Statistical Modeling of Tear Strength for One Step Fixation Process of Reactive Printing and Easy Care Finishing

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ABSTRACT

Statistical modeling imparts significant role in predicting the impact of potential factors affecting the one step fixation process of reactive printing and easy care finishing. Investigation of significant factors on tear strength of cotton fabric for single step fixation of reactive printing and easy care finishing has been carried out in this research work using experimental design technique. The potential design factors were; concentration of reactive dye, concentration of crease resistant, fixation method and fixation temperature. The experiments were designed using DoE (Design of Experiment) and analyzed through software Design Expert. The detailed analysis of significant factors and interactions including ANOVA (Analysis of Variance), residuals, model accuracy and statistical model for tear strength has been presented. The interaction and contour plots of vital factors has been examined. It has been found from the statistical analysis that each factor has an interaction with other factor. Most of the investigated factors showed curvature effect on other factor. After critical examination of significant plots, quadratic model of tear strength with significant terms and their interaction at $\alpha = 0.05$ has been developed. The calculated correlation coefficient, R^2 of the developed model is 0.9056. The high values of correlation coefficient inferred that developed equation of tear strength will precisely predict the tear strength over the range of values.

Key Words: Design of Experiment, Easy Care Finishing, Reactive Printing, Statistical Modelling, Tear Strength.

1. INTRODUCTION

DoE [1-6] is an important tool used to analyze and improve the existing process as well as for the development of new process. Various hypothetical and investigational studies have been carried out depicting the comprehensive information of process factors and operating parameters of reactive dye printing and crease resistance finishing [7-14]. Furthermore, reports in literature revealed that one step fixation process of reactive dye printing and easy care finishing using cotton fabric has already been examined [15-16]. This paper investigates effects on tear strength for single step fixation of reactive printing and easy care finishing of cotton fabric. The statistical model for tear strength has been developed to predict the relationship of different factors being studied. The statistical analysis of tear strength of cotton fabric comprising ANOVA

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(Analysis of Variance), model accuracy analysis, and analysis of residual has been presented in section 2 and 3. The experiment design is completely randomized with two replicates. The results of tear strength were examined through statistical software Design Expert.

2. EXPERIMENTAL

2.1 Fabric

Commercially pre-treated and mercerized cotton satin fabric having gsm of 136 g/m^2 and construction of 40x40/ 130x73 has been used for this work.

2.2 Chemicals

The easy care finishing bath was prepared by adding $MgCl_2$ (Magnesium Chloride), wetting agent (Imercol PCLF), an-ionic and silicon softener (Ceranine L & Solusoft MW). The easy care finishing agent used was modified dimethyloldihydroxy ethylene urea namely Arkofix NEC (Archroma). The final finish bath was prepared with different concentrations of crease resistant as outlined in Table 1.

Sodium alginate, sodium bicarbonate, urea, reduction inhibitor and sodium hexametaphosphate was added to prepare the stock paste for printing. However, urea is not added in the stock being prepared for the tests using the fixation method of E-Control. The final print paste for respective test run was formed by adding different concentration of reactive dye namely Drimarine Red P2B (Archroma), based on the MCT (Monochlorotriazine) reactive group as stated in Table 1.

2.3 Method

The completely randomized run order of $2^1.3^3$ mixed factorial design having 54 runs with two replicates has been generated using software Design Expert. The experimental trials have been conducted according to the run order. The one step fixation of printing and easy care finishing is conducted as follows: At first, ready to print fabric was padded with the easy care finishing liquor such that pickup of the fabric should maintain to 70%. In the second stage finished fabric was dried at 100°C for 1 min. In the third stage, the fabric was printed with the reactive print paste. The treated fabric was finally fixed in one step using different fixation methods and temperature as specified in Table 1. The fixed samples were then rinsed, soaped, washed and dried.

2.4 Evaluation of Tear Strength

After conducting the experimental runs, tear strength of each sample processed from one step fixation of reactive printing and easy care finishing were evaluated using Elmandorf tear strength tester using standard test method ASTM D1424. Two replicates of each test were conducted to maintain the accuracy of the results. Before conducting the test samples were conditioned for four hours in standard conditions.

