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Analysis of structural effects formation in fancy yarn

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The fancy effects formation using one process and hollow spindles has been studied. A composite design has been formulated and three variables, namely delivery speed of fancy yarn, rotational speed of hollow spindle and supply speed of effect component, considered to understand how technological parameters influence the formation of fancy effects, like closed loop, opened loop, loop-knot, plain knot and knot made from various loops, and their combinations. Procedure of counting the effects per unit length using twist tester and stereomicroscope for precise establishment of fancy effect is also accomplished. It is observed that the technological parameters contribute significantly to structural effects formation. On the basis of graphical pictures of the mathematical model that express the relationship between the number of effects of plain knot-knot made of various loops per unit length of fancy yarn and all the parameters of technological process of production, the particular interrelations have been investigated and the received model could be used to predict the number of fancy effects of certain nature, to control the effect formation process, and to enlarge the base of information needful for yarn design.

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1 Introduction

Nowadays, the yarns with structural effects like loops, waves, knots, snarls, chenille pile, etc. or/and optical effects like colour and lustre/dull outcomes are ones of the most important products of spinning, twisting, wrapping, texturing, printing, knitting, etc. Fancy yarns are always found to be up-to-date, as there is no alternative to them because of their special aesthetic and high decorative impact to the woven, knitted or nonwoven materials as well as other textile products.[1-3]

The search for new textile products in terms of fashion and appearance has been continuously leading to the design of new types of fancy yarns with impression of lively colour, exclusivity in effect's structure, flamboyant effects of texture, etc. The kind and the character of fancy effects determine the fancy yarns' appearance and decorative level, and beyond all manner of doubt the exterior, texture, coloration, textile feeling of woven and knitted fabric. Yarn effects are developed by plying single yarns with those having different colour, count, twist, fibre type and length, etc. as well as by varying the parameters of manufacture process. The structure of fancy yarn effect is very important factor because it can very noticeably enhance the aesthetic and ornamental effects of a fabric. The plain fabric can combine the elegance and simplicity of the plain structure with the high decorative effect of fancy yarn.

Effects formation in one process fancy yarn twisting and geometry of fancy yarn structure, which affect the quality of the fancy yarn, is influenced by variations in parameters, such as raw material and linear density of core, effect, and binder components and also twisting process variables.[4,5]

Several studies[6,7] deal with the experimental analysis of yarn twisting into loop and snarl, and with the application of theoretical criteria for predicting the snarling parameters as well as presenting the mathematical modelling of snarling in textile yarns. The modelling results provide a comprehension into the snarling mechanism and can be used to simulate the fancy loop or fancy snarl yarn appearance.

The colour composition of the fancy sliver having a varying colour effects along its length can be controlled by varying the amount of pre-drafts given to the input slivers of different colours before they are fed into a main drafting section.[8]

The basic parameters describing the structure of loop fancy yarns have been characterised.[9] The essential correlation was found between effect yarn crimp and distance between particular loops as well as

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between fancy yarn twist and height of the particular loops of fancy yarn.

In the present work, the effect of three technological process factors, namely delivery speed of fancy yarn, rotational speed of hollow spindle, and speed of supply of the effect yarn, on effect formation with the help of a composite design for the experiments has been studied. The regression analysis of the results obtained from the experiments has been used to establish the relationship of various structural effects with these factors. The details of the experiments and the subsequent analysis are reported in this paper.

2 Materials and Methods

The composite design of second order with experimental points on the cube, number of levels (3), and number of variables (3) was chosen because of its obvious advantages, such as the corner points can be investigated, meanwhile the maximum values decide operation possibilities; all combinations of factors are easily compatible; and the number of factor value combination is small (14).

The codes used for various factors were: X_1 (SD), the delivery speed of fancy yarn; X_2 (SHS), the rotational speed of hollow spindle; and X_3 (SS), the speed of supply of the effect component. The various factors and their coded levels are given in Table 1.

