Influence of Overfeed and Twist on Fancy Yarns Structure

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In this study the design of fancy yarns and structural indices of fancy yarns such as the height of the effects, the width of the effects, distances between effects and number of effects per unit length of fancy yarns are investigated. The researched fancy yarn structural indices depend on the overfeed, that is determined by the speed of supply of the effect yarn and the delivery speed of fancy yarns upon the fancy yarn twist, which is determined by the rotational speed of a hollow spindle. It was calculated minimum and maximum values of structural indices and their limits of variation. The fancy yarns structural indices primarily depend on overfeed. With increase of this factor the values of the height and the width of the effects, number of effects per unit length are increasing too. In that case distances between effects decrease.
Keywords: fancy yarns, effect, structural indices, overfeed, twist.

INTRODUCTION

An especially pressing and important problem of today is creating high quality new textile products and analysis of their properties and usage possibilities. Modern – day fashion and popularity of woven, knitted and nonwoven fabrics from fancy yarns, also attention to functional, usage properties requires to pay attention to designing new fancy yarns and analysis of their properties [1, 2].

Fancy yarns are textile yarns with virtually unlimited pattern designs. Fancy yarns present deliberate, decorative continuous or programmed effects of color and/or form, and they are used to create some variation in the aesthetic appearance, to décor product: woven fabrics, knitted materials, garment and other textiles as well. The variety of fancy yarns is very large: they differ by their structure features, fiber components, manufacture way and etc. Fancy yarns can give to product special features such as soft, friability, relief, good exportation features [3 – 5].

Using one process manufacture way it is possible to produce fancy yarns with very different effects such as loops, waves, knots, spiral structure and combined effects, with different particular properties, etc. It was noticed, that usually mechanical indices of fancy yarns are studied [6 – 9]. On the other hand, producing products with optimal properties one must forecast structural and geometrical rate such as: the height of the effects, the width of the effects, distances between effects, number of effects per unit length of fancy yarns, variety of the effects, effects position, etc. [10 – 13].

Researched fancy yarn structural indices depend on the overfeed, that is determined by the speed of supply of the effect yarn (X_1) and the delivery speed of fancy yarns (X_2) upon the fancy yarn twist, which is determined by the rotational speed of hollow spindle (X_3).

The aim of the research presented in this article is to develop the relationships between the overfeed (η) and twist of fancy yarns (K) and such indices of fancy yarns: the height of the effects (h), the width of the effects (s), number of effects per unit length of fancy yarns (z).

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EXPERIMENTAL

The object of this research – fancy yarns with structure effects like loops, waves, knots, spirals and combined effects. Fancy yarns components were: core and effect components – twisted, bulk PAN yarns, each of 31 tex × 2; binder component – multifilament PA yarn, 5,0 tex.

Fancy yarns were produced by one process method using fancy-twisting machine Jantra-PrKV 12 (Bulgaria) with hollow spindles of the type FAG (Germany) at fourteen different factor value combinations. This machine works by Prenomit technology. The right selection of the experimental model is very significant for the efficiency of the research.

The second order composite model with experimental points on the cube was chosen [14]. Number of levels and variables was chosen 3. This design was very suitable for the study because of its obvious advantages: the corner points can be successively investigated – this enables to study larger part of the space; it is important to investigate the points that correspond to the maximum values of the factors because they determine machine productivity and operation possibilities; all the combinations of factors are easily compatible due to the drive scheme of the machine used; the number of factor value combination is rather small.

The independent variables chosen were:

– the speed of supply of the effect yarn X_1: 40–80 m/min (0.67–1.33 m/s),
– the delivery speed of fancy yarn X_2: 30–50 m/min (0.50–0.83 m/s),
– the rotational speed of hollow spindle X_3: 14000–20000 min^{-1} (233.3–333.3 s^{-1}).

The code and real independent variables of manufacturing fancy yarns are presented in the Table 1.

Overfeed η shows how many times effect component is faster than the core component. In the manufacturing process overfeed η was varied from 0.80 to 2.67 and fancy yarn twist K from 280 m^{-1} to 666.7 m^{-1}. In the minimal overfeed spiral effect has been formed in the majority of places.

