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The Optimal Design of Three-layer Plated Fabrics

Abstract
According to the new plating theory, a novel plating yarn carrier with three guide eyes for the weft knitting machine was designed in this paper. Using this kind of yarn carrier, the laying lengthwise angle of the ground yarn was greater than that of the face yarn. The laying lateral angle of the ground yarn was smaller than that of the face yarn. The laying position of the middle yarn was between those values. At the same time, we developed a kind of moisture comfort elastic-plated fabric with cotton yarn outside, superfine polypropylene fibre inside and lycra in the middle. Through the knitting tests, it was found that the novel plating yarn carrier can effectively control 'misplating' problems. The orthogonal experiment results showed that the best face appearance was gained when the laying angles were at the 2nd or 3rd position, the cotton was 40S, the lycra was 20D, and the polypropylene was 55 dtex /72f.

Key words: *plating, yarn carrier, laying, face appearance, orthogonal experiment.*

Introduction

The long-standing and difficult problem of weft-plated stitch is that the ground yarn easily appears on the face side of the fabric. Traditional plating theory [1] insists that the feeding tension of the face yarn should be greater than that of the ground yarn, and through the appropriate allocation of the guide eyes, the laying lengthwise angle and lateral angle of the face yarn should both be smaller than that of the ground yarn.

Will the traditional plating theory achieve the expected effect? Many researchers have had different opinions. Wiedmaier & Buhler [2] maintained that the knitting effect of weft plating was influenced by the yarn type, the knitting devices and the stitch structure. The yarn type had a great influence on the plating effect. To obtain an attractive cover effect, the face yarn should be thicker than that of the ground yarn. For their following paper, the two researchers [3] studied the influence of machine configuration, installation and operation on the plating effect, and concluded that both the face and ground yarns should have a steady loop length. When the diameter of the face yarn to that of the ground yarn had the proportion of 1.4 : 1, the best cover effect was gained. Schmidt [4] theoretically analysed the possibility of fancy plated stitch on a large-diameter circular knitting machine; he concluded that the face yarn and the ground yarn should be close to the needle, and should have enough distance in the vertical direction. The feeding tension of the face yarn should be a little smaller than that of the ground yarn. Ge Hongshu [5] concluded that the yarn property was the major factor influencing the plating effect. The prior order is as follows: yarn rigidity > μ_s > μ_{BF} > yarn diameter > yarn section character > yarn elasticity.

Along with the lycra used in knitted fabrics, many kinds of lycra plated fabrics [6] were developed, such as lycra+cotton, lycra+silk, lycra+wool and lycra+polymer. The knitting technology of lycra-plated fabrics has been studied in many works [7 - 11]. Researchers came to the same conclusion, namely that a positive feeding device should be used for lycra. In the literature [12], all kinds of factors influencing the wool+lycra plated fabric on a flat knitting machine were discussed in detail. Zhang Peihua [13] concluded that the face yarn should use finer fibre when knitting wool+lycra plated fabric, and the loop length should increase by 30% compared with that of the fabric knitted by a single yarn. The feeding tension should be moderate.

In this paper, a new plating yarn carrier with three guide eyes for a weft knitting machine was designed according to the new plating theory [14]. Using the new yarn carrier, a three-layer plated fabric can be knitted. Until now, there has been no related report on this kind of yarn carrier. The concept of the design was that the laying lengthwise angle of the ground yarn should be greater than that of the face yarn, the laying lateral angle of the ground yarn should be smaller than that of the face yarn, and the laying position of the middle yarn should fall between these values. At the same time, the feeding tension of the ground yarn should be a little greater than that of the face yarn.

Experimental

A kind of moisture comfort elastic-plated fabric, with cotton yarn outside, superfine polypropylene fibre inside and lycra in the middle, was developed in this study. Superfine polypropylene fibre has a good capillary effect, and cotton yarn displays good moisture absorbability. The cotton outside could absorb the sweat transmitted by the superfine polypropylene inside, and release the sweat into the atmosphere to keep the skin dry. The lycra in the middle gave the fabric favourable elasticity.

