Interactive Effect of Blend Proportion and Process Parameters on Ring Spun Yarn Properties and Fabric GSM using Box and Behnken Experimental Design

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Abstract— **This investigation has been designed using box and behnken method 4 level and their three variables such as dyed viscose percentage in mélange yarn, spindle speed of ring frame, twist multiplier of yarn and a knitting parameter namely stitch length of fabric. Response surfaces were generated using the general form of equation of the box and behnken method. This allows the response of the property with respect to four variables on a property. The result shows that, with the increase of percentage of dyed viscose fibre in blended yarn, although the yarn evenness and total imperfections improve but yarn strength and elongation% has been somewhat decreased. With increasing spindle speed yarn total imperfections and strength has been increased for each blend ratios. When twist multiplier is high, then at higher spindle speed yarn strength has been decreased somewhat. Yarn irregularity is lowest at spindle speed 15500 rpm. Yarn elongation has been decreased with the increase of viscose fibre percentage and spindle speed. It is also observed that fabric GSM has been increased with increasing dyed viscose percentage in blended yarn and lowering stitch length.**

Keywords— ***mélange yarn, spindle speed, twist multiplier, stitch length, box and behnken method, fabric GSM.***

I. INTRODUCTION

"Textile process, be it yarn manufacture, fabric manufacture, chemical processing or garments making involves an interaction of a large number of variables related to the process, input material, ambient condition, etc"[1]. "Spinning process is one of the important production processes in the textile industry. The quality of yarn of the yarns produced is very important in determining their applications further" [2]. There are various spinning process parameters that affect yarn quality. Many studies have been performed to investigate the effect of spinning process parameters on ring spun yarn [3]-[5]. Yarn quality is a concept defined by customer demands several properties simultaneously. Yarn evenness deals with the variation in yarn fineness. This is the property commonly measured as the variation in mass per unit length along the yarn. It is basic and important one, since it can influence so many other properties of the yarn and of fabric made from it [6]. The strength of spun yarn is recognized as one of the most important quality parameter of yarn [8]. Along with yarn count and yarn twist, yarn unevenness, thin and thick places, neps, yarn strength and elongation are the main yarn properties for yarn production [9]. On the other hand, yarn quality is important factor that decisively influence the knitted fabric quality along with knitting parameters such as stitch length**.** Production of single jersey knitted fabric using dyed viscose and cotton blended yarn is now common in knitted fabric manufacturing**.** Blending different types of fibres is a widely practiced means of enhancing the performance and the aesthetic qualities of a fabric. Blended yarns from natural and man-made fibres have the particular advantage of successfully combining the good properties of both fibre components, such as comfort of wear with easy care properties. It is a critical problem in fibre blending technology to choose appropriate types of fibres and blend ratios depending on the final product [7]**.**

In this investigation percentage of dyed viscose in blend composition of mélange yarn**,** spindle speed and twist multiplier independent variables have been selected to produce 28'^s^Ne carded ring spun yarn. These parameters have influence on yarn characteristics such as evenness, total imperfections, strength and elongation. Every yarn samples has been converted to single jersey knit fabric. Their GSM has been calculated.

In this investigation, an attempt has been made to find out the interactive effect of our selected independent variables on yarn and fabric properties by using box and behnken experimental design.

II. MATERIALS AND METHOD

A. *Preparation of yarn samples*

CIS cotton and dyed viscose were blended together in three different blend ratios (95/5, 90/10 and 85/15, cotton/viscose) to prepare the mélange yarn for this study. At first, Cotton fibres were opened and cleaned in modern blow room line and then blended with dyed viscose fibres based on different blend ratios in Rieter Unimix (B-70). Then blended fibres were carded on Rieter C-60. Carded sliver were drawn on modern draw frame (SBD-45 & RSBD-22) and then fed to roving frame (FL-100) to produce roving (0.72 Ne). Conventional ring spinning system (LR/60A) was used to produce 28'^s^ Ne yarn. As per as the factorial design (TABLE 1), the 27 yarn samples were prepared. Twist per inch (T.P.I) was calculated by the formula,

$$T.P.I = T.M*(count)^{1/2} \quad (1)$$

Where, T.M is twist multiplier.

TABLE 2 shows the different levels of variables. Every yarn samples were wound onto cone.