TABLE 1. POTENTIAL DESIGN FACTORS AND LEVELS OF $2^1.3^3$ MIXED FACTORIAL DESIGN [17]

Factors		Levels		
		-1	0	+1
A	Dye concentration (%)	1	2	3
B	Conc. Of Crease Resistant (g/l)	100	150	200
C	Fixation Method	Curing		E-Control
D	Fixation Temperature(°C)	130	140	150

3. RESULTS AND DISCUSSION

The tear strength values were statistically analyzed using software Design Expert. Prior to the ANOVA model accuracy has been examined through various residuals plots. The four plots of residuals were examined and presented in Fig. 1(a-d). The study of residuals plots shown that the residuals of tear strength model are normally distributed and significant evidence of possible outliers was not found. So the tear strength model can be used to predicted results with 95% confidence interval. The ANOVA was conducted for the tear strength model. The results of significant factors are stated in Table 2.

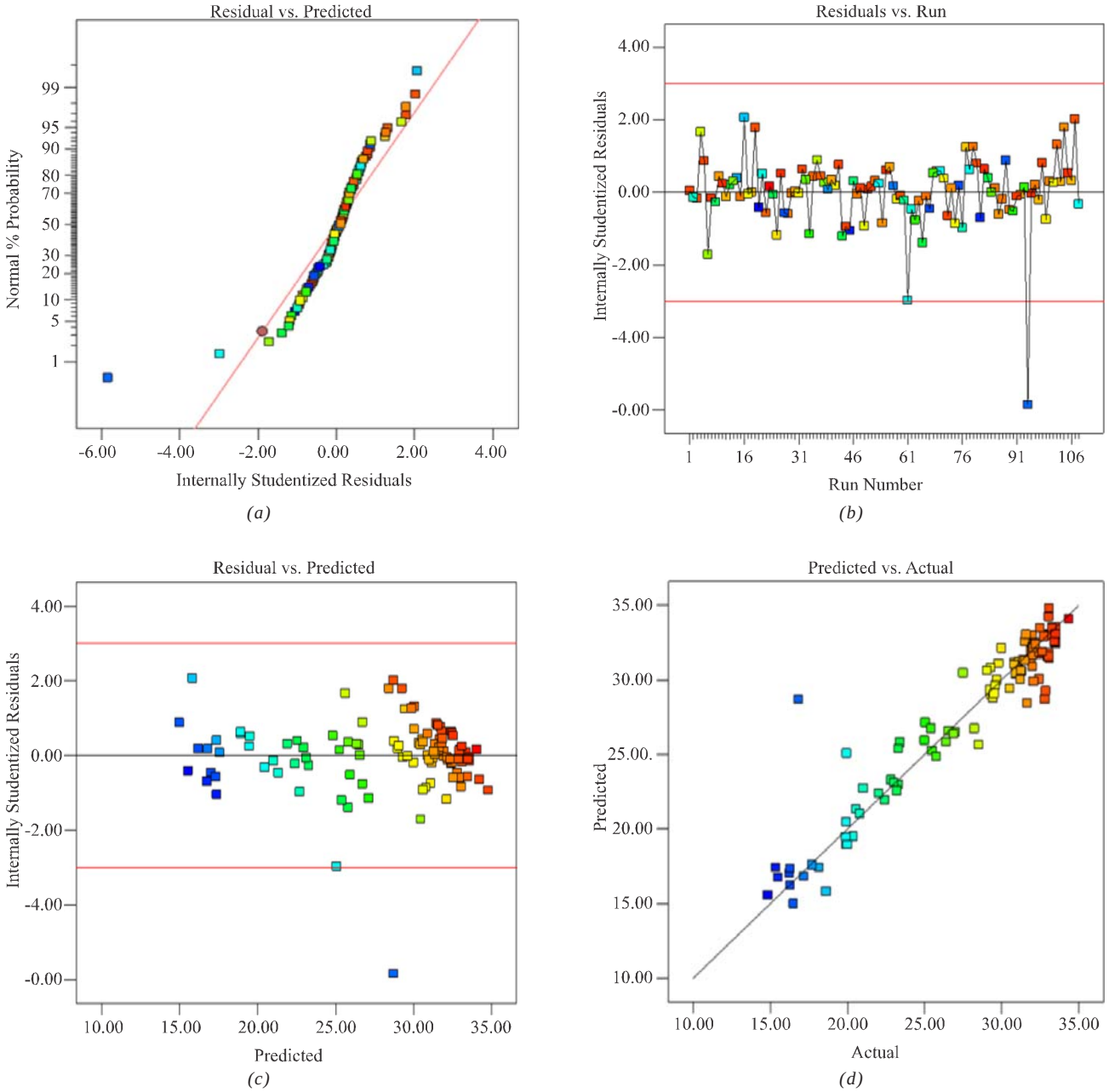

FIG. 1. RESIDUAL PLOTS FOR TEAR STRENGTH

The fifth model has been selected for tear strength. The Model p-value comes out to <0.0001 which indicates that tear strength is significant with respect to one step fixation process. The analysis demonstrated that two out of four factors are vital for tear strength for theone step fixation process of reactive printing and easy care finishing. However, various interactions have been identified significant for the specified process such as interaction of concentration of dye with fixation method and temperature (AC and AD), concentration of crease

TABLE 2. ANOVA FOR TEAR STRENGTHOF SIGNIFICANT MODEL TERMS [17]

Source	Sum of Squares	Degree of Freedom	Mean Square	F-value	Prob>F	Remarks
Block	29.31	1	29.31			
Model	3144.47	48	65.51	11.60	<0.0001	Significant
A-Chroma	177.06	1	177.06	31.35	<0.0001	
D-Fixation emperature	61.00	1	61.00	10.80	0.0017	
AB	28.60	1	28.60	5.06	0.0283	
AC	91.79	1	91.79	16.25	0.0002	
AD	133.16	1	133.16	23.57	<0.0001	
BD	63.28	1	63.28	11.20	0.0014	