Knitting material

1) Face yarn: cotton

The cotton yarn has two kinds of linear density: 145.7 dtex and 182.1 dtex. The twist of 145.7 dtex cotton yarn is 92.69 T/10cm, and the coefficient of twist is 354.12. The twist direction is S. The twist of 182.1 dtex cotton yarn is 89.73 T/10cm, and the coefficient of twist is 383.14. The twist direction is S. The producer is the Jinan Cotton Yarn Factory (China).

2) Middle yarn: lycra

The lycra has two kinds of linear density: 22dtex and 55dtex. The producer is the Dupont Company (USA).

3) Ground yarn: polypropylene

The polypropylene has two kinds of linear density: 55 dtex /72F or 90 dtex /39F. The producer is the Huzhou Chemical Fibre Factory (China).

Knitting machine

The weft circular knitting machine (Type: PL-TS3B) was chosen to knit the fabric. The main parameters of the machine are as follows:

- Cylinder diameter: 30 inches
- Gauge: 28 needles/inch
- Knitting system: 90 feeders
- Needle: 2640 pieces.

Design of the yarn carrier

The fabric structure was cotton yarn outside, superfine polypropylene filament inside, and lycra in the middle. According to the traditional plating theory, the

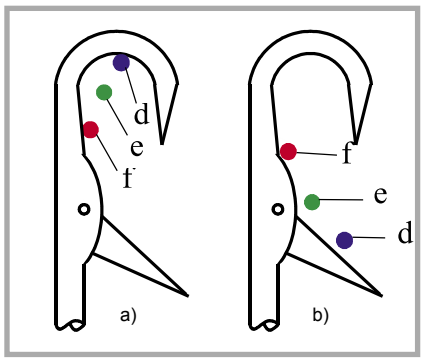

Figure 1. *Plating theory; a) traditional, b) new theory.*

laying lengthwise angle and lateral angle of cotton should both be smaller than that of polypropylene, and the lycra should be in the middle. The laying position is shown in Figure 1.a. There 'd' is polypropylene, 'e' is lycra and 'f' is cotton. According to the new plating theory, the laying lengthwise angle of polypropylene should be greater than that of cotton, the laying lateral angle of polypropylene should be smaller than that of cotton, and that of lycra should be between those values. The laying position is shown in Figure 1.b. This kind of laying position should ensure the cotton yarn enters the hook first and keeps steady. Then, the polypropylene filament enters the hook along with the closure of the needle latch. This guarantees that the yarn position remains steady, and decreases the misplating problems [14].

Configuration of the yarn carrier

The configuration of the yarn carrier is as shown in Figure 2. 'a' is the guide eye of the ground yarn, 'b' is the guide eye of the middle yarn and 'c' is the guide eye of the face yarn. The guide eye 'a' is fixed, but 'b' and 'c' can slide in the groove to change the laying lengthwise angle. (The unit is mm.)

Laying position

Laying position is the main factor affecting the plating result. Three laying positions were studied in this paper. Table 1 gives the laying lengthwise angles and lateral angles of polypropylene, lycra and cotton at three laying positions. α refers to the laying lengthwise angle and β refers to the laying lateral angle.

Dyeing

Polypropylene being hard to dye, a one-bath process to dye cotton only was adopted in this paper. Thus the cotton outside was dyed, but the polypropylene inside retained the primary colour. If the cover effect was perfect, then dyeing the cotton alone did not affect the face appearance of the fabric. If the cover effect was not good, white specks would be found on the face side of the fabric. This kind of dyeing process helped to check the misplating problems of the ground yarn. Figure 3 is the photo of the face side and reverse side of one of the fabrics. The colour of the face side is deeper than that of the reverse side. The white specks in the reverse side of the fabric are the polypropylene yarns that were not dyed.