TABLE 1. Box and Behnken design for three variables

Experiment No.	Level of variables			
	X_1	X_2	X_3	X_4
1.	-1	-1	0	0
2.	-1	1	0	0
3.	1	-1	0	0
4.	1	1	0	0
5.	0	0	-1	-1
6.	0	0	-1	1
7.	0	0	1	-1
8.	0	0	1	1
9.	-1	0	0	-1
10.	-1	0	0	1
11.	1	0	0	-1
12.	1	0	0	1
13.	0	-1	-1	0
14.	0	-1	1	0
15.	0	1	-1	0
16.	0	1	1	0
17.	-1	0	-1	0
18.	-1	0	1	0
19.	1	0	-1	0
20.	1	0	1	0
21.	0	-1	0	-1
22.	0	-1	0	1
23.	0	1	0	-1
24.	0	1	0	1
25.	0	0	0	0
26.	0	0	0	0
27.	0	0	0	0

TABLE 2. Actual levels corresponding to coded level

Variable	Coded level		
	-1	0	1
Blend ratio (cotton/dyed viscose),x_1	95/5	90/10	85/15
Spindle speed (rpm),x_2	14500	15500	16500
Twist Multiplier, x_3	3.60	3.63	3.66
Stitch length (mm),x_4	2.60	2.70	2.80

B. Testing of yarn samples

The Uster tester 5 was used to measure the evenness of yarn and yarn imperfections/1000m.Yarn imperfections has been calculated by adding the value of Thick place(+50%)/1km, Thin place(-50%)/1km and Neps(+200%)/1km. Testing speed was 400m/min. Average result of ten samples for each experiment was taken. Single yarn strength and Elongation% were tested by MAG Elestretch single yarn strength tester.

C. Preparation of fabric samples

A Pailong model pl-xscs/60E power operated circular knitting machine was used for the production of the knitted fabric samples as per as the box and behnken factorial design. Its diameter was 32 inch with a needle gauge E24. Yarns were fed with a positive feeder. All grey fabric samples were processed in same baths. The grey fabrics were first scoured with hydrogen peroxide. Following scouring, washing and rinsing processes were carried out. Then all the fabrics were dyed in greymell color.

D. Testing of fabric samples

The aerial density of fabric (g/m^2) of the knitted fabrics was measured by cutting the sample size of 10×10cm.The sample was then weighed in the electronic balance and the value was multiplied by 100.

III. Result and Discussions

The experimental results for all the 27 samples are given in TABLE 3. Response surface equations for various yarn and fabric results are given in TABLE 4 along with the co-efficient of determination. Response surface equation and the value of R^2 have been calculated by MATLAB. During calculation of response surface equation of some dependent variables, some independent variables have been omitted because of their negligible effects.

TABLE 3. Experimental results

Experiment No.	Yarn U%	Yarn Imperfections/1km	Yarn Strength (g/tex)	Yarn Elongation%	Fabric GSM
1.	10.98	195.5	13.75	4.20	147.53
2.	10.74	203.6	13.83	3.98	145.19
3.	10.66	189.6	13.56	4.06	154.61
4.	10.48	221	13.58	3.92	151.75
5.	10.59	214.6	13.29	4.51	162.42
6.	10.65	225.2	13.13	4.36	143.03
7.	10.72	200.5	13.87	3.83	163.11
8.	10.47	197.4	14.01	3.75	139.90
9.	11.02	193.9	13.96	3.97	141.02
10.	10.96	206.7	14.08	4.10	138.74
11.	9.98	183.5	13.70	3.85	161.18
12.	10.21	204.6	13.81	3.76	142.50
13.	10.43	179.1	13.19	4.64	157.08
14.	10.61	191.8	14.15	3.31	154.14
15.	10.05	223.2	13.24	4.37	159.30
16.	10.34	231.5	14.16	3.18	155.27
17.	10.39	207.4	12.98	4.46	150.06
18.	10.28	211.5	13.86	3.20	149.22
19.	9.87	176	13.08	4.13	152.49
20.	9.76	185.5	14.06	3.35	151.16
21.	9.69	186.4	13.55	3.27	156.60
22.	10.06	194.1	13.62	3.39	142.23
23.	10.24	217.7	13.64	3.25	156.55
24.	10.50	229	13.57	3.31	137.47
25.	9.96	180.5	13.48	3.40	148.32
26.	10.08	205.4	13.73	3.12	151.5
27.	10.19	199.7	13.61	3.28	153.2

