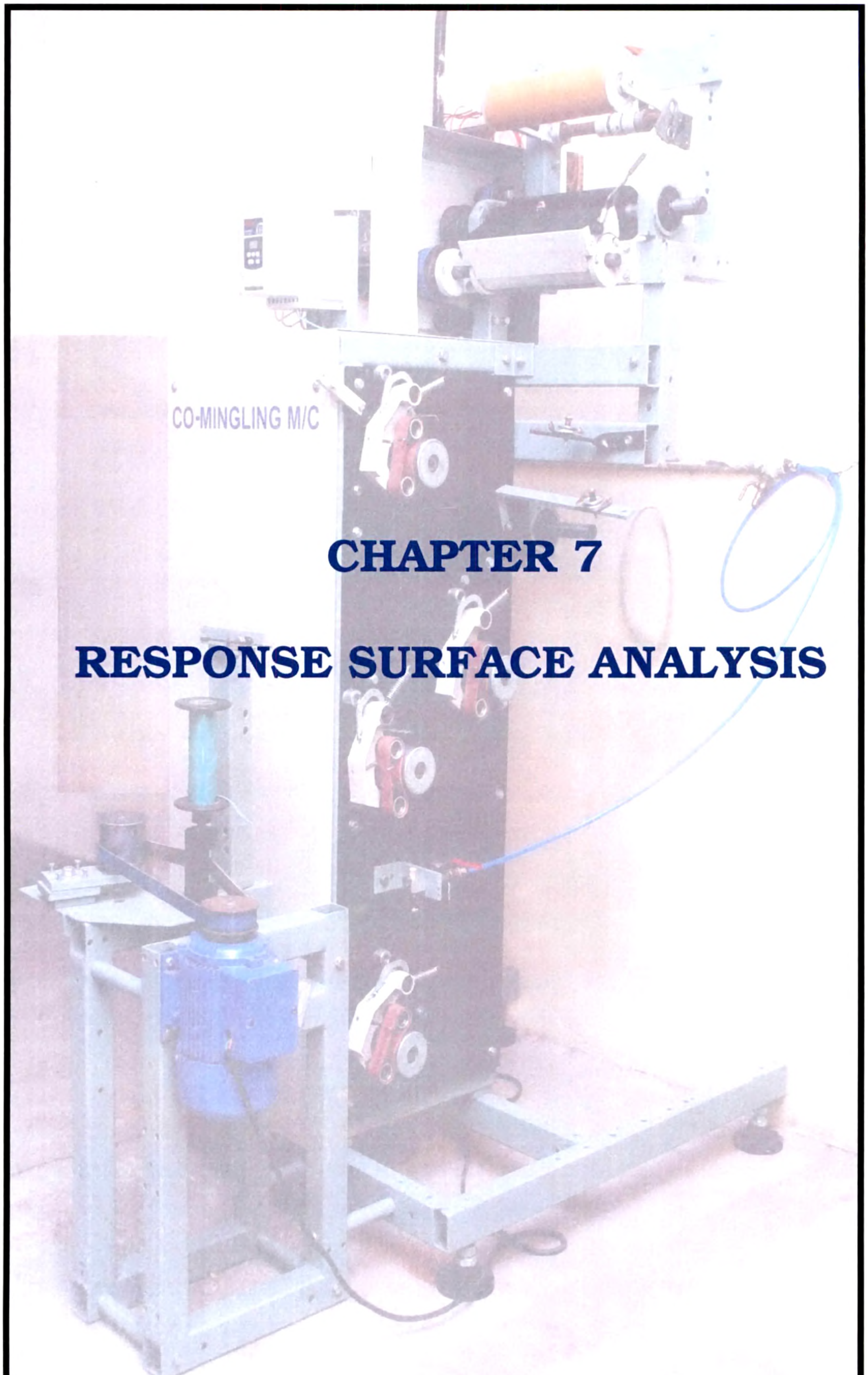
CHAPTER 7

RESPONSE SURFACE ANALYSIS



CHAPTER 7 RESPONSE SURFACE ANALYSIS

Analysis of Effect of Processing Parameters on Commingling Behaviour of Glass/Polypropylene Hybrid Yarn

7.1 INTRODUCTION

Response surface methodology comprises of a group of statistical techniques for empirical model building and model exploitation to design and analyze the experiments. In most of the exploratory types of investigation, especially research related works the experimental designs are used. The response surface analysis using Box-Behnken design is useful to find out the co-relation between the response and variables. In many investigations, the experimental designs are generally used for some of the following purposes:

- To confirm desired results with minimal data collection for an alternative design, process or assembly method.
- To distinguish between critical and non-critical factors.
- To locate sources of variability and correlate process variables with characteristics of product.
- To compare different processes and machines, for average level of variation.

Box and Draper[78] have listed various properties of a response surface design to be used when fitting a polynomial model to the data collected at design points. Some of the important properties are:

- The design should generate a satisfactory distribution of information throughout the region of interest.
- The fitted value of the response is as close as possible to the true value of the response.
- The design should give delectability of model's lack of fit.

- The experiments should be performed in blocks preferably with a minimum number of experimental points.
- The design should provide the information regarding an internal estimate of the error variance σ^2.
- The design should ensure simplicity in calculation of the model parameters to be estimated.

7.2 RESPONSE SURFACE METHODOLOGY

Formulation of the right kind of experimental design is extremely important. The simplest among the prevailing experimental methods is the 'one factor-at-time' method. In this method, experimenter varies the level of only one factor keeping the level of other factors at a specific set of conditions. This method is simple but misleading and sometimes leads to unreliable interpretations and wrong conclusions. Moreover, interaction effects present between different factors cannot be examined.

The deficiencies of the 'one factor-at-time' method can be overcome through the use of 'factorial experiment' method in which the effects of different factors are investigated simultaneously. The treatment consists of all the combinations that can be formed from the different factors. The main advantages of factorial experimental method are:

- If the variables act additively, the factorial does the job with more precision.
- If the variables do not act additively, unlike the 'one factor-at-time' method the factorial can detect and estimate interaction to measure non-additivity.

It also gives more efficiency compared to 'one factor-at-time' method, and involves all the data in computing the interaction effects. The factorial experiments in which each variable occurs at 2 levels, are called first order factorial design. At an early stage of an investigation, in the absence of sufficient knowledge concerning the shape of the true response surface, generally experimenter's first attempts to approximate the shape by fitting a first order model to the response values. When the first order model suffers from lack of fit arising from the existence of non-linearity in responses, a second order model is able to fully explain the observed behaviour. In such situations, a higher order design is needed. For all practical purposes, the second order design is quite adequate to explain the behaviour of the response. The general form of a second-degree polynomial is illustrated by the equation,

$$Y_u = b_0 + \Sigma_{bi}\, x_{ju} + \Sigma_{bii}\, x_{ju}^2 + \Sigma\, b_{ij}\, x_{ju}\, x_{ju} + e_u$$

The surface contains linear terms in x_{ju}, squared terms in x_{ju}^2, and the interaction terms in $x_{ju}\, x_{ju}$. The residual e_u measures the experimental error. In order to estimate the regression coefficient (b_0, b_i, b_{ii}, b_{ij}) in the model, each variable x_{ju} must take at least three different levels. This suggests the use of factorial designs of the 3^h series, is that number of experimental trials (3^h) can be excessively large when a large number of input variables are under study. For this purpose, some effects are compounded so that the number of treatment combinations in a block is within the economic range of the experimenter. On the other hand, in a factorial experimental design, depending on the degree of fractionalization, a number of interaction effects or higher order effects cannot be estimated independently due to compounding of these effects with some other effects. Box and Wilson[81] have specified specifically engineered central composite design and Box-Behnken design to fit the criteria for multi-level designs.

The central composite design is an efficient design that allows investigation of interactions and linear effects with far fewer runs than the fully crossed factorial with five levels. In the design, the factorial part estimates the main and interaction effects; the rotatable part estimates the quadratic effects and centre point observation estimates the variance due to pure error in the system which helps in estimating lack of fit of the model. Sometimes it is not possible to obtain the required 5 levels for the central composite design. In such circumstances a modified central composite design with most of the factors at 5 levels and a few at 3 levels can be employed. Such a design would not suffer terribly in the analysis. Depending on the field of application, the other form of deviation from the central composite can also be observed.

7.2.1 Box-Behnken Design

The concept of Box-Behnken design makes logical use of the 2^K factorial. To build a Box-Behnken design, factors are taken in pairs followed by building 2^2 factorials for all possible pairs while holding the other factors at a centre point. Box-Behnken design is considered to be very efficient as compared to the full factorial design. Through the use of the above design, information on single linear effect, single quadratic effects along with the two factor linear interaction can be obtained.

In Box-Behnken 3 level design for 3 factors, there are 15 combinations; six center point observations were added for considering experimental error due to unaccounted factors. In contrast, the central composite design has 26 treatments including centre points observations. Due to the machine constraint, it is difficult to achieve five levels for the factors considered. Hence, Box-Behnken design is chosen for the study, which can adequately fulfill the basic objectives of the present investigation.

7.2.2 Response Surface Application

The influence of process variable on characteristics of glass/polypropylene hybrid yarns has been studied using Box-Behnken response surface design. The characteristics of these yarns are evaluated for its optimum behaviour in terms of homogeneous mixing of component yarns by visual inspection of SEM micrograph. The important processing parameters that influence commingled hybrid yarns are air pressure, overfeed and take-up speed. There has been great deal of study on the effect of these parameters on characteristics of hybrid yarn. However, most of these studies have been carried using the airflow and yarn movement as an individual factor without considering their interaction effects. Recently the interest in hybrid yarn for application in thermoplastic composites has been increased. Hence, an investigation on the effect of these parameters, especially with interaction effects of all the processing parameters on yarn properties is carried out. The effect of three process parameters of commingling process viz. air pressure, overfeed and take-up speed, on commingling characteristics of hybrid yarn viz. nip frequency, nip stability and nip regularity has been evaluated.

This hybrid yarns are suitable for producing preforms for thermoplastic composites and to investigate further the effects of individual process variables and their interaction effects on glass/polypropylene hybrid yarns characteristics, the Box-Behnken response surface design has been used.

7.3 MATERIALS AND METHODOLOGY

7.3.1 Preparation of Yarn Sample

Glass filament of 2700 denier and polypropylene filament of 840 denier are commingled at commingling machine, fabricated for producing hybrid yarns. The passage of yarn during the process through commingling machine is used as described in Chapter 6. The overfeed of polypropylene yarn is adjusted at 0%, 1% and 2% by changing the speed ratio of overfeed roller and output roller. The ceramic jet with circular cross-section is used for this purpose, the detail of which is given in Chapter 6 (see Fig. 6.2).

7.3.2 Box-Behnken Design

The Box-Behanken design is used to plan the experiments for producing hybrid yarn using key processing variables. The Box-Behnken design is selected mainly to the reduce number of experiments. The various factors and their coded levels selected for the experiment are given in Table 7.1. The experimental runs based on the factor level combination for glass/polypropylene hybrid yarn are given in Table 7.2. Total of fifteen yarn samples have been made including standard sample produced at [0, 0, 0] level.

