Optimization of Formability in Fused Shirt Components using Response Surface Design of Experiment

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Abstract- Formability is the ability of fused fabrics to form into a given shape or form without any puckering on seams. This property is essential in fused shirt components like the collar and cuff. This study employs the response surface method to design a set of experiment to obtain fused samples considering different levels of fabric areal weight and interlining areal weight. The experimental design is further analyzed to propose the regression equation to predict the formability is fused shirting components. The study found the factors that significantly influence the formability and tries to explain the relationship. This knowledge is useful in predicting the formability achieved with a specific combination of fabric and interlining which has application in product development.

Keywords- Formability, Fusible interlining, Response surface technique, Fused fabric

I.INTRODUCTION

The aesthetic appearance of finished seams in fused shirt components like the collar, cuff and placket is assessed by the seam appearance. A good seam on the fused fabric is made when it can be compressed in a plane without buckling. This property can be objectively assessed by evaluating formability. Formability of the garment cut part is a function of its bending rigidity and extensibility. This property determines the likelihood of seam puckering after the part has been stitched. It is further described the ability of the fabric to form into desirable garment parts [1].

The properties of the fabric to perform well in the process of garment construction was studied by Lindberg [2]. In case of cuff and the collar, when stitched and turned to the face side, the inner layer must compress (conform to smaller radius of curvature) and the outer layer must expand to accommodate a particular profile without puckering. The formability of the fused part can be indicative of the ability to deform in such a manner. Formability is the measure of amount of compression that a fabric can undergo before it buckles.

Measurement of formability is derived from the bending stiffness and the compression modulus of the fabric. As compression modulus is difficult to be measured, the extension modulus is useful in the measurement, assuming that at small strains around zero on the force extension curve, the slope of the curve is same at the positive and negative stresses. The amount of fabric of length l can be compressed before it buckles is given by Equation 1.

$$B = K * Cb / l^2 \qquad (1)$$

Where B is compression, K is constant, C is Compressibility, the slope of the force extension curve and b is bending rigidity.

Many studies have reported that formability is an essential property that influences the handle of fused components [2-5]. Studies have been conducted to understand the factors influencing formability in fused fabrics. Mousazadegan et al. have reported that a rigid fabric structure leads to higher buckling and presence of weft floats reduces the buckling behavior [6]. Jevsnik and Gersac reported that warp and weft density improve formability [7]. Fan reported that the orientation of interlining, weight of fabric affects buckling [8]. Formability is known to improve after multiple cycle of dry-cleaning and washing [8]. Minazio reported that seam appearance can be improved in fabrics with poor formability by increasing its pressing performance [9].Fan et al. proposed interlining selection based on favorable range of values for mechanical properties which includes formability [10]. The above discussion shows the importance of formability of the fused components to achieve good quality levels in garment production. The present study aims to predict the formability of the fused components using response surface technique. The central composite design with two factors has been used to analyze the formability of samples fused as per experiment design.

II. MATERIALS AND METHODS

2.1 Materials–

100% cotton plain weave fabrics commonly used for shirting application were selected for the study. They were fused with 100% cotton woven fusible interlining. The physical properties of the fabrics and interlinings are presented in Table I. The fusible interlinings used in the study have high density polyethylene resin.

Table I: Physical properties of the fabric and fusible interlining

Fabric code	**Areal weight (g/m^2)**	**Yarns per inch (epi*ppi)**	**Yarn count (Ne)**
F1	115	70*56	30s*24s
F2	132	80*55	25s*25s
F3	110	70*56	30s*24s
F5	135	90*160	55s*45s
F6	123	90*160	55s*45s
Interlining code	**Areal weight (g/m^2)**	**Yarns per inch (epi*ppi)**	**Resin dots per cm^2**
I1	110	50*50	170
I2	225	50*51	152
I3	166	50*52	170
I4	86	75*55	170
I5	248	60*60	152

2.2 Experimental-

The fused fabric components were made using the central composite design of experiment with two factors namely fabric areal weight (FW) and interlining areal weight (IW). The Minitab software was used to analyze the design. The design has 8 cube points, 10 center points in cube and 8 axial points. This makes 13 base runs and with 2 replicates of the design translates to 26 total set of experiments. The design and selection of combination of the fabric and interlining is given in Table II.

2.3 Measurement of formability using FAST

The FAST system was usedto measure the bending rigidity and extension of fused fabric samples. Formability is a measure of the extent to which a fabric can be compressed in its own plane before it will buckle. This parameter, as the product of the bending rigidity and the extensibility of the fabric at low loads, is defined in the FAST system as formability(mm^2). The same was calculated using the Equation (3)

$$\text{Formability} = \text{Bending Rigidity} * (\text{Extension (20gms)} - \text{Extension (5gms)})/14.7 \quad (3)$$

The formability of each fused sample as per the experiment run is presented in Table II.