TABLE 4. Response surface equations for dependent variables

Dependent variable	Response surface equation	Co-efficient of determination (R^2)
Yarn U%	$10.2586 - 0.2842x_1 - 0.0067x_2 + 0.0150x_1x_2 + 0.1564x_1^2 + 0.0876x_2^2$	0.3295
Yarn imperfections/1 km	$202.6583 - 4.8667x_1 + 15.7917x_2 + 5.8250x_1x_2 - 5.9344x_1^2 + 4.5281x_2^2$	0.5938
Yarn Strength (g/tex)	$13.6711 - 0.0558x_1 + 0.0167x_2 + 0.4333x_3 - 0.0150x_1x_2 + 0.0250x_1x_3 - 0.0100x_2x_3 + 0.0508x_1^2 - 0.0004x_2^2 - 0.1029x_3^2$	0.8354
Yarn Elongation%	$3.4407 - 0.0700x_1 - 0.0717x_2 - 0.4875x_3 + 0.0200x_1x_2 + 0.1200x_1x_3 + 0.0350x_2x_3 + 0.3343x_1^2 + 0.0718x_2^2 + 0.3481x_3^2$	0.7151
Fabric GSM	$154.2133 + 3.4942x_1 - 8.0842x_4 - 4.1000x_1x_4 - 4.0475x_1^2 - 4.1350x_4^2$	0.8293

A. Yarn Irregularity

To get maximum yarn evenness the attenuation of fibre strand should be achieved with the minimum variation in its linear density. Since fibre of different lengths will tend to move differently during drafting, this will increase the yarn irregularity% [10]. Fig. 1 shows the influence of blend ratio (cotton/dyed viscose) and spindle speed on yarn irregularity. The yarn irregularity decreases with the increase of dyed viscose% in blend compositions. This can be attributed due to the fact that an increase of viscose% will decrease short fibre percentage because of higher length of viscose fibre. Length uniformity will also increase; as a result yarn evenness will be increased. However, spindle speed 15500 rev/min gives better result of yarn evenness rather than 14500 rev/min and 16500 rev/min. From the R^2 value of yarn irregularity%, it can be concluded that the selected independent variables do not influence yarn irregularity significantly.

B. Yarn imperfections

Fig. 2 shows that with increasing the spindle speed, yarn imperfections also increase. This may be explained in such a way that in higher spindle speeds, fibres can be dragged out of front roller nip point. As a result yarn imperfections have been increased. However, with increasing percentage of dyed viscose, yarn imperfection/1000m has been decreased.

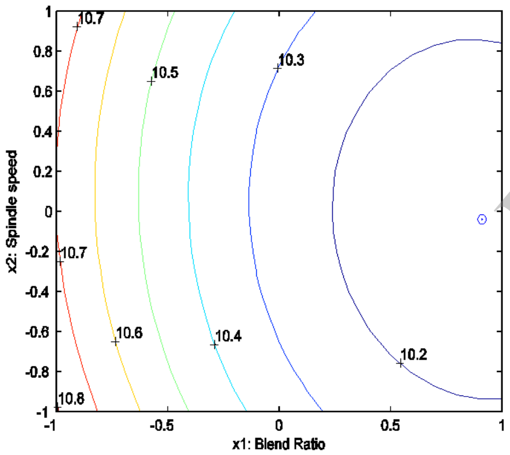

Fig. 1. Effect of blend ratio and spindle speed on yarn irregularity.

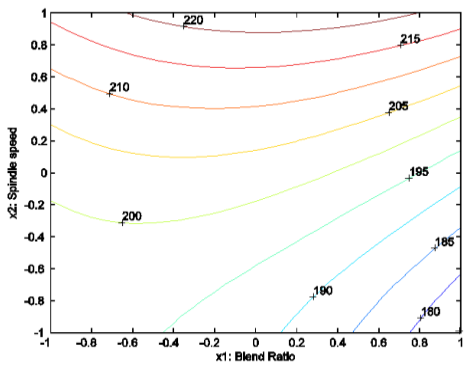

Fig. 2. Effect of blend ratio and spindle speed on total yarn imperfection.

This may be explained according to [11] that the increase of more long fibre in the mix allows better control of fibre movement during drafting. From the R^2 value of yarn imperfections, it can be concluded that the selected independent variables influence yarn imperfections significantly.

