Renjini Girija, Sudhakar Rajagopal
Bangalore University, Department of Apparel Technology and Management, Bangalore Karnataka 560056, India

Predicting Drape of Fused Collar using Design of Experiment
Napovedovanje drapiranja fiksiranega srajčnega ovratnika z uporabo sistematične zasnove poskusa

Original scientific article/*Izvirni znanstveni članek*
Received/*Prispelo* 7-2021 • Accepted/*Sprejeto* 2-2022

Corresponding author/*Korespondenčna avtorica:*
Dr. Sudhakar Rajagopal, Assist. Prof.
E-mail: sudhakar@bub.ernet.in
ORCID ID: 0000-0001-6349-1052
Phone: +91 9845804755

Abstract
The fused collar components used in shirt manufacturing requires a specific fall and drape that depends on the type of used interlining. The interlining selection is primarily based on the subjective evaluation of fused composites. There is a need to predict the behaviour of fused shirt collars objectively. The drape of fused composites can be indicative of the shape and fall of the shirt collar. The aim of this paper was to propose a set of polynomial equations using DOE that can predict the drape behaviour of fused shirt collars before and after the washing. The Plackett-Burman design was used to screen the influential factors and the full factorial design was used to derive the polynomial equation explaining the effect of factors on the drape behaviour of fused shirting samples. The prediction was attempted with easily measurable parameters of component materials and the fusing process. The study found that the fabric weave, cover factor, raw material, interlining weight and pressure applied during the fusing process have a significant effect on the drape of fused collars. This information can be used in the 3D sampling of fused shirt components.
Keywords: design of experiment, drape coefficient, fused fabric components, shirt collar

Izvleček
Fiksirane komponente ovratnika, ki se uporabljajo pri izdelavi srajc, zahtevajo poseben pad in sposobnost oblikovanja, ki je odvisna od vrste uporabljene medvloge. Izbira medvloge temelji predvsem na subjektivnem ocenjevanju fiksiranca, zato je toliko pomembnejše objektivno napovedovanje obnašanja fiksiranih srajčnih ovratnikov. Parametri drapiranja fiksiranca lahko pokažejo, kakšna sta oblika in pad srajčnega ovratnika. S sistematično zasnovo poskusa (DOE) so bile razvite polinomske enačbe za napovedovanje drapiranja fiksiranih srajčnih ovratnikov pred pranjem in po njem. Za spremljanje vplivnih dejavnikov je bil uporabljen Plackett-Burmanov delni faktorski načrt, popolni faktorski načrt pa je bil uporabljen za izpeljavo polinomske enačbe, ki pojasnjuje vpliv dejavnikov na drapiranje fiksiranih srajčnih vzorcev. Napovedovanje je bilo preizkušeno z uporabo vrednosti preprosto merljivih parametrov sestavnih materialov in postopka fiksiranja. Študija je pokazala, da med parametre, ki pomembno vplivajo na drapiranje fiksiranih ovratnikov, spadajo: vezava, faktor kritja, surovina, površinska masa medvloge in pritisk pri fiksiranju. Pridobljena spoznanja je mogoče uporabiti pri 3-D vzorčenju fiksiranih srajčnih komponent.
Ključne besede: sistematično načrtovanje eksperimenta, koeficient drapiranja, komponente fiksiranca, srajčni ovratnik

1 Introduction

Formal shirts are constructed with a collar fused with an interlining. The drape of the collar is an important aesthetic and functional feature in a shirt. The drape of the collar explains its ability to fall or hang due to its weight, anchored from the points of its joining seam with the shirt stand or neckline. It contributes to the wearing comfort [1]. The way the collar drapes or falls is an important determinant in classifying it as a formal, semi-formal or casual category wear. The drape of the collar is a complex three-dimensional double curvature form. The specific form or shape of the collar is achieved with the application of a fusible or non-fusible interlining [2]. The collar cut fabric parts are fused with two interlining layers, i.e. the skin and patch in formal shirts (cf. Figure 1).

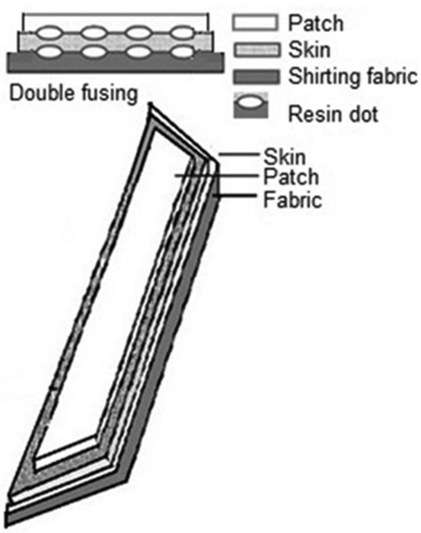

Figure 1: Schematic diagram of collar component with skin and patch interlining

The drape of the fabric is measured using a drape meter. The drape coefficient (DC) is the ratio of the projected area of the draped specimen to the original area of the specimen. The fabrics that easily deform and have lower stiffness have low DC [3, 4]. Shirt collars are normally fused with interlinings to make them stiff. Due to higher stiffness, the formability of the component reduces significantly [5, 6]. High stiffness along with low formability in garment parts can pose problems in sewing operations and lead to reduced wearing comfort [7]. Studies on the changes in DC in different fabrics before and after fusing the interlining have shown that it increases to similar levels after the fusing, irrespective of the original DC of the fabric [8]. The presence of resin in the fused components restricts the movement of yarns within the fabric structure, which contributes to higher bending stiffness and higher DC. Furthermore, the fabric grain direction in the fused fabrics that have the least bending rigidity deforms more readily.

