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Investigate the Impact of Traveller Weight, Top Roller Shore Hardness and Spacer Size on Ring Frame Yarn Properties for Process Optimization

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Abstract

This research is expected to address mainly for the existing problem of the spinning process in yarn strength, yarn evenness and yarn total imperfections. This was done by identifying the ring frame machine components that affect quality and proposing an engineered process an optimum value of ring machine components of the spinning department in Almeda textile factory. In this research, samples were prepared at the existing production lines at different values of process factors and ensuing interactions based on 2 level factorial experimental designs. Design expert, fitting software for DOE based experiments, was employed to analyze the results. The factors studied are the fiber parameters used for production (fiber length, fineness, trash content, honeydew) and the impact of traveller weight, ring top roller shore hardness and spacer size, on yarn total imperfections, U% and yarn strength are the intended responses to be evaluated. The top roller hardness, spacer size and traveler weight have an impact on the ring spun yarn. Finally the optimum machine components value of the process factors are chosen by the software to have top roller shore hardness (65), traveler weight (35) and spacer size of (3 mm) for 65/35 P/C 36 Ne yarn were selected. These setups of machine components produce a yarn having yarn unevenness (12.9%), yarn total imperfections (326) and yarn strength (19.7 cN/Tex).

Keywords: Optimization • Spacer • Top roller • Traveller • Yarn

Introduction

The ring spinning machine was invented in year 1828 by the American Thorp. In 1830, another American, Jenk contributed the traveler rotating on the ring. During the last 160 years, the machine has passed many considerable modifications, but the principle of yarn forming remained unchanged [1,2]. Travelers are required to wind up very different yarn types: Smooth/hairy; compact/voluminous; strong/weak; natural fibers/synthetic fibers. These widely varying yarns cannot all be spun using one traveler type. Differences are found in: Form; raw material; finishing treatment of the materials; wire profile; size of the yarn clearance opening for the thread (height of the bow) [3]. Several investigations have been carried out on the influence of the ring traveller. In some studies, it was observed that yarn hairiness decreased as the weight of the traveller increased, whereas in some others it was stated that as the traveller weight is increased the hairiness gradually decreased to a certain point, and then started to increase [4-6]. By reducing yarn breaks, the spinning costs become lower and the productivity increases [7].

By selecting the right ring and traveller, these performances can be substantially influenced.

The purpose of cots is to provide uniform pressure on the fibre strand to facilitate efficient drafting and use of aprons help to have better grip and control on fibers particularly floating fibers [8]. A front line cot in ring spinning should also offer sufficient pulling 1 force to overcome drafting resistance. Mathematically, Force of pulling required at front line cot ≥ frictional resistance between fibers+force exerted by the aprons on fibers [9,10].

Spacers are found in drafting zone which used between top and bottom aprons to create space between them. Spacer size is coded by color means that the different spacer colors have different size. Using of minimum possible spacer size in roving machine gives better results for rove and yarn property. Evenness and total imperfection could be improved by closing down the apron spacing. SKF recommends smallest possible spacer for all the counts. It's

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however, often necessary to use a wider spacer for a coarser counts. If there are undrafted places in the yarn when it leaves the front rollers, the break draft should be increased. Spacer should be increased only if the draft results remain unsatisfactory after the break draft has been increased. The optimum selection of spacer size not only improves the yarn strength and evenness, but also reduces long thin and thick faults in the yarn.

Materials and Methods

This research work focused on the factors affecting the quality of ring spun yarns. The ring spun yarns are analyzed with respect to the process parameters at ring frame machine. However, understanding the input material is crucial before the machine configurations.

65/35 P/C blend is used to yarns manufacturing. The rove (1 Ne) used to produce 36 Ne ring spun yarn is prepared from the 65% polyester and 35% cotton. The polyester has 33.3 mm cut length and 11% crimp. The cotton fiber has 27.4 mm staple length, 3.5 mic fineness and 3.8 % trash content.

Experimental design

Using of the design expert 7.0.0 software have designed the experiment with the number of factors, required number of replication and the response what is expected.

Manufacturing of ring spun samples

Three process factors of ring frame machine; top roller shore hardness, spacer size and traveler weight, are selected and their effect on three yarn properties is studied. The other machine configurations are maintained constant as shown in Table 1.

