PROCESS PARAMETER INFLUENCE STUDY OF MECHANICAL COMPACT SPINNING SYSTEM

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BONAFIDE CERTIFICATE

Certified that this project titled "**PROCESS PARAMETER INFLUENCE STUDY OF MECHANICAL COMPACT SPINNING SYSTEM**" is the bonafide work of Mr.S.Sambath, who carried out the research under my supervision. Certified further, that to the best of my knowledge the work reported herein does not form part of any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

Compact Yarn production systems presently in the market, namely Rieter's **Com4 spin, Suessen's EliTe and Zinser's Air Com-Tex 700** uses pneumatic force to compact the drafted strand in a separate zone before it is twisted so as to achieve better integration of fibres in to the yarn, thereby resulting in high tenacity and less hairy yarn. The use of pneumatic for compaction complicates the design and makes the retrofitting of the system difficult and costly. This has necessitated an innovation of a simple system that will condense the drafted strand of fibres, which could be retrofitted easily at lower cost.

This Project Work deals with the process parameter influence study of one such system developed for that, which is working with a principle of Semi-Positive Mechanical Compaction. This study is carried out using **Box Behnken statistical model** for the important three process parameters that influences the yarn quality, such as Spindle Speed, Traveler weight and Twist Factor with 3 levels. As per the statistical model for three factors and three levels, 15 different combination runs are carried out and the yarn quality characteristic responses taken for analysis are Zweigle Hairiness-S3, Zweigle & Uster Hairiness Index, Evenness, Total Imperfection, Single Thread Strength-RKm and Breaking Elongation.

The findings from the analysis of the yarn test results of the study are that:

- Moderate to higher Spindle Speed with moderate Traveler Weight and TM

Will yield a yarn with reasonably lower (up to 50 %) Hairiness - S3 Value.

- Similarly, moderate Spindle Speed with moderate Traveler Weight and TM only will yield a yarn with reasonably lower Zweigle-Hairiness Index (up to 50 %) and Uster- Hairiness Index (up to 10 %).
- For higher TM yarn lower Spindle Speed is necessary to get Lower Hairiness-S3 Value and lower hairiness index of both.
- Heavier Traveler will yield a yarn with less C.Vm % (2 %) and Imperfection (25 %).
- Lower TM yields a yarn with lesser Imperfection (25 %).
- Higher T.M , up to certain value, yields higher RKm (13 %), which is a well known fact
- For a given TM moderate Traveler Weight and higher Spindle Speed yield yarn with higher RKM (3 %).
- Breaking elongation of yarn is having only positive correlation with Spindle Speed only, but not with TM and Traveler Weight.

From the above findings one can derive the optimum process parameter as moderate to higher Spindle Speed with moderate Traveler Wt. and TM, which will yield a quality yarn with reasonably lower Hairiness, Evenness & Imperfections, and higher Strength-RKm and Breaking Elongation. But, for getting ideally low Evenness and Imperfections the Spindle Speed needs to be restricted to moderate.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

The high productive modern machines of weaving and knitting demands high performance yarn. The strength, elongation and hairiness characteristics of yarn are crucial factors that influence the performance of yarn. Towards improving those characteristics compact yarn has come into the existence.

The compact yarn systems that are commercially available to day, viz.. Rieter com4, Suessen EliTe, and Zinser Air Com-Tex uses pneumatic force to condense the drafted fiber strand in the extra zone provided in the drafting system before it is twisted into yarn.

1.1 NEED FOR ALTERNATE SYSTEM

As the use of pneumatic force complicates the design and makes the retrofitting of the system difficult, the investment for the system is getting costlier and Indian spinning mills can not afford it. This has necessitated looking for an innovation of a simple system that will condense the drafted strand of fibers, which could be retrofitted easily at lower cost.

In the innovative research work pursued by Ganesan, an attempt has been made to achieve condensation of drafted strand using non-pneumatic mechanical means that it is cost effective and could be easily retrofitted. Towards establishing and perfecting the performance of the above system that is being developed a process influence study is needed.

To meet the above need this project has been designed using Box-Behnken statistical model on design of experiment. This project work has been designed to meet the above need.

CHAPTER 2

LITERATURE REVIEW

2.1 Functioning of commercial available systems

The following section elucidates the functioning of various systems based on pneumatic & mechanical principle that are available in the market namely,

Pneumatic Principle,
a. Rieter Com4 Spin
b. Suessen EliTe
c. Zinser Air-Com Tex 700

Mechanical Principle,
d. RoCos System
e. Semi Positive-Nip System
Developed By prof. S.Ganesan

2.1.1. RIETER COM4 Spin (Dr.H. Stalder[9], 2000)

In Rieter Comp Spin System, an intermediate zone is inserted between drafting & yarn formation. In this intermediate zone the drafted fiber band is condensed laterally by means of aerodynamic forces. The effect of this condensing laterally by means of aerodynamic forces is that the fiber band which is to be fed to the spinning triangle becomes so small which virtually disappears (Fig.1). In the process, all the fibers from the remaining spinning triangle are collected & fully integrated in the yarn. The Com4 Spin process is illustrated in Fig.2 and Fig.3 The fiber condensing zone immediately follows a three roller drafting system with double aprons. The delivery roller of the drafting system is replaced by a perforated drum for this purpose. A fixed suction system generating a vacuum is fitted inside this perforated drum. This results in a current of air flowing from the outside to the inside of the drum. The fibers supplied from the delivery nip line of the drafting system are thus held firmly on the surface of

The perforated drum and move with the circumferential speed of the drum. A subsequent, second top roller also presses on the drum.

Operating principle

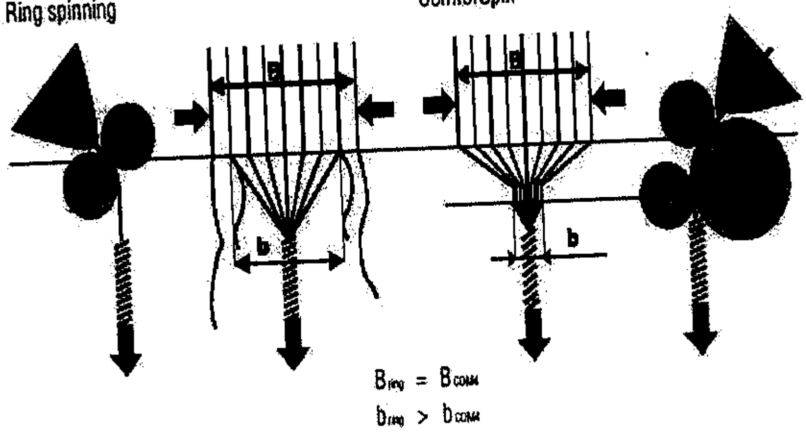


Fig. 2.1

There is a non-rotating insert the drum with a specially shaped, diagonal slot to allow the passage of air. The angle of the slot and the air flowing in to it has the combined effect that the fibers being carried on the circumference of the drum are moved sideways.

The only fully compacting process

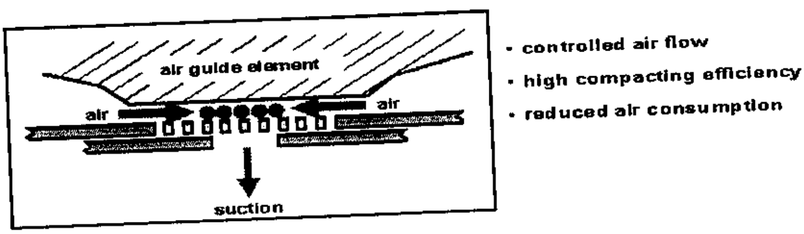


Fig.2.2

The fiber band in the condensing zone is thus condensed gently to width 'B', which is only a fraction of the width 'A' of the fiber band emerging from the drafting system (as explained in fig.1). The fiber band emerging from the drafting system has virtually no strength due to the fact that the number of fibers in the cross section is small and no twist has yet been inserted. It is therefore extremely important to guide these fibers carefully through the entire length of condensing surface of Com4 that has a high quality surface finish with a low coefficient of friction between the fibers and the condensing surface.