There have been previous studies on predicting drape in fused fabrics. The image analysis of nodes formed by draped fused fabric composites showed that parallel nodes are formed in the fabric direction with the least bending stiffness [9]. The draped fused panel was simulated using the finite element method and similarities were reported between the simulated model and the drape of the actual fused fabric [10]. In suiting and jacket, the properties of the component fabrics of fused composites and the fusing parameters of time, temperature and pressure have a significant effect on the fused composite properties [11–16]. The effect of these parameters on the fused shirt components needs further study. The literature indicates that the drape of the fused fabric is a good indicator of its ability to conform to required collar shape and fall. The understanding of the drape behaviour of the fused composites and predicting the same can be used in the 3D sampling process. It will also aid in ensuring the desired appearance in product development. This study aims to understand the relationship between various properties of the fabric, interlining, fusing process conditions and drape of fused collar composites.

2 Materials and methods

2.1 Materials

Shirting fabrics of medium weight used for formal men's shirts were selected for this study. The properties of selected fabrics were established using the standard test method for thread density (warp and weft) (ASTM D 3775-17e1), yarn number (ASTM D 1059-17), and type of weave and fabric weight (ASTM D 3776-20). The fabric physical properties are listed in Table 1. 100% cotton woven interlinings with high-density polyethylene adhesive resin were used in the fusing of samples. The patch interlinings used are of two different areal weights (135 g/m^2 and 160 g/m^2). The selected interlining finish was the flat and raised finish. Fabrics were cut to the length of two metres and kept in standard atmosphere for conditioning. The fusing was done on a full-width

Table 1: Shirting fabrics used in experimental design

Fabric code	Fabric weave	Fibre blend	Mass per unit area (g/m²)	Yarn linear density of warp × weft	Threads in fabric length × width ends × picks	Fabric cover factor
				(tex)	(1/cm)	
F1	Plain	PES/CO [a)]	130	15 × 15	57 × 35	25
F2	1/1 and 3/1 twill	PES/CO	132	10 × 10	44 × 37	20
F3	2/2 matt	CO [b)]	118	12 × 12	54 × 36	24
F4	Plain	PES/CO	107	8 × 11	52 × 41	22
F5	Plain	PC	130	24 × 25	31 × 22	21
F6	2/2 matt and 3/1 twill	CO	145	10 × 10	51 × 35	21
F7	1/1 & 2/1 twill	CO	136	11 × 12	59 × 41	24
F8	2/1 twill	PES/CO	145	20 × 20	51 × 38	26
F9	7/7 matt & plain	PES/CO	114	9 × 10	72 × 41	25
F10	Plain	PES/CO	132	11 × 12	67 × 31	25
F11	1/1 and 3/1 twill	PES/CO	101	8 × 8	59 × 35	21
F12	Plain	CO	134	11 × 13	64 × 35	25
F13	2/1 herringbone	PES/CO	115	8 × 8	51 × 43	21
F14	Plain	CO	109	12 × 12	55 ×51	25
F15	Plain	PES/CO	124	19 × 25	28 × 22	19
F16	Plain	CO	116	20 × 20	25 ×21	17
F17	Plain	CO	135	7 × 7	61 × 28	20
F18	1/1 & 2/1 twill	CO	133	8 × 8	61 × 29	21
F19	2/2 matt	CO	109	12 × 11	67 × 31	25
F20	Plain	CO	111	12 × 11	48 × 30	21

[a)] 50% polyester/50% cotton

[b)] 100% cotton

fabric with the interlining following the experimental design on a continuous fusing machine (Hashima model HP-600LFS). The fusing was conducted at two different temperature settings (150 °C and 170 °C), time settings (15 s and 20 s) and pressure settings (0.1471 MPa and 0.2941 MPa), following the experimental design. The samples were double fused with skin interlining (90 g/m²) according to the fusing procedure followed for collar fusing in shirt manufacturing (cf. Figure 1).

2.2 Methods

The experiments were designed to initially filter the most relevant factors and build a predictive regression model using the identified factors. The factors considered for the screening design of the experiment were the physical properties of the fabric, interlining physical properties and fusing parameters. The physical properties of the fabric are mass per unit area (g/m²), fibre blend, weave structure, fabric cover factor and finish. The interlining properties included weight per unit area and finish. The fusing process factors included time, temperature and pressure applied during fusing. The ends per inch and picks per inch of the fabric were determined using a pick glass as per ASTM D3775. The warp and weft yarn linear density were measured using a Beesley balance (ASTM D 1907). The cover factor of the fabric was calculated using Peirce's formula [17]. Each of the ten factors were considered in two levels as shown in Table 2.

The initial fusing was carried out in line with the screening design matrix of the Plackett-Burman design with ten factors and twenty runs (cf. Table 3). The DC evaluated on fused samples before and after the washing was analysed. The factors that showed a statistically significant impact on drape coefficient

(P-value < 0.05) were selected for the forming of the full factorial design. The designs were replicated twice and the adequacy of the model was checked using its adjusted squared coefficient of determination (adj. R^2) [18].

