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VIRTUAL FIT EVALUATION FOR OPTIMIZATION OF GARMENT COMPONENT'S PARAMETERS

GİYSİ BİLEŞENLERİNİN PARAMETRELERİNİN OPTİMİZASYONU İÇİN SANAL UYUM DEĞERLENDİRMESİ

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VIRTUAL FIT EVALUATION FOR OPTIMIZATION OF GARMENT COMPONENT'S PARAMETERS

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ABSTRACT: Apparel fit is influenced by body proportion, fabric, and design parameters, but much of the fit evaluation is carried out in a static model, which leads to time consumption and higher development costs. In this work, an attempt has been made to quantify the fit objectively for a basic crewneck T-shirt for men's wear made of cotton and cotton-lycra blended single jersey knitted fabric. A parametric avatar model was created, and virtual patterns were developed by changing the design parameters at three levels in the CAD platform. The fit is objectively quantified as strain and ease in different garment fit zones of the body. Virtual 3D fit software evaluates the fit zones of the garment by incorporating the low-stress mechanical properties of the knitted fabrics into an avatar model. There is a significant influence on pattern parameters and material compositions; cotton-lycra garments reveal lower ease at various fit zones.

***Keywords*:** Armhole curve, ease, garment fit, low-stress

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ÖZ: Giysi uyumu vücut oranı, kumaş ve tasarım parametrelerinden etkilenir, ancak uyum değerlendirmesinin çoğu statik bir modelde gerçekleştirilir, bu da zaman tüketimine ve daha yüksek geliştirme maliyetlerine yol açar. Bu çalışmada, pamuk ve pamuk-likra karışımlı süprem örme kumaştan yapılmış erkek giyimi için temel bir kruvaze yaka tişört için uyumu objektif olarak ölçmek için bir girişimde bulunulmuştur. Parametrik bir avatar model oluşturulmuş ve CAD platformunda tasarım parametreleri üç seviyede değiştirilerek sanal kalıplar geliştirilmiştir. Uyum, vücudun farklı giysi uyum bölgelerindeki gerginlik ve rahatlık olarak objektif olarak ölçülür. Sanal 3D fit yazılımı, örme kumaşların düşük gerilimli mekanik özelliklerini bir avatar modeline dahil ederek giysinin fit bölgelerini değerlendirir. Desen parametreleri ve malzeme bileşimleri üzerinde önemli bir etki vardır; pamuk-likra giysiler çeşitli uyum bölgelerinde daha düşük rahatlık gösterir.

Anahtar Kelimeler: Kol deliği kıvrımı, kolaylık, giysi uyumu, düşük stres

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1. INTRODUCTION

Consumers purchasing apparel products are attracted to the design elements where fit plays an essential role in purchasing decisions**,** as well-fitted apparel allows freedom of movement and comfort for the wearer without any restrictions. [1]. It also presents challenges for retailers, as many apparel products are unsold due to fit issues, as the product is not fitted to the correct size of the consumer; even online retailers are facing major fit issues due to a lack of information on measurements and body shapes for producing the proper fit apparel [2, 3]. A major clothing brand is also experiencing sizing and fit issues with customers [4]. In the manufacturing process, the development of fit samples is the essential process of getting approval from the client to manufacture the right-fitting apparel for consumers, which will also reduce the prototype [5].To develop an apparel product with a good fit, a proper understanding of the relationship between ease, the shape of the human body, and a garment is important. To a certain extent, body cathexis affects the fit through negative and positive feelings about the body of the wearer [6, 7]. The fit of apparel is a combination of ease, line, grain, balance, and set. The ease is the difference in measurements between the individual wearer's body and the garment, as well as the ease that includes functional and styling purposes. The functional ease of the garment allows the body movement without any restriction. Functional ease, which is very crucial in apparel [8, 9].