C. Yarn Strength

Fig. 3 – Fig. 5 show that with the increase of twist multiplier yarn strength increases for every blend ratios. The strength of a thread twisted from staple fibers increases with increasing twist [12]. On the other hand, with the increase of spindle speed, strength of 5% and 10% grey mélange has been increased. This may be attributed because of fibre migration in spinning triangle and fibre straightening because of higher spinning tension at higher spindle speed. However, figure indicates higher percentage of dyed viscose in blend composition gives lower yarn strength in comparison with lower value of viscose percentage in blended yarn. From the R^2 value of yarn strength, it can be concluded that the selected independent variables influence yarn strength significantly.

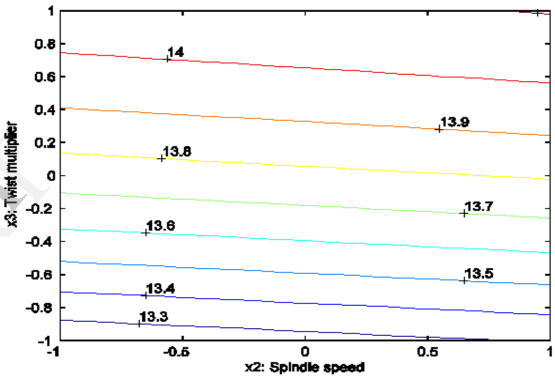

Fig. 3. Effect of twist multiplier and spindle speed on yarn strength[Blend ratio(cotton/viscose) 95/5]

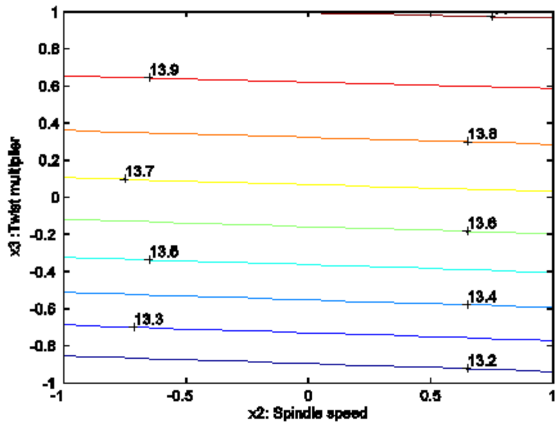

Fig. 4. Effect of twist multiplier and spindle speed on yarn strength [Blend ratio(cotton/viscose) 90/10]

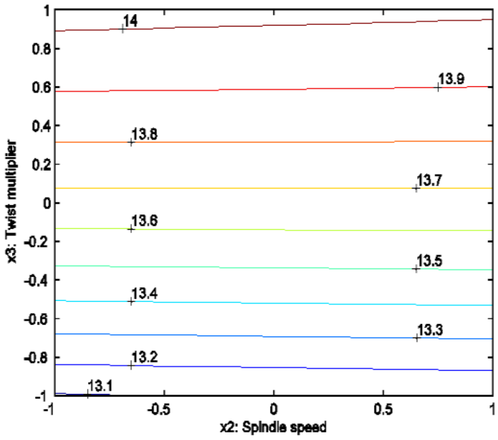

Fig. 5. Effect of twist multiplier and spindle speed on yarn strength
[Blend ratio(cotton/viscose) 85/15]

D. Yarn Elongation

Fig. 6 – Fig. 8 show, with increasing spindle speed, yarn elongation has been decreased. It can be explained such a way that, with increasing spindle speed, spinning tension also increases .It is well known that at higher spinning tension original curliness of fibre will be decreased. Ultimately yarn elongation will be less. However, it is observed that with increasing blend ratio, elongation has been decreased. It may be because of using higher percentage of viscose fibre in the mix that is more straight fibre than cotton.

E. Fabric aerial density (GSM)

Effect of stitch length and blend ratio of cotton and viscose fibre are shown in Fig. 9. It is seen that with increasing stitch length, fabric GSM decreases. It is well established that higher stitch length will produce fabric of lower GSM. However, fabric GSM has been increased with the increase of percentage of viscose in blend composition. A possible reason is that, due to higher density (g/cm^3) of viscose fibre than the density of cotton fibre.