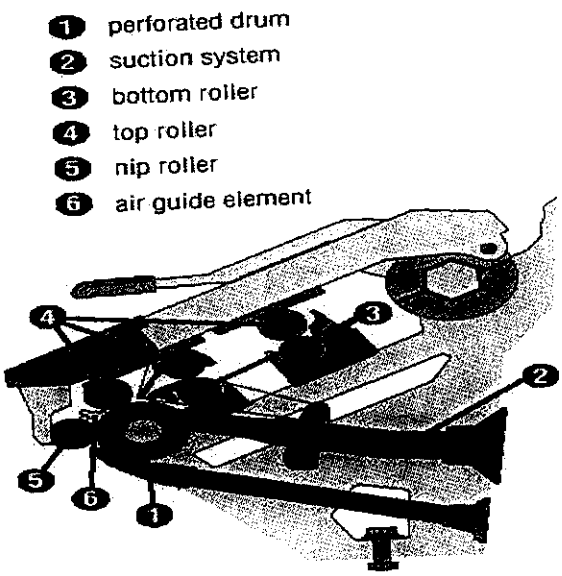


Fig.2.3- COM4 drafting system

2.1.2 Salient Features

Studies on Rieter Com4 system reveals the following features,

- Production of less hairy yarn. (S3 < 50-70 %)
- 10-15% higher strength and elongation than ring yarn.

- Compared to conventional yarns, COM4 yarns display significantly better Strength and elongation values. Even with reduced twist up to 20 %, the COM4 yarns still display values for it equivalent to normally twisted ring yarn.
- Softer and silkier yarn.
- Better running performance in the down stream processes.
- Required only 50% size that is attained at ring yarn.

2.1.3 Limitations

- Bigger diameter of bottom perforated roller, restricts minimum setting for short fiber processing.
- Absence of tension draft b/w front top roller and delivery top roller May cause disturbance of fiber straightening and orientation.

2.2. Suessen EliTE

In the Suessen EliTe spinning system as shown in fig.4, compacting is archived by introduction of a new condensing zone according to Suessen EliTe spinning catalogue. A tubular profile subjected to negative pressure is closely embraced by a lattice apron. Delivery top roller fitted with rubber cot presses the lattice apron against the hollow profile and drives the apron at the same time forming the delivery nipping line the tubular profile has a small slot in the direction of fibre flow, which commences at the immediate vicinity of the front roller nipping line. This creates an air current through the lattice apron via the slot towards the inside of the profile tube. The air current seizes the fibers after they leave the front roller nipping line and condense the fiber strand, which is conveyed by the lattice over a curved path and transported to the delivery nipping line.

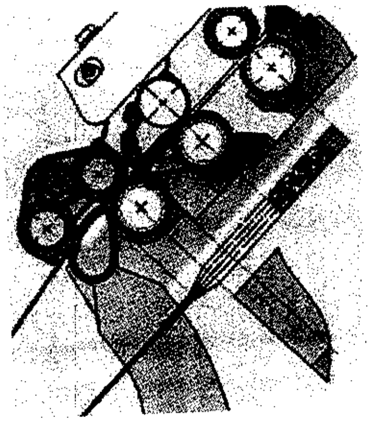


Fig.2.4 suessen elite spinning

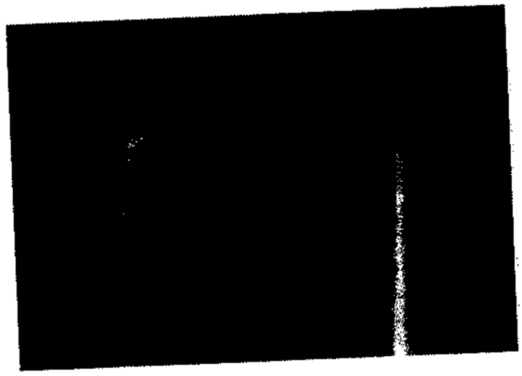


Fig.2.5 Fiber triangle variation

As the slot, being under negative pressure (infig.6), reaches right up to delivery nipping line, the fiber assembly remains totally closed. The spinning triangle and the serious disadvantages, in respect to yarn structure, strength and hairiness of the finished yarn disappear. The diameter of the delivery top roller is slightly bigger than the front top roller, hence a tension in the longitudinal direction during the condensing process.

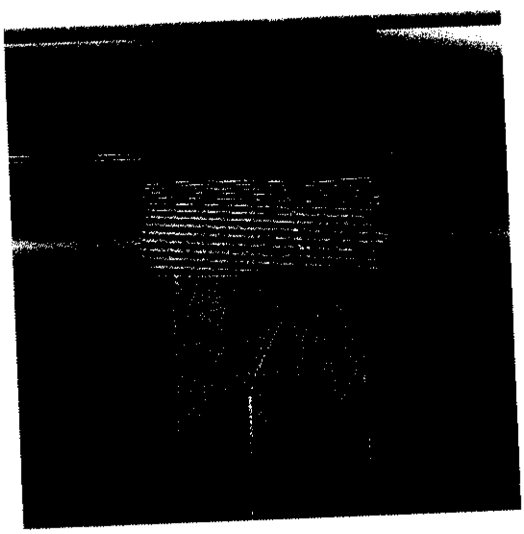


Fig.2.6

The consequence of this tension is that curved fiber will be straightened and thus support the condensing effect of negative pressure acting on the fiber

Band in the slot area of the profile tube. When processing very short fibers like carded cotton, the suction slot is arranged at an angle to the direction of fiber flow ensuring that the fiber ends, during their transport from the front roller to the delivery nipping line are well bound into the strand of fibers.

Three measures described above-condensing right up to the delivery clamping line, light tensioning of the fiber band during condensing and rotation of fiber band around its axis during condensing, result in the fiber band reaching the delivery clamping line ideally straightened, with individual parallel and optimally condensed fibers. This creates a cross sectional force during the fiber transport, which in turn causes the fiber assembly to rotate around its own axis so that the fiber ends are closely embedded into the yarn assembly.

The delivery top roller is connected to front top roller via a gear. This ensures that both rollers are synchronized. The tension essential for perfecting condensing of the fiber assembly, is guaranteed by a small difference in the diameters of front top roller and delivery top roller.

The effect of air current is all the more regular and the spinning results all the better, because of the smaller and closely spaced perforation of the lattice apron. In this respect it is interesting to note that a lattice apron has more than 3000 pores/sq. cm, compared with approximately 80 openings in a perforated drum.

Most Important for satisfactory and uniform spinning results over the complete length of the machine is an identical level of suction from the spinning position, as well as the possibility to adjust and reliably be achieved, if separate and adjustable suction sources are available for spinning section.

2.2.1 Salient Features

Studies on EliTe Spinning System reveal the following Features (Mourad Krifa [8], 2003)

- The hairiness is highly reduced (S3 < 50-70%)
- The twist to strength ratio is said to be substantially better, allowing
- Lower twist levels. (15%) Hence softer yarns can be produced.
- They can be used for all commonly used raw materials, including blends across the entire spinning count ranges.

2.2.2 Limitations

- Maintenance cost per spindle is very high, because of the frequent Cutting of perforated aprons and profile tube.
- The lattice aprons are more prone to slippage. this may impair the Quality of the final yarn.
- The variation in the speed of lattice apron may cause end breakages Or improper condensing (due to change in tension draft between the Front top roller and the delivery top roller).

2.3. ZINSER AIR-COM-TEX 700 (Ishtiaque [2], 2003)

In this process, the fiber band emerging from the conventional three cylinder drafting system is taken from the draft nip line by the air flow and is condensed under suction on an apron surface (in fig.7). The aprons are perforated in a pearl-necklace fashion in the middle (shown in fig.8). Aprons run

Over stationary hollow bodies subjected to negative pressure. These hollow bodies are provided with straight slots in the direction of apron movement. The fibers are subjected to suction in area of perforations and are thereby condensed.