Table II: Experiment runs with factors, levels, materials used and formabilityvalues for each run

Experiment Run	FW	IW	Fabric code	Interlining code	Formability	Experiment Run	FW	IW	Fabric code	Interlining code	Formability
1	115	110	F1	I1	1.96096	14	115	110	F1	I1	1.53492
2	132	110	F2	I1	1.35954	15	132	110	F2	I1	1.35954
3	115	225	F1	I2	3.97025	16	115	225	F1	I2	3.58342
4	132	225	F2	I2	3.0299	17	132	225	F2	I2	5.99572
5	110	167	F3	I3	2.75974	18	110	167	F3	I3	1.9648
6	135	167	F5	I3	4.47088	19	135	167	F5	I3	4.47088
7	123	86	F6	I4	1.86979	20	123	86	F6	I4	1.46979
8	123	248	F6	I5	4.46957	21	123	248	F6	I5	5.48864
9	123	167	F6	I3	1.33945	22	123	167	F6	I3	3.1287
10	123	167	F6	I3	5.07699	23	123	167	F6	I3	4.77699
11	123	167	F6	I3	3.22231	24	123	167	F6	I3	3.46144
12	123	167	F6	I3	1.43906	25	123	167	F6	I3	2.45637
13	123	167	F6	I3	1.81468	26	123	167	F6	I3	3.4685

III. RESULTS AND DISCUSSIONS

The formability is a function of bending rigidity and extension of the fused sample. The studied samples have very high bending rigidity and very less extension as they are fused with heavy and stiff fusible interlining. Thereby the formability is in the range of 0-5 mm^2 for the fused shirt parts. It is also observed that as the bending rigidity increases, the formability of the sample also tends to increase. The experimental design given in Table II was analyzed and the results of ANOVA of the same is presented in Table III. The analysis shows that model is valid with a P-value of 0.005. The R square of the model is 54.47%. The most significant factor influencing the formability of fused shirting samples is interlining weight (IW) with a contribution of 47.67% to the total effect. The interlining used in this study is woven cotton interlining which is very stiff used in collars and cuffs. Thereby the effect of the interlining is much more than that of the fabric in determining the formability of the fused sample. The interactions are not significantly influencing the formability with P value more than 0.05. The model is valid as the P value of the error is more than 0.05 (0.509). The regression equation that predicts the formability in fused components using fabric areal weight (FW) and interlining areal weight is given in Equation 3.

Formability = 20.0 - 0.282 FW - 0.052 IW + 0.00095 FW*FW + 0.000007 IW*IW + 0.000575 FW*IW

Table III: Analysis of variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Model	5	27.7881	54.47%	27.7881	5.5576	4.79	0.005
Linear	2	27.0875	53.10%	27.0875	13.5438	11.66	0.000
FW	1	2.7715	5.43%	2.7715	2.7715	2.39	0.138
IW	1	24.3160	47.67%	24.3160	24.3160	20.94	0.000
Square	2	0.0684	0.13%	0.0684	0.0342	0.03	0.971
FW*FW	1	0.0613	0.12%	0.0658	0.0658	0.06	0.814
IW*IW	1	0.0072	0.01%	0.0072	0.0072	0.01	0.938
2-Way Interaction	1	0.6321	1.24%	0.6321	0.6321	0.54	0.469
FW*IW	1	0.6321	1.24%	0.6321	0.6321	0.54	0.469
Error	20	23.2247	45.53%	23.2247	1.1612		
Lack-of-Fit	3	2.8848	5.66%	2.8848	0.9616	0.80	0.509
Pure Error	17	20.3399	39.87%	20.3399	1.1965		
Total	25	51.0128	100.00%				

The main effect of the factors is presented in Figure 1-a. The figure shows that the formability increases slightly as the fabric areal weight increases from 100 g/m^2 to 135 g/m^2. Similar results were observed in suiting fabrics [11]. Further, the formability increases when interlining weight increases from 85 g/m^2 to 250 g/m^2. The influence of increasing weight of interlining is more than the increase in the fabric areal weight, which is seen in the slope of both the graph. The interaction effect of the two factors is presented in Figure 1-b. The graph shows that the formability increases with increasing areal weight of the interlining. Similar results were reported for fused suiting fabrics by Kim and Kim [12]. The difference in the formability between the levels of interlining weight when fabric of weight- 100 g/m^2 is lesser when compared to the difference in formability when fabric weight is higher (135 gm^2).