The fabric elongation, recovery characteristics, and garment style features should also be considered as important parameters in the design of apparel. Negative ease is required in the design of products made from stretch fabric for the application of action sportswear. Another factor is the line, which introduces fullness in the form of a dart, pleat, tuck, or gathering to make the wearer appear shorter or taller. The set is referred to as the garment construction aspects, it is often termed "workmanship," where the finished appearance of the apparel should be free from puckering and have a smooth appearance without any conspicuous construction defects. The set indicates the absence of wrinkles in the constructed garments.

The balance is achieved by making the visual space of the various parts of the apparel equal or unequal; the balance can be introduced in horizontal, vertical, or radial spaces. Understanding the anatomy of human figures determines the introduction of balance into the visual space. It is also related to how the garments hang evenly on the left and right sides of the body. The grain is the direction in which the pattern components are arranged to cut and sew the garment panels; grain directions affect fit and are frequently related to sets of yarn arrangements in fabric formation such as weaving or knitting. Many researchers determine the fit subjectively; the competent expert is asked to judge the fit in the critical zone by scale ratings.

Evaluation of the apparel fit is very important for product design and manufacturing [10]. Nowadays, with the advent of 3D CAD technology that can virtually simulate the garment over the parametric avatar model by developing the 2D pattern in CAD software and virtually stitching the components of a garment, such an avatar can be created based on the individual body measurements. It also has a scope for comparing virtual and real fit by quantifying the ease and strain in the different fit zone regions [11, 12]. When making a decision, objectively quantifying the fit will also aid in correlating with subjective assessment. Deepti Gupta also reported that with CAD/CAM technologies, garment fit testing can be measured very accurately on a virtual platform with different postures [13]. The 3D technology also incorporates fabric properties, particularly low-stress mechanical properties, into the design of 2D patterns and virtual simulations. It has a provision to create a library of fabric properties and integrate it into the CAD system, which will also reduce prototyping and make the product in a shorter time. Automated virtual pattern development systems provide a better custom fit based on consumer demand and requirements [14]. Several researchers are currently attempting to relate the mechanical properties of various woven fabric materials by determining the strain and ease distribution of apparel fit. Penelope Watkins has also made extensive attempts in stretch garment design for assessing the fit objectively [15].

This study focuses on the optimization of pattern design variables on men's basic garment style made from single jersey knitted cotton and cotton-lycra blended fabric, which are ideal for casual wear due to tactile comfort characteristics [16,17,18].The aim of the work is to find the relationship between pattern design parameters and garment fit in the various critical fit zones for the wearer by considering the low-stress mechanical properties of the fabric. The strain and ease in different fit zones are quantified by performing experiments in a virtual simulation and reporting the findings in the statistical model.

2. MATERIAL AND METHOD

2.1 Material

The single jersey knitted fabrics of 100% cotton (F1) and the blends of 95% cotton and 5% lycra (F2) are sourced and tested for their various parameters, as shown in Table 1. Low-stress mechanical properties of the knitted fabric are also tested with the specimen size of 20 cm x 20 cm in the Kawabata evaluation system. The tests, such as tensile, bending, shear, and friction, were determined and shown in Table 2. The tested values were fed into the virtual software. The total handle value is also determined for the fabrics.

2.2 Pattern Development method in virtual platform

The patterns for basic knitted T-shirt styles used for 100% cotton and 95% cotton-5% lycra fabrics were developed in the Lectra-Modaris V8R1 3D fit software. In the virtual simulation platform, seventeen patterns were created to determine the garment fit. The patterns were developed by altering the ease and pattern shape in the fit zones. The selection of ease was changed in the side seam of the pattern in three levels, and the shoulder drop was changed where the shoulder length connects the neck and arm region. The armhole curve is concave on three levels. For the shape of the armhole, the sleeve patterns were made by changing the sleeve cap curve and sleeve cap height. The main intention of changing the sleeve pattern is to determine the fit in the upper arm region. To quantify the ease and strain at the fit zones objectively, a parametric avatar model has been created based on the measurements of the subject. The subject measurements are 104 cm- full chest, 46 cm- across the shoulder, and 25 cm- in the upper arm to create a parametric avatar model to find the fit virtually, and zones of fit were assessed in the chest, shoulder, and upper arm regions.