After the fusing, the samples for drape evaluation were prepared by cutting four circular samples with 25 centimetres in diameter. The samples were mounted on the face as well as the backside and the average of eight readings was noted. The drape

Table 2: Factors and levels used in screening design of experiment

S. no.	Factor	Code	Level (–1)	Level (+1)
1	Fabric weight (g/m^2)	Fgsm	100–125	130–150
2	Fabric weave	FW	Plain	Combination
3	Fabric cover factor	FC	17–21	23–26
4	Fabric fibre content	FFC	Cotton	50% polyester/50% cotton
5	Fabric finish	FF	Silicon finish	None
6	Interlining weight (g/m^2)	Igsm	225	250
7	Interlining finish	IF	Raised	Flat
8	Time (s)	t	15	20
9	Temperature (°C)	T	150	170
10	Pressure (MPa)	P	0.1471	0.2941

Table 3: Plackett-Burman design of experiment and drape coefficient (DC) of fused samples

S. no.	Fgsm	F W	FC	FFC	FF	Igsm	IF	*t*	*T*	P	Fabric code	DC before washing (%)		DC after washing (%)	
												Replicate I	Replicate II	Replicate I	Replicate II
1	+1	–1	+1	+1	–1	–1	–1	+1	+1	–1	F1	86.09	91.51	87.78	88.46
2	+1	+1	–1	+1	+1	–1	–1	+1	–1	+1	F2	93.20	94.89	86.43	88.12
3	–1	+1	+1	–1	+1	+1	–1	+1	–1	–1	F3	92.05	91.51	85.75	84.91
4	–1	–1	+1	+1	–1	+1	+1	+1	–1	–1	F4	86.09	85.92	80.34	80.17
5	+1	–1	–1	+1	+1	–1	+1	+1	–1	–1	F5	97.26	96.58	87.11	87.11
6	+1	+1	–1	–1	+1	+1	–1	+1	+1	–1	F6	88.80	86.77	86.43	86.43
7	+1	+1	+1	–1	–1	+1	+1	+1	+1	+1	F7	84.40	83.72	87.95	87.78
8	+1	+1	+1	+1	–1	–1	+1	+1	–1	+1	F8	89.48	88.80	84.57	84.40
9	–1	+1	+1	+1	+1	–1	–1	+1	+1	–1	F9	89.58	89.44	85.41	85.41
10	+1	–1	+1	+1	+1	+1	–1	+1	+1	+1	F10	84.99	85.28	80.68	80.17
11	–1	+1	–1	+1	+1	+1	+1	+1	–1	+1	F11	86.94	89.14	83.05	82.54
12	+1	–1	+1	–1	+1	+1	+1	+1	–1	–1	F12	90.73	88.46	81.18	81.35
13	–1	+1	–1	+1	–1	+1	+1	+1	+1	–1	F13	94.89	91.51	87.45	87.11
14	–1	–1	+1	–1	+1	–1	+1	+1	+1	+1	F14	70.86	81.35	84.23	84.91
15	–1	–1	–1	+1	–1	+1	–1	+1	+1	+1	F15	87.28	89.71	84.74	84.40
16	–1	–1	–1	–1	+1	–1	+1	+1	+1	+1	F16	87.45	87.11	83.05	82.88
17	+1	–1	–1	–1	–1	+1	–1	+1	–1	+1	F17	78.44	82.03	84.23	84.40
18	+1	+1	–1	–1	–1	–1	+1	+1	+1	–1	F18	85.41	88.80	84.74	86.09
19	–1	+1	+1	–1	–1	–1	–1	+1	–1	+1	F19	79.56	81.69	91.17	92.52
20	–1	–1	–1	–1	–1	–1	–1	+1	–1	–1	F20	87.45	91.51	85.75	85.25

coefficient (DC) of the fused samples was calculated as given in Equation 1.

$$Drape\ coefficient = \frac{\frac{w}{W} - a}{A - a} \times 100\ (\%) \quad (1),$$

where w is the mass of draped pattern, W is the mass/unit area of the paper, A is the area of the circle with a diameter of 25 cm and a is the area of the circle with a diameter of 12.5 cm (ASTM D 3691-19). The samples were washed following the standard ASTM D 2724-19. The DC of each fused sample was evaluated before and after the washing.

3 Results and discussion

The drape coefficient of the fabric gives a partial measurement of its hand and can be used to predict fabric deformation [19]. The fused fabric drape is more complex than fabric drape due to the effect of component fabric properties, interlining properties and their combined properties [6]. The drape in stiff composites such as the shirt collar gives an indication to the formability along the neckline and fall of the collar. The average DC of the fabric samples before the fusing is 36.21%. After the fusing, the average DC increased to 89%, and after washing the fused samples, the average DC reduced to 85%. DC increased significantly after the fusing to the interlining and reduced slightly after the washing (cf. Figure 2).

3.1 Drape coefficient of collar samples before washing

The screening design analysis shows that DC (before washing) is influenced by four significant factors: fabric weave (FW), fabric cover factor (FC), fabric fibre content (FFC) and pressure (P). After the washing, there is a change in factors that have a significant effect on the drape. These are fabric weave, fabric fibre content and interlining areal weight. The full factorial design with four factors and thirty-two runs was used to analyse the results before the washing (cf. Table 4), and the Adj. R^2 for this model with all the terms was 74%. The model, factors and interactions (FW × P, FC × P, FC × FFC × P) are statistically significant (P-value < 0.05).