The following structural indices of fancy yarns were analyzed, forecasted and designed: the height of the effects

Table 1. The code and real independent variables of manufacturing fancy yarns

Var. No.	Code independent variables			Real independent variables		
	X_1	X_2	X_3	X_1, m/min	X_2, m/min	X_3, min^{-1}
1	–	–	–	40	30	14000
2	+	–	–	80	30	14000
3	–	+	–	40	50	14000
4	+	+	–	80	50	14000
5	–	–	+	40	30	20000
6	+	–	+	80	30	20000
7	–	+	+	40	50	20000
8	+	+	+	80	50	20000
9	–	0	0	40	40	17000
10	+	0	0	80	40	17000
11	0	–	0	60	30	17000
12	0	+	0	60	50	17000
13	0	0	–	60	40	14000
14	0	0	+	60	40	20000

h, the width of the effects *s*, the distance between effects *a*, the number of the effects per unit length *z*. These structural indices were measured like it is presented in Figure 1.

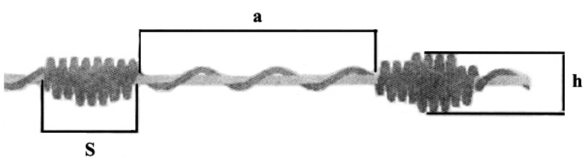

Fig. 1. Measuring structural indices of fancy yarns

The yarns were tested on a standard test equipment using standard test methods: the structural indices of fancy yarns were tested with a stereo-microscope "SMZ660 Zoom Stereomicroscope 6.1:1 Zoom Ratio" and displayed with a computer. The effects were made bigger 5 times, than structure effects of fancy yarns were measured up with computer program LUCIA. The number of the effects per unit length of fancy yarns was calculated using twist tester. The number of tests is 25 tests for each index.

RESULTS AND DISCUSSIONS

The general relation between the response *Y* (in this case *h*, *s*, *a*, *z*) and parameters X_1, X_2, X_3 are [14]:

$$Y = B_0 + \sum_{i=1}^{M} B_i X_i + \sum_{i=1}^{M-1} \sum_{j=i+1}^{m} B_{ij} X_i X_j + \sum_{i=1}^{M} B_{ii} X_i^2 , \qquad (1)$$

where: *M* is the number of variables; B_0 is the constant term; B_i are the coefficients of the main factor effects; B_{ij} are the coefficients of the interaction effects; B_{ii} are the coefficients of the quadratic effects.

The relations between the coefficients are presented in the Table 2. Some obtained coefficients are not significant and they are shown in brackets.

Table 2. Coefficients of the relations obtained

Coefficients	Responses			
	h, mm	*s*, mm	*a*, mm	*z*, m^{-1}
B_0	1.65	1.98	2.08	103.62
B_1	0.94	0.84	–4.39	73.29
B_2	–0.35	–0.41	–5.66	–23.34
B_3	–0.10	–0.20	–0.76	7.54
B_{12}	0.20	0.43	8.5	–3.55
B_{13}	–0.09	(–0.03)	0.82	3.37
B_{23}	(0.03)	0.05	0.77	–2.62
B_{11}	–0.36	–0.75	(0.06)	–27.47
B_{22}	0.21	0.36	5.06	2.87
B_{33}	(–0.01)	0.21	2.86	14.17

In order to design new fancy yarns are used these mathematical models, which supplied inequality:

$$F_A \rangle F_T , \qquad (2)$$

where: F_A is the criterion of mathematical models; F_T is the table criterion.

The comparison of the criterion F_A of mathematical models with the table criterion F_T [15] is given in the Table 3.

Table 3. The comparison of the criterion F_A of mathematical models with the table criterion F_T

The structural index of fancy yarns	Criterion F	
	F_A	F_T
The height of the effects, *h*	4.80	3.78
The width of the effects, *s*	15.77	4.43
Distances between effects, *a*	1.79	5.69
The number of the effects per unit length, *z*	237.9	8.57

Using criterion *F* it was established that the mathematical models of the dependencies of the structural indices of fancy yarns: the height of the effects (*h*), the width of the effects (*s*), the number of effects per unit length of fancy yarns (*z*) upon the independent variables of manufacturing fancy yarns X_1, X_2, X_3 are suitable for further interpretation. Mathematical model of distances between effects (*a)* aren't informative.