2.3 Garment Fit Assessment and analysis

Design expert software 8.7.0.1 was used to analyze the effect of the interaction of pattern design parameters on the fit of the basic knitted style. The coded levels of the parameters are mentioned in Table 3. Ease reduction is determined by dividing the average value of F2 and F1 for both chest and armhole ease from the optimized pattern parameters. Based on the optimized pattern parameter, garments were constructed and the wear study was carried out subjectively. The subjects were asked to wear the garments, the following questions were asked to the wearer:1**.** Does the garment fit exactly to your body's contour? 2. How does it feel while rotating the arm region 3. Does it feel compatible while twisting your hip region? 4. How does it feel while having motion in scapula region? 5. Does circumduction feel (hip) comfortable? 6. Would you kindly rate the comfort of the garment? The subject were asked to rate using a Likert scale. Excellent -5, Very good-4, Preferable fit-3, Fair-3, Poor fit-1, Not fit-0.

Table 1. Fabric parameters of the tested samples

Fabric particulars	F1 (100% cotton)	F2 (95% Cotton and %5 Lycra)
Fabric weight (g/m^2)	162	145
Fabric thickness (mm)	0.61	0.73
Loop length (cm)	0.31	0.38

Table 2. Low stress mechanical properties of single jersey knitted fabric

Fabric	Tensile				Bending		Shear		Friction	Handle value
	LT	WTgf.cm/cm^2	RT%	EMT%	B gf.cm^2/cm	2HB gf.cm/cm	G gf/cm.deg	2HG gf/cm	MIU	THV
F1	0.707	0.83	37.07	9.365	0.027	0.010	0.79	3.71	0.208	4.13
F2	0.461	1.09	59.4	17.07	0.010	0.014	0.58	1.88	0.223	4.48

Table 3. Coded Levels For Developing Virtual Patterns

Pattern Parameter	F1 and F2 Garments		
	Level 1	Level 2	Level 3
Chest ease (cm)	5	6	7
Shoulder drop (cm)	2	2.5	3
Armhole curve (cm)	0.5	1	1.5

Table 4. Fit zone ease and strain

S.No.	Chest Ease (cm)	Shoulder drop (cm)	Armhole curve shape (cm)	Chest Region –Fit		Shoulder Region -Fit		Upper arm Region Fit	
				F1 Fabric	F2 Fabric	F1 Fabric	F2 Fabric	F1 Fabric	F2 Fabric
1	6	3	0.5	9.86	4.71	-1.71	0	0	0
2	6	2	1.5	10.83	4.92	-16.1	-0.17	-1.79	0
3	6	2.5	1.5	15.93	7.62	-7.45	0	5.04	0
4	7	2.5	1.5	9.29	5.72	-5.7	-2.61	0.3	1.98
5	7	2.5	0.5	12.43	6.78	-4.88	-2.4	5.6	1.72
6	6	2.5	1.5	15.93	7.62	-7.45	0	5.04	0
7	5	3	1.5	9.43	1.78	-1.41	-1.98	-0.01	0
8	7	3	1.5	15.56	7.48	-0.62	-2.89	3.51	0.97
9	6	2	0.5	6.37	5.4	-8.52	-0.57	1.51	0
10	6	3	1.5	12.2	3.63	-2.82	-3.08	1.29	0.52
11	6	2.5	1.5	15.93	7.62	-7.45	0	5.04	0
12	5	2.5	1.5	5.17	5.91	-3.76	-2.73	0	0.82
13	6	2.5	1.5	15.93	7.62	-7.45	0	5.04	0
14	7	2	1.5	13.74	5.431	-1.43	-0.22	0	0
15	5	2	1.5	5.72	4.75	-1.54	-2.9	1.89	0.87
16	5	2.5	0.5	7.13	6.5	-3.49	-2.93	0	0
17	6	2.5	1.5	15.93	7.62	-7.45	0	5.04	0

3. RESULTS AND DISCUSSION

The results in Table 4 show the strain and ease obtained from the virtual simulation of the avatar for the various critical fit zones. The Table 5 shows the ANOVA test results of the fit repsonses for F1 and F2 fabric . The effect of the independent variables on garment fit at various fit zones is discussed.