The condensing fiber band thus undergoes a substantial reduction in width within the condensing zone. This is caused by the newly developed condenser element which separates the air and guides the apron nip in one single part.

Fig. 2.7

Immediately after the drafting system nip line, the fibers orient themselves towards the apron perforation through the easing air flow. On the apron surface, an air stream applied from the side cause a fiber bundling above the perforations row. Through the newly developed supporting profile, the air sucked-in is selectively used as a lateral force and thus allows a larger traversing width. Thus the fixing of the fiber band on the perforation is guaranteed.

The fiber band is brought together by the air stream over the row of holes and is fixed there up to the nip line. This is affected by the favorable apron guiding in the area of the last pair of rolls. Directly after the actual condensing zone, the fiber band is fixed between perforated apron and bottom

Fig.2.8

Roll and is thus fed to the nip point. The yarn is formed by twisting the condensed band.

2.3.1 Salient Features

- It is capable of producing short & long staple yarns.
- The yarns produced are less hairy and excellent profile.
- Higher yarn yield can be achieved from the given raw material.

2.3.2 Limitations

- Condensing is effective for small width which restricts the roving Traverse to a minimum level.

2.4 Mechanical Compacting – Commercially Available

2.4.1 RoCoS System (Hans Stahlecker [6], Rotocraft)

Rotorcraft has developed a magnetic mechanical compacting system in the name of RoCos and LMW in collaboration with them has started marketing lakshmi RoCos compact yarn spinning system recently. The schematic diagram of RoCos system is given below.

The bottom roller 1 supports the front roller 2 and delivery roller 3. The condensing zone extends from clamping line A to clamping line B. the very precise magnetic compactor 4 is pressed by permanent magnets with out clearance against cylinder 1. It forms together with the bottom roller an enclosed compression chamber.

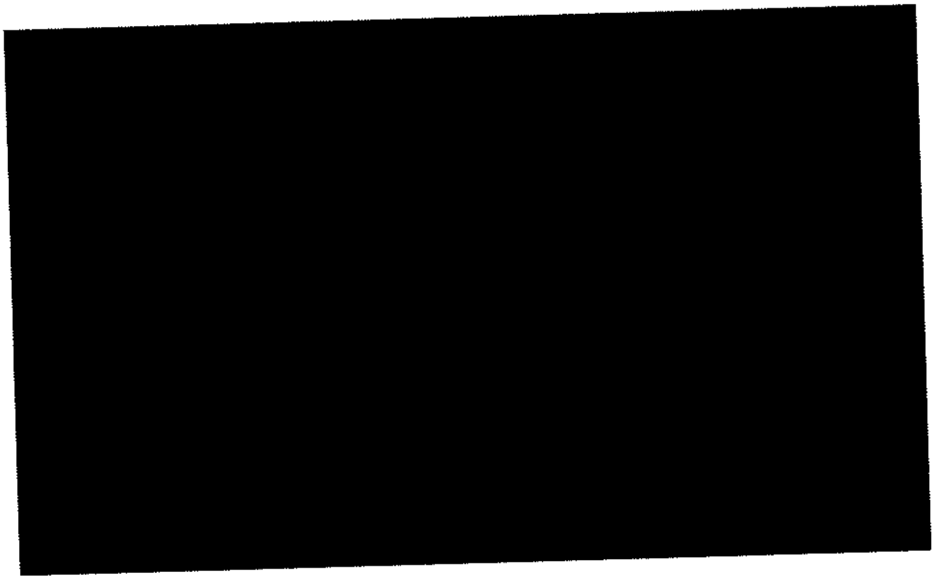


Fig.2.9 shows RoCos drafting arrangement

2.4.2 Salient Features

- No air suction.
- No extra perforated drums or aprons.
- No extra power.
- No erectors for installation.

2.5. Mechanical Compacting System Developed By Prof. S.Ganesan [5] (2004)

2.5.1 Basic Concepts

The basic requirement of condensing system is to bring the drafted fiber strand that emerges from the front roller, which are spread to the width of 2-4 mm depending on the roving hank to some where nearer to double the yarn diameter (0.3-0.6 mm) before twisting it to form yarn. In the normal ring spinning system, the twisting force only converges the drafted fiber strand and in this process many edge fibers are not properly getting integrated in to the yarn. Here condensing and twisting are happening simultaneously for a portion of yarn. By performing the condensing and twisting operation. sequentially in the compact yarn system marketed, the fibers of yarn brought closer resulting in better inter fiber cohesion and strength.

2.5.2 Different Type of Mechanical Condensers Developed

Using mechanical condenser also, one can achieve condensation of fibers of drafted strand before it is twisted. Mechanical condensers workings on different principle namely Negative Nip, Semi-positive Nip creates floating performance evaluation. Use of negative nip and semi-positive nip creates fixed demarcation point of condensation and twisting; where as the positive nip creates fixed demarcation point. Following are the two condensers working on the above principles.

2.5.3 Locating V-Grooved Roller In Front Of Front Bottom Rollers

On locating a V- grooved roller(C) in front of front bottom roller (B) as Given the schematic diagram below so as to press the yarn that is being spun will prevent the free flow of twist to a point nearer to front roller nip.

The converging point of condensation will move downwards creating a long spinning triangle and based on spinning tension fluctuation, it is expected to move little up and down. The drafted fiber strand getting converged in to the V-grooved result in condensing action.

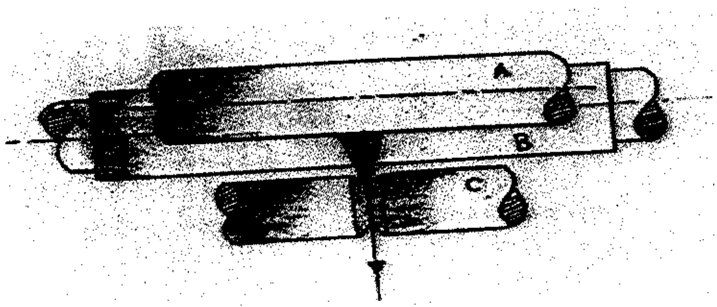


Fig.2.10

2.5.4 Locating the Spring Loaded Disc In Front Of Front Bottom Roller

By locating light spring loaded disc (D) in front of front bottom roller and guiding the yarn in between it helps to converge the drafted strand as given below in the schematic diagram. Here also the converging point of condensation will move downwards creating a long spinning triangle and based on tension fluctuation.

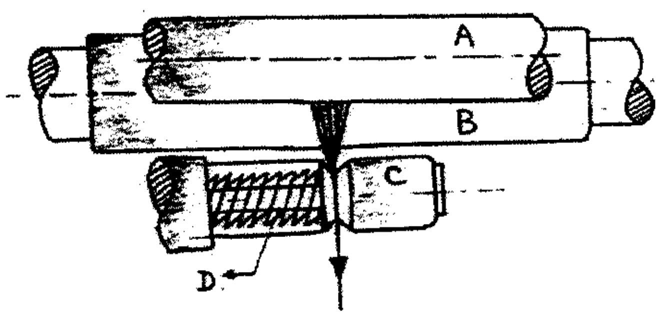


Fig.2.11

2.6 A Study on the Semi-Positive Nip System (S.Ganesan [5], 2004)

The findings of a study on the above system for 40s Combed cotton yarn with the following process parameters are given below

2.6.1 Ring Spinning m/c operating condition

Count spun-Ne	40s Combed
Spindle speed-rpm	15000
T.M	4.0
Roving hank	1.40 Ne
Angle of draft	45° and 65°

- With the use of Semi-Positive Nip Mechanical Compacting System, it is possible to achieve significant reduction in the hairiness S3 value and Zweigle hairiness index.