Overfeed is very important factor, which influences the structure of fancy yarns, sizes and distribution of effects in the yarn [2, 9, 11 – 13]. Mostly appeared fancy yarns structural effects are presented in Figure 2.

Similar arcs, knots, different loops were analyzed by S. Petrulyte [13] and K. E. Grabowska [9, 12].

It is evident from Fig. 3, that 3, 7 and 9 variants numbers of fancy yarns (see Table 1) are with waves and have spiral structure and they are produced with the smallest overfeed. Core and effect components switch round together on these yarns. When fancy yarns twist *K* is 425 m^{-1} and overfeed $\eta = 1$, core and effect components are mostly twisted (see Fig. 3, b).

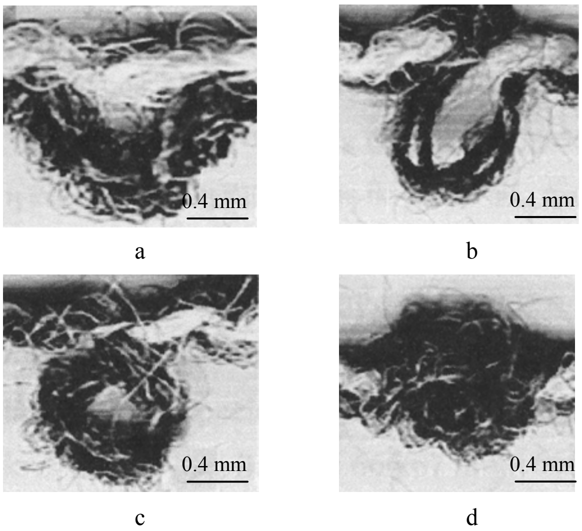

Fig. 2. Fancy yarns structural effects: a – arc, b – open loop, c – close loop, d – knot

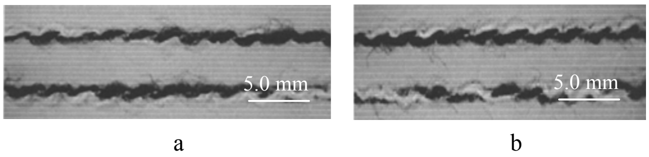

Fig. 3. Fancy yarns with spiral structure: a – of 7 variant number; b – of 9 variant number

When the overfeed η is 1.2 – 1.3, then different effects of fancy yarns (bosses, arcs, open loops) are formed (see Fig. 4). These structural effects are determined for 1, 5 and 12 fancy yarns variants. When overfeed η is 1.3 and fancy yarns twist K is 466.7 m^{-1}, then the height of the effects h of fancy yarn has been changed from 0.79 mm (see Fig. 4, a) to 3.91 mm, the width of the effects s – 1.45 mm ÷ 3.85 mm, the number of the effects per unit length z – 32 m^{-1} ÷ 42 m^{-1} has changed, too. When fancy yarns twist is increasing on maximum value 666.7 m^{-1}, the height and width of the effects are less, but the index z is higher – 38 m^{-1} ÷ 52 m^{-1}.

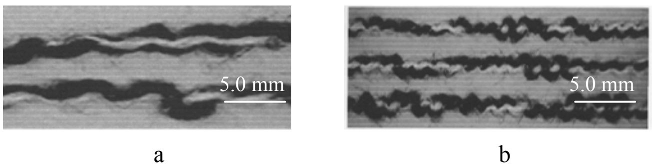

Fig. 4. Fancy yarns with bosses, arcs, open loops: a – of 1 variant number; b – of 5 variant number

When overfeed is average $\eta = 1.5 \div 1.6$ and fancy yarns twist K is changing from 280 m^{-1} to 500 m^{-1}, then in fancy yarns bosses, open and close loops are formed, in some places knots are occurring (see Fig. 5). In structure fancy yarns open and close loops are seen, the height of the effect rises to 5.86 mm and width of the effects – 4.28 mm (see Fig. 5, a). When twist of yarn is increasing to 400 m^{-1}, then the number of the effects per unit length z is changing from 142 m^{-1} to 160 m^{-1} (see Fig. 5, b).