The general relationship between response Y (number of effects), like opened loop - plain knot (OL-PK) and plain knot - knot made from various loops (PK-KVL) per unit length of fancy yarn, and different parameters such as X_i and X_j (coded values of three process parameters) can be expressed as given below:

$$Y = b_0 + \sum_{i=1}^{k} b_i X_i + \sum_{i=1}^{k} b_{ii} X_i^2 + \sum_{i=1}^{k-1} \sum_{\substack{j=2,\\ i<j}}^{k} b_{ij} X_i X_j, \qquad \ldots(1)$$

where b_0, the constant term; b_i, the coefficients of main factor effects; b_{ii}, the coefficients of quadratic effects; b_{ij}, the coefficients of interaction effects; and k, the number of factor chosen (three in this case). Regression equations were generated to observe the linear, quadratic and interactive effects of process variables on fancy yarn indices.

Table 1 — Factors and their levels

Factor	Level –1	Level 0	Level +1
Delivery speed of fancy yarn (X_1), m/s (m/min)	0.50 (30)	0.83 (50)	1.17 (70)
Speed of hollow spindle (X_2), s^{-1} (min^{-1})	266.67 (16000)	333.33 (20000)	400.00 (24000)
Speed of supply of effect component (X_3), m/s (m/min)	1.50 (90)	1.67 (100)	1.83 (110)

The fancy yarns were produced at different factor level combinations with various structural effects in one process using hollow spindles on the machine JANTRA (Bulgaria). The yarns were produced using the principle as presented in Fig. 1. The effect component making different outcomes is locked into position by the interaction of the core and the wrapping binder component. This is done by passing the core and the effect yarns down the centre of the hollow spindle containing the package with the binder component. The binder component balloons off to wrap around the effect intermediate product as it enters the hollow shaft. After the hollow shaft, the effect intermediate product is given a false twist. As the hollow spindle rotates, the binder yarn is wrapped around the other components.

In most cases, the fancy yarns have a multi-thread structure composed of different components, such as one core, one effect, and one binder yarn. But the continuous search for novelties turned into reality, producing new fancy yarns structures like fancy yarn consisting of one core/effect and two effect/core yarns. The composition of the components used in this study was novel exactly: the core component–twisted cotton yarn, 18.5 tex×2; the effect component-two linen spun yarns, 56 tex and 56 tex each; and the binder component–5 tex filament polyamide yarn.

Procedure of counting of effects per unit length was fulfilled using standard apparatus (twist tester) that permits testing yarn length of 500 mm and

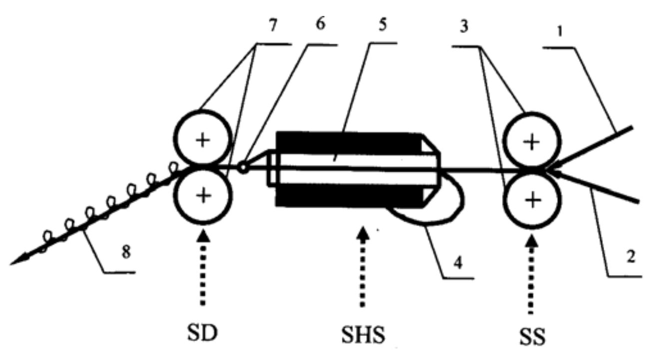

Fig. 1 — Principle of formation of effect intermediate product and fancy yarn using hollow spindle [1 – core component, 2 – effect component, 3 – supply rollers, 4 – binder component, 5 – hollow spindle with binder component, 6 – separator-regulator, 7 – delivery rollers, and 8 – fancy yarn]

stereomicroscope for precise establishment of kind and character of fancy effect. The number of effects per unit length of fancy yarn was measured in 500 mm, analysing 20 tests per package and later on was evaluated in number per meter. The mean, standard deviation and coefficient of variation between samples were calculated for statistical analysis.

3 Results and Discussion

Different kinds of the fancy effects, such as closed loop (CL), opened loop (ON), loop-knot (LK), plain knot (PK), knot made of various loops (KVL) and their combinations are shown in Fig. 2. The investigated fancy yarns are compound of four components. Such structure enabled to create periodical effects that are very distinguished, particularly because of their distinct exterior. Two linen yarns used as effect component and large interval of changing of technological parameters make it possible to create large variety of effects, e.g. petty ones that produces a very subtle checked decoration, which adds distinction to a textile material without calling attention to it as well as marked and great effects that could merely strike at a distance. The microscopic pictures of investigated effects obtained by the stereomicroscope and photographed by digital camera are shown in Fig. 3.