Parameters	Value	Parameters	Value
Machine model	G 30 ring frame	Total draft	39
Rove count-Ne	1 Ne	Yarn TM	3.8
Yarn count-Ne	36^S (65/35 P/C)	Yarn TPI	23.17
Main draft setting	50 mm	Cradle length	36 mm
Break draft setting	70 mm	Spindle speed	10000 rpm
Break draft	1.18	Ring diameter	42 mm
Main draft setting	50 mm		

Table 1. Machine configuration at ring frame machine.

Testing of samples

The samples are conditioned for 24 hrs at 21°C temperature and 63% RH. The yarns produced in G-30 ring frame machine are tested for, yarn strength, and total yarn imperfection using Uster Tensorapid-3 testing machines and Uster evenness tester 3, yarn count using count test and yarn twist with twist tester. The testing methods were for Uster evenness tester 3 ISO 2649, yarn strength Uster Tensorapid-3 by ASTM-1578 and fiber properties high volume instrument by ASTM-5867 testing methods.

After the test results are collected, the data analysis and discussion is done accordingly.

Statistical optimization and experimental design of yarn production process

Design expert 7.0.0 software has been used in optimizations of the yarn production. The independent variables used were, top roller shore hardness, traveller weight and spacer size of the ring machine and the responses were yarn strength (cN/Tex), yarn elongation (%), yarn unevenness (Um %), and yarn total imperfections (in number) of ring spun yarn. 40 experiments (Table 2) were performed by design expert 7.0.0 software to optimize the machine components. The statistical significance of the model and variable were determined by ANOVA at 5% significance level. Yarn strength, unevenness, elongation and imperfection (response factors) were analyzed by ANOVA and 3D response surface plot.

Run	A:RSH, °	B:SS, mm	C:TW, mg	Yarn u%	Yarn strength	YTI
1	65	2.5	31.5	13.02	18.24	398
2	65	3	35	13.42	19.83	343
3	65	2.5	35	12.56	21.07	309
4	65	2.5	35	13.17	20.14	315
5	65	3	35	12.82	18.94	342
6	85	2.5	35	14.3	19.43	340
7	65	2.5	35	13.41	19.97	370

8	65	3.25	35	12.64	19.38	286
9	65	3	35	12.73	20.03	315
10	85	3	31.5	13.95	18.14	392
11	65	3	31.5	13.26	18.32	332
12	85	3	35	13.62	19.14	419
13	65	2.5	31.5	13.14	18.42	391
14	85	2.5	31.5	14.05	17.82	442
15	65	3	35	13.04	20.47	348
16	85	3	31.5	14.14	18.54	388
17	85	2.5	35	13.76	20.04	418
18	85	3	35	13.88	20.06	359
19	65	2.5	31.5	13.07	17.92	289
20	85	3	31.5	14.2	18.28	401
21	65	2.5	31.5	13.5	18.32	301
22	65	3	31.5	12.91	18.42	323
23	85	3	31.5	14.02	18.71	355
24	65	3	31.5	12.52	18.22	272
25	65	2.5	35	13.6	19.81	350
26	85	2.5	31.5	14.4	18.34	441
27	85	3	35	14.22	21.02	377
28	65	2.5	31.5	13.42	18.27	350
29	85	2.5	35	14.6	19.75	390
30	85	2.5	31.5	14.03	18.52	391
31	65	3	31.5	13.01	18.04	395
32	85	3	31.5	13.75	18.43	341
33	85	2.5	35	14.23	20.23	409
34	85	2.5	35	13.98	19.84	406
35	85	2.5	31.5	13.97	18.29	397
36	65	2.5	35	12.91	20.95	276
37	85	2.5	31.5	14.15	17.97	402
38	85	3	35	13.95	19.24	422
39	85	3	35	13.75	19.96	332
40	65	3	31.5	13.32	18.36	359

Table 2. Design experiment and yarn test results at ring spinning section.

Characterization of yarn property

To examine the combined effect of independent variable of ring frame components (top roller shore hardness, spacer size and traveller weight) on yarn strength, unevenness, elongation and total yarn total imperfection, the tests were conducted and analyzed. Effect of top roller shore hardness, spacer size and traveler weight on yarn unevenness: Unevenness and imperfection of the yarn was determined as per ISO 2649 using Uster 3 unevenness tester. Each sample was tested with five replicas and the average values were taken for analysis.