Table 7.1 Three Factors/Level of Experiment Design

Level	Factors		
	Air pressure (bar) X_1	Overfeed (%) X_2	Take-up speed (m/min) X_3
-1	5	0	50
0	6	1	75
1	7	2	100

Table 7.2 Various Experimental Runs of Factor/Level Combinations

Sr. No.	X_1	X_2	X_3	Air pressure (bar) X_1	Overfeed (%) X_2	Take-up speed (m/min) X_3	Sample code
1	-1	-1	0	5	0	75	S_1
2	+1	-1	0	7	0	75	S_2
3	-1	+1	0	5	2	75	S_3
4	+1	+1	0	7	2	75	S_4
5	-1	0	-1	5	1	50	S_5
6	+1	0	-1	7	1	50	S_6
7	-1	0	+1	5	1	100	S_7
8	+1	0	+1	7	1	100	S_8
9	0	-1	-1	6	0	50	S_9
10	0	+1	-1	6	2	50	S_{10}
11	0	-1	+1	6	0	100	S_{11}
12	0	+1	+1	6	2	100	S_{12}
13	0	0	0	6	1	75	S_{13}
14	0	0	0	6	1	75	S_{14}
15	0	0	0	6	1	75	S_{15}

7.3.3. Measurement of Yarn Characteristics

All the fifteen hybrid yarn samples are evaluated for important characteristics to investigate the influence of process variables on yarn properties. The various characteristics of commingled hybrid yarn has been evaluated such as linear density, tensile strength, elongation at break along with commingling characteristics viz. nip frequency, nip stability and nip regularity. The methods of measurement of these characteristics are described in Chapter 5. Table 7.3 shows the average values of these characteristics, which are used for response surface analysis using the computer software 'MINITAB'. Regression equations, contour plots and surface plots are generated to observe the linear and interaction effects of process variables on hybrid yarn characteristics.

7.4 RESULTS AND DISCUSSION

The effect of process variables viz. air pressure, overfeed and take-up speed on properties of commingled hybrid yarn produced from glass filament and polypropylene filament has been taken into consideration by using the response surface methodology based on the Box- Behnken design. The data obtain from MINITAB is listed in Table 7.4 and Table 7.5 indicating constants for regression equation and its p-value respectively. The regression equations

Table 7.3 Properties of Glass/Polypropylene Commingled Hybrid Yarn

Sample Code	Linear density	Tenacity cN/tex	Extension at break (%)	Nip frequency (nips/meter)	Nip stability (cycle)	Nip regularity (cm)
S_1	3471	25.2	1.8	12.3	10.2	3.1
S_2	3491	22.5	1.8	25.7	11.0	2.4
S_3	3595	32.4	2.9	24 3	7 8	2.1
S_4	3463	29.7	2.6	27.2	7.5	1.9
S_5	3575	28.8	2.2	13.8	10.2	1.9
S_6	3542	32 4	2.6	28.3	12.4	1.8
S_7	3502	24.3	2.2	19.4	14.9	2.6
S_8	3473	31.5	2 3	20.5	9.3	2 3
S_9	3425	21.6	1.8	17.4	8.0	2.0
S_{10}	3522	31.5	2.6	17.9	11.1	2.1
S_{11}	3496	19.8	1.7	22.2	10.1	2.5
S_{12}	3570	29.7	2.7	17.1	5.6	1.8
S_{13}	3482	31.5	2.4	17.6	17.2	2.1
S_{14}	3565	28.8	2.6	15.3	9.4	2.1
S_{15}	3524	31.5	2.3	16.8	14 3	2.2

Table 7.4 Values of Constants for Regression Equation

Factor	Linear density	Tenacity	Extension	Nip frequency	Nip stability	Nip regularity
Constant	3523.60	30.600	2.4333	16.5667	13.6333	2.1333
X_1	-21.7500	0.6750	0 0250	3.9875	-0.3625	-0.162
X_2	33 3750	4.2750	0.4625	1 1125	-0.9125	-0.262
X_3	-2.8750	-1.1250	-0 0375	0.2250	-0 2250	0 175
X_1*X_1	0.5750	0.2250	-0.0167	3.8292	-0 7542	0.1458
X_2*X_2	-19.1750	-3.3750	-0.1417	1.9792	-3.7542	0 0958
X_3*X_3	-1.1750	-1.5750	-0.0917	0.1042	-1.1792	-0.129
X_1*X_2	-38.0000	- 0.0000	-0.0750	-2.6250	-0.2750	0.125
X_1*X_3	1.0000	0.9000	-0 075	-3 3500	-1 9500	-0.050
X_2*X_3	-5.750	0.0000	0.0500	-1.4000	-1.9000	-0.200

are formed using the value of regression constants, which are given in Table 7.6 along with regression co-efficient value R^2. The response surface graphs obtained by varying two variables at a time keeping the third variable at a constant level have been studied.

Table 7.5 P-Values of Regression Equation

Factor	Linear density	Tenacity	Extension	Nip frequency	Nip stability	Nip regularity
Constant	0.0	0 0	0.0	0 0	0.0	0 0
X_1	0.281	0 538	0.689	0 015	0.727	0.102
X_2	0.123	0.009	0.001	0 359	0.396	0 023
X_3	0.879	0.321	0 553	0.846	0.828	0.084
X_1*X_1	0.984	0.887	0 855	0.065	0.624	0.277
X_2*X_2	0 502	0.075	0.164	0.277	0.049	0.459
X_3*X_3	0 966	0.343	0.339	0 951	0.452	0.330
X_1*X_2	0.196	1.000	0 410	0.153	0 851	0.326
X_1*X_3	0.970	0.560	0 410	0.084	0 220	0.682
X_2*X_3	0 830	1.000	0.575	0 410	0.230	0.142

Table 7.6 Regression Equations and Regression Coefficients (R^2)

Hybrid yarn characteristic	Regression Equations	R^2
Linear density	$3523.60 - 21\ 75X_1 + 33.38X_2 - 2.88X_3 + 0\ 58X_1^2 - 19.17X_2^2 - 1\ 17X_3^2 - 38.0X_1X_2 + 1.0X_1X_3 - 5\ 75\ X_2X_3$	0.607
Tenacity	$30.60 + 0.675X_1 + 4.275X_2 - 1.125X_3 + 0.225X_1^2 - 3.375X_2^2 - 1\ 575X_3^2 - 0.0X_1X_2 + 0.90X_1X_3 + 0.0X_2X_3$	0.836
Extension	$2.433 + 0\ 025X_1 + 0.462X_2 - 0\ 037X_3 - 0.0167X_1^2 - 0.141X_2^2 - 0.091X_3^2 - 0\ 075X_1X_2 - 0.075X_1X_3 + 0\ 050X_2X_3$	0.931
Nip frequency	$16.566 + 3\ 987X_1 + 1.112X_2 + 0.225X_3 + 3.829\ X_1^2 + 1.979\ X_2^2 + 0.104X_3^2 - 2.625X_1X_2 - 3.35X_1X_3 - 1.1400X_2X_3$	0.854
Nip stability	$13\ 633 - 0.362X_1 - 0\ 912X_2 - 0\ 225X_3 - 0.754X_1^2 - 3\ 754\ X_2 - 1\ 179X_3^2 - 0\ 275X_1X_2 - 1.750X_1X_3 - 1\ 900X_2X_3$	0.708
Nip regularity	$2\ 133 - 0\ 162\ X_1 - 0.262X_2 + 0.175\ X_3 + 0.145\ X_1^2 + 0.095\ X_2^2 - 0.129\ X_3^2 + 0\ 125\ X_1X_2 - 0.50\ X_1\ X_3 - 0.20\ X_2X_3$	0.844

7.4.1 Effect of Processing Parameters on Linear Density of Hybrid Yarn

The effect of processing parameters on linear density of hybrid yarn has been studied. Fig. 7.1(a), Fig. 7.1(b) and Fig. 7.1(c) shows contour plots, surface plots and residual plots of linear density as response. It can be clearly seen from Fig. 7.1(a) that the linear density of hybrid yarn mainly varies due to overfeed and air pressure during process. The higher overfeed value gives higher linear density due to extra length of filament. However, due to the higher value of pressure the filament breakage increases, which leads to reduction of the final yarn denier. Even at high take-up speed it gives less time to the filament for nip formation.

So, even with high overfeed by increasing take-up speed, the mass per unit length of yarn reduces, keeping the overfeed value constant. At higher take-up speed and air pressure the final denier of yarn is reduced due to less time available for interlacement and higher breakage of glass filament. This was observed practically during specimen preparation. Finally it is evident from the results that the yarn denier value is more at higher overfeed and air pressure. Also high pressure with low overfeed gives poor quality of yarn due to higher filament breakage.

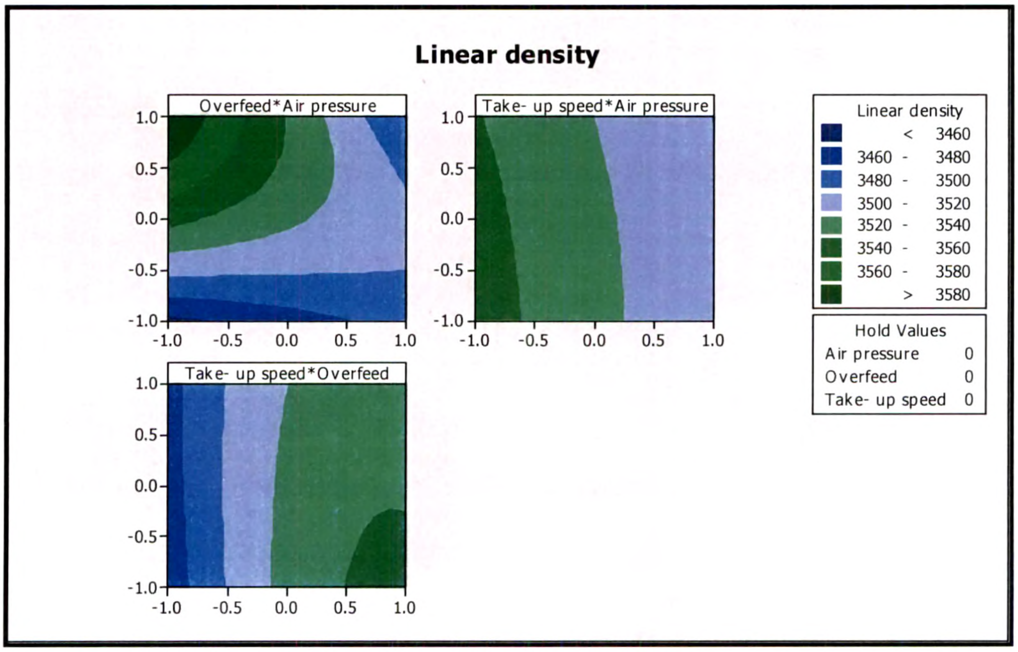


Fig. 7.1(a) Contour plots of hybrid yarn linear density at different processing parameters