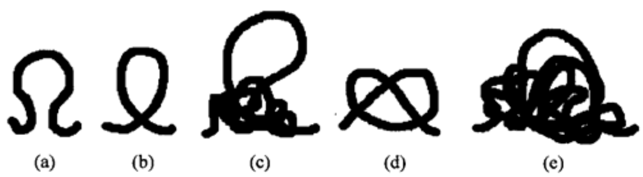

Fig. 2 — Various kinds of fancy effects [(a) opened loop, (b) closed loop, (c) loop-knot, (d) plain knot, and (e) knot made from various loops]

Table 2 shows all main, quadratic, and interaction effects and informativity of the models. To estimate the coefficients in the general relation between the response *Y* and technological parameters of fancy yarn twisting, the regression procedure was followed. The analysis of variances shows that the variances of the results of OL-PK and PK-KVL are uniform, whenever the variances of the results of other investigated indices are not uniform. Hence, the further analysis was carried out with the investigation of such periodical effects like OL-PK and PK-KVL in fancy yarns. The minimum and maximum

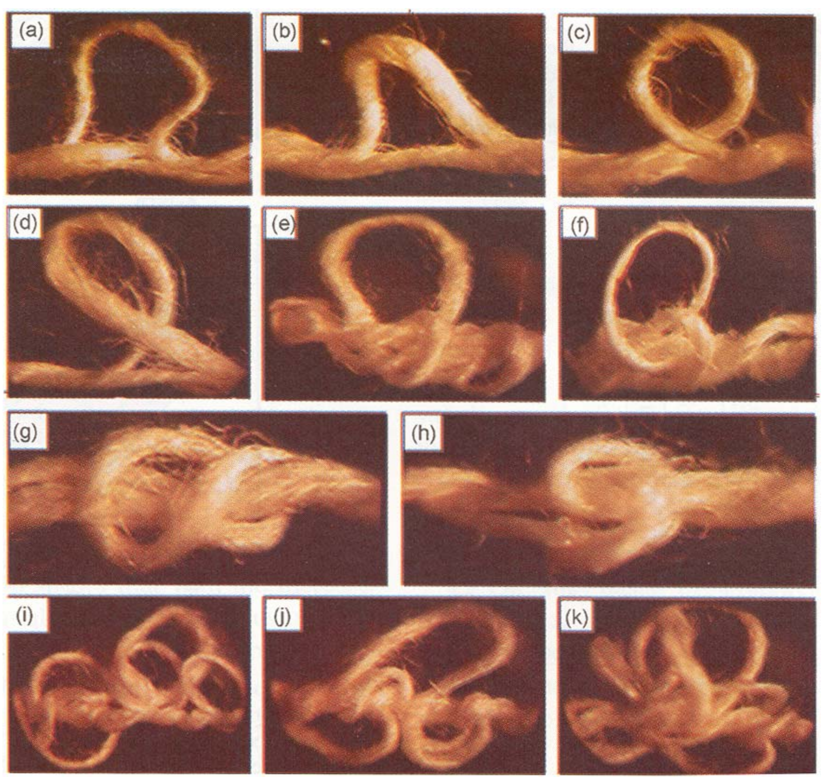

Fig. 3 — Microscopic pictures of effects in fancy yarns [(a), (b) – opened loop; (c), (d) – closed loop; (e), (f) – loop-knot; (g), (h) – plain knot; and (i), (j), (k) – knot made from various loops]

experimental values of fancy yarn indices that are determined by the values of factors X_1, X_2, X_3 in the designing space are presented in the Table 3.

The received mathematical models were investigated from informative point of view with the probability of 0.95 (Table 2). It is found that the mathematical model that expresses the relationship between the number of effects of PK-KVL in the unit of fancy yarn length and the technological parameters of fancy yarn manufacture is informative and fit for further interpretation. It is further observed that the model that expresses the relationship between the number of OL-PK effects per unit length of fancy yarn and the SD, SHS, SS is not informative and hence it is dissociated from the further analysis.

It is also found that the influence of all the factors and their interaction effects is significant for the investigated index of fancy yarn structure, except the coefficient of the main SHS factor effect.