  60° drafting angle (50-70% reduction) is given better performance than

  45° drafting angle (5-8% reduction)

- For 45° drafting angle, semi-positive nip MCS has shown, 1.2% and 5.8% improvement in single thread tenacity and breaking elongation respectively.
- For 60° drafting angle, MCS shown 3.3% and 9.4% improvement in single thread tenacity and breaking elongation respectively.

2 .7 Advantages of Compact Yarn (Chellamani[1], 2000& Ishtiaque[2], 2003)

From the literature review the following advantages of compact yarn could be summarized in comparison with ring spun yarns

- Higher fiber utilization.
- Fewer weak points in the yarn structure.
- Strength & Elongation of compact yarn is higher by 15-20%
- Higher tenacity with same twist factor or same tenacity with reduced Twist factor up to 20 % resulting in higher production.
- Zweigle-S3 Hairiness lowers by as much as 50%
- Abrasion resistance better to tune of 25%.
- Greater reduction of pilling tendency of fabrics.
- Work of rupture at breaking point will be more because of higher Breaking load and higher extensibility.
- Tearing strength and value of air permeability will be more.
- Due to better embedding of fibers in compact yarn, approximately 6% Fewer combing noils are possible.
- Owing to the lower hairiness and higher tenacity of compact yarns, the Ends-down rate in beaming is reduced by up to 30%, which results in Higher beaming efficiency and production.
- Compact warp yarns help to save up to 50% of sizing agent and Hence cost can be saved in sizing & de-sizing process.
- Intensive dye penetration in dyeing & Greater brilliance of color.
- No singeing before printing required
- In knitting, fiber abrasion is reduced by 40% due to lower hairiness

2.8 Statistical Model for Design of Experiment (e-Hand Book[3,7])

2.8.1 Uses of DOE:

- Choosing Between Alternatives
- Selecting Key Factors Affecting a Response
- Response Surface Modeling To:

  Hitting a target

  Max or Minimizing a Response

  Reducing Variation

  Making a Process Robust

  Seeking Multiple Goals

- Regression Modeling

2.8.2 How do you select an Experimental Design?

Experimental Design Objectives

Types of designs are listed here according to the experimental objective they meet.

Comparative objective: If you have one or several factors under investigation, but the primary goal of your experiment is to make a conclusion about one important factor, and the question of interest is whether or not that factor is "significant", then you have a comparative problem and you need a comparative design solution.

Screening objective: The primary purpose of the experimental is to select or screen out the few important main effects from the many less important ones. These screening designs are also termed main effects designs.

Response Surface objective: The experiment is designed to allow us to estimate interaction and even quadratic effects, and therefore give us an idea of the shape of the response surface we are investigating. For this reason, they are termed response surface method (RSM) designs. RSM designs are used to

1. Find improved or optimal process setting
2. Troubleshoot process problems and weak points
3. Make a product or process more robust against external and non-controllable influences. "Robust" means relatively insensitive to these influences.

Optimizing responses when factors are proportions of a mixture

Objective: If you have factors that are proportions of a mixture and you want to know what the best proportions of the factors are so as to maximize (or minimize) a response, then you need a mixture design.

Optimal fitting of a regression model objective: If you want to model a response as a mathematical function (either known or empirical) of a few continues factors and you desire "good" model parameter estimates (i.e., unbiased and minimum variance), then you need a regression design.

Table 2.1- comparison study on statistical objectives

Number of factors	Comparative Objective	Screening Objective	Response surface objective
1	1- factor completely randomized design	-	-
2-4	Randomized Block Design	Full or fractional factorial	Central composite or Box-Behnken
5 or more	Randomized Block Design	Fractional factorial or placket-Burman	Screen first to reduce number of factors

2.8.3 Comparisons of response surface designs:

For three factors, the Box- Behnken design offers some advantage in requiring a fewer number of runs.

Table 2.2-No. of runs required for CC and Box-Behnken with diff. Factor		
Number of Factors	Central composite	Box-Behnken
2	13(5center points)	-
3	20 (6center points)	15
4	30 (6center points)	27
5	33(frac.Fac)or 52 full fac)	46
6	54(frac.Fac)or 91 full fac)	54

2.8.4 Scope for further study

From above literature survey, following scope for further study is visualized.

1. The above study was confined to the commercially available drafting angle of 45° and 60°. Hence 75° and 90° drafting angle could also be studied using suitable Pilot Ring Frame.
2. Ring Frame process parameters influence and its interaction on the Performance of the system using statistical Model,

Out of the above two the later one is taken up in this project work.

CHAPTER 3

OBJECTIVE

The main objective of this project work is to study the Ring Frame process parameters influence and its interaction on the performance of the system to achieve high quality yarn in respect of Strength and Hairiness using statistical Model.

The following important process parameter is considered for the study

- Spindle Speed
- Traveler Weight
- T.M.

CHAPTER 4

MATERIALS AND METHODS

4.1 Material

100% Combed Cotton - 40 Ne Warp yarn is selected for the study

4.2 Process Variable

The following process variable is selected for the study

a. Spindle speed

b. Traveler weight

c. T.M.

The present study aims to investigate the three processing parameters, i.e. the spindle speed, traveler weight, T.M., on yarn quality in respect of yarn tenacity and hairiness, etc using statistical Model of Design of experiment- Box-Behnken.

Table 4.1 - Details of Process Variable and its Code

Variables	Spindle Speed X_1 [rpm]	Traveler Number X_2 [g/1000]	TM X_3
-1	13500	22	3.9
0	15000	25	4.1
1	16500	28	4.3

4.3 Details of Run based on Box-Behnken Model

Table 4.2 - Variable Combination with Code for the Run			
Run	Spindle Speed (Code)	Traveler Number (Code)	TM (Code)
1	13500 (-1)	22 (-1)	4.1 (0)
2	13500 (-1)	28 (1)	4.1 (0)
3	16500 (1)	22 (-1)	4.1 (0)
4	16500 (1)	28 (1)	4.1 (0)
5	13500 (-1)	25 (0)	3.9 (-1)
6	13500 (-1)	25 (0)	4.3 (1)
7	16500 (1)	25 (0)	3.9 (-1)
8	16500 (1)	25 (0)	4.3 (1)
9	15000 (0)	22 (-1)	3.9 (-1)
10	15000 (0)	22 (-1)	4.3 (1)
11	15000 (0)	28 (1)	3.9 (-1)
12	15000 (0)	28 (1)	4.3 (1)
13	15000 (0)	25 (0)	4.1 (0)
14	15000 (0)	25 (0)	4.1 (0)
15	15000 (0)	25 (0)	4.1 (0)

Trial run based on the above combination to be carried out to produce yarn and study it quality parameters

CHAPTER 5

RESULTS AND DISCUSSION

The detailed mean test results of the above referred characteristics are given in Table 5.1 below.

Table 5.1 - Mean Results of Yarn Quality for all the Fifteen Runs

Run No.	Process Code			Quality Characteristics						
	SS-X1	TW-X2	TM-X3	Zweigle S3 (Nos)	Zweigle Index	Uster Index (cm/cm)	C.V.%	Total Imperfection (Nos/Km)	Elongation (%)	RKm (g/tex)
1	-1	-1	0	788.1	155	3.98	15.72	415	5.19	16.2
2	1	-1	0	914.4	183	4.11	16.02	444	4.91	16.16
3	-1	1	0	650.9	132.5	4.07	15.66	368	5.26	16.51
4	1	1	0	642.2	124.2	4.1	15.97	406	4.62	16.21
5	-1	0	-1	1093.1	198.6	4.35	15.55	326	5.28	15.63
6	1	0	-1	803.5	104.2	4.34	15.95	397	4.77	15.45
7	-1	0	1	621.3	115.8	3.92	15.79	418	5.62	17.02
8	1	0	1	1147	206.2	4.35	16.04	441	4.85	16.63
9	0	-1	-1	890.9	145.1	4.33	16.11	490	4.67	15.93
10	0	1	-1	664.5	95.3	4.27	15.86	420	4.61	16.18
11	0	-1	1	1245.1	267.3	4.34	16.12	558	4.62	16.86
12	0	1	1	680.8	151	3.98	15.86	454	4.42	17.47
13	0	0	0	659.8	120	4.05	16.02	465	4.71	16.78
14	0	0	0	665.4	120.8	4.07	15.82	408	4.71	16.36
15	0	0	0	728.2	143.6	4.08	15.85	395	4.54	16.28

Using software such as Systat, subsequent to feeding of the all the mean results of 15 runs for each Response (Quality Paramenters), the co-efficients of response surface poynomial second order equation which is given below is derived alongwith the Regression co- efficient (R^2).

$$Z= B_0 + B_1x_1+B_2x_2 + B_3x_3+ B_{12}x_1x_2+ B_{13}x_1x_3 + B_{23}x_2x_3+B_{11}x_1^2+B_{22}x_2^2+B_{33}x_3^2$$

The polynomial equation and regression constant found are tabulated in Table 5.2 given below.