Effect of top roller shore hardness, spacer size and traveler weight on yarn strength and elongation: Strength and elongation of the yarn was determined as per ASTM D-1578 Uster Tensorapid-3 yarn strength tester. Each sample was tested with five replicas and the average values were taken for analysis.

Results

Optimization of machine setting using factorial design

Yarn strength, elongation, unevenness and total imperfection are very essential properties of yarn which must be controlled to fulfil the standard required by the user. Yarn strength and elongation are an important parameter in determining the durability and serviceability of the fabric made from the yarn and unevenness and imperfection are related to appearance and ends down of yarn during yarn manufacturing. The combined effect of top roller shore hardness, traveller weight and spacer size of ring frame machine on yarn strength, elongation, unevenness, and total imperfection has been studied and optimized using design expert 7.0.0 software factorial design and surface response method. The design allows a random manufacturing of different samples given a chance to produce same samples at different times, to avoid other nuisance factors. Generally, the process factors are designed to be at the ring section and analyzed for their effects on the ring spun yarns.

Design experiment

Top roller shore hardness, traveller weight and spacer size are considered in this study. Top roller shore hardness (°) coded as "A", spacer size (mm), coded as "B" and traveler weight (mg.), coded as "C".

The design of experiment for the ring spinning section is prepared using "design-expert 7.0.0 software" as shown in Table 2. Accordingly, three factors at two levels (high and low) are replicated five times, that is, a total of 40 samples are designed, manufactured and tested at ring frame machine. The 23 factorial designs allow a random manufacturing of different samples, giving a chance to produce same samples at different times, to avoid other nuisance factors. Accordingly, following three properties of rotor spun yarns yarn strength (cN/Tex), yarn unevenness (U%) and yarn total imperfections (number) (most common determinant factors for determining the quality of ring spun yarns) are analyzed.

The other configurations of the ring frame machine are kept constant as shown earlier. The model and its degree of order are selected to be factorial and main effects respectively.

Fitting the models

The dependent variables (strength, elongation, evenness and imperfection) and independent variables (top roller shore hardness, spacer size and traveller weight) were examined to draw regression equations showing an empirical relationship between the tested variable and the machine settings in the actual units which can predict the responses under the given range. Therefore, to determine the factor level which yields optimum strength, elongation, evenness and total yarn imperfection of the yarn, mathematical regression between dependent and independent variables (Equation 1, 2 and 3) were developed. The final equation in terms of the actual factors generated by the factorial design is:

Yarn uneveness=50.38-0.5223 × roller shore hardness-13.855 × spacer size-1.117443 traveller weight+0.1990 × Roller shore hardnes × spacer size+0.017057 × roller shore hardness × traveller weig +0.40114 × spacer size × traveller weight-5.94286 E-003 × roller shore hardness × spacer size × traveller weight (1)

Yarn strenght=-115.1795+1.2695 × roller shore hardness+40.008 × spacer size+4.33414 × traveller weight-0.42160 × roller shorehardnes × spacer size-0.041914 × roller shore hardness × Traveller weight-1.30771 × spacer size × traveller weight+0.01400 × roller shore hardness × spacer size × traveller weight (2)

Yarn total imperfection=-1902.45+46.93 × Roller shore hardness +886.00 × spacer size+50.52857 × travellerweight-17.3600 × Roller shore hardnes × spacer size-1.14571 × Roller shore hardness × traveller weight-22.62857 × spacer size × traveller weight+0.45714 × Roller shore hardness × spacer size × traveller weight (3)

Examination of model adequacy

Model individual significance and regression goodness was by ANOVA. In this research, ANOVA was used to analyze the selected model and model coefficient. The regression terms and the model are said to be significant when the p value is less than 5%. As shown in Table 3, the model is significant (p<0.05) for top roller shore hardness, spacer size and traveller weight for unevenness, top roller shore hardness, traveller weight and spacer size for total yarn imperfection and all independent variables (top roller shore hardness, traveller weight and spacer size were significant for the responses (yarn elongation, and yarn strength). The lack of fit for all independent variable is statically not significant (p>0.05) which strengthen the reliability of the model.