On the basis of graphic pictures of the mathematical models, which express the connection between the fancy yarn structure and the parameters of production of technological process of these yarns, the particular interrelations were analysed.

Table 2 — Tests of hypotheses concerning the individual parameters in the models and informativity of the models

Variable	Coefficients[a]			Informativity of models	
	OL-PK, m^{-1}	PK-KVL, m^{-1}		OL-PK	PK-KVL
Constant	78.86	41.82	From tables		
SD	7.56	–9.19			
SHS	4.91	(–0.59)		4.44	5.69
SS	–7.73	6.24			
SD × SHS	3.84	6.33			
SD × SS	(1.40)	–10.76	Calculated value		
SHS × SS	–5.58	–5.77			
$(SD)^2$	7.39	2.93		2.36	12.74
$(SHS)^2$	(–0.73)	–6.82			
$(SS)^2$	–11.66	–3.04			

[a]No significant coefficients are shown in brackets.

Table 3 — Minimum and maximum experimental values of fancy yarn indices

Fancy yarn effects	Coded value			Experimental value[a]	
	X_1	X_2	X_3	Minimum	Maximum
OL-PK	–1	–1	+1	50.3	—
	+1	+1	–1	-	113.8
PK-KVL	+1	–1	–1	17.8	—
	–1	–1	+1	—	73.8

[a]No. of effects per unit-length of fancy yarn.

Three dimensional response surface diagrams (Fig. 4) show the influence of delivery speed of fancy yarn, rotational speed of hollow spindle, and speed of supply of the effect component on the number of

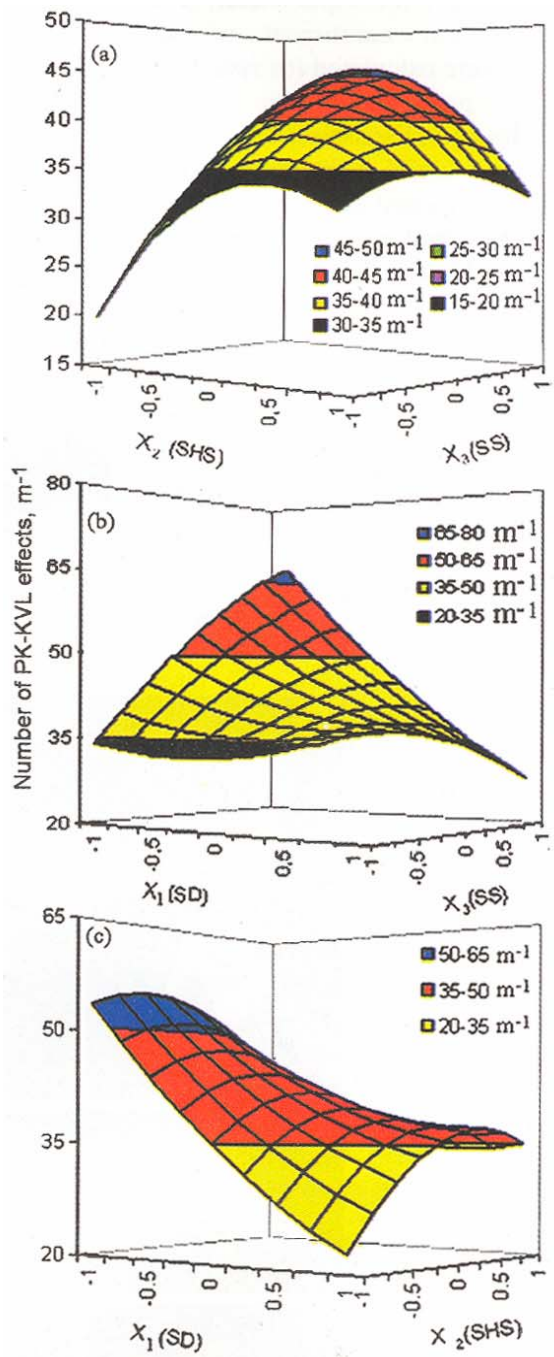

Fig. 4 — Dependence of number of effects of plain knot - knot made of various loops per unit length of fancy yarn on the (a) rotational speed of hollow spindle X_2 (SHS) and the speed of supply of effect component X_3 (SS); (b) delivery speed of fancy yarn X_1 (SD) and the speed of supply of effect component X_3 (SS); and (c) delivery speed of fancy yarn X_1 (SD) and the rotational speed of hollow spindle X_2 (SHS)

effects of PK-KVL in the unit of fancy yarn length. In these figures, the third factor has a stationary point and factor value is equal to zero.