CD	48.04	1	48.04	8.50	0.0050	
A2	56.80	1	56.80	10.05	0.0024	
D2	66.20	1	66.20	11.72	0.0011	
ACD	29.53	1	29.53	5.23	0.0259	
AD2	60.44	1	60.44	10.70	0.0018	
CD2	174.69	1	174.69	30.93	<0.0001	
A2BD	25.20	1	25.20	4.46	0.0390	
A2CD	60.17	1	60.17	10.65	0.0018	
B2CD	22.73	1	22.73	4.02	0.0496	
A2B2D	41.06	1	41.06	7.27	0.0092	
A2BD2	54.92	1	54.92	9.72	0.0028	
A2CD2	42.27	1	42.27	7.48	0.0082	
AB2CD	39.78	1	39.78	7.04	0.0103	
B2CD	23.95	1	23.95	4.24	0.0440	
Residual	327.62	58	5.65			
Lack of Fit	191.62	53	3.62	0.13	1.0000	Not Significant
Pure Error	136.00	5	27.20			
Cor Total	3501.40	107				
Std. Dev.	2.38	C.V%	8.49	PRESS	964.09	
R2	0.9056	Adj R2	0.8276	Pred R2	0.7223	

resistant and fixation temperature (BD) and fixation method and temperature (CD). The plots of numerous momentousinteractions of tear strength have been presentedfrom Figs. 2-5, whereas some cruical contour plots have been shown from Figs. 6-8. The ANOVA illustrates that the tear strength of the one step fixation process primarily depends on the concentration of reactive dye and fixation temperature. Nevertheless, the interaction and curvature effect of concentration of reactive dye and crease resistant, fixation method and temperature should be critically examined before predicting the statistical model. The interaction plot shown in Fig. 2 depicts that at lower value of dye concentration curing mode of fixation gives higher value of tear strength, however at higher values both Econtrol and curing mode of fixation gives comparable results of tear strength. Figs. 3-4 revealed that irrespective of concentration of dye and crease resistant, fixation temperature of 130-135p Cprovides improved values of tear strength. The interaction plot of fixation mode and fixation temperature shown in Fig. 5 ascertained that Econtrol fixation method at 130-135°C can be effectively used for the single step fixation process for getting higher values of tear strength. By considering all the significant mian factors and