	Source	Sum of square	Df	Mean of square	F-value	P-value
Yarn unevenness	Roller shore hardness (A)	7.64	1	7.64	97.4	<0.0001
	Spacer size (B)	0.42	1	0.42	5.41	<0.0266
	Traveller weight (C)	0.053	1	0.053	0.68	0.4167
	AB	0.00049	1	0.00049	0.0062	0.9375
Yarn strength	Roller shore hardness	0.014	1	0.014	0.071	0.792
	Spacer size	0.082	1	0.082	0.43	0.5189

	Traveller weight	19.81	1	19.81	102.9	0.0001
	AB	0.48	1	0.48	2.5	0.1235
Yarn total imperfection	Roller shore hardness	22050	1	22050	17	0.0002
	Spacer size	2016.4	1	2016.4	1.55	0.2215
	Traveller weight	348.48	1	348.48	0.27	0.6078
	AB	1166.4	1	1166.4	0.9	0.3501

Table 3. ANOVA output of yarn unevenness, total imperfection and yarn strength.

Discussion

Effect of top roller shore hardness, traveller weight and spacer size on yarn unevenness and total imperfection (U% and TYI)

As shown in Figure 1, the yarn irregularity, in terms of both unevenness and total imperfection, increases with increasing hardness of the top roller. When the top roller is softer, it easily deforms and form larger area of surface contact and enhances the guidance of the very few fibers under the high draft. The increase in area of contact of the rubber top roller with the fluted bottom roller shortens the uncontrolled area between aprons and the nipping point (spinning triangle). This helps in shortening the path and controlling the short fibers floating improving the evenness of yarn. Additionally as the guidance increases the spinning triangle also gets shorter. This will helps to reduce the number of randomly twisted fibers on the yarn surface which helps to reduce the yarn hairiness. The spacer size has also an impact but it is not significant as shown from Table 3 and Figure 1. The F value is very small which means its impact is very small.

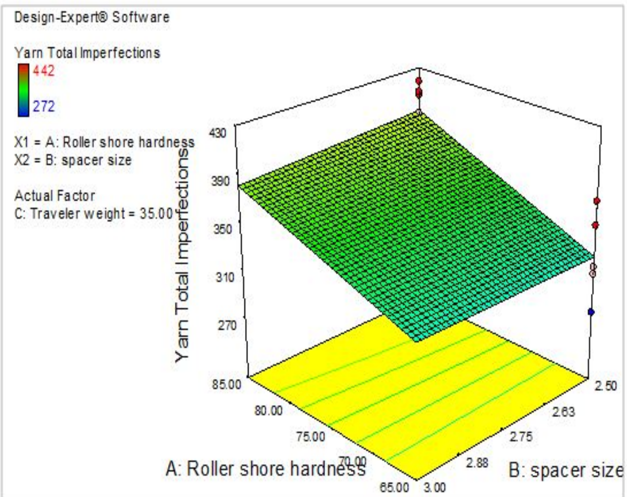

Figure 1. Effect ring frame process factors on yarn total imperfection.

The yarn imperfection increases with the increment of the traveller weight. As the traveller weight increases the friction between yarn and traveller gets high. This will increase the hairiness of the yarn which affects the yarn imperfection. But its impact is not.

Effect of top roller shore hardness and traveller weight on yarn strength

As shown in Figure 2. The yarn strength increases with increasing traveler weight. The increase in traveler mass overrides the air drug and helps to consume maximum of the rotational speed. This can help to increase the twist flow, of course the twist length too, in the spinning zone resulting more number of twists and better binding in of ridge fibers in the yarn body. This binding of fibers, consolidates the fiber strands and yarn strength will increase. As the top roller shore hardness increases the yarn strength also decrease the vice versa is true. The soft top roller helps for guidance of the fibers toward the core of the yarn and contributes for the strength of the yarn. But the life time of the top roller will reduced (Figure 3).