The terms FW × FC, FW × FFC, FCC × P, FW × FC × FFC, FW × FC × P, FC × FFC × P and FW × FC × FFC × P are insignificant (P-value > 0.05) and removed to form the final model (cf. Table 5). The Adj. R^2 for this reduced model after removing insignificant terms is 68.30%. The lack of fit has

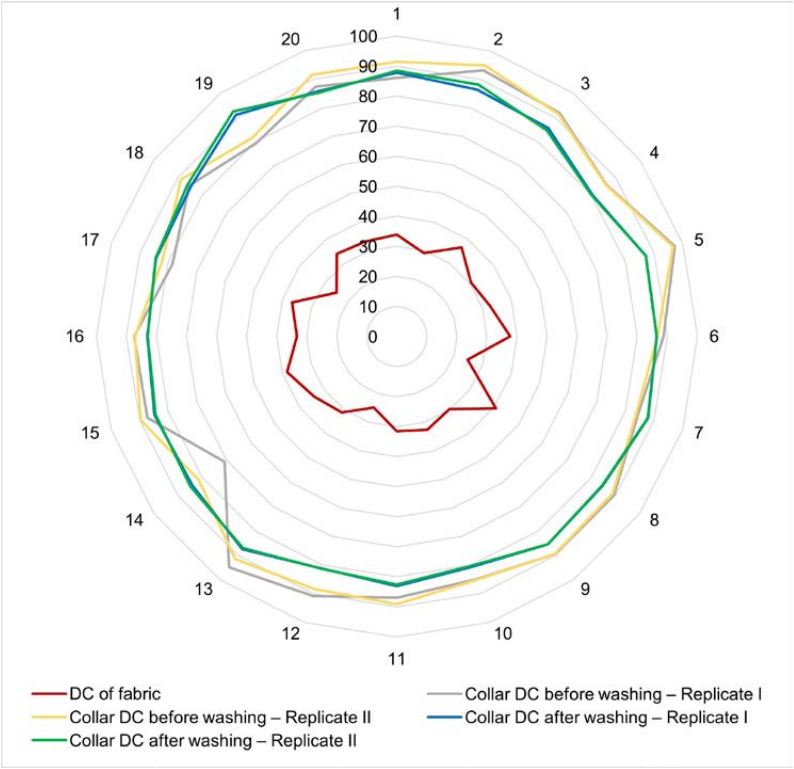

Figure 2: Drape coefficient (DC) of fabric and fused collar samples

the P-value of 0.185 (more than 0.05). The highest contribution to the total effect in the model by individual factors is by fabric cover factor (16.65%), followed by pressure (12.96%), fabric fibre content (9.75%) and fabric weave (4.25%). The contribution of the interaction between fabric weave and pressure is 13.71%, fabric cover factor and pressure is 9.21%, and fabric cover factor, fabric fibre content and pressure is 8.93%. The regression equation for the model after removing insignificant terms predicting the DC of collar samples before the washing is given in Equation 2.

$$Drape\ coefficient\ of\ collar\ samples\ before\ washing = 88.705 + 0.980\,FW - 1.940\,FC + 1.485\,FFC - 1.712\,P + 1.760\,FS \times P - 1.443\,FC \times P + 1.421\,FC \times FFC \times P \quad (2)$$

Fabric weave affects the drape of the fused samples [8]. The DC of fused samples of the plain fabric is lower than the samples with the combination weave fabrics (cf. Figure 3a). Interestingly, the fused samples with a lower cover factor show higher DC than the fabrics with a higher cover factor. The fused fabric with a low cover factor forms a compact composite as the lower cover factor allows a better and even penetration of the resin between yarn interstices. The interaction between the fabric weave and cover factor (cf. Figure 3b) implies that the samples with plain fabrics of a low cover factor have higher DC than the samples with a high cover factor and plain weave. Drape instability is reported in fabrics with a higher cover factor [20] and this instability can cause the results seen in the fused collars of the fabrics with a high cover factor. The fabrics with polyester-cotton content have registered higher DC than 100% cotton fabrics. Both 100% cotton and PC blend fabrics with a low cover factor have higher DC than other samples (cf. Figure 3a). The polyester content in the PC blend fabrics is prone to crystallisation and shrinkage when exposed to high temperature (150 °C to 170 °C) [21] and this led to higher DC. The fabric with a lower cover factor allows higher resin penetration into the interstices, making the fused collar gain higher stiffness. This leads to higher DC due to the effect of higher bending stiffness in the fused samples. The results imply that at lower pressure, the DC of fused samples of both fibre content types has higher DC (cf. Figure 3a). The interaction of pressure with fabric weave and fabric cover factor is significant (cf. Table 5). The lower pressure of 0.1471 MPa has a relatively smaller effect on DC between two fabric weave levels and the fabric cover factor. However, when the pressure is increased to 0.2941 MPa, DC is higher for the combination weave fabrics with low cover factors (cf. Figure 3c).

Table 4: Full factorial design for drape coefficient (DC) of samples before washing

S. no.	FW	FC	FFC	P	Fabric code	DC (%)	S. no.	FW	FC	FFC	P	Fabric code	DC (%)
1	–1	–1	–1	–1	F20	87.45	17	–1	–1	–1	–1	F20	91.51
2	+1	–1	–1	–1	F6	88.80	18	+1	–1	–1	–1	F6	86.77
3	–1	+1	–1	–1	F12	90.73	19	–1	+1	–1	–1	F12	88.46
4	+1	+1	–1	–1	F3	92.05	20	+1	+1	–1	–1	F3	91.51
5	–1	–1	+1	–1	F5	97.26	21	–1	–1	+1	–1	F5	96.58
6	+1	–1	+1	–1	F13	87.45	22	+1	–1	+1	–1	F13	91.51
7	–1	+1	+1	–1	F1	86.09	23	–1	+1	+1	–1	F1	91.51
8	+1	+1	+1	–1	F9	89.58	24	+1	+1	+1	–1	F9	89.44
9	–1	–1	–1	+1	F16	87.45	25	–1	–1	–1	+1	F16	87.11
10	+1	–1	–1	+1	F18	91.02	26	+1	–1	–1	+1	F18	92.36
11	–1	+1	–1	+1	F14	70.86	27	–1	+1	–1	+1	F14	81.35
12	+1	+1	–1	+1	F7	84.40	28	+1	+1	–1	+1	F7	83.72
13	–1	–1	+1	+1	F15	87.28	29	–1	–1	+1	+1	F15	89.71
14	+1	–1	+1	+1	F2	93.20	30	+1	–1	+1	+1	F2	94.89
15	–1	+1	+1	+1	F10	84.99	31	–1	+1	+1	+1	F10	85.28
16	+1	+1	+1	+1	F8	89.48	32	+1	+1	+1	+1	F8	88.80