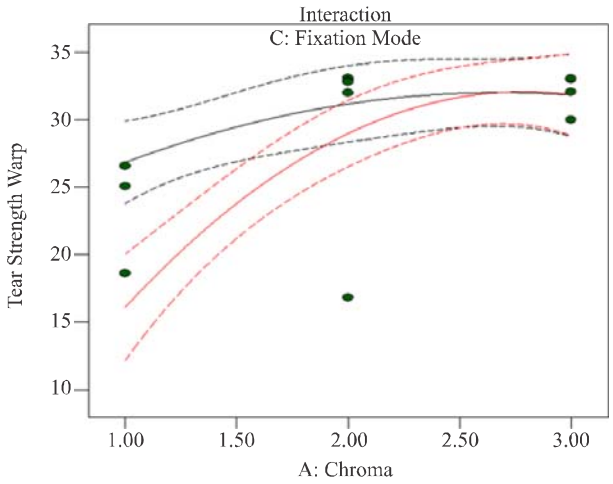

FIG. 2. INTERACTION OF DYE CONCENTRATION AND FIXATION METHOD

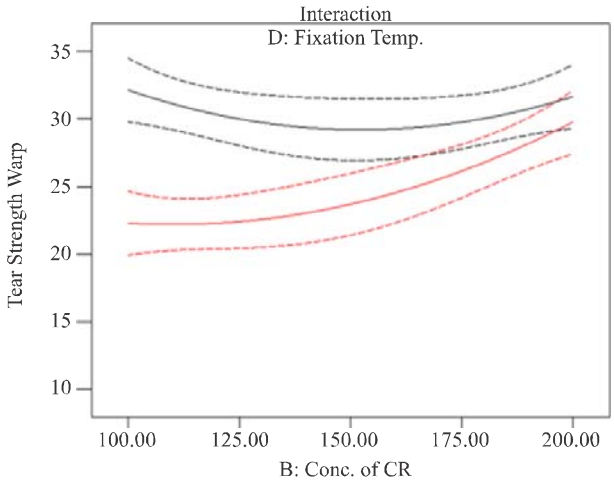

FIG. 3. INTERACTION OF DYE CONCENTRATION AND FIXATION TEMPERATURE

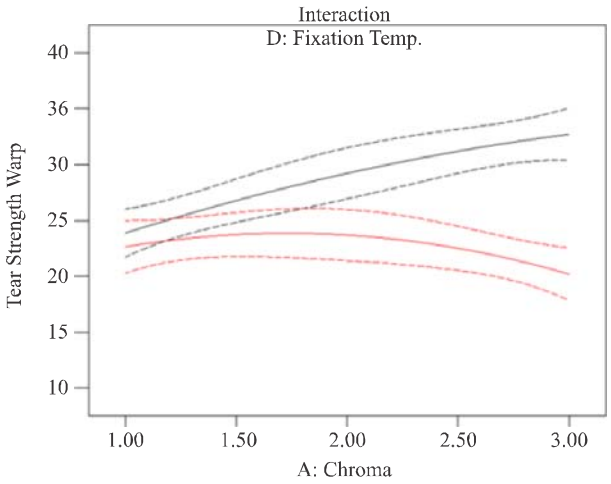

FIG. 4. INTERACTION OF CONCENTRATION OF CREASE RESISTANT AND FIXATION TEMPERATURE

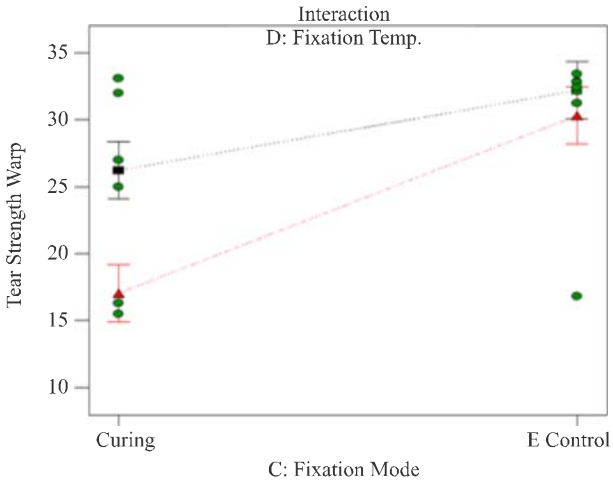

FIG. 5. INTERACTION OF FIXATION METHODAND FIXATION TEMPERATURE

interaction statistical model of tear strength has been developed through software Design Expert and presented in Equation (1). The developed equation shall explicitlypredict the relationship of significant factors and interactions of tear strength in one step fixation process of reactive printing and easy care finishing process over the range of values bieng considered in this research work [17].