When overfeed is average $\eta = 2$, then different effects of fancy yarns (periodically open and close loops, knots) are formed (see Fig. 6). These structural effects are determined for 10 fancy yarns variant, which is without arcs.

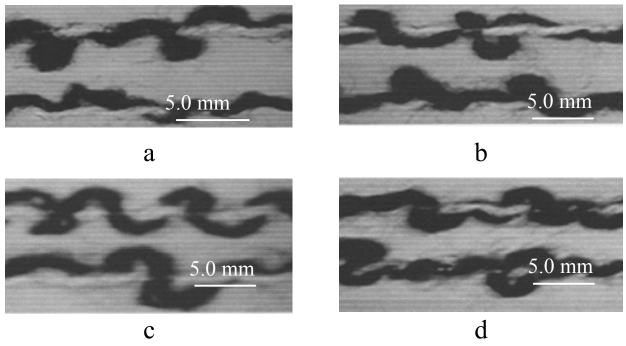

Fig. 5. Fancy yarns with bosses, open and close loops, knots: a – of 4 variant number; b – of 8 variant number, c – of 13 variant number; d – of 14 variant number

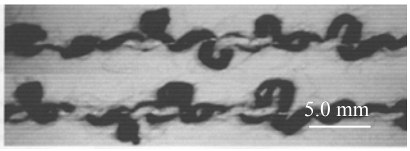

Fig. 6. Fancy yarns of 10 variant number

When overfeed and fancy yarns twist is higher ($\eta = 2.67$ and $K = 666.7$ m^{-1}), then the index z reaches the maximum value ($z = 192$ $m^{-1} \div 210$ m^{-1}), but the distances between effects a reaches the minimum value – about 2.93 mm (see Fig. 7).

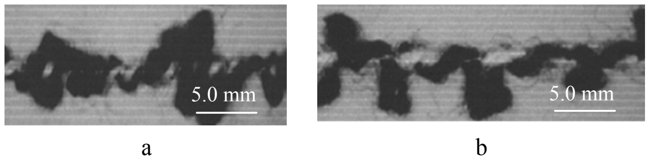

Fig. 7. Fancy yarns: a – of 6 variant number; b – of 2 variant number

When the overfeed is increasing, the height of the effects h of fancy yarn and the width of the effects s are increasing, too. When twist of fancy yarns is increasing, the number of different effects in fancy yarns is growing up, but the size of these effects is the least. Similar tendencies are presented and analyzed in [9, 12, 13].

The influence of the factor η is significant for the investigated indices of fancy yarns: h, s and z. It is evident from Figs. 8 – 12. In Figures 8 – 10 the factor – the rotational speed of hollow spindle X_3 has a stationary point and factor value is equal to –1, 0, +1. In Figures 11, 12 the factor – the speed of supply of the effect yarn X_1 has a stationary point and factor value is equal to –1, 0, +1.

The height of the effects, the width of the effects of fancy yarn and the number of effects per unit length of fancy yarn are very significant factors stipulating the structure of fancy yarns. They influence the appearance, decorative level, texture of textile garment very much. It was found that as the overfeed η increases, structural indices have a tendency to increase too (see Figs. 8 – 10).

These tendencies are the same for all indices. Dependencies of the height of the effects and the number of effects per unit length of fancy yarn have high coefficients of determination ($R^2 = 0.8087 \div 0.8255$). Coefficients of determination are also important ($R^2 = 0.6534 \div 0.6822$), so it can be stated that the width of the effects depends on overfeed.