Table 5: Analysis of variance for drape coefficient of collar samples before washing

Source	Master model		Predictive model				
	DF	P-value	DF	Cr (%)	Adj. SS	Adj. MS	P-value
Model	15	0.000	7	75.46	545.89	77.984	0.000
Linear	4	0.000	4	43.61	315.49	78.873	0.000
FW	1	0.039	1	4.25	30.71	30.713	0.053
FC	1	0.000	1	16.65	120.45	120.446	0.000
FFC	1	0.004	1	9.75	70.55	70.546	0.005
P	1	0.001	1	12.96	93.79	93.788	0.002
2-way interaction	6	0.002	2	22.92	165.78	82.891	0.000
FW × FC	1	0.061	–	–	–	–	–
FW × FFC	1	0.169	–	–	–	–	–
FW × P	1	0.001	1	13.71	99.15	99.154	0.001
FC × FFC	1	0.814	–	–	–	–	–
FC × P	1	0.004	1	9.21	66.63	66.629	0.006
FFC × P	1	0.115	–	–	–	–	–
3-way interaction	4	0.038	1	8.93	64.61	64.612	0.007
FW × FC × FFC	1	0.909	–	–	–	–	–
FW × FC × P	1	0.169	–	–	–	–	–
FW × FFC × P	1	0.536	–	–	–	–	–
FC × FFC × P	1	0.005	1	8.93	64.61	64.612	0.007
4-way interaction	1	0.197	–	–	–	–	–
FW × FC × FFC × P	1	0.197	–	–	–	–	–
Error	16	–	24	24.54	177.55	7.398	
Lack of fit	–	–	8	11.12	80.47	10.058	0.185
Pure error	–	–	16	13.42	97.08	6.067	
Total	31	–	31	100.00			

3.2 Drape coefficient of collar samples after washing

The screening design analysis shows that DC (after washing) is influenced by three significant factors: fabric weave, fabric fibre content and interlining areal weight. The full factorial design formed with the three factors for a further analysis is presented in Table 6. The model, the factors and their interactions except for FW × FFC and FW × Igsm are statistically significant (P-value < 0.05) (cf. Table 7). After removing the insignificant terms, the regression equation (cf. Equation 3) that explains the effect of fabric weave, fabric fibre content and interlining areal weight is as follows:

$$\begin{aligned}&Drape\ coefficient\ of\ collar\ samples\ after\ washing\\&= 87.022 + 2.073\,FW - 0.508\,FFC - 3.004\,Igsm\\&- 1.988\,FFC \times Igsm + 1.100\,FW \times FFC \times Igsm\end{aligned} \quad (3)$$

Fabric weave (22.63%) and interlining areal weight (47.50%) contribute significantly to the effect, whereas the fabric fibre content has only 1.36% contribution to the effect on DC (cf. Table 7). The significant interactions are FFC × Igsm and FFC × FW × Igsm. The lack of fit in the model has the P-value of 0.181 (more than 0.05). As noted earlier, DC reduced after the washing. Figure 4a shows the main effects of the drape of the collar sample before the washing. The washed samples with plain fabrics have lower DC than the samples with the combination weave fabrics (cf. Figure 4b). The fused plain fabrics have a lower DC than the fused fabrics with combination weaves [22]. The same result is seen in the fused samples before and after the washing. As discussed earlier, this is due to the resin evenly spreading in the plain weave. The resin integrates into the woven structure interstices making the fused composite