3.1 Effect of pattern parameters on fit in the chest region

Figure 1 shows the effects of chest ease and shoulder drop on garment fit at the chest region for the garments made from F1 and F2 knitted fabrics. The garment fit made from F1 fabric influenced by the chest ease significantly (p value 0.0018<0.05), but the interaction between chest ease and shoulder drop, shoulder drop and armhole curve, and chest ease and armhole curve shows insignificant influence (p-value 0.5985, 0.7407, and 0.558> 0.05) at the 95% significant level. The F1 material's virtual pattern side seam has been drafted straight without any concave shape that makes it more ease in the chest region, at a maximum of 15.93 cm and a minimum value of 5.72 cm. Sufficient ease is also required for the wearer to provide ergonomic comfort for normal activities. Winfred Aldrich reported that for leisure wear and sportswear made from jersey fabric, the side seam of the pattern for men's wear is drawn straight for easy fitting [19]. The fit at the chest region for the garment made of F2 fabric was also influenced by chest ease (p value 0.00134<0.05). The interaction between chest ease and shoulder drop is having significant influences (p-value 0.0216 is less than 0.05). As there is an increase in shoulder drop measurements, the ease is also reduced in the chest region. The other factors could be the reduction of ease for F2 fabric, and blending of lycra material also contributes to good elongation and recovery in the chest region. The interaction of shoulder drop and armhole curve and chest ease and armhole curve shows insignificant influences for F2 fabric (p-value 0.7908 and 0.7353> 0.05) at 95% level.

3.2 Effect of pattern parameters on fit in shoulder region

The Figure 2 shows the effects of shoulder drop and armhole curve on garment fit at the shoulder region for the garments produced from F1 and F2 fabrics. The F1 fabric shows the selected chest ease, shoulder drop, and armhole curve having significant influences on the fit of the garment individually. The interaction between chest ease and shoulder drop, shoulder drop and armhole curve, and chest ease and armhole curve are also significant influences (p-value < 0.05). The F1 material exhibits more strain in the shoulder region due to the deeper armhole curve. Regarding F2 material, the interaction between chest ease and shoulder drop (p-value 0.0026), shoulder drop, and armhole curve (p-value 0.0031) shows significant influences. The p-values are less than 0.05. Figure 2 also shows an increase in the shoulder drop reflects strain in the shoulder fit zone, but the overall strain is less when compared to F1 material. Since the low-stress mechanical properties tensile strain (EMT) and tensile resilience (RT) are higher for F2 fabric, eventually it will have good wearing comfort. The bending rigidity and bending hysteresis are lower for the F2 fabric. So, the F2 fabric bends easily and has a higher ability to recover.

3.3 Effect of pattern parameters on fit in upper arm region

The Figure 3 shows the effects of shoulder drop and armhole curve at the upper arm region for F1 and F2 fabric garments. The F1 fabric shows the individual parameters, and the interaction between chest ease and shoulder drop, shoulder drop and armhole curve, chest ease and armhole curve shows significant influence as (p-value < 0.05). The interaction between chest ease and shoulder drop shows that an increase in the shoulder drop provides less ease in the upper arm region for F1 fabric garments. By varying the chest ease and the interaction between the chest ease and armhole curve for F2 fabric, it also shows significant influences on garment fit at the upper arm region as a p-value <0.05. But the F2 material's strain and ease have been noticed in the interaction of chest ease and shoulder drop. This may be due to shear properties that affect the surface fitting characteristics in the upper arm region; the F2 fabric has shear rigidity, shear hysteresis shows lower, and eventually, the fabric has an excellent ability to recover after it is sheared, which influences lower ease. It is also observed that, based on the low stress properties, the compression resiliency of the F2 fabric is higher when compared to the F1 fabric, which influences the reduction in ease in the upper arm region. The interaction of shoulder drop and armhole curve, chest ease and armhole curve shows insignificant influence for F2 fabric (p-value 0.4886 and 0.5191> 0.05) at 95% level.