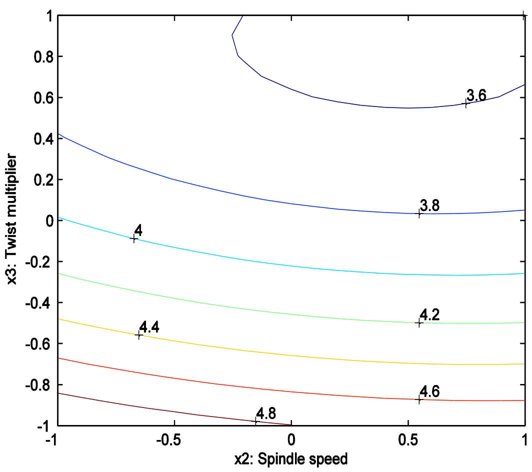

Fig. 6. Effect of twist multiplier and spindle speed on elongation.
[Blend ratio(cotton/vicose): 95/5]

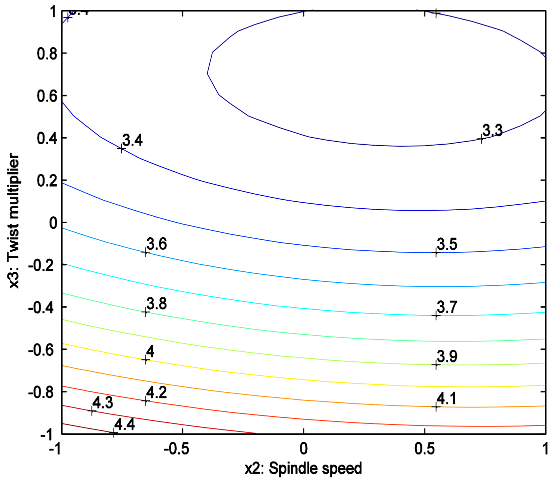

Fig. 7. Effect of twist multiplier and spindle speed on elongation.
[Blend ratio(cotton/vicose): 90/10]

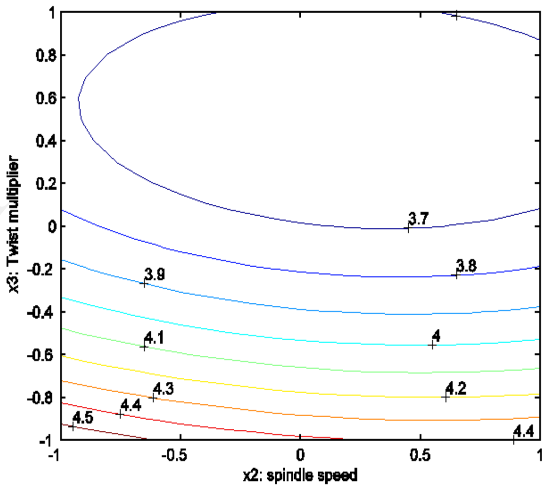

Fig. 8. Effect of twist multiplier and spindle speed on elongation.
[Blend ratio(cotton/vicose): 85/15]

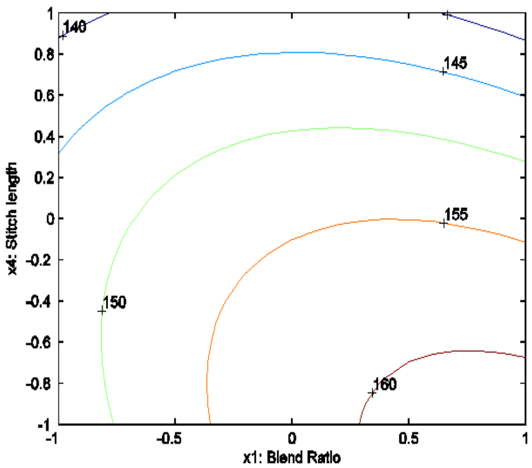

Fig. 9. Effect of blend ratio and stitch length on fabric GSM.

IV. CONCLUSION

With increasing percentage of dyed viscose in mélange yarn, yarn irregularity, imperfection, strength and elongation has been decreased. On the other hand fabric GSM has been increased with high percentage of viscose fibre in mélange yarn. Spindle speed 15500 gives better yarn evenness. As spindle speed increases, the yarn elongation has been decreased. For lower viscose percentage in mélange yarn, higher spindle speed gives greater yarn strength. Yarn imperfection has been increased with increase of spindle speed. Twist multiplier shows their regular positive effect on yarn strength although yarn elongation result is exceptional. Fabric GSM has been increased with higher viscose percentage and lower stitch length. From R^2 value of dependent variables show that selected independent variables has high impact.

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