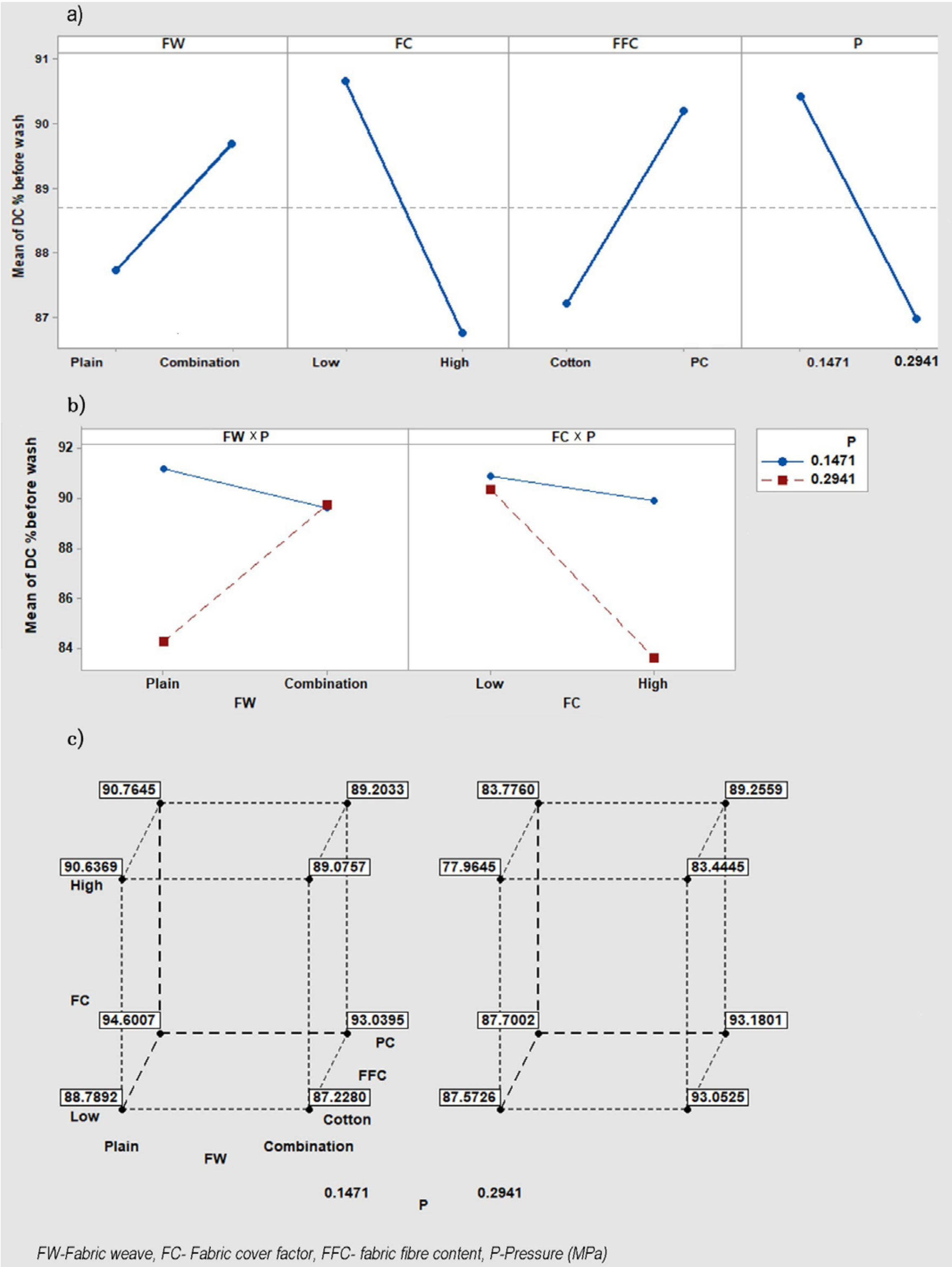

Figure 3: Effect plots for drape coefficient of fused collar samples before washing

Table 6: Full factorial design for drape coefficient (DC) of collar samples after washing

S. no.	FW	FFC	Igsm	Fabric code	DC (%)	S.no	FW	FFC	Igsm	Fabric code	DC (%)
1	–1	–1	–1	F14	84.74	9	–1	–1	–1	F14	85.41
2	+1	–1	–1	F18	91.51	10	+1	–1	–1	F18	92.52
3	–1	+1	–1	F1	90.83	11	–1	+1	–1	F1	90.83
4	+1	+1	–1	F2	91.51	12	+1	+1	–1	F2	92.86
5	–1	–1	+1	F12	84.74	13	–1	–1	+1	F12	85.75
6	+1	–1	+1	F3	88.12	14	+1	–1	+1	F3	87.45
7	–1	+1	+1	F4	78.64	15	–1	+1	+1	F4	78.64
8	+1	+1	+1	F11	84.74	16	+1	+1	+1	F11	84.06

Table 7: Analysis of variance for drape coefficient of collar samples after wash

Source	Master Model		Predictive Model				
	DF	P-Value	DF	Cr (%)	Adj. SS	Adj. MS	P-Value
Model	7	0.000	5	98.67	299.89	59.98	0.000
Linear	3	0.000	3	71.49	217.26	72.42	0.000
FW	1	0.000	1	22.63	68.76	68.76	0.000
FFC	1	0.008	1	1.36	4.12	4.12	0.010
Igsm	1	0.000	1	47.50	144.37	144.37	0.000
2-way interactions	3	0.000	1	20.82	63.27	63.27	0.000
FW × FFC	1	0.073	–	–	–	–	–
FW × Igsm	1	1.000	–	–	–	–	–
FFC × Igsm	1	0.000	1	20.82	63.27	63.27	0.000
3-way interactions	1	0.000	1	6.37	19.36	19.36	0.000
FW × FFC × Igsm	1	0.000	1	6.37	19.36	19.36	0.000
Error	8	–	10	1.33	4.04	0.40	–
Lack of fit		–	2	0.46	1.40	0.70	0.181
Pure error		–	8	0.87	2.63	0.33	–
Total	15		15	100.00	303.93		

compact. This compactness improved the drapability of the fused fabrics.

The collar samples made of 100% cotton fabrics had lower DC than the PC blend fabrics before the washing. However, after the washing, the cotton fabric samples maintained DC at a similar level, whereas the collar samples made of PC blends showed a reduction in DC. This means that the collars made of PC blend fabrics may lose their shape after the washing. The fused samples with lower interlining areal weight (225 g/m^2) exhibited a higher DC than those fused with a higher weight interlining (250 g/m^2), as seen in Figure 4a. The loss of the sizing material in interlining after the washing made the fused samples softer. This led to lower DC in the fused collars with higher weight interlining. For cotton fabrics, DC is similar for both levels of interlining areal weight; however, for PC blend fabrics, there is a significant difference between the two levels of interlining areal weight (cf. Figure 4b). The reduction of DC is greater in the samples of PC blended fabrics and higher weight interlining (250 g/m^2). Moreover, the influence of the interlining areal weight is significant only in the washed samples and not before the washing. The highest DC is achieved in the samples with PC fabrics with a combination weave fused with the interlining areal weight of 225 g/m^2. The lowest DC is achieved in the samples with PC blend fabrics of plain weave fused with the interlining areal weight of 250 g/m^2 (cf. Figure 4c).