Results and discussion

Counting the white specks at the face side of the fabric could be a means of evaluating the plating effect. The orthogonal experimental method [15] was used to establish the optimal knitting technology. The laying position and yarn fineness were changed, while other factors were kept invariable. Four factors were considered, and every factor had two levels, as seen in Table 2. The 'misplating problem' in the 1st laying position was relatively obvious, so only the 2nd and 3rd positions were considered in the experiment (the 'misplating.problem' means the possibility of ground yarn appearing easy on the fabric's face-side).

This experiment was of four factors and two levels. The least orthogonal table was $L_8(2^7)$ There were 7 arrays in $L_8(2^7)$. Usually 4 arrays could be arranged for the four factors. Array 1, array 2, array 4 and array 7 were arranged for the four factors in this paper. The test results are shown in Table 3.

Note: The intuitive grade is the numerical value that people use to evaluate the

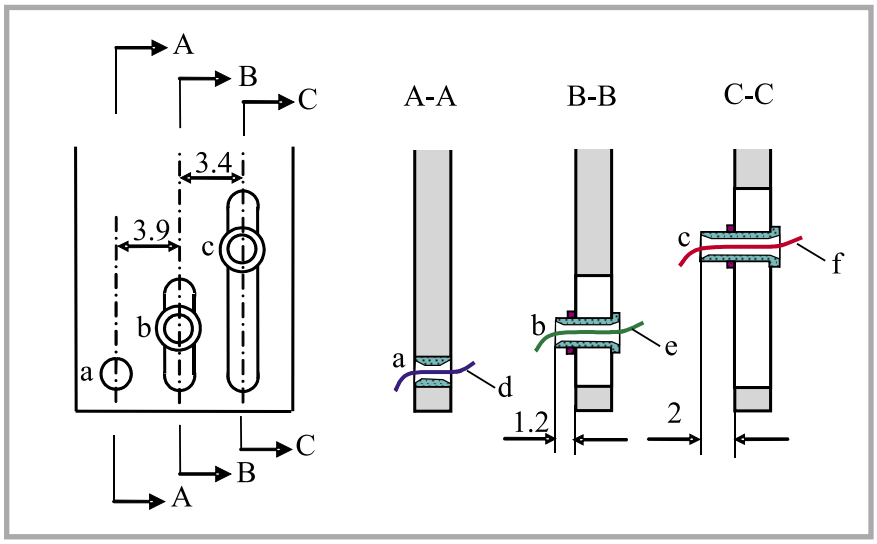

Figure 2. *Configuration of the yarn carrier.*

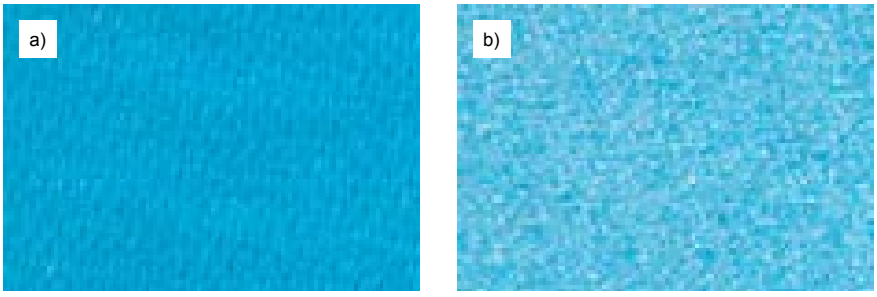

Figure 3. *Photo of one of the fabrics; a) face side, b) reverse side.*

Table 1. *Laying angles of three yarns at three laying positions.*

Laying position	1st position		2nd position		3rd position	
Laying angle	α	β	α	β	α	β
Polypropylene	12.27°	24.99°	12.27°	24.99°	12.27°	24.99°
Lycra	6.56°	27.90°	6.56°	27.94°	6.56°	26.58°
Cotton	4.19°	33.57°	4.19°	36.21°	4.19°	36.21°

face appearance of the fabric at first sight. The exact grade is the numerical value that people use to evaluate the face appearance of the fabric by counting the white specks visible on the face side of the fabric under a microscope. The composite grade is the sum of the intuitive and exact grades. Here '2' is good; '1' is medium; '0' is bad. The greater the numerical value is, the better the face appearance will be.