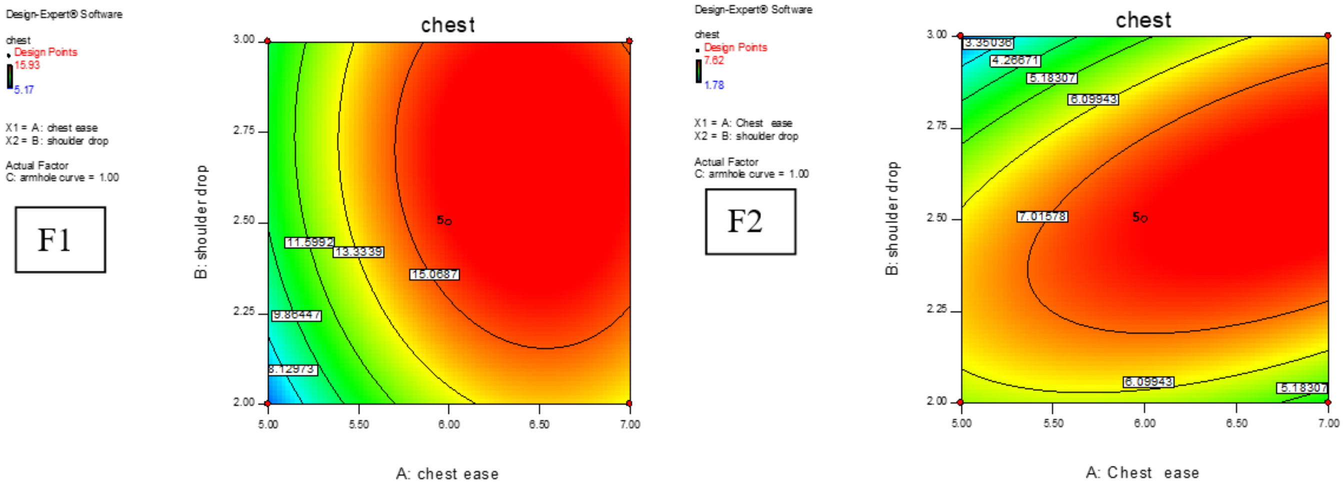


Figure 1. Effect of chest ease and shoulder drop on fit at Chest region for F1 and F2 fabric made garments