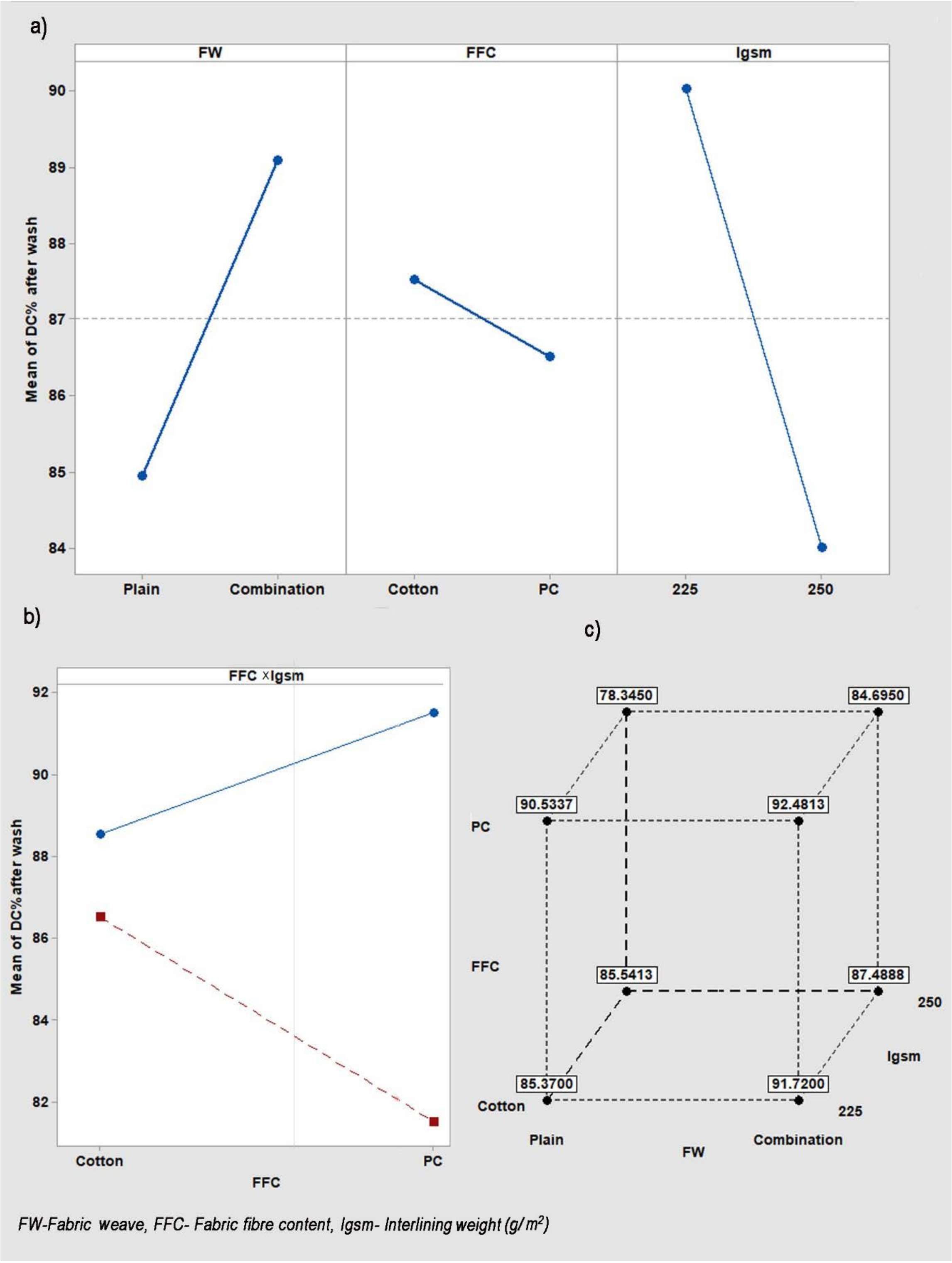

Figure 4: Effect plots for drape coefficient of collar samples after washing

4 Conclusion

The shirt collars are designed to possess a very high level of drape coefficient. In most cases, the collars are double fused to enhance this property. Since collars should conform to the desired shape and form after being sewn to the shirt neckline, it is important to understand the effect of various factors that lead to increased drape coefficient in the fused collar components. A very high drape coefficient was found in the samples with polyester/cotton blend fabrics of a low cover factor. A lower cover factor in fabrics is due to higher interstices between yarns – it is a function of yarn density and count. These spaces allow higher penetration of resin causing higher drape coefficient. Furthermore, lower pressure of 0.1471 MPa was found insufficient for the penetration of the adhesive resin, which also led to higher drape coefficient of most fused samples. The washed samples consisting of 100% cotton fabric were found to have lower drape coefficient than the corresponding unwashed samples. Additionally, the effect of the interlining weight is observed only after the samples are washed. This study shows the effect of various factors that contribute to the drape property of fused composites. The factors chosen to explain the fused collar behaviour are easily measurable without the need for complex methods or expensive testing instruments. This facilitates commercial applications in the 3D sampling of shirts. The regression equation was derived to predict the value of drape coefficient of fused collars given the type of fabric and interlining property. The information is useful in the objective selection of the right materials for the required aesthetic and functional property of the fused collar.