From the results of the experiment, the following conclusions were drawn:

1) The priority order of the four factors at two levels influencing the test results was B>C>D>A. The fineness of the cotton had the greatest effect on the test results. The 2nd laying position and the 3rd position had no effect on the test results.
2) According to the range R, the changing rules of the test results were as follows: the face appearance was equivalent at the 2nd and 3rd position; the face appearance was improved when cotton was changed from 32S to 40S; the face appearance was improved when lycra was changed from 40D to 20D; the face appearance was improved a little when polypropylene was changed from 90 dtex /39F to 55 dtex /72F.
3) According to the composite grade, there was relativity in factor B and factor C. When B and C were both at the 1st level, the face appearance was the worst; when B and C were at the 2nd level, the face appearance was the best; when B and C were at different levels, the face appearance was average. So B and C should both be avoided at the 1st level.
4) The best knitting condition was A_1(or A_2) B_2 C_2 D_2 . In other words, the best face appearance was achieved when the laying angles were at the 2nd or 3rd position, the cotton was 40S, the lycra was 20D, and the polypropylene was 55 dtex /72f.

According to the experience of Wiedmaier and Buhler [3], when the fineness proportion of the face yarn to the ground yarn was about 1.4 : 1, the best cover effect is achieved. The specific gravity of polypropylene is 0.91 g/cm^3, and that of cotton is 1.54 g/cm^3. After data conversion, cotton should be about 13 tex when polypropylene is 55 dtex /72F; this agreed with the test results in this paper. Choosing the cotton yarn of 40S (about 14.57 tex) had a better cover effect than choosing the cotton yarn of 32S (about 18.21 tex) when the polypropylene filament was 55 dtex /72F.

Table 2. *Factors and levels of orthogonal experiment.*

Factor / Level	A	B	C	D
	Laying position	cotton	lycra	polypropylene
1	2nd position	32 S	40 D	90 dtex /39F
2	3rd position	40 S	20 D	55 dtex /72F

Table 3. *Results of orthogonal experiment.*

Test No. / Factor	A	B	C	D	Test results		
	1	2	3	4	Intuitive grade	Exact grade	Composite grade
1	1	1	1	1	0	0	0
2	1	2	1	2	1	2	3
3	1	1	2	2	1	2	3
4	1	2	2	1	2	2	4
5	2	1	1	2	0	1	1
6	2	2	1	1	1	2	3
7	2	1	2	1	1	1	2
8	2	2	2	2	2	2	4
K_1 K_2	10 10	6 14	7 13	9 11	(1) K_1 and K_2 is the composite grade of every factor at the 1st level and 2nd level respectively		
R	0	2	1.5	0.5	(2) R is the range of each factor. The value of range reflects the effect of each factor to the test results.		
Optimal level	A_1 or A_2	B_2	C_2	D_2			
Priority order	4	1	2	3			

Conclusions

1) The new yarn carrier with three guide eyes can knit three-layer plated fabric and effectively control the misplating problems. The design concept for the new yarn carrier was that the laying lengthwise angle of the ground yarn was greater than that of the face yarn; the laying lateral angle of the ground yarn was smaller than that of the face yarn, and the laying position of the middle yarn was between those values. The feeding tension of the ground yarn was also a little larger than that of the face yarn.
2) We developed a moisture comfort knitted fabric with cotton yarn outside, superfine polypropylene fibre inside and lycra in the middle. Through orthogonal experiments, it was demonstrated that the best cover effect was achieved when the laying angles were at the 2nd or 3rd positions, the cotton was 40S, the lycra was 20D, and the polypropylene was 55 dtex /72f.

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