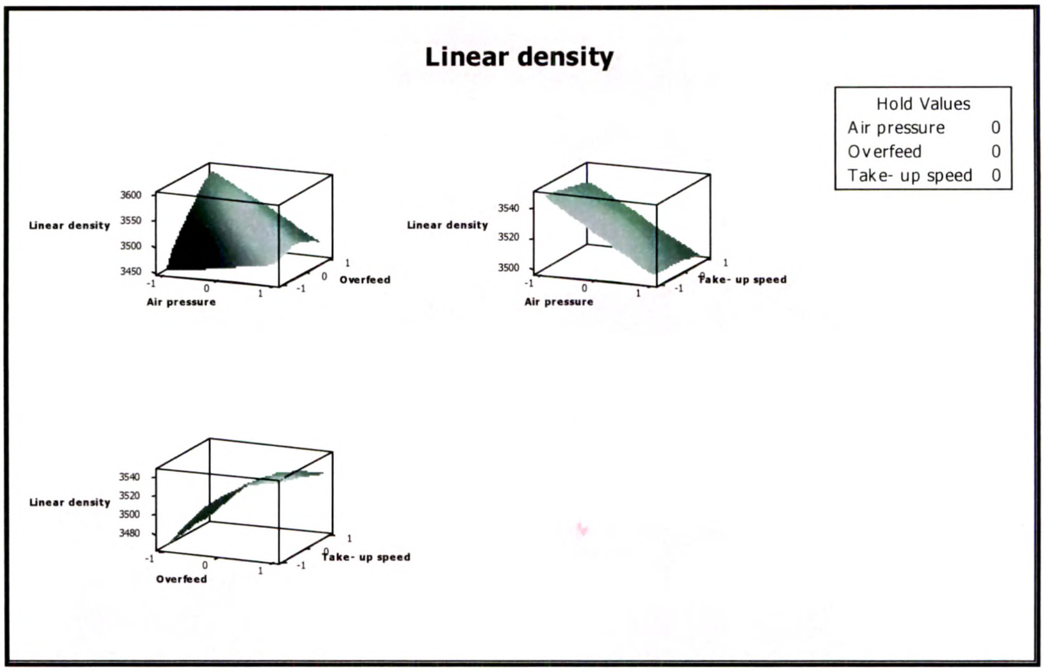


Fig. 7.1(b) Surface plots of hybrid yarn linear density at different processing parameters

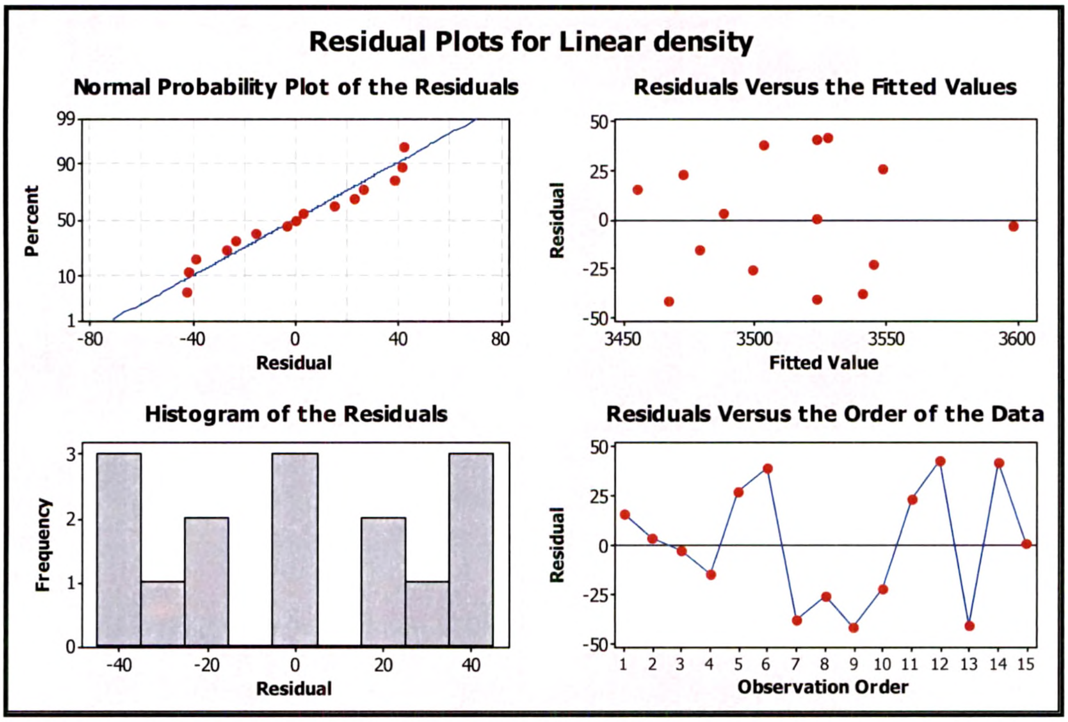


Fig. 7.1(c) Residual plots for linear density as response

The p-values given in Table 7.5 for overfeed (0.123) and air pressure (0.281) indicates that these factors are important in deciding linear density of the final hybrid yarn. The interaction between air pressure and over feed also have low p-value (0.196) and indicate significant effect of this interaction value on final denier of hybrid yarn. The Table 7.6 gives estimated regression co-efficient value; 60% shows poor correlation and high variability, which introduces the error.

7.4.2 Effect of Processing Parameters on Hybrid Yarn Tenacity

Tenacity value measured in cN/tex indicates that higher the linear density more is the tenacity due to more area per unit length. The processing parameters have significant effect on yarn tenacity. Fig. 7.2(a), Fig. 7.2(b) and Fig. 7.2(c) shows contour plots, surface plots and residual plots of tenacity as response.

Fig. 7.2(a) shows that the constant values of take-up speed gives increase in tenacity with high value of overfeed and air pressure due to high number of nips. Similar effect has been observed for high value of tenacity due to low take-up speed and high pressure; but as take-up speed increases the nip frequency reduces with poor regularity, resulting in poor yarn tenacity. Similarly higher value of overfeed with low take-up speed at constant pressure gives better tenacity due to overfeeding of yarn but in this case nip characteristics are poor at low air pressure, which improve with high pressure. Hence, overfeed is an important factor in deciding the yarn tenacity.

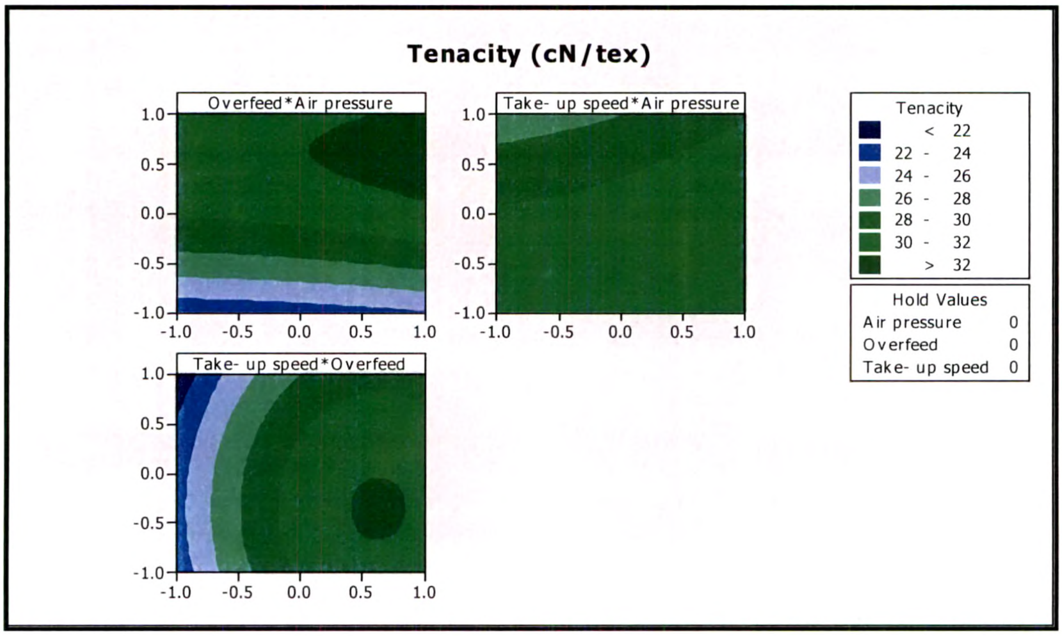


Fig. 7.2(a) Contour plots of hybrid yarn tenacity at different processing parameter

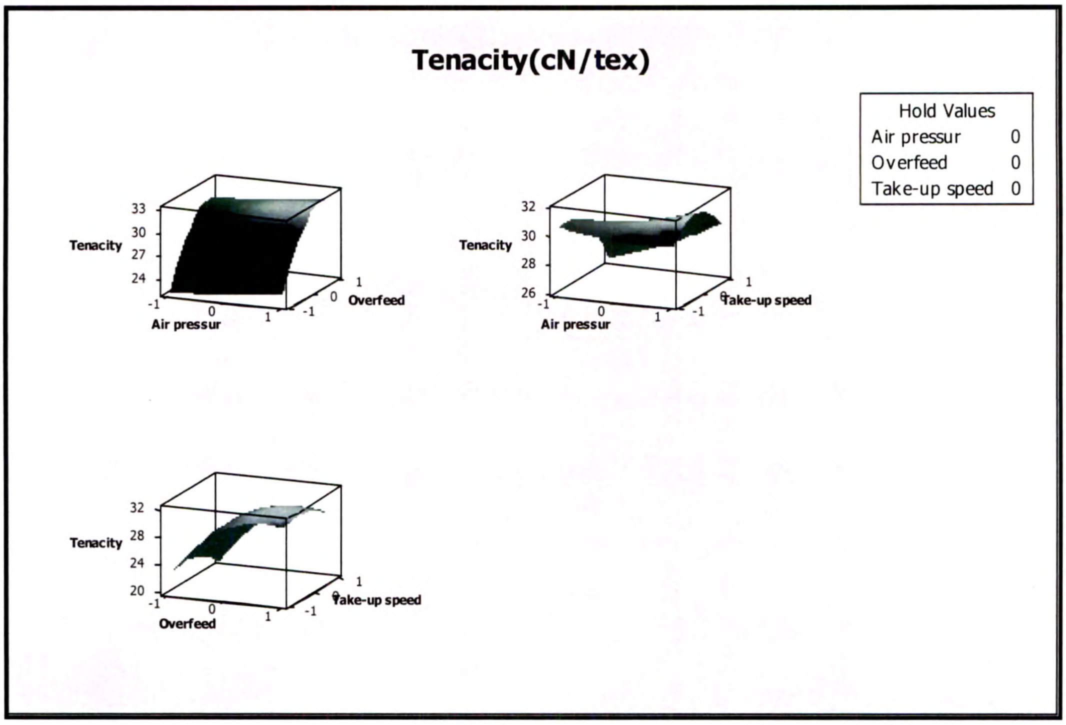


Fig. 7.2(b) Surface plots of hybrid yarn tenacity at different processing parameters