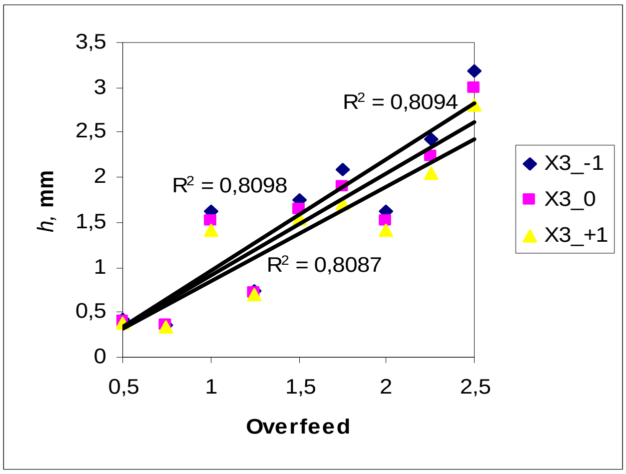

Fig. 8. Dependence of the height of the effects (*h*), mm upon the overfeed (*η*)

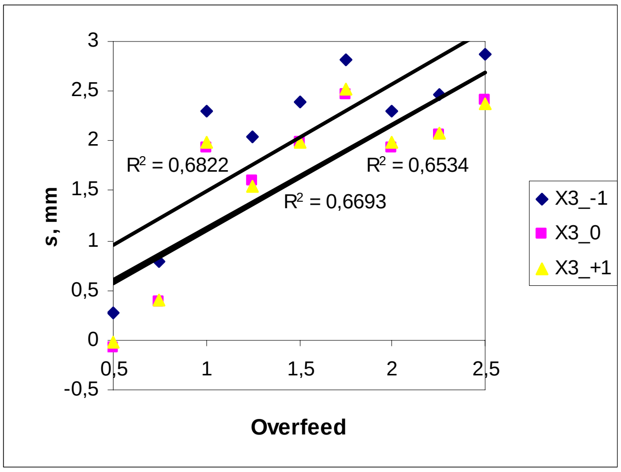

Fig. 9. Dependence of the width of the effects (*s*), mm upon the overfeed (*η*)

The influence of the factor *K* for the investigated structural indices *h* and *z* of fancy yarns are presented in Figs. 11 – 12.

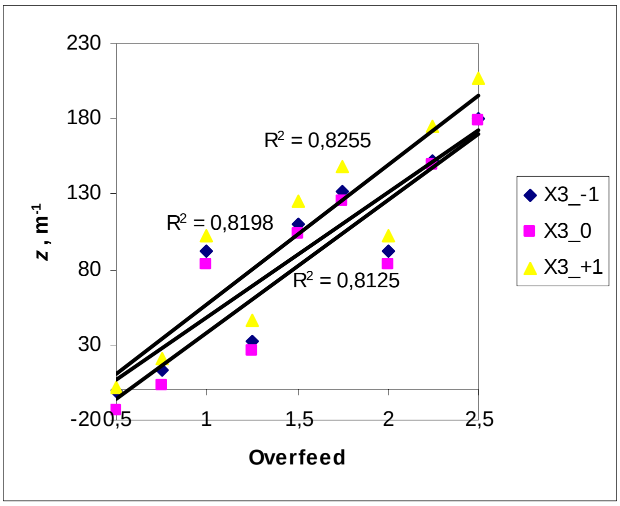

Fig. 10. Dependence of the number of effects per unit length of fancy yarn (*z*), m^{-1} upon the overfeed (*η*)

Coefficients of determination are high ($R^2 = 0.738 \div 0.8819$) only of the number of effects per unit length of fancy yarn, so its structural index depends on fancy yarn twist *K*. On the other hand coefficients of determination of dependencies *h* and *s* are low ($R^2 = 0.0137 \div 0.453$) and it can affirm that these dependencies of the height and the width of the effects of fancy yarns on fancy yarns twist *K* are not established.

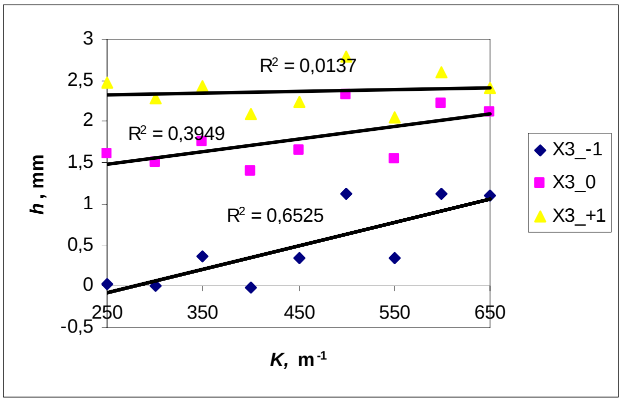

Fig. 11. Dependence of the height of the effects (*h*), mm upon the twist (*K*), m^{-1} of fancy yarns