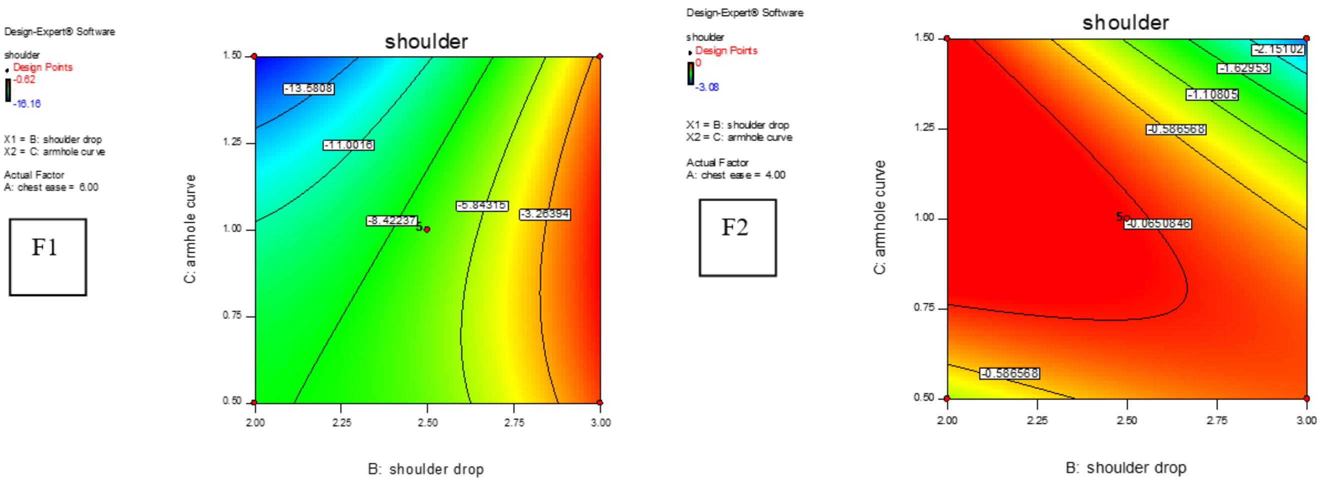


Figure 2. Effect of shoulder drop and armhole curve on fit at Shoulder region for F1 and F2 made garments

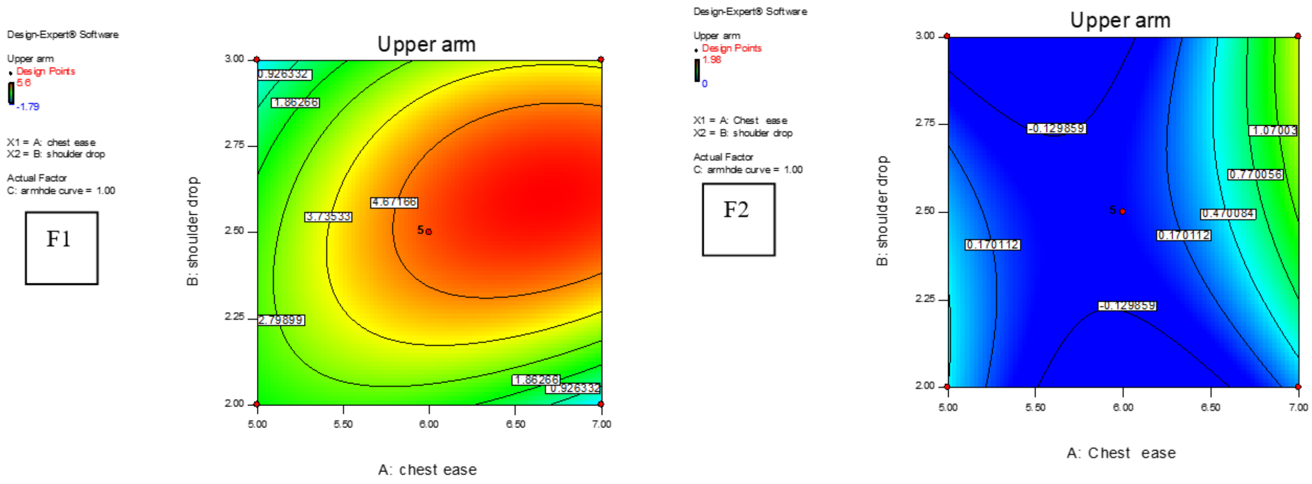


Figure 3. Effect of chest ease and shoulder drop on fit at Upper arm region for F1 and F2 made garments

Table 5. ANOVA Test results for the responses –Chest,Shoulder and Upper arm

	Chest		Shoulder		Upper arm	
Source	F1 p-value	F2 p-value	F1 p-value	F2 p-value	F1 p-value	F2 p-value
Model	0.0046	0.0134	< 0.0001	0.0003	< 0.0001	0.0333
A-chest	0.0018	0.0314	< 0.0001	0.0669*	< 0.0001	0.0285
B-shoulder drop	0.0693*	0.2681*	< 0.0001	0.0080	< 0.0001	0.5851 *
C-armhole curve	0.7361*	0.2249*	< 0.0001	0.0469	< 0.0001	0.1833*
AB	0.5985*	0.0216	< 0.0001	0.0026	< 0.0001	0.0474
AC	0.7407*	0.7908*	< 0.0001	0.6197*	< 0.0001	0.4886*
BC	0.5558*	0.7353*	< 0.0001	0.0031	< 0.0001	0.5191*