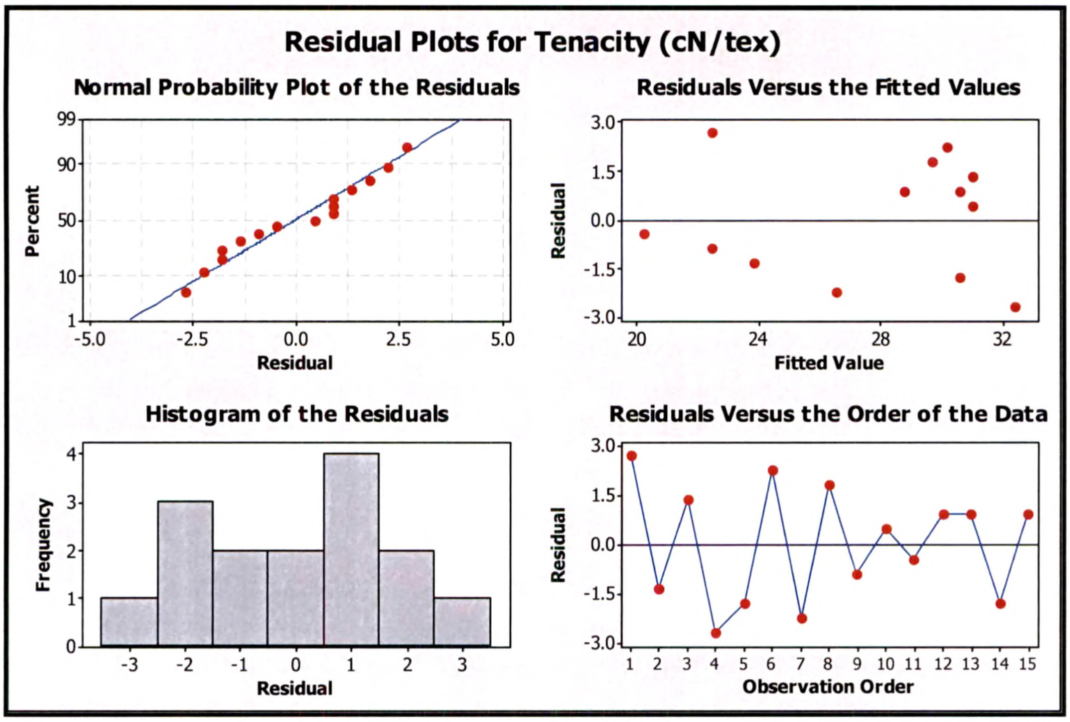


Fig. 7.2(c) Residual plots for tenacity as response

It is clearly seen from Table 7.5 that p-value for overfeed is 0.009 and $(\text{overfeed})^2$ is 0.075. The small p-value indicates that overfeed is important factor in deciding yarn tenacity. The Table 7.6 gives regression co-efficient value 83%, which shows good correlation but high variability, which introduce the error.

7.4.3 Effect of Processing Parameters on Extension of Hybrid Yarn

At any values of air pressure, with increase in overfeed, extension increases due to excess length of filaments. Fig. 7.3(a), Fig. 7.3 (b) and Fig. 7.3(c) shows contour plots, surface plots and residual plots of extension as response. At any values of air pressure, with increase in overfeed, extension increases due to excess length of filaments. The Fig 7.3 a) indicates the interaction effect of air pressure and take-up speed. At constant value of overfeed, with high pressure and low take-up speed gives more extension of hybrid yarn because of high number of nip formations, average nip stability and poor nip regularity. The effect of various processing parameter on extension of hybrid yarn at is not significant as compared to parent yarn extension.

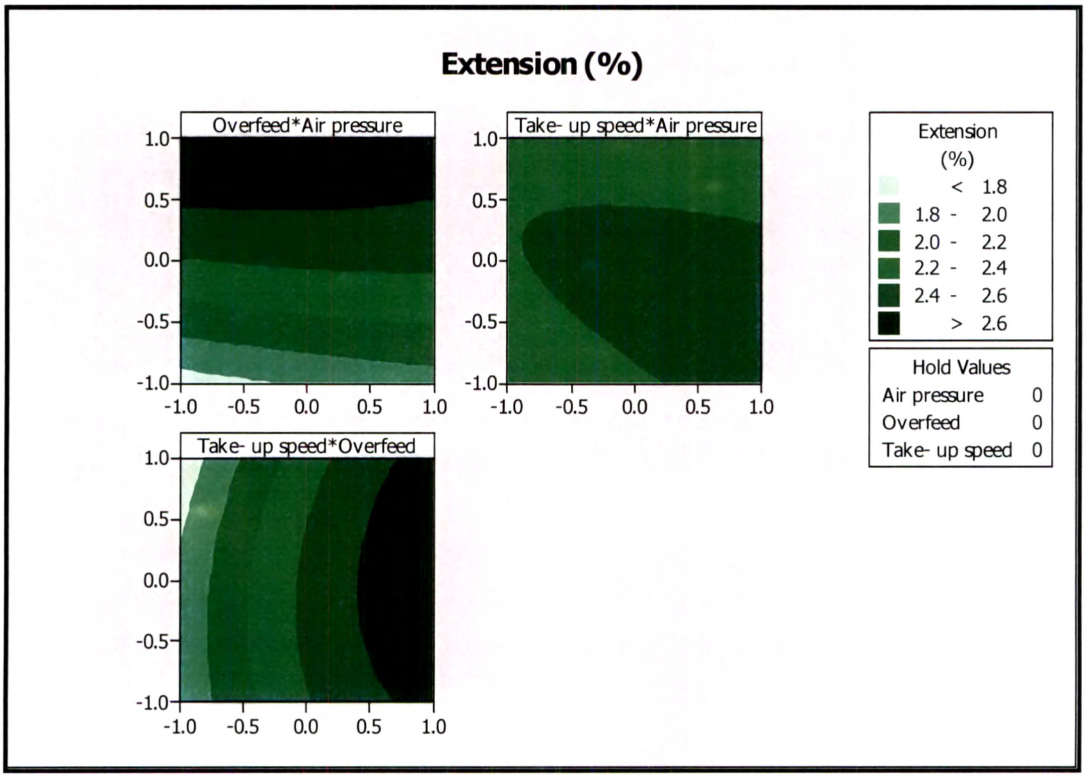


Fig. 7.3 (a) Contour plots of hybrid yarn extension at different processing parameters

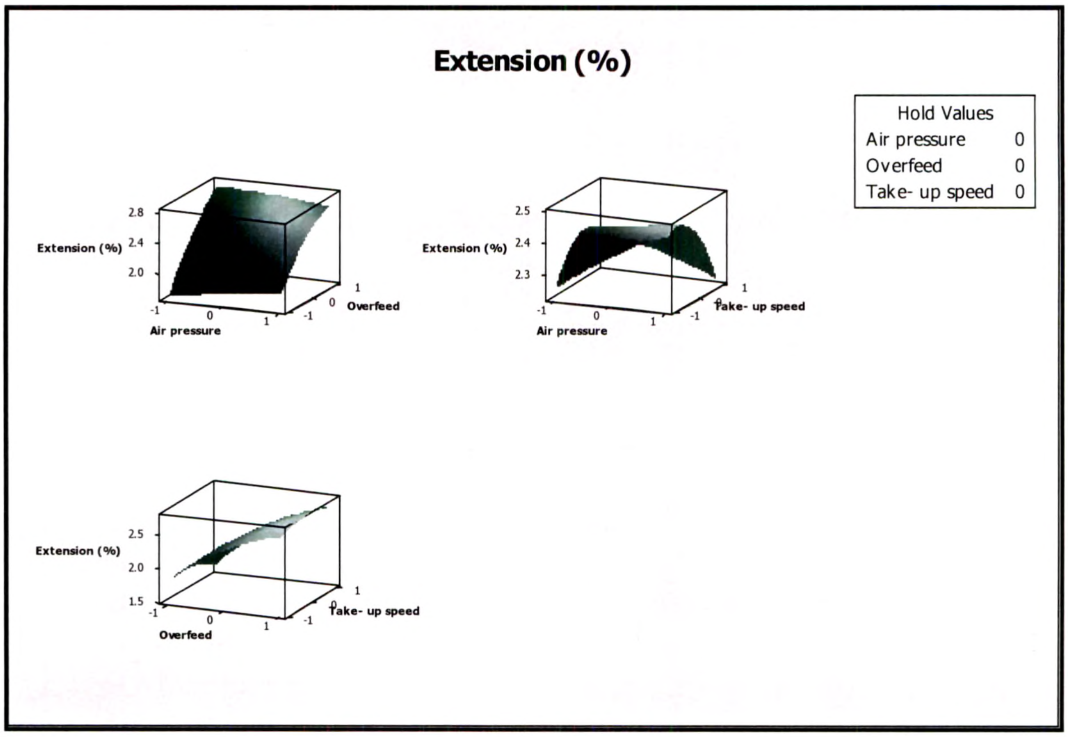


Fig. 7.3 (b) Surface plots of hybrid yarn extension at different processing parameters

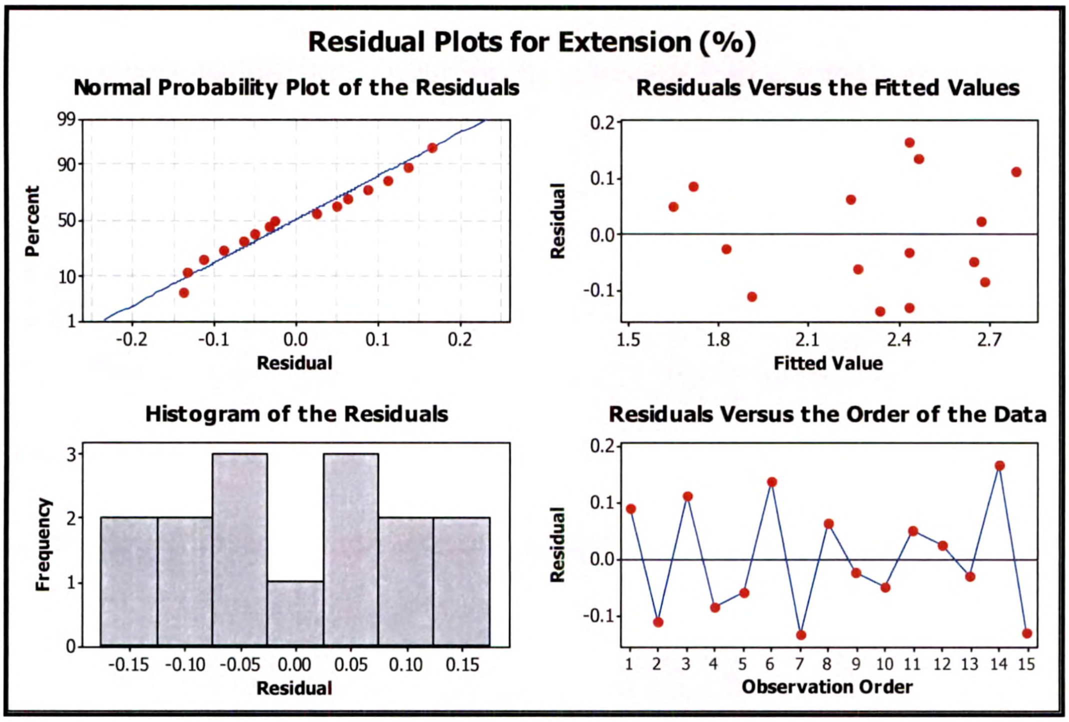


Fig. 7.3(c) Residual plots for extension as response

Table 7.5 shows the p-value for overfeed is 0.001 and $(\text{overfeed})^2$ is 0.164, which indicates that the overfeed is most dominant processing parameter out of the three parameters studied. The noted value in Table 7.6 for regression co-efficient is 93%. It means good correlation and less variability due to which chance in error occurring is less.

