.64	4.00	4.09	+9.9	+12.4
2	2.37	2.38	2.59	+0.4	+9.3
5	2.45	2.50	2.81	+2.0	+14.7
5	2.45	2.50	2.77	+2.0	+13.1
3	1.88	2.06	2.16	+9.6	+14.9
2	1.88	1.94	2.17	+3.2	+15.4
4*	2.28	2.41	2.63	+5.7	+15.4
4*	1.92	2.10	2.34	+9.4	+21.9
5	2.32	2.33	2.64	+0.4	+13.8
4*	2.32	2.48	2.78	+6.9	+19.8
5	2.32	2.45	2.64	+5.6	+13.8
5**	2.62	2.85	2.99	+8.8	+14.1
8	2.94	3.14	3.25	+6.8	+10.5
3	2.71	2.81	2.94	+3.7	+8.5
2	2.32	2.32	2.45	0	+5.6

* individual case when $d_e = d_{c1} > d_{c2}$;
** individual case when $d_c = d_{e1} > d_{e2}$.

value less than 5 %. While the values obtained using the 2nd method in many cases (13 results) in twice and more exceed the deviations calculated according to the 1st method.

As it seen from the Table 4, there are 10 cases with the deviations between the theoretical and experimental values that not exceed 5 % when the distribution was of kind II. Here the experimental value interferes between the theoretical values. The results of the Tables 3 and 4 show sufficiently good agreement between the theoretical and experimental values. In many cases (41), when the distribution was of kinds I, II and III, the deviations not exceed 10 %. Very good agreement was obtained for 6 results. Here the deviations are up to 1 %.

Table 4. Theoretical and experimental results of the coil length of binder yarn (distribution of kinds II and III)

Type (see Tab. 1)	Experi-mental value l_E, mm	Theoretical value l_T, mm, according to		Deviation, %, according to	
		1st method	2nd method	1st method	2nd method
Kind II of distribution:					
2	3.14	3.10	3.26	–1.3	+3.8
2	3.14	3.10	3.19	–1.3	+1.6
2	2.18	2.04	2.27	–6.4	+4.1
2	2.76	2.74	2.86	–0.7	+3.6
2	1.78	1.75	1.99	–1.7	+11.8
5	3.20	2.95	3.23	–7.8	+0.9
3	2.46	2.42	2.75	–1.6	+11.8
Kind III of distribution:					
8	4.12	3.86	3.94	–6.3	–4.4
8	4.80	4.41	4.48	–8.1	–6.7
5	4.80	4.38	4.58	–8.8	–4.6
2	3.29	2.75	2.96	–16.4	–10.0
2	2.06	1.76	2.00	–14.6	–2.9

It is supposed that the obtained character of distribution could be determined by such factors:

- the real form of cross-sections of fancy yarn components remotes from the extreme ideal structures because the yarns of the core and effect component get less or more deformed in cross direction,
- twist level and diameter of core and effect components, errors due to the unevenness of the parameters influencing on the coil length of the binder yarn, i.e., linear density and overall density of core, effect and binder yarns,
- very contrasting combinations of raw material (linen, cotton spun yarns, PES textured yarns, PA multifilament yarns, etc.).

CONCLUSIONS

Experimental verification of the theoretical methods was done using 29 types of various fancy yarns of traditional and complex structure. The fancy yarns were made using different raw material and linear density of core, effect, and binder components as well as changing the technological parameters of manufacture: rotational speed of hollow spindle and delivery speed of fancy yarns. There were obtained three kinds of distribution of theoretical and experimental results of the coil length of the binder yarn: first (17 variants), second (7 variants), and third (5 variants). Good agreement between the theoretical calculations and experimental results was obtained for 21 results (according to the 1st and 2nd method). Here the deviations not exceed 5 %. The following factors could be important for the obtained distribution of theoretical and experimental values: inadequacy between the real and ideal form of cross-sections of fancy yarn components, twist level and diameter of yarns of core and effect component, errors due to unevenness of the parameters influencing on the coil length, very contrasting combinations of raw material of the fancy yarns. Though the method satisfying the requirement of the precondition about the circle shaped cross-section of the effect intermediate product is more precise in many cases but in some cases the 2nd method appeared more suitable.

The theoretical methods would be helpful for further investigations and design of new assortment of the fancy yarns of traditional and complex structure.

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