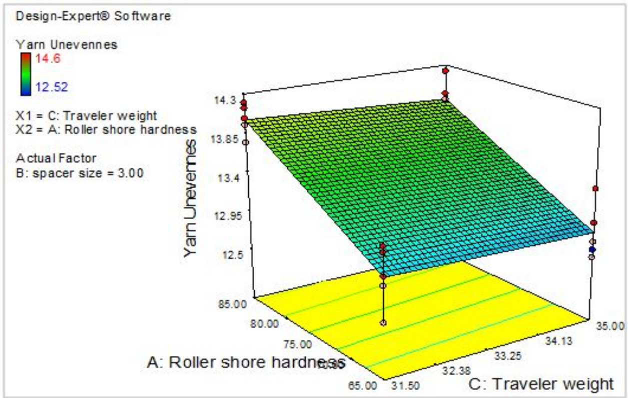

Figure 2. Effect ring frame process factors on yarn unevenness.

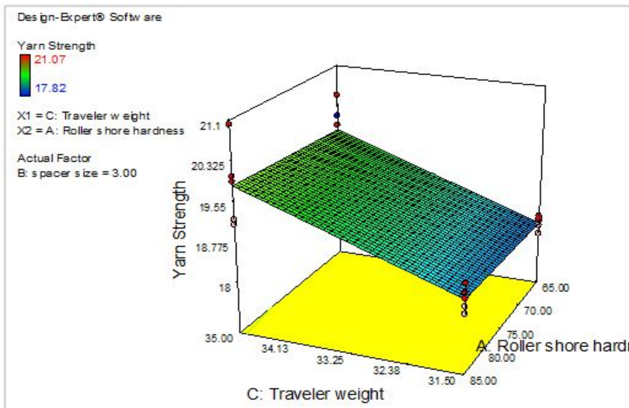

Figure 3. Effect of ring frame process factors on yarn strength.

Optimization of machine components

The optimum setup of the machine components is shown in Table 4. These results show the rank of the setups based on their effect on ring spun yarn unevenness, yarn total imperfections and yarn strength. Thus, the optimum setup of the components would be; top roller hardness (65°), spacer size (3 mm) and traveller weight (35 mg). These setups of machine components produce a yarn having yarn unevenness (12.9%), yarn total imperfections (326) and yarn strength (19.7 cN/Tex) Of course; there are also options other than this configuration when the priority of yarn properties is changed.

Constraints							
Name		**Goal**		**Lower limit**	**Upper limit**	**Weight**	**Importance**
Roller shore hardness		Is in range		65	85	1	3
Spacer size		Is in range		2.5	3	1	3
Traveller weight		Is in range		31.5	35	1	3
Yarn unevenness		Minimize		12.52	14.6	1	5
Yarn strength		Is in range		17.82	21.07	1	3
Yarn total imperfections		Minimize		272	442	1	5
Solutions							
Number	**Roller shore hardness**	**spacer size**	**Traveller weight**	**Yarn unevenness**	**Yarn strength**	**YTI**	
1	65	3	35	12.9	19.7	327	Selected
2	65	3	35	12.9	19.62	327	
3	65.1	3	35	12.9	19.35	327	
4	65	2.96	35	12.9	18.99	327	
5	65	3	34.8	12.9	19.38	327	
6	65	2.96	35	12.9	18.89	327	
7	65	3	34.7	12.9	18.49	328	
8	65	2.94	35	13	19.02	326	
9	65	3	34.6	12.9	18.87	328	
10	65	3	34.4	12.9	19.59	328	
11	65	2.88	35	13	18.67	326	
12	65	2.85	35	13	18.35	326	
13	65	2.84	35	13	19.22	326	
14	65.7	3	35	13	18.68	329	
15	65	2.76	35	13	19.8	325	
16	65	3	33.66	13	19.33	330	

Table 4. The optimum ring frame configurations in rank.

Conclusions

Based on the experimental results of this study the following conclusions can be drawn

- The yarn irregularity, in terms of both unevenness and total imperfection, increases with increasing hardness of the top roller.
- The yarn strength increases with increasing traveler weight. The increase in traveler mass overrides the air drug and helps to consume maximum of the rotational speed.

The top roller hardness, spacer size and traveler weight have an impact on the ring spun yarn. So, to produce ring spun yarn with optimum properties the optimum value of the process factors are chosen by the software to have top roller shore hardness (65), traveler weight (35) and spacer size of (3 mm) for 65/35 P/C 36 Ne yarn. These setups of machine components produce a yarn having yarn unevenness (12.9%), yarn total imperfections (326) and yarn strength (19.7 cN/Tex).

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