7.4.4 Effect of Processing Parameters on Hybrid Yarn Nip Frequency

Nip frequency is the number of nips formed during commingling process, which decide the characteristics of mingled yarn. The better nip formation decides the performance of yarn in the final product and proper mixing of two filaments in the final yarn. Thus, this is one of the most important properties of mingled yarn to decide the yarn quality. The three processing parameters along with type of jet decide the nip frequency, which also affect the yarn tenacity and extension as discussed earlier. Fig. 7.4(a), Fig. 7.4(b) and Fig. 7.4(c) shows contour plots, surface plots and residual plots of nip frequancy as response.

The Fig. 7.4(a) shows that at constant take-up speed, the nip frequency increases with increase in air pressure. Also low take-up speed and high air pressure give higher value of nip frequency. But there is no significant effect of interaction between take-up speed and overfeed on nip frequency. Hence for deciding the nip frequency, air pressure and take-up speed are the important factors.

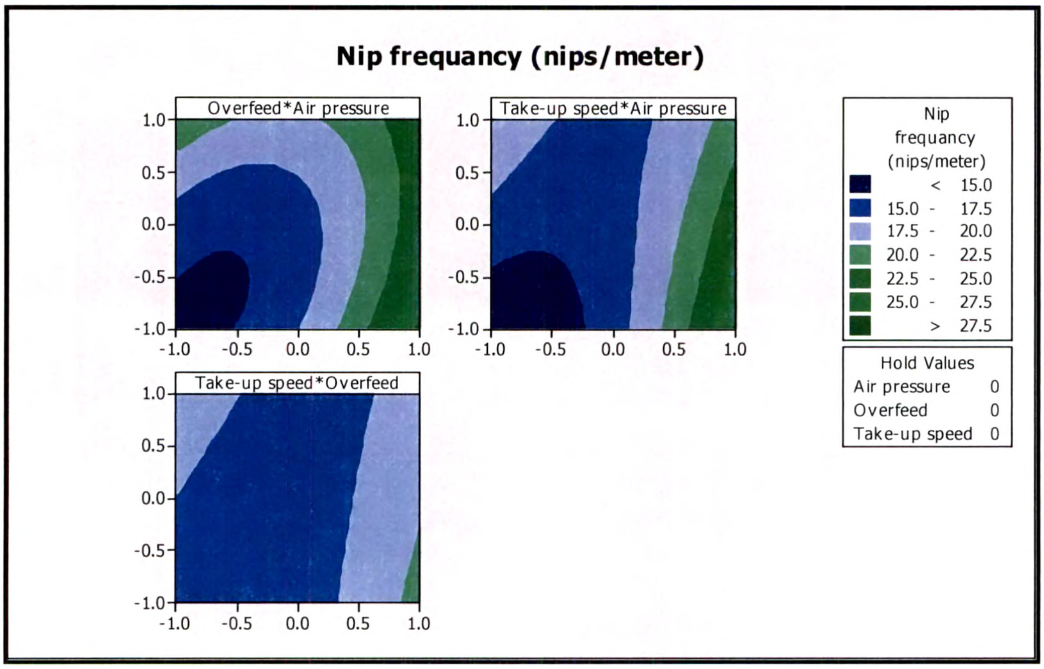


Fig.7.4 (a) Contour plots of hybrid yarn nip frequency at different processing parameters

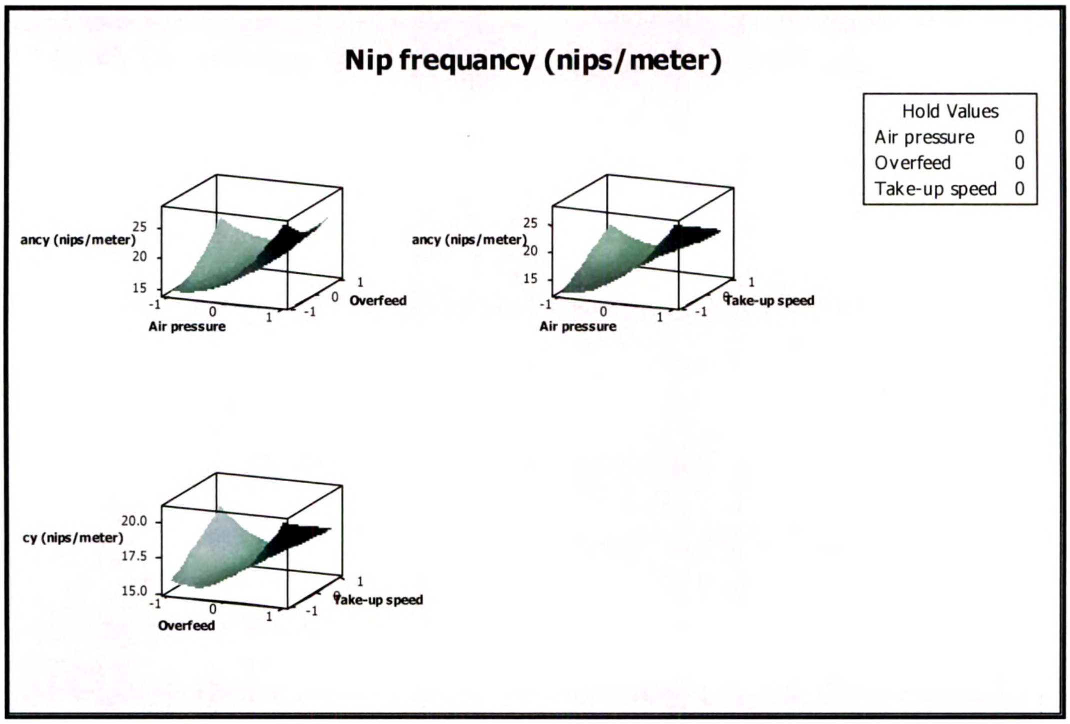


Fig.7.4 (b) Surface plots of hybrid yarn nip frequency at different processing parameters

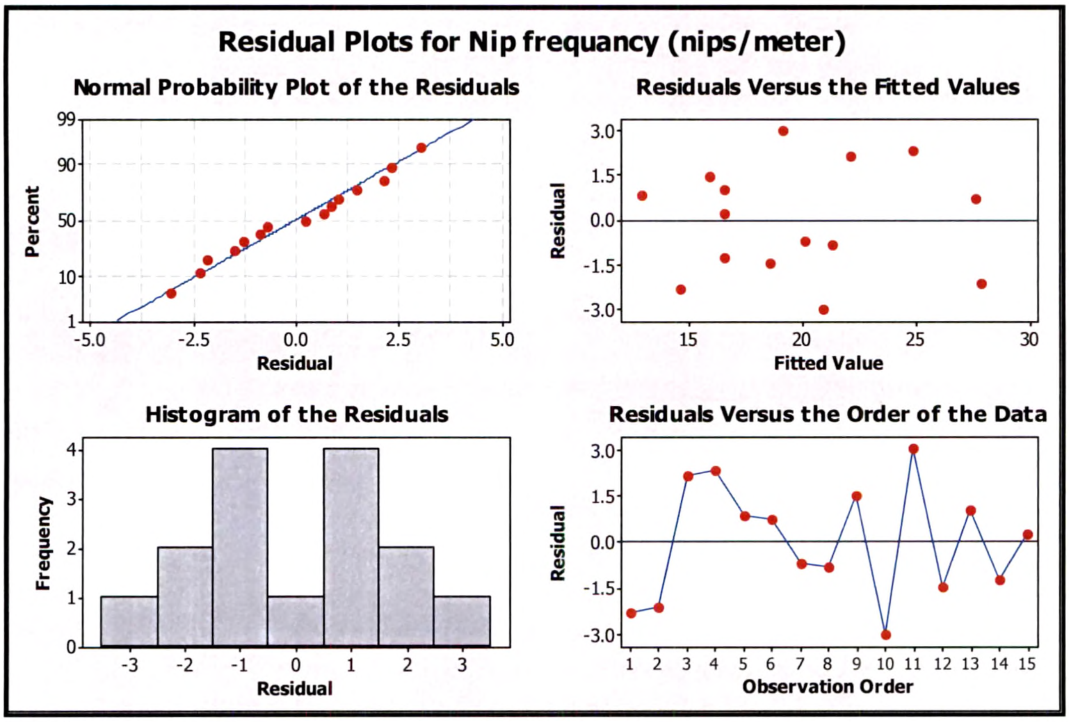


Fig. 7.4(c) Residual plots for nip frequency as response

The Table 7.5 shows the lower p-value of air pressure, (air pressure)^2 and interaction with other two parameters are equally important to decide mingling characteristics of hybrid yarn. Table 7.6 indicates correlation up to 83% but with high variability, so chances of introducing error are high.

7.4.5 Effect of Processing Parameters on Hybrid Yarn Nip Stability

Nip stability is a measure of stability of nip structure formed by commingling process. The nip form should be stable to withstand the strain applied on yarn during subsequent process. The nip stability is measured in terms of cycles. Higher nip stability improves the yarn quality. Fig. 7.5(a), Fig. 7.5(b) and Fig. 7.5(c) shows contour plots, surface plots and residual plots of nip stability as response.

Fig. 7.5(a) shows that nip stability is more at (0,0,0) level (6 bar air pressure, 1% overfeed, 75m/min take-up speed). The higher value of take-up speed with lower air pressure gives better nip stability. Similar trend is observed at low take-up speed and high air pressure. The lower overfeed and low pressure gives higher nip frequency but poor nip stability. Similarly, low take-up speed with low overfeed value shows the same trend of poor stability. Thus nip stability is dominated by the interaction effect of all three processing parameters than their individual effect.