Statistical Model of Tear Strength

$$\text{Tear Strength} = +30.08 + 18A - 0.10B - 1.10C - 2.76D + 1.39AB + 2.69AC - 2.28AD + 0.27BC + 1.99BD + 1.83CD - 3.41A^2 + 1.43B^2 - 3.63D^2 \quad (1)$$

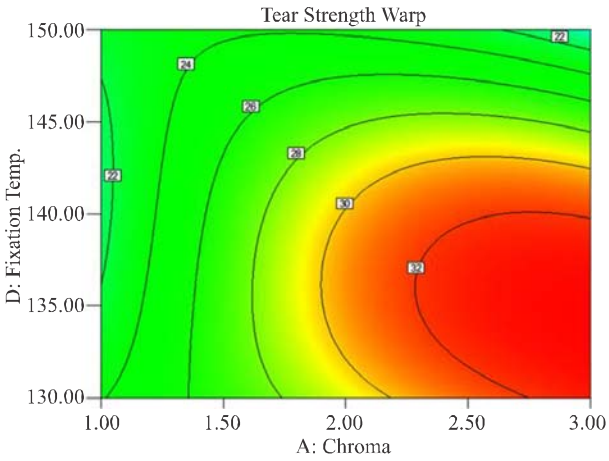

FIG. 6. CONTOUR PLOT OF DYE CONCENTRATION

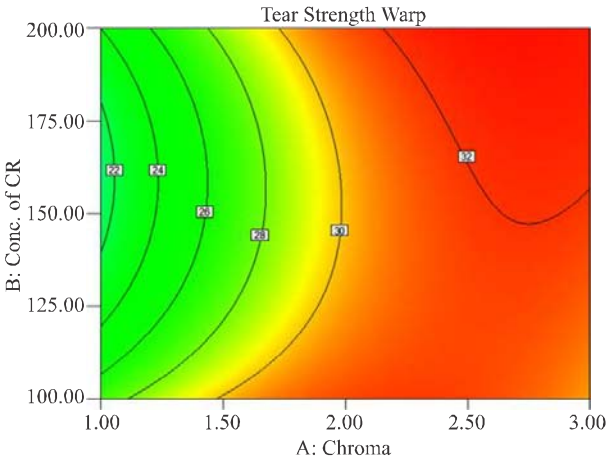

FIG. 7. CONTOUR PLOT OF DYECONCENTRATION

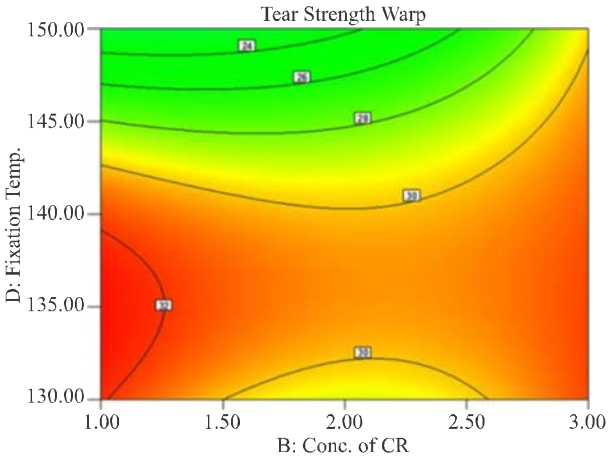

FIG. 8. CONTOUR PLOT OF CONCENTRATION OFCREASERESISTANT AND FIXATION TEMPERATURE

4. CONCLUSION

The statistical analysis of various factors revealed the quadratic effect of significant factors and interactions on the tear strength of one step fixation process. Furthermore, the model had been tested for adequacy and found that the assumption of normality and independency are not violated. R^2 values were very high, suggesting that models accounted for most of the variability.The developed equation of tear strength modeled the relationship of significant factor and interaction on the tear strength. The high values of coefficient of determination implied that the predicted statistical model will effectively depict the tear strength of single step fixation process over the range of values. It had been found from the plots of vital interactions that one step fixation process using an Econtrol method at 130-135°C yields higher values of tear strength.

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