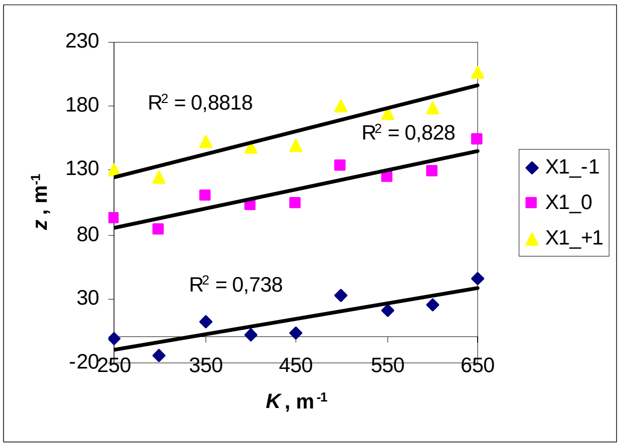

Fig. 12. Dependence of the number of effects per unit length of fancy yarn (z), m^{-1} upon the twist (*K*), m^{-1} of fancy yarns

Table 4. Minimum and maximum values of fancy yarn indices that are defined by the values of factors X_1, X_2, X_3 in experimental space

Indices of fancy yarns	Coded values of factors			Calculated value, min/max *
	X_1	X_2	X_3	
The height of the effects, *h*, mm	–	–	+	0.50/7.84
	+	–	–	
The width of the effects, *s*, mm	–	–	+	1.01/5.18
	+	–	–	
Distances between effects, *a*, mm	+	–	–	0.50/71.79
	–	–	–	
The number of the effects per unit length, *z*, m^{-1}	–	–	–	32/210

*– fancy yarns variants of 3, 7 and 9 numbers are with waves and has spiral structure and there isn't possibility to measure the sizes of effects of these variants yarns.

There were calculated mathematical statistical characteristics for all the investigated structural indices and the minimum and maximum values of fancy yarn indices that are determined by the values of the factors X_1, X_2, X_3 in the experimental space. These data are presented in the Table 4.

According to these data one can find the limits of variation of studied fancy yarns structural indices.

For example, a coefficient of the variation of structural indices has varied as following: the height of the effects h to 15.56 %, the width of the effects s – to 8.78 %, the distances between effects a – to 12.14 %, the number of the effects per unit length z – to 9.58 %.

CONCLUSIONS

According to the regression analysis the factors of fancy yarns manufacturing parameters, as the speed of supply of the effect component X_1, the delivery speed of fancy yarns X_2, the rotational speed of hollow spindle X_3 and their interaction are significant for the structural indices.

The mathematical models of the dependencies of the structural indices of fancy yarns: the height of the effects (h), the width of the effects (s), the number of effects per unit length of fancy yarns (z) upon the independent variables of manufacturing fancy yarns X_1, X_2, X_3 are suitable for further interpretation.

It was found that the minimum values of h and s indices were achieved when the coded values of the factors are: $X_1 = -1$, $X_2 = -1$, $X_3 = +1$ and maximum values of these indices, when $X_1 = +1$, $X_2 = -1$, $X_3 = -1$. The distances between effects a have maximum values when $X_1 = -1$, $X_2 = -1$, $X_3 = -1$, but in the same coded values in the number of the effects per unit length z we get the opposite results.

It was estimated that the height of the effects h of researched fancy yarn varied from 0.50 mm to 7.84 mm, the width of the effects s – on 1.01 mm – 5.18 mm range, the distances between effects a – on 0.50 mm – 71.79 mm range and the number of the effects per unit length z – on 32 m^{-1} – 210 m^{-1} range.

Studied fancy yarns structural indices primarily depend on the overfeed η. With increase of this factor the values of these indices are increasing too. In that case distances between effects decrease. The values of these indices depend on the fancy yarns twist K too.

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