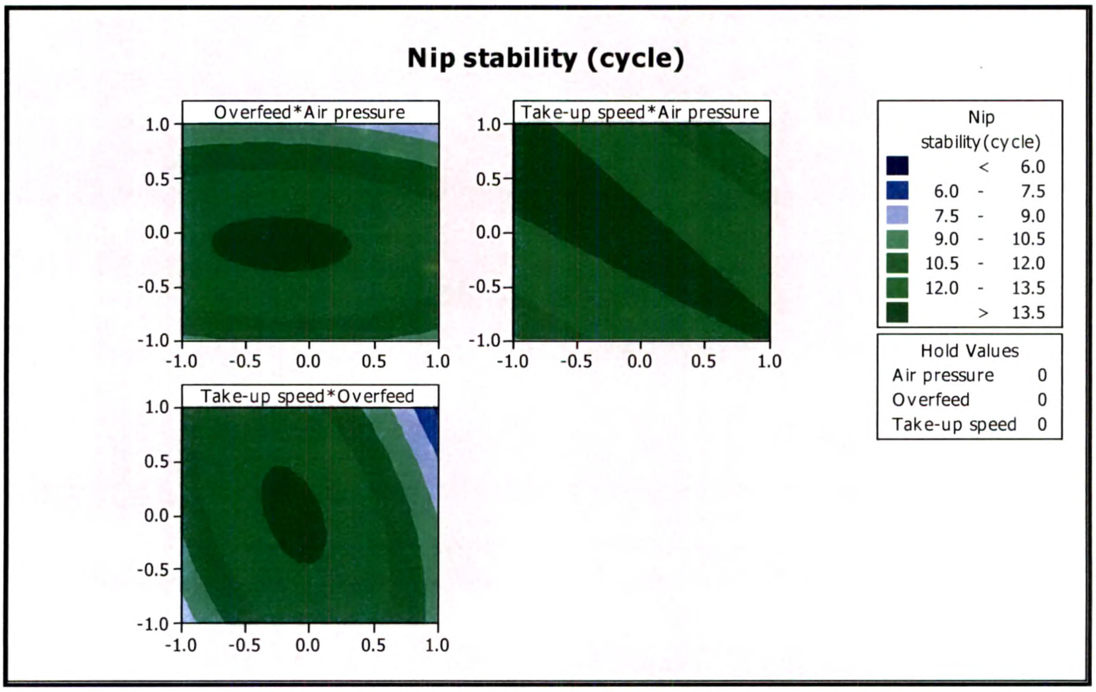


Fig. 7.5(a) Contour plots of hybrid yarn nip stability at different processing parameters

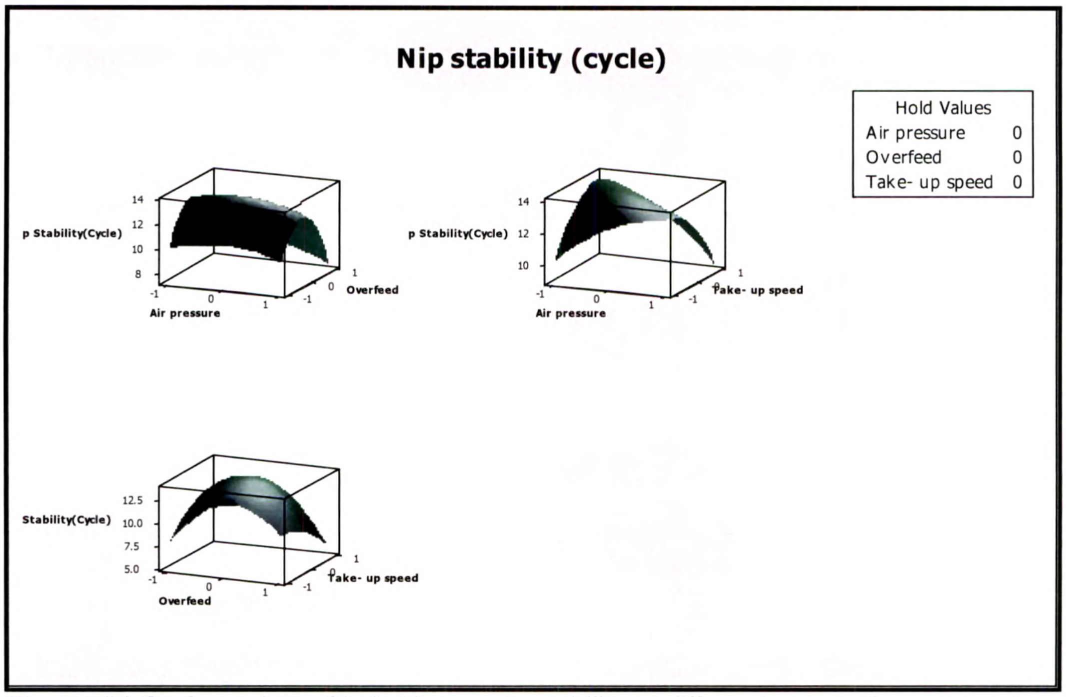


Fig. 7.5(b) Surface plots of hybrid yarn nip stability at different processing parameters

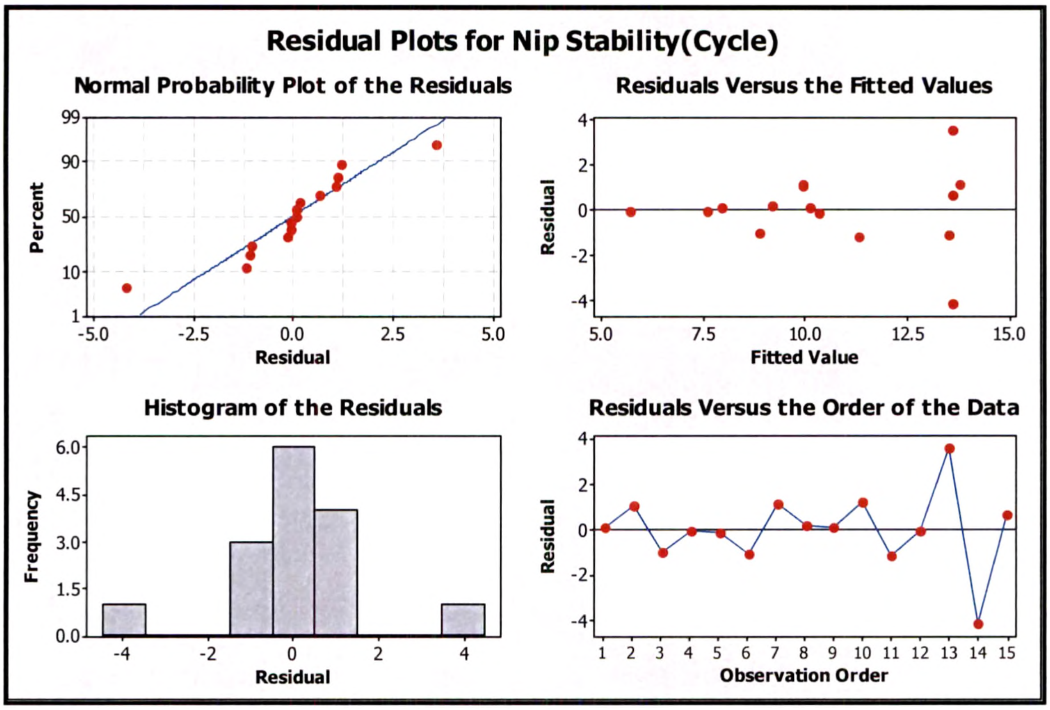


Fig. 7.5 (c) Residual plots for nip frequency as response

The p-value in Table 7.5 also indicate that interaction value along with (overfeed)^2 value have significant effect on nip stability. The co-efficient value is 70% with high variability, which introduces the error.

7.4.6 Effect of Processing Parameters on Hybrid Yarn Nip Regularity

The nip regularity is a measure of opening length of nip in commingled hybrid yarn, which can also be measured in terms of degree of opening. The lower value of degree of opening indicates good interlacing properties. Fig. 7.6(a), Fig. 7.6(b) and Fig. 7.6(c) shows contour plots, surface plots and residual plots of nip regularity as response.

Fig. 7.6(a) shows that with increase in air pressure, the open length of nip reduces and this gives higher nip frequency with stable nip due to good interlacement. Similar trend is observed with low take-up speed with 1% over feed value.

The p-value in Table 7.5 also indicate that interaction value of all three parameters have significant effect on nip regularity, nip frequency and nip stability. Table 7.6 indicates good correlation upto 84% with low variability, so chances of introducing error is less.

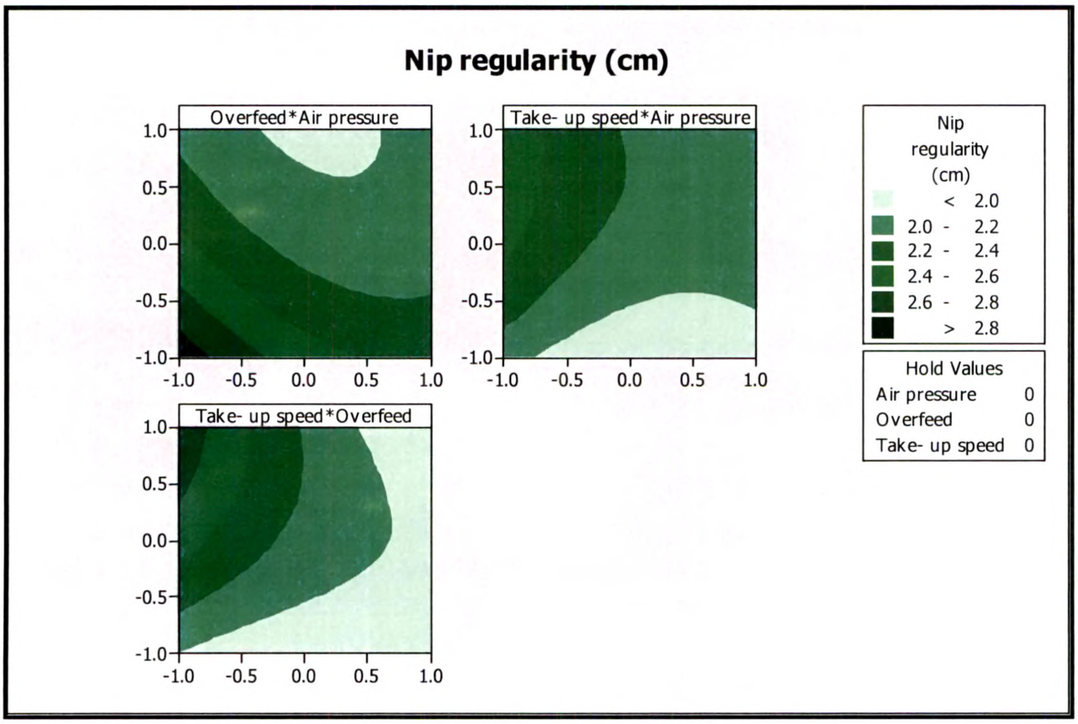


Fig. 7.6(a) Contour plots of hybrid yarn nip regularity at different processing parameters

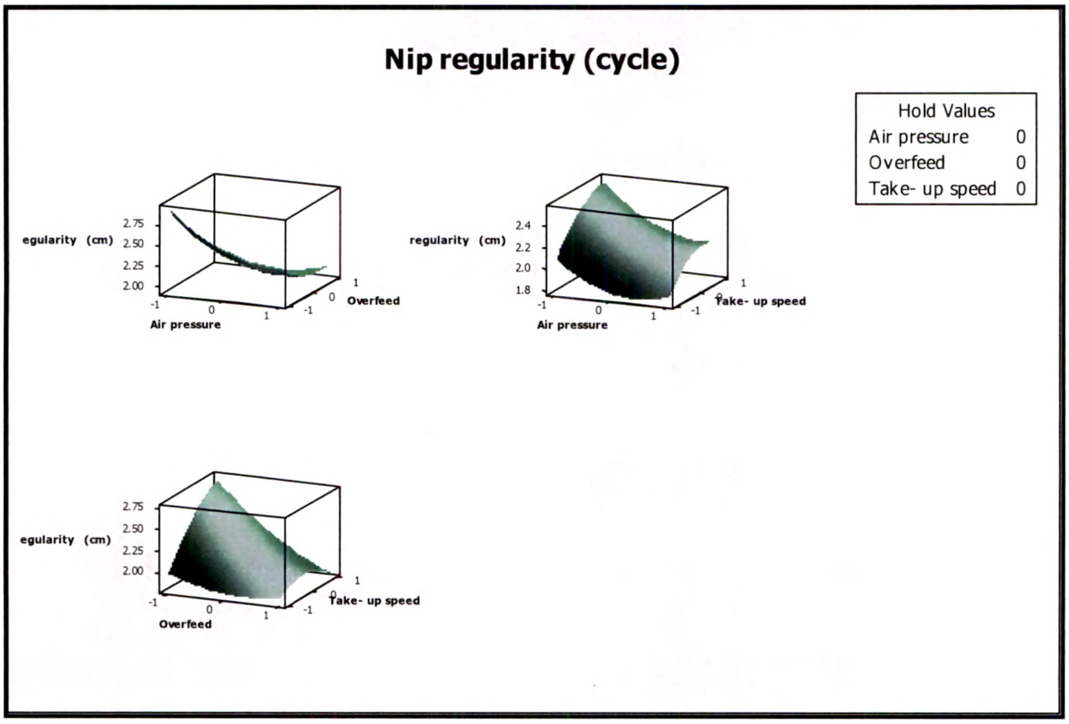


Fig. 7.6(b) Surface plots of hybrid yarn nip regularity at different processing parameters