Table 5.2 - Polynomial Equation and Regression Constant

Parameter	Second order Polynomial Equation	Regression co- eff.- R2
Zweigle Hairiness – S3 Value	$Z = 721.286-150.013X_2 +171.989X_3^{2} +203.825X1X_3$	0.79
Zweigle-Hairiness Index	$Z = 150.840-30.925X_2+24.637X_3+46.200X_1X_3$	0.715
Uster-Hairiness Index	$Z = 4.066+0.073X_1-0.083X_3+0.169X_3^2+0.110X_1X_3$	0.759
CV_m %	$Z = 15.949+0.157X_1-0.078X_2-0.111X_1^2$	0.763
Total Imperfection	$Z = 455.714-32.375X_2+29.750X_3-53.839X_1^2$	0.65
RKM Value	$Z = 16.551+0.153X_2+0.599X_3-0.325X_1^2$	0.894
Elongation	$Z = 4.61-0.275X_1+0.451X_1^2$	0.86

Based on the above equation, while subsituting valuses for one parameter out of three, the interaction of other two could be plotted in 3D graph and analized. The analysis of such 3D graphs for all the quality paramaeters discussed in the following sections, wherever interaction for two parameters could be seen. For others it is metioned in the graph.

5.1 Effect of Traveler Weight & TM on Hairiness-S3 at Different Spindle Speed (Fig.5.1)

- For moderate and high Spindle Speed (15000-16500 rpm), irrespective of TM used (3.9- 4.3), the Hairiness-S3 attains the lower value(400-600), when Traveler Weight(28)is maximum
- Further, increase in TM results in increased Hairiness-S3 values (1000-1200). But increasing trend is non linear and less with moderate Spindle Speed (15000).

- However, for low Spindle Speed (13500) increase in TM helps to obtain lower Hairiness- S3 (From 950-1250 to 550-850)

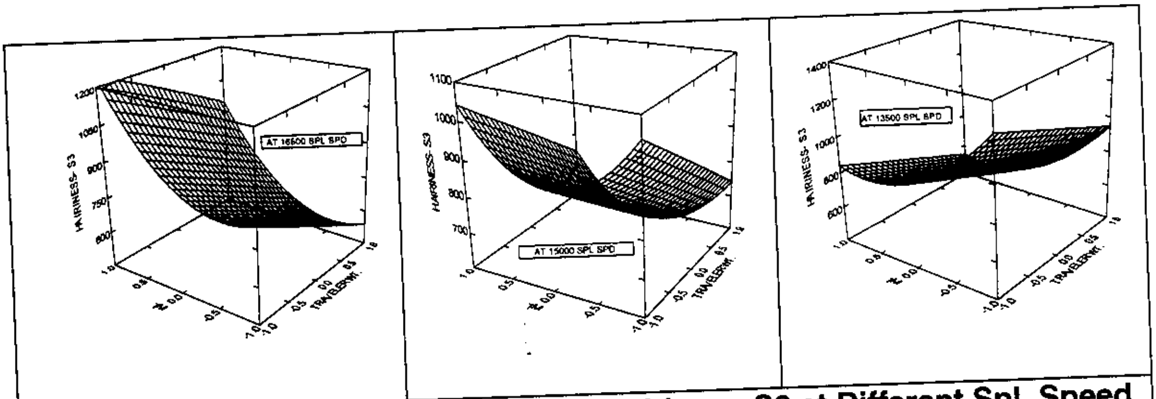


Fig. 5.1-Effect of Traveler Wt. & TM on Hairiness-S3 at Different Spl. Speed

5.2 Effect of Spindle Speed & TM on Hairiness-S3 at Different Traveler Wt. (Fig 5.2)

- For the entire Traveler Wt. used (22-28), any one out of the two factors namely, Spindle. Speed & TM being kept high gives the least Hairiness S3 (300-600).
- But both the parameters on being kept low or high results in significant increase in Hairiness-S3 Values (1000-1200).

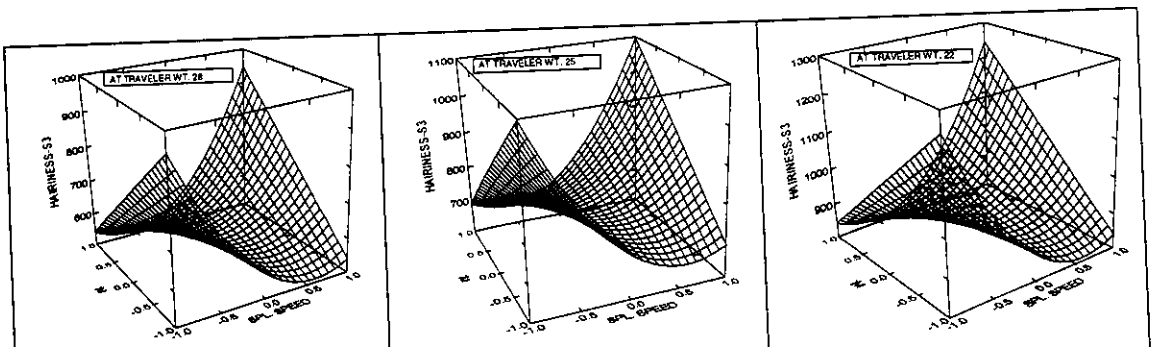
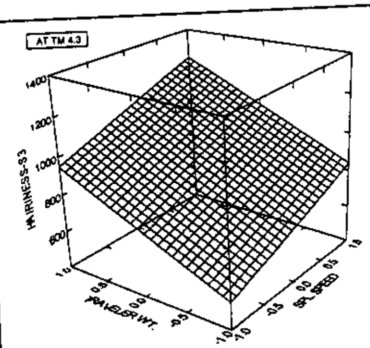


Fig. 5.2-Effect of Spl. Speed and TM on Hairiness-S3 at Different Tr. Wt.

5.3 Effect of Spindle Speed and Traveler Wt on Hairiness-S3 at Different TM (Fig.5.3)

- For Higher TM, the Hairiness-S3 attains the least value (400-500) at lower Spindle Speed and lower Traveler Wt.
- However, for lower TM, the Hairiness-S3 attains the least value (500) at low Spindle Speed & higher Traveler Wt.



At TM 4.1 it is having linear relation with Traveler Wt only and no interaction with Spl. Speed could be noted. Hence 3D graph could not be plotted

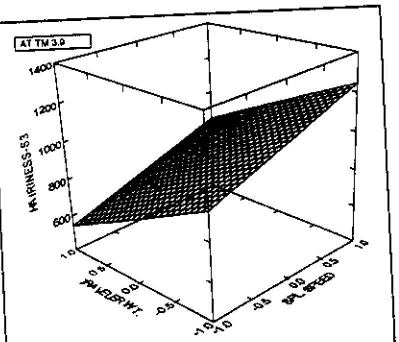


Fig. 5.3-Effect of Spl. Speed & Traveler Wt. on Hairness-S3 at different TM

5.4 Effect of Traveler Wt. and TM on Zweigle-Hairiness Index at Different Spl. Spd. (Fig. 5.4)

- For moderate and high Spindle Speed (15000-16500 rpm) used, the Zweigle-Hairiness Index attains the least (<50), when the Traveler Weight (28) is maximum and TM is minimum. Further, for these Spindle Speeds increase in TM shows the significant increase in Zweigle- Hairiness Index (From110-155 to 210-250).
- However at slower Spindle Speed (13500 rpm) increased TM helps to obtain lower Zweigle- Hairiness Index (From 140-200 to 60-160).