References

1. SANAD, REHAM ABDELBASET, CASSIDY, TOM. Fabric objective measurement and drape. *Textile Progress*, 2015, **47**(4), 317–406, doi: 10.1080/00405167.2015.1117243.
2. MAHAR, T.J., AJIKI, I., DHINGRA, R.C. AND POSTLE, R. Fabric mechanical and physical properties relevant to clothing manufacturing. Part 3: shape formation in tailoring. *International Journal of Clothing Science Technology*, 1989, **1**(3), 6–13, doi: 10.1108/eb002950.
3. KAWABATA, S., NIWA, M. Fabric performance in clothing and clothing manufacturing. *Journal of the Textile Institute,* 1989, **80**(1), 19–50, doi: 10.1080/00405008908659184.
4. HAMDI, T., GHITH, A., AND FAYALA, F. Fuzzy logic method for predicting the effect of main fabric parameters influencing drape phenomenon. *AUTEX Research Journal*, 2020, **20**(3), 220–227, doi: 10.2478/aut-2019-0034.
5. BEHERA, B.K., MISHRA, R. Effect of crease behaviour, drape and formability on appearance of light weight worsted suiting fabrics. *Indian Journal of Fibre & Textile Research*, 2007, **32**(3), 319–325, http://nopr.niscair.res.in/handle/123456789/340.
6. JEVŠNIK, S., GERŠAK, J., GUBENŠEK, I. The advance engineering methods to plan the behaviour of fused panel. *International Journal of Clothing Science and Technology*, 2005, **17**(3/4), 161–170, doi: 10.1108/09556220510590858.
7. MASTEIKAITE, V., SACEVICIENE, V., CIRONIENE, V. Compressed loop method for the bending behaviour of coated and laminated fabrics analysis. *Textile Research Journal,* 2014, **43**(3), 350–365, doi: 10.1177/1528083712454154.
8. SHARMA, K.R., BEHERA, B.K., ROEDEL, H., SCHENK, A. Effect of sewing and fusing on drape behaviour of suiting fabrics. *International Journal of Clothing Science and Technology*, 2005, **17**(2), 75–90, doi: 10.1108/09556220510581227.
9. KOEING, S.K., KADOLPH, S.J. Comparison of performance characteristics of seven fusible interfacing. *Textile Research Journal*, 1983, **53**(6), 341–346, doi: 10.1177/004051758305300603.
10. JEVŠNIK, S., GERŠAK, J. Modelling the fused panel for a numerical simulation of drape. *Fibres & Textiles in Eastern Europe,* 2004, **12**(1), 47–52.
11. TYLER, D.J. Alternative method of joining materials. In *Carr and Latham's technology of clothing manufacture*. Edited by David J. Tyler. John Wiley & Sons, 2009, 221–246.
12. VILUMSONE-NEMES, I. Automation in spreading and cutting, In *Automation in garment manufacturing.* Edited by Rajkishore Nayak and Rajiv Padhye. Woodhead Publishing, 2018, 139–164.
13. FAN, J., LEEUWNER, W., HUNTER, L. Compatibility of outer and fusible interlining fabric in tailored garments Part I: Desirable range of mechanical properties of fused composites. *Textile Research Journal*, 1997, **67**(2), 137–142, doi: 10.1177/004051759706700210.
14. GERŠAK, J., ŠARIĆ, A. Objective evaluation of a stabilized garment parts. *International Journal*

of Clothing Science and Technology, 1995, **7**(2/3), 102–110, doi: 10.1108/09556229510087218.
15. SHISHOO, R., KLEVMAR, P.H., CEDNAS, M., OLOFSSON, B. Multilayer textile structures - relationship between the properties of a textile composite and its components. *Textile Research Journal*, 1971, **41**(8), 669–679, doi: 10.1177/004051757104100807.
16. YOON, S.Y., PARK, C.K., KIM, H.S., KIM, S. Optimization of fusing process conditions using taguchi method. *Textile Research Journal*, 2010, **80**(11), 1016–1026, doi: 10.1177/0040517509349784.
17. PEIRCE, F.T. 26—The "handle" of cloth as a measurable quantity. *Journal of the Textile*
18. *Institute Transactions,* 1930, 21(9), T377–T416, doi: 10.1080/19447023008661529.
19. MONTGOMERY, D.C. *Design and analysis of experiments.* John Wiley & Sons, 2013.
20. CUSICK, G.E. 46—The dependence of fabric drape on bending and shear stiffness. *Journal of the Textile Institute Transactions,* 1965, **56**(11), T596–T606, doi: 10.1080/19447026508662319.
21. JEONG, Y.J., PHILLIPS, D.G. A study of fabric-drape behaviour with image analysis. Part II: the effects of fabric structure and mechanical properties on fabric drape. *Journal of the Textile Institute,* 1998, **89**(1), 70–79, doi: 10.1080/00405009808658598.
22. MILITKÝ, JIŘÍ. Tensile failure of polyester fibers. In *Handbook of properties of textile and technical fibres*. Edited by Anthony R Bunsel. Woodhead Publishing, 2018, 421–514, https://doi.org/10.1016/B978-0-08-101272-7.00013-4.
23. HUNTER, L., FAN, J., CHAU, D. Fabric and garment drape. In *Engineering Apparel Fabrics and Garments*. Edited by J. Fan and L. Hunter. Woodhead Publishing, 2009, 102-125.