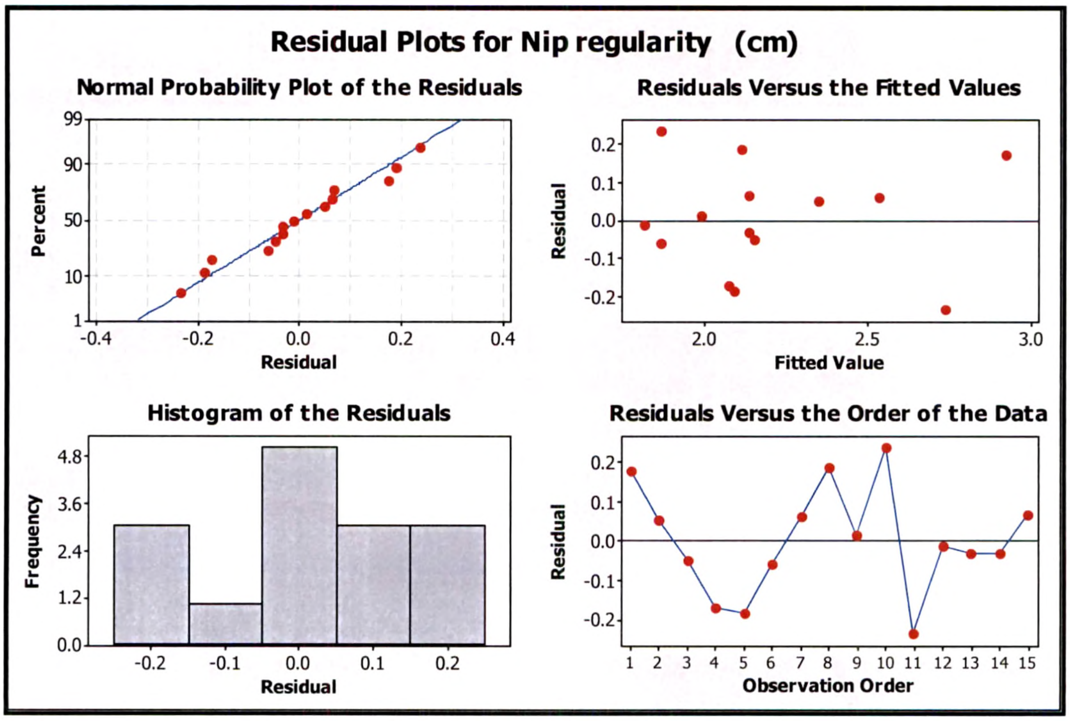


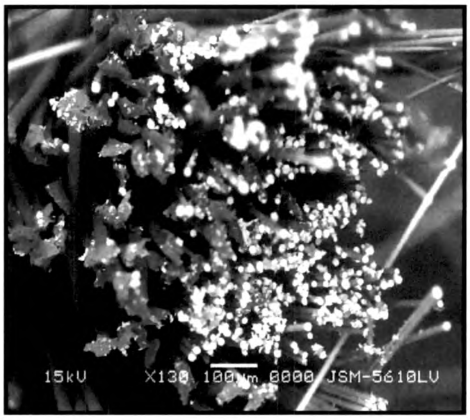
Fig. 7.6(c) Residual plots for nip regularity as response

7.5 STRUCTURE COMMINGLED HYBRID YARN

7.5.1 Cross Section of Hybrid Yarns Produced at Various Processing Conditions

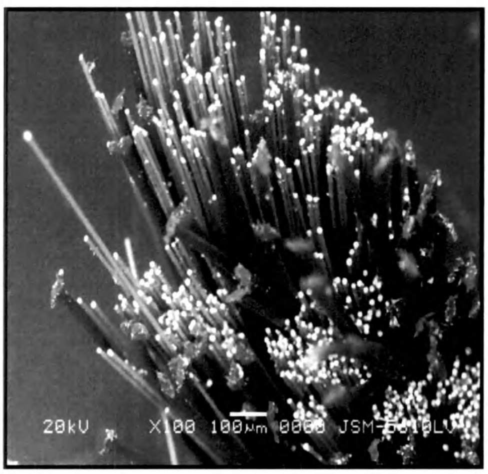
The application of the SEM to textile material is mainly confined to study the surface topography, internal structure, and cross section of textile fiber. In the present study the cross sectional views of hybrid yarns have been investigated to understand the mixing behaviour of glass/polypropylene hybrid yarn produced with various processing parameters. Fig. 7.7 shows the cross sectional view of yarn sample S_1 to S_{15} along with the value of air pressure, overfeed and take-up speed respectively.

(a) S_1 (5 bar, 0%, 75 m/min)

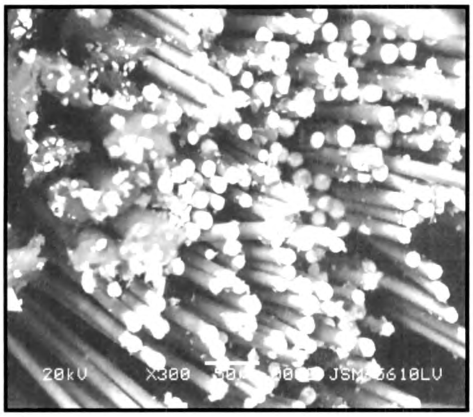


(b) S_2 (7 bar, 0%, 75 m/min)

(c) S_3 (5 bar, 2%, 75 m/min)



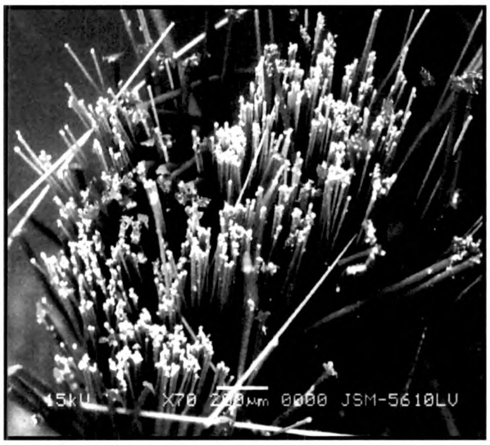
(d) S_4 (7 bar, 2%, 75 m/min)



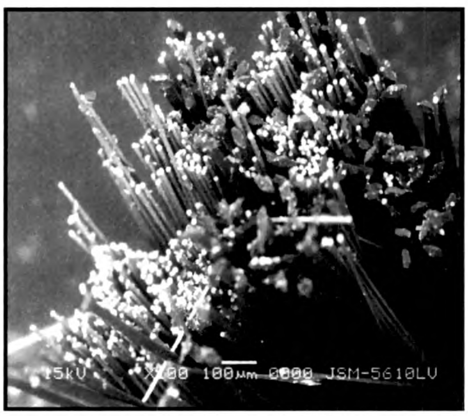
(e) S_5 (5 bar, 1%, 50 m/min)

(f) S_6 (7 bar, 1%, 50 m/min)

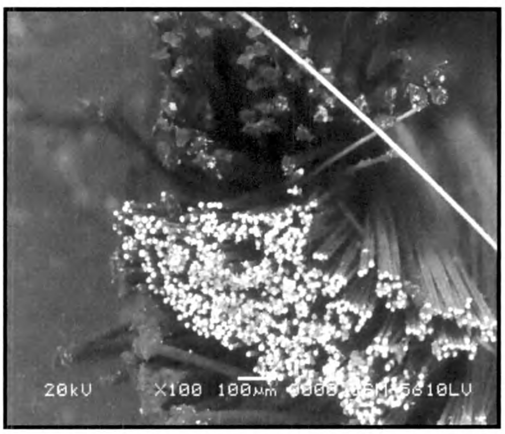
(g) S_7 (5 bar, 1%, 100 m/min)



(h) S_8 (7 bar, 1%, 100 m/min)



(i) S_9 (6 bar, 0%, 50 m/min)



(j) S_{10} (6 bar, 2%, 50 m/min)

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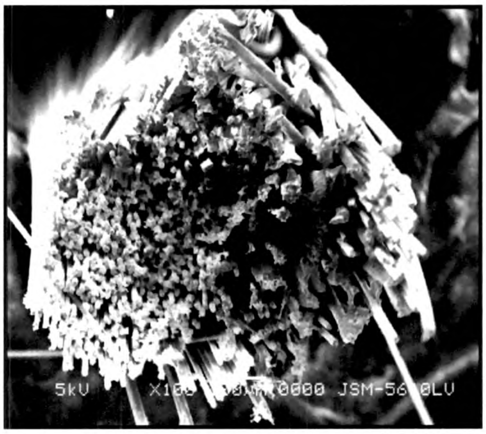
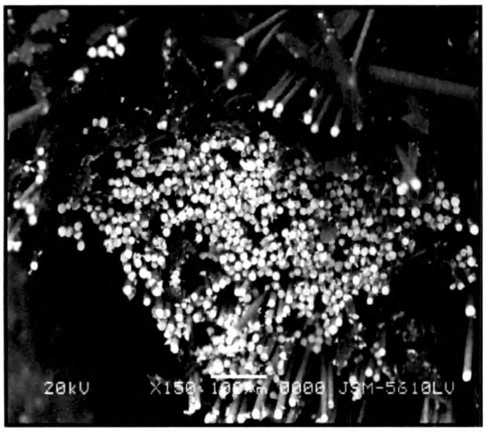
(k) S_{11} (6 bar, 0%, 100 m/min)

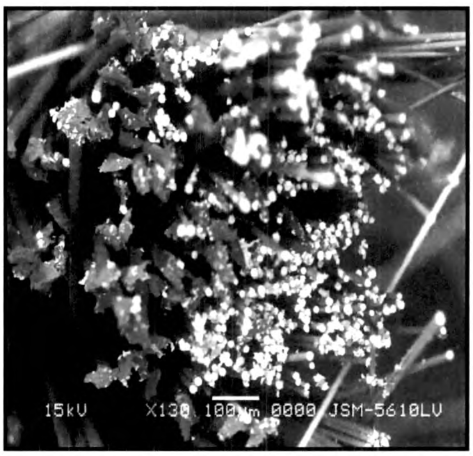


(l) S_{12} (6 bar, 2%, 100 m/min)



(m) S_{13} (6 bar, 1%, 75 m/min)

(n) S_{14} (6 bar, 1%, 75 m/min)



(o) S_{15} (6 bar, 1%, 75 m/min)

Fig 7.7 Various commingled hybrid yarns cross section of sample S_1-S_{15}

It shows that the mixing pattern of glass and polypropylene varies according to different processing conditions. The standard sample S_{13}, S_{14} and S_{15} shows better commingling behaviour of hybrid yarn produced using air pressure of 6 bar with 1% over feed and take-up speed of 75 m/min. The sample S_1 and S_2 also give considerable good mingling of glass and polypropylene but S_2 gives better mixing as high air pressure used during the process. The combinations of high air pressure with high take-up speed at 0% overfeed are not suitable parameters to give better mingling properties.