* *not significant at 95% level*

3.4 Determination of ease reduction

The Table 6 shows the best optimized solutions obtained from the design expert software for pattern parameters. The chest and armhole ease have significantly reduced for the F2 fabric; the reduction of ease is around 12 to 13%, and a conversion factor has been derived by dividing the average value of F2 and F1 for both chest and armhole ease. The conversion factor was found as (5.76/5.02=0.87 for chest ease and 1.33/1.55=0.88 for armhole ease). This conversion factor can be used for the reduction of ease measurement for fabric having 95% cotton and 5% lycra constitution, which also contributed to the fabric savings.

3.5 Virtual simulation and subjective assessment

Based on the optimized parameters obtained from the design expert software, the actual garment was constructed, and the fit is evaluated in the static and dynamic movements from the wearer's perspective. The opinion from the subject stated that the garment fits well without any discomfort in the selected critical zones, such as the chest region, armhole region, and upper arm region, as shown in Figure 4. The F2 fabric garment fits better, and it is also observed from Table 2 the total handle value of F2 fabric is higher as compared to F1 fabric. The final virtual simulated garment and optimized response values for crtical fit zone responses are shown in Figure 5 a and b.

Table 6. Optimized pattern parameters for F1 and F2 fabrics

Solutions numbers	Chest Ease (cm)		Armhole curve ease (cm)	
	F1	F2	F1	F2
1	5.6	5	1.5	1.34
2	5.62	5.02	1.5	1.36
3	5.72	5.03	1.5	1.36
4	5.66	5.05	1.5	1.38
5	5.42	5.05	1.5	1.36
6	5.57	5	1.49	1.28
7	5.6	5	1.5	1.32
8	5.91	5.07	1.5	1.39
9	5.37	5	1.5	1.24
10	6.24	5	1.5	1.35
11	6.04	5.02	1.46	1.37
12	6.38	5	1.5	1.18
Average	5.76	5.02	1.5	1.33

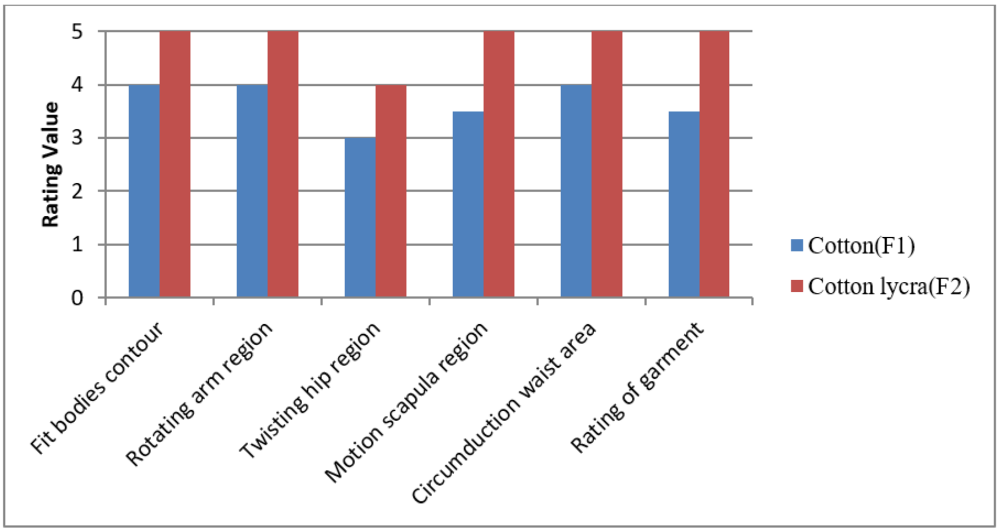