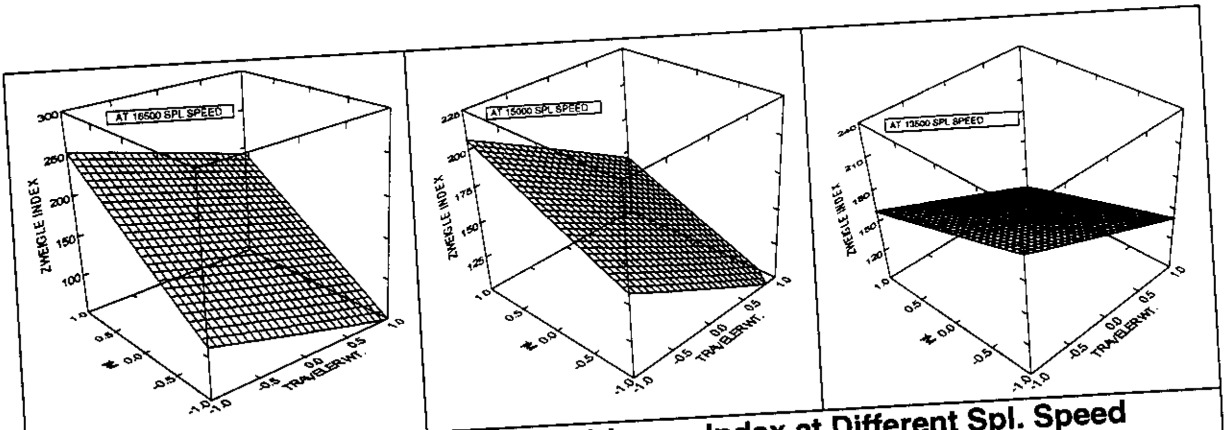


Fig. 5.4-Effect of Tr. Wt.& TM on Z-Hairiness- Index at Different Spl. Speed

5.5 Effect of Spl. Speed & TM on Zweigle-Hairiness Index at Different Traveler Wt. (Fig. 5.5)

- For the entire Traveler Wt. used (22-28), lower Spindle Speed & higher TM gives the least Zweigle-Hairiness Index (50-100)
- But both these two parameters on being kept low or high cause significant increase in Zweigle-Hairiness Index (180-240).

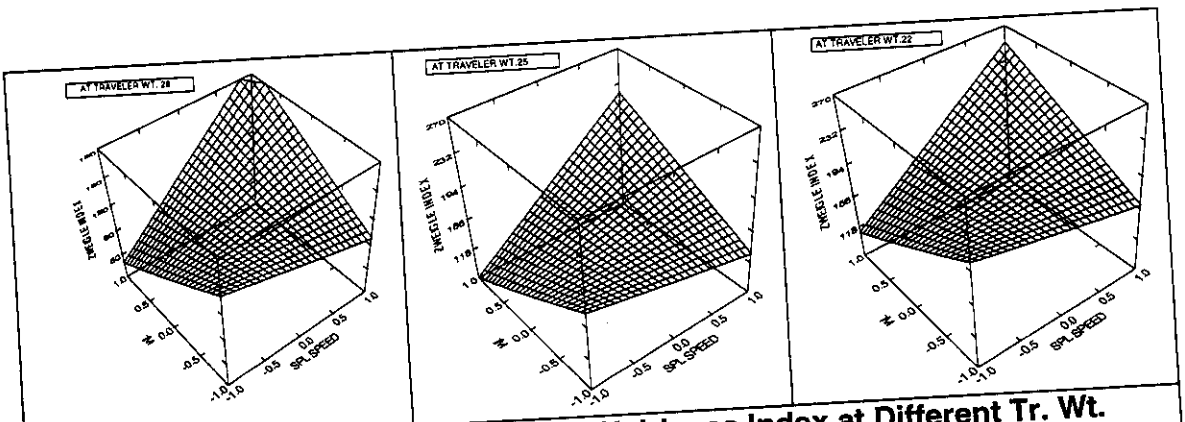
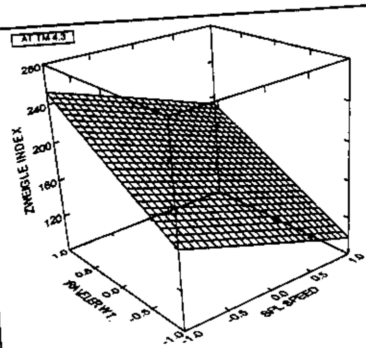


Fig.5.5-Effect of Spl Speed & TM on Z-Hairiness Index at Different Tr. Wt.

5.6 Effect of Spl. Speed & Traveler Wt. on Zweigle-Hairiness Index at Different TM (Fig. 5.6)

- For higher TM (4.3), the Zweigle-Hairiness Index attains the least (<50), when Spindle Speed is kept high & Traveler weight low.
- However, for lower TM (3.9), it attains the least (<50), when Traveler weight & Spindle Speed is kept low.



At TM 4.1 it is having linear relation with Traveler Wt only and no interaction with Spl. Speed could be noted. Hence 3D graph could not be plotted

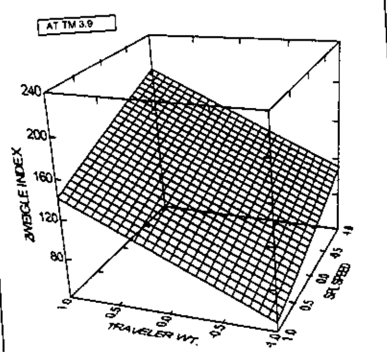
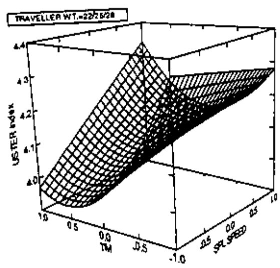


Fig.5.6-Effect of Spl Speed & Tr. Wt. on Z-Hairiness Index at different TM

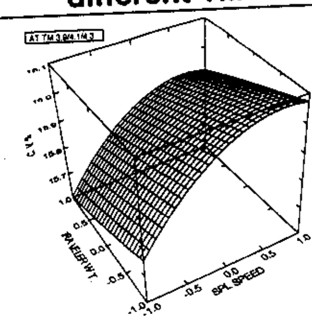
5.7 Effect of Spl. Speed & TM on Uster-Hairiness Index at Different Traveler Wt. (Fig. 5.7)

- For the entire Traveler Wt. used (22-28), Uster-Hairiness Index attains the least (<4.0), when the Spindle Speed is lowest & TM is slightly less than the highest value used (4.2).
- Increase in Spindle Speed at higher TM (4.3) causes significant increase in the Uster-Hairiness Index (from 4.0 to 4.3). However, the increase is less (4.15) for moderate TM, and there is a slight decrease in Index for low TM.

Effect of Traveler Wt. & TM on Uster-Hairiness Index at Different Spindle Speed	Fig. 5.7-Effect of Spl. Speed and TM on Uster-Hairiness Index at Different Traveler Weight	Effect of Spindle Speed and Traveler Weight on Uster-Hairiness Index at Different TM
No interaction with Traveler Wt noticed. Hence 3D graph could not be plotted		No interaction with Traveler Wt noticed. Hence 3D graph could not be plotted

5.8 Effect of Spindle Speed & Traveler Weight on Evenness at Different TM (Fig.5.8)

- For the entire TM used (3.9-4.3), Evenness (CV %) attains the least value (15.6 %) for higher Traveler Weight (28) & lower Spindle Speed (13000 rpm).
- However the influence of Spindle Speed is very high on C.V. % and it reaches the maximum (16.0 %) for the highest Spindle Speed and lowest Traveler Weight.