While formulating the design, it was assumed that the number of effects per unit length and the character of the effects depend upon overfeed of the effect component and fancy yarn twist. The results and subsequent analysis indicate that the delivery speed of fancy yarns and the supply speed of the effect component are most important factors as compared to SHS. Analysing the points of the design space where the maximum value of response was achieved as well as the centre point of the experiment, it is observed that the SD changes the response in 1.5-3.5 times and SS changes the response in 1.4-2.6 times, whenever the rotational speed of hollow spindle significantly changes the response only in the point of design space with minimum value of response.

The regression analysis used only those coefficients of the relations that are significant. The sign of any coefficient for a main effect indicates the direction in which the response moves when the variable concerned changes from a lower level to a higher level. The quantity by which the response changes for some amount of change in a controlled variable is given by the amount of change in the variable multiplied by the value of the coefficient. As observed from Table 2, the main effect of the supply speed of the effect component has positive contributions to PK-KVL formation while the delivery speed of fancy yarn has negative contribution.

It is found that the number of effects per unit length of fancy yarn (Fig. 4) changes with the increase in overfeed of effect component that is determined by the speed of supply of the effect component and the delivery speed of fancy yarn. When the supply speed of effect component increases in all its interval and the delivery speed of fancy yarn decreases in all its interval (Fig. 4b), the response increases from 28.0 m^{-1} to 67.9 m^{-1} and this intensive increase in the response is evident investigating all points of the design space. Figure 4a shows that with the increase in SS in its entire interval when coded values of SHS changes from –1 to +0.5 and SD is equal to zero, the response increases approximately two times, e.g. from 20.0 m^{-1} to 40.4 m^{-1}. As it can be observed from the response surface (Fig. 4c), when the delivery speed of fancy yarn decreases in all its interval and SS is equal to zero, the response increases. However, at the lower values of the speed of hollow spindle the change in the formation of PK-KVL effects is more intensive. Nevertheless, the number of PK-KVL per unit length of fancy yarn depends not only upon the overfeed of effect component but also upon the fancy yarn twist level that is determined by the rotational speed of hollow spindle and the delivery speed of fancy yarn. The change in response is ambiguous with the increase in twist of fancy yarn to examine all points in the experimental space. As it is evident from Fig. 4a with the increase in SHS in all its interval when SD is equal to zero, the response increases from minimum to average values; later, X_2 influences the decrease in response till 31.5-35.0 m^{-1}. Ambiguous influence of fancy yarn twist on the effect formation process is evident from Fig. 4 c. Here, the increase in fancy yarn twist increases the response not in all points of experimental space but in the interval of coded values of SD approximately from +0.75 to –1. Such alteration could be explained by the changes in character of effect and its transverse and longitudinal dimensions.

The minimum (18.1 m^{-1}) and maximum (73.2 m^{-1}) values of number of effects per unit length of fancy yarn were calculated. Such values are determined by the factors X_1, X_2, X_3 in the experimental space.

The coefficients of variation analysing the series of the results of the number of effects per unit length of fancy yarn do not exceed 14.1 %, except in two cases where these are higher. 4.7 % is found to be the minimum value.

4 Conclusions

4.1 The regression analysis shows that the influence of all the factors, such as delivery speed of fancy yarn, rotational speed of hollow spindle, and supply speed of the effect component as well as all their interaction effects, is significant, except the coefficient of the main SHS factor effect as far as number of effects of plain knot - knot made of various loops formation is concerned.

4.2 On the basis of graphical pictures of the mathematical model that expresses the connection between the number of effects of plain knot-knot made of various loops per unit length of fancy yarn and all the parameters of technological process of production, the particular interrelations have been investigated and the received model could be used to predict the response and to create new fancy yarns with desired structure.

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