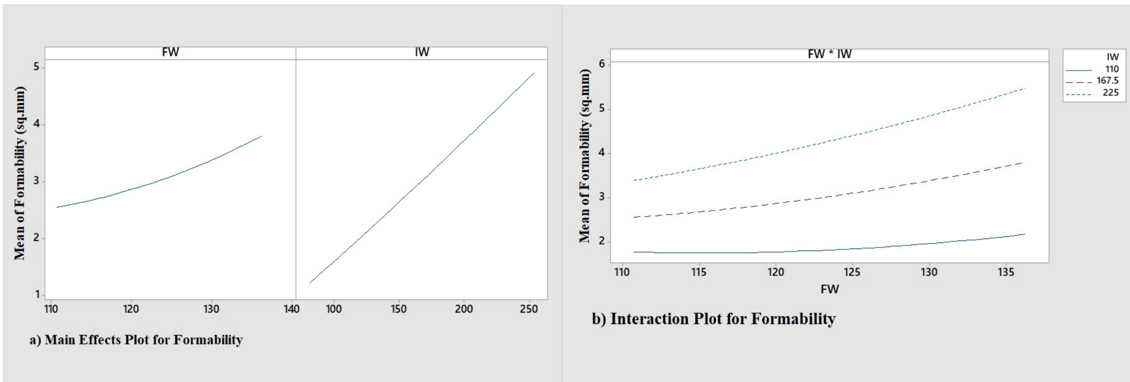

Figure 1: Main plot and interaction plot for formability

The contour plot is presented in Figure 2- a. The contour plot shows the changes in formability when the fabric weight and interlining weight is changed. The lower values of formability are seen in samples with lower weight fabrics fused with lower weight interlining. Formability range of 0 to 2 mm^2 is expected in all fabrics fused with interlining weight of 100-120 g/m^2. As the interlining weight is increased, the formability increases to similar level irrespective of the weight of the fabric. The same is clear from the surface plot shown in Figure 2-b.

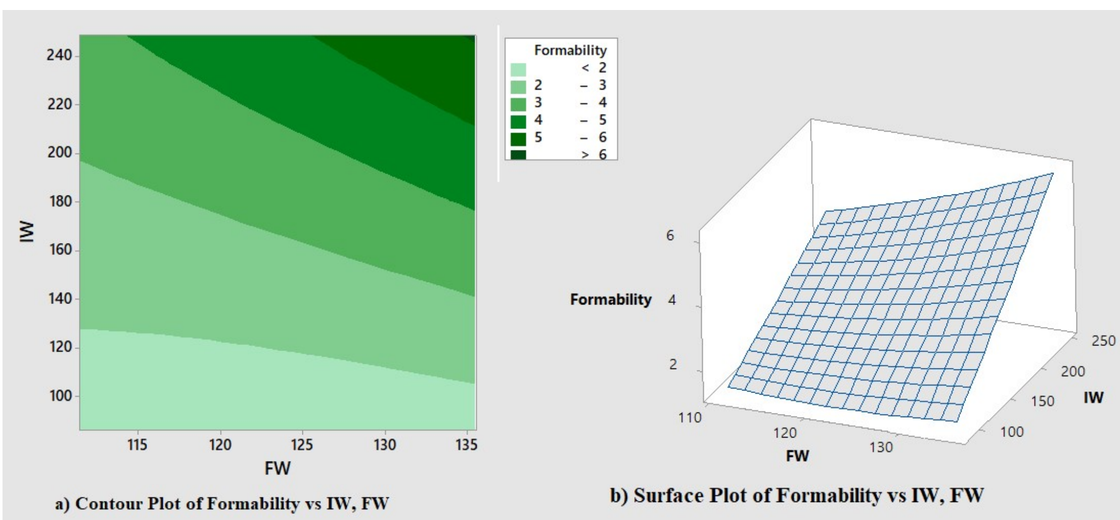

Figure 2: Contour plot and Surface plot for formability

IV. CONCLUSION

Formability is an important parameter that influences the appearance of the finished collar, cuff and placket in a shirt. This feature of the fused fabric components has been predicted in this study using two factors known to influence the formability, namely the fabric areal weight and interlining areal weight. It is clear from the analysis that the fused components behave differently from the fabrics, due to the presence of the fusible interlining. This study presents aregression equation that can be used to predict formability in fused shirting components when fabric and interlining weight are known. This knowledge will help in selection of interlining for a given fabric, in order to optimise the formability value. The study also has helped in understanding the formability of the fused components have a direct correlation to the fabric areal weight. This is bending rigidity of fused shirt components is very high and the extensibility is very low (almost negligible). Thus, a higher bending rigidity results in higher formability value.

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