Effect of Traveler Wt. & TM on Evenness-C.V.% at Different Spindle Speed	Effect of Spindle Speed and TM on Evenness-C.V.% at Different Traveler Weight	Fig.5.8- Effect of Spindle Speed & Traveler Wt. on Evenness-C.V.% at different TM
No interaction with TM noticed. Hence 3D graph could not be plotted	No interaction with TM noticed. Hence 3D graph could not be plotted	

The main reason for the behavior explained in sections 3.1 to 3.7 is that higher spinning tension achieved at higher Spindle Speed & Tr. wt. reduces the fluttering action of the yarn resulting in low hairiness values. Where as at lower spinning tension observed at lower Spindle. Speed and Traveler Wt. higher TM helps to reduce the Hairiness

5.9 Effect of Traveler Wt. & TM on Imperfection at Different Spindle Speed (Fig.5.9)

- For the entire Spindle Speed used the imperfection attains the lowest (330) when traveler Weight is higher (28) & TM is lower (3.9).
- It linearly increases (460-520) with decrease in Traveler Weight & increase in TM.

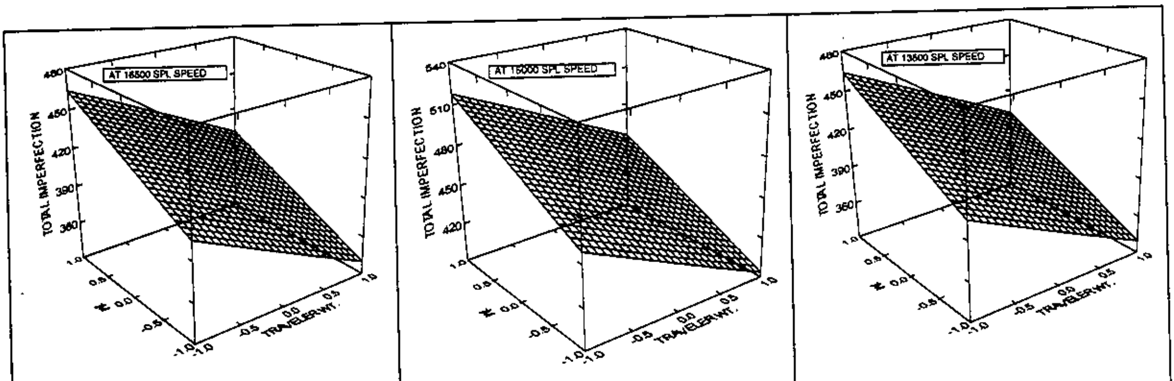


Fig.5.9-Effect of Traveler Wt. & TM on Imperfection at Different Spl Speed

5.10 Effect of Spindle Speed & TM on Imperfection at Different Traveler Wt. (Fig.5.10)

- For the entire Traveler Weight used (22-28), lower Spindle Speed gives lower imperfection and it increases linearly with Spindle Speed.
- However for all the Traveler Weight used and irrespective of Spindle Speed, the increase in imperfection (from345-375 to 400-465) is noticed, when TM

Increases from lower to moderate (From 3.9 to 4.1) and subsequently it decreases back to normal with the further increase TM (4.3).

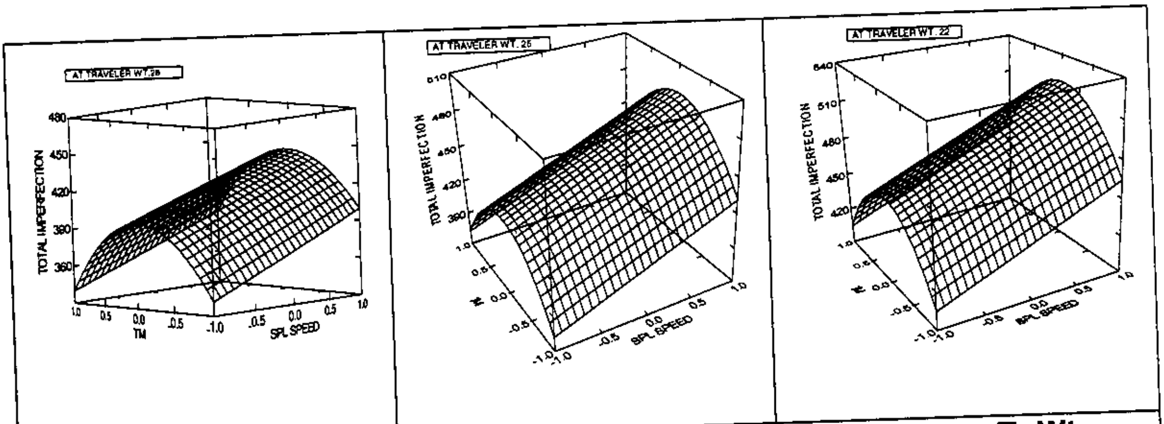


Fig.5.10-Effect of Spl. Speed and TM on Imperfection at Different Tr Wt.

5.11 Effect of Spindle Speed & Traveler Wt on Imperfection at Different TM (Fig. 5.11)

- For the entire TM used (3.9-4.3), the imperfection attains lowest (330-360) for lower Spindle Speed and it increases linearly (420-480) with Spindle Speed.
- However, for the entire TM used and irrespective of Spindle Speed, the increasing imperfection (From 345-375 to 400-465) is noticed, when Tr. Wt increases from lower to moderate (From 22to 25) and subsequently it decreases with further increase in Tr. Wt.

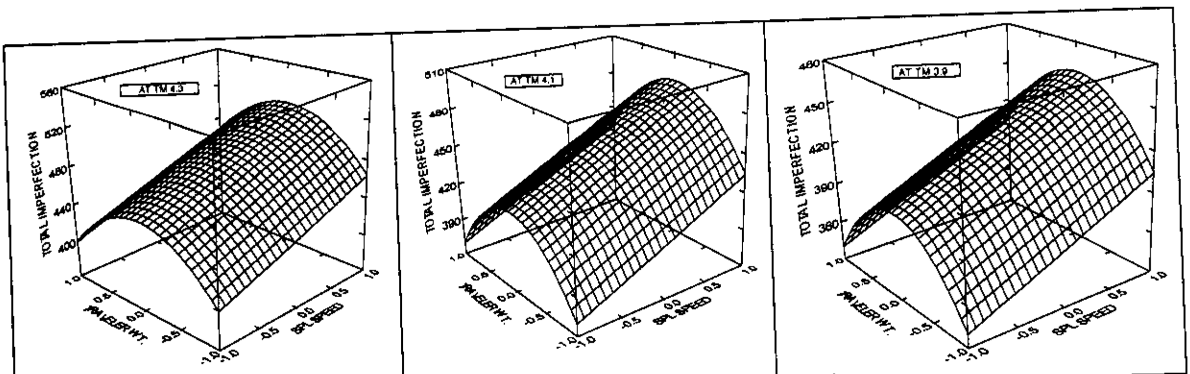


Fig. 5.11-Effect of Spl Speed & Traveler Wt. on Imperfection at Different TM

The reason for higher evenness and imperfection given above (Section5.8 to 5.11) at higher Spindle Speed is that of lack of fibre control associated at high drafting speed.

5.12 Effect of Traveler Weight & TM on Strength-RKM at Diff. Spindle Speed (Fig. 5.12)

- For the entire Spl. Speed used, RKM reaches the highest (16.7-17.0) for high Tr. Wt. and TM.
- However there is a marked linear decrease in RKM value (From 16.7-17.0 to 15.4-15.5) with decrease in TM than with the decreases in Tr. Wt. which is a well known fact.