The cross sectional a view of sample S_{11} clearly shows that there is no mixing of glass and polypropylene. Similar result is observed in case of sample S_{12} at higher over feed value has been observed. Some combinations of parameters give clustering effect and show poor opening of glass filament (S_6 and S_{10}). SEM study indicates that the process parameters are the main factors, in deciding the mixing behaviour of component yarns in the commingled yarn.

7.5.2 SEM of Hybrid Yarns Manufactured by Different Methods

Different methods of manufacturing have been used to compare the mixing behaviour of glass/polypropylene hybrid yarn. Four different methods have been used to prepare hybrid yarn viz. Friction spinning, hollow spindle wrapping, commingling and combination of wrapping/commingling technique. Various yarn characteristics such as linear density, tensile strength and breaking elongation have been measured. Table 7.7 shows various properties of hybrid yarns using different manufacturing techniques.

Fig 7.8 shows cross section of glass/polypropylene friction spinning yarn where glass in core and polypropylene fibres in staple form covers the core. (Friction yarn have been prepared at SITRA, Coimbatour. The Fig. 7.9 and Fig. 7.10 show yarn prepared using hollow spindle wrapping process with core and sheath structure. Fig. 7.11 shows the hybrid yarn made by commingling process with air interlacing of two-component yarn.

In this work, the two techniques viz. hollow spindle-wrapping process and commingled process are combined together, to produce new types of hybrid yarns by wrapping the commingled yarn. The main advantages of this type of yarn are that it gives homogenous mixing, less filament brakeage and smooth surface. The core components of hybrid yarns are mingled, which gives homogenous mixing in core. This core is wrapped, which improves of strength and surface characteristics of yarn due to less filament brakeage and smooth surface due to wrapping. This yarn is used to make final laminate sample using hot press. Fig. 7.12 (a) and Fig. 7.12 (b) shows sample of fabric and laminate.

Table 7.7 Properties of Glass/Polypropylene Hybrid Yarn Produced Using Different Manufacturing Techniques

Sample code	Content of glass /polypropylene hybrid yarn	Linear density (denier)	Tenacity (cN/tex)	Extension (%)
C_1	Friction spun hybrid yarn (2700 denier core Glass + Polypropylene Fiber)	4833	27.00	3.3
C_2	Hollow spindle wrapped hybrid yarn (2700 denier core Glass + 840 denier Polypropylene wrapped)	4032	23.28	3.6
C_3	Commingled hybrid yarn (2700 denier Glass + 840 denier Polypropylene)	3482	31.50	2.4
C_4	Hybrid wrapped yarn with commingled core (2700 denier Glass-840 denier PP commingled core+840 denier PP wrapped)	5449	22.50	3.0

Fig 7.8 Friction spun hybrid yarn

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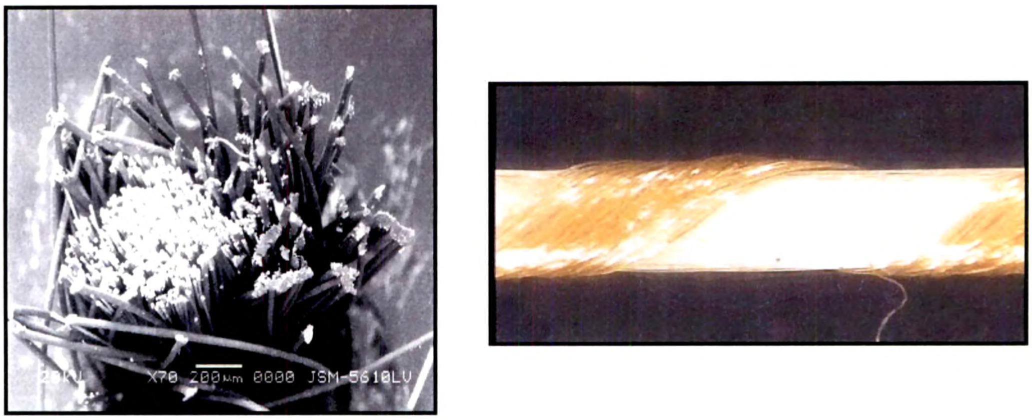

Fig. 7.9 Hollow spindle wrapped hybrid yarn

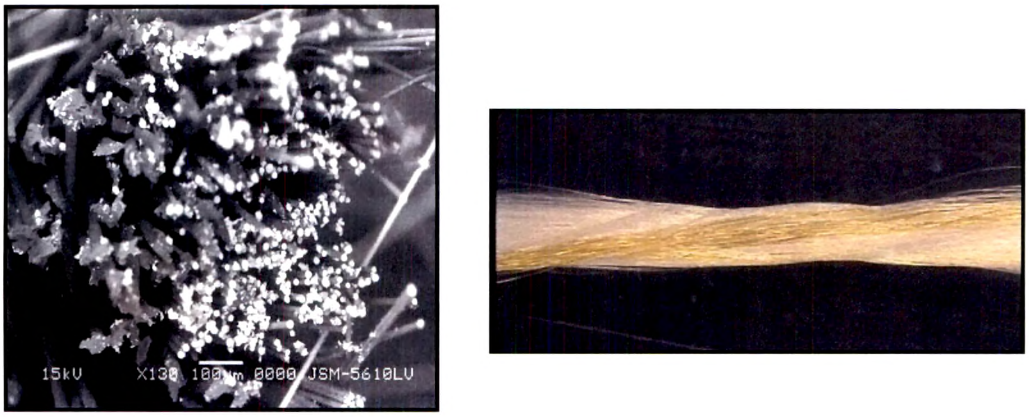

Fig. 7.10 Commingled hybrid yarn

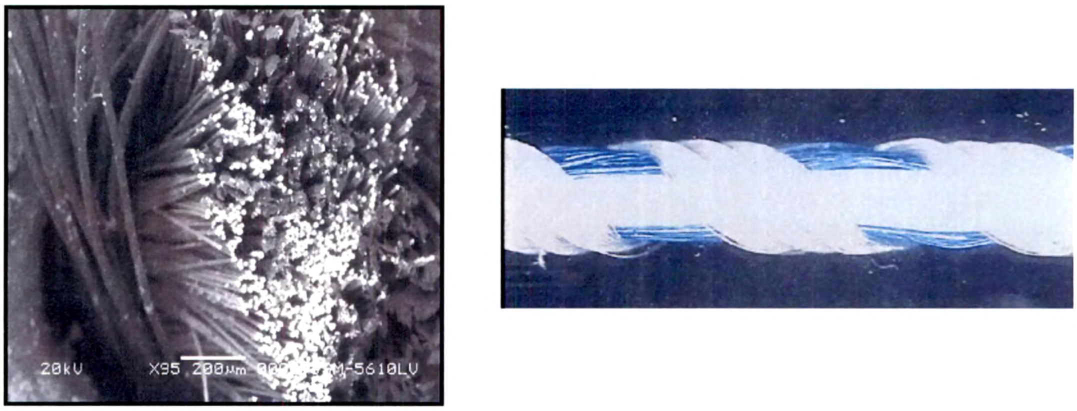

Fig. 7.11 Hybrid wrapped yarn with commingled core

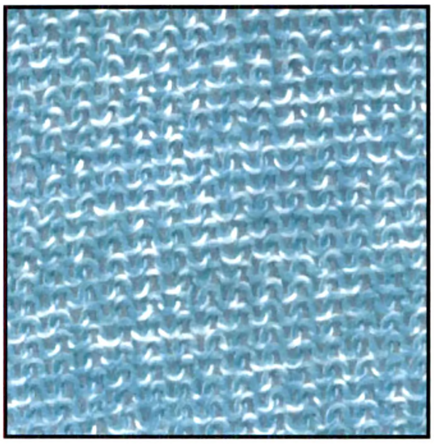

Fig. 7.12 (a) Knitted preforms made from hybrid wrapped yarn with commingled core

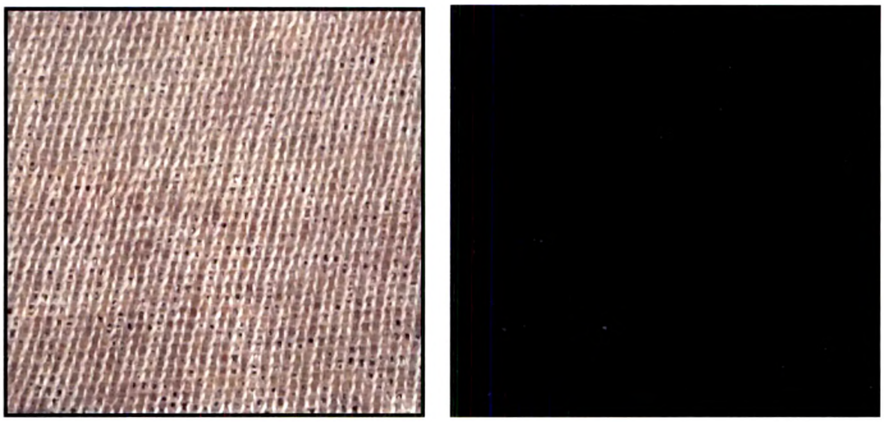

Fig. 7.12 (b) Laminates made from hybrid wrapped yarn with commingled core

7.6 CONCLUSIONS

The response surface analysis of glass/polypropylene hybrid yarns has been made to study the effect of processing parameters. The three processing parameters of commingling process viz air pressure, overfeed and take-up speed have significant effect on characteristics of hybrid yarn. Commingling behaviour of there yarns during different process conditions and with different methods has been studied. The some of the conclusions drawn are listed below.

1. The effects of individual parameter as well as interaction effects are equally important in deciding final yarn quality.

2. Lower P-value give significant effect of variables and high error introduce chances of variability in process, which has been studied by response surface analysis.
3. It is evident from result that the final resultant yarn linear density value significantly affected by air pressure and overfeed but give high breakage and poor quality of yarn.
4. The tenacity of hybrid yarn is affected by overfeed value. With higher pressure and increasing overfeed; tenacity improves only at low take-up speed viz. 50 m/min.
5. The main quality parameters of commingled yarn viz. nip frequency, nip stability and nip regularity are mainly effected by interaction value of three processing parameters. It has been observed that high air pressure at 1% overfeed with lower take-up speed gives the best combination in terms of processing glass/polypropylene hybrid yarn.
6. SEM of hybrid yarn cross section shows that commingled yarn give best mixing of glass and polypropylene compare to any other methods of manufacture is achieved with high air pressure and low take-up speed with average overfeed value (1%).
7. The hybrid wrapped yarn with commingled core gives hybrid yarn with homogenous mixing like commingled yarn and strength with good surface quality like wrapped yarn.