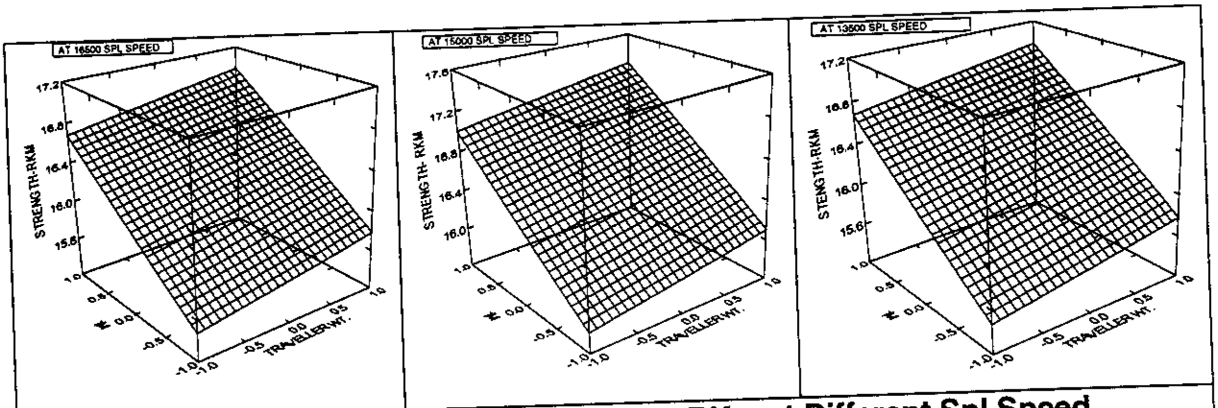


Fig. 5.12-Effect of Tr. Wt. & TM on Strength –RKm at Different Spl Speed

5.13 Effect of Spindle Speed& TM on Strength-RKm at Diff. Traveler Weight (Fig.5.13)

- For the entire Tr. Wt and TM used, higher RKM (strength) value is attained (17-17.2) for higher Spindle Speed (16500) and the increase is linear with Spindle Speed. Higher Spg. tension resulting at higher Spl. Speed helps to achieve higher Packing Density and Strength
- However, irrespective of Spindle Speed there is an increase in RKM value (From 15.4-15.5 to 16.7-17.0), when TM is increased from lower to moderate

(From 3.9 to 4.1) and it subsequently decreases with the further increase in TM, which is a known behaviour.

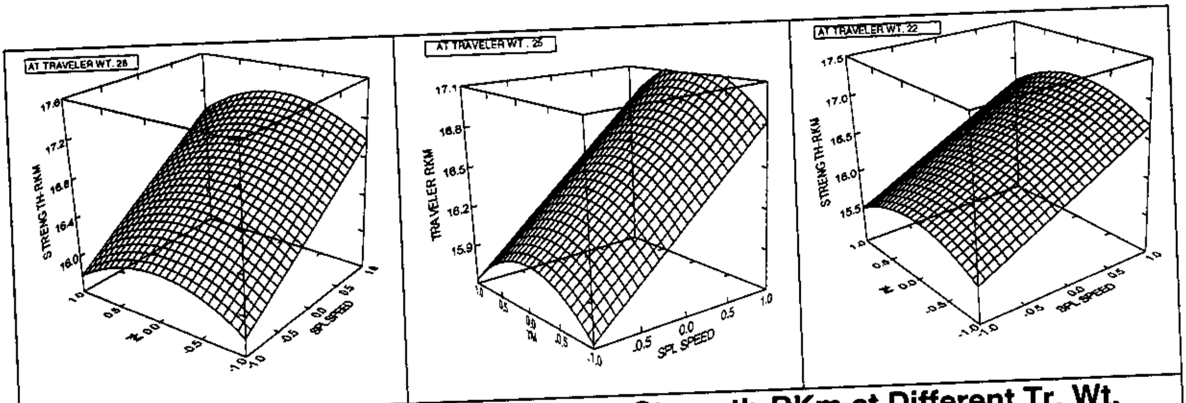


Fig. 5.13-Effect of Spl Speed and TM on Strength-RKm at Different Tr. Wt.

5.14 Effect of Spindle Speed& Traveler Weight on Strength-RKM at Different TM (Fig. 5.14)

- For the entire TM and Tr. Wt. used, higher RKM value (16.7-17.2) is obtained for higher Spindle Speed. There is a linear decrease in RKM value with the decrease a Spindle Speed.
- However, for lower to moderate increase in Tr. Wt. there is an increase in RKM and subsequently it decreases with further increase in Tr. Wt.

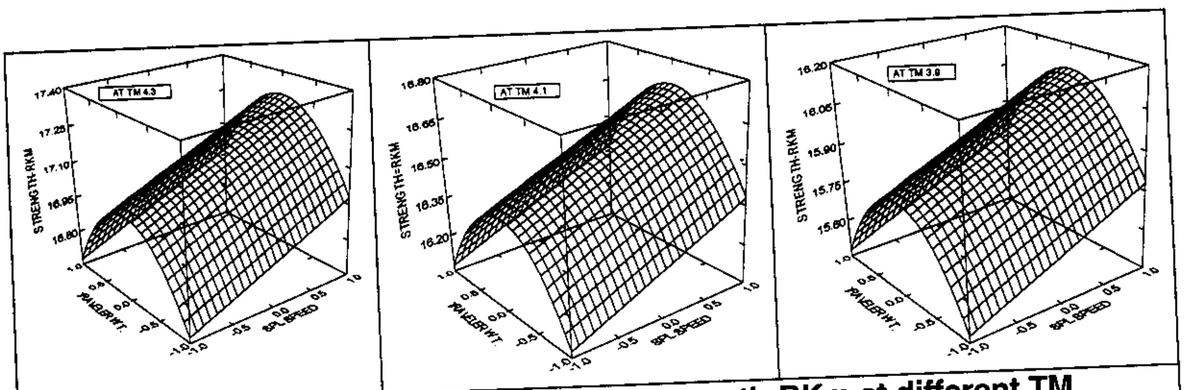


Fig. 5.14-Effect of Spl Speed & Tr. Wt. on Strength-RKm at different TM

5.15 Effect of process parameter on Breaking Elongation

- Out of the three process parameters taken for the study no two parameters is having positive correlation with Breaking Elongation of yarn. Only Spindle Speed is having co- relation.

Higher Tension due to increased Spl. Speed and Traveler Wt. help to obtain better packing density of yarn there by resulting higher Strength and Breaking elongation.

CHAPTER 6

CONCLUSIONS

From the above Box-Behnken statistical model study on "Effect of process parameter on the performance of a Semi-Positive Nip Mechanical Compacting System" for 40s Combed Cotton Yarn, one can conclude the following:

- Moderate to higher Spindle Speed with moderate Traveler Weight and TM will yield a yarn with reasonably lower (up to 50 %) Hairiness- S3 Value.
- Similarly, moderate Spindle Speed with moderate Traveler Weight and TM only will yield a yarn with reasonably lower Zweigle-Hairiness Index (up to 50 %) and Uster- Hairiness Index (up to 10 %).
- For higher TM yarn lower Spindle Speed is necessary to get Lower Hairiness- S3 Value and lower hairiness index of both.
- Heavier Traveler will yield a yarn with less C.Vm % (2 %) and Imperfection (25 %).
- Lower TM yields a yarn with lesser Imperfection (25 %).
- Higher T.M , up to certain value, yields higher RKm (13 %), which is a well known fact
- For a given TM moderate Traveler Weight and higher Spindle Speed yield yarn with higher RKM (3 %).
- Breaking elongation of yarn is having only positive correlation with Spindle Speed only, but not with TM and Traveler Weight.

From the above conclusions one can derive the optimum process parameter as moderate to higher Spindle Speed with moderate Traveler Wt.

And TM, which will yield a quality yarn with reasonably lower Hairiness, Evenness & Imperfections, and higher Strength-RKm and Breaking Elongation. But, for getting ideally low Evenness and Imperfections the Spindle Speed needs to be restricted to moderate.

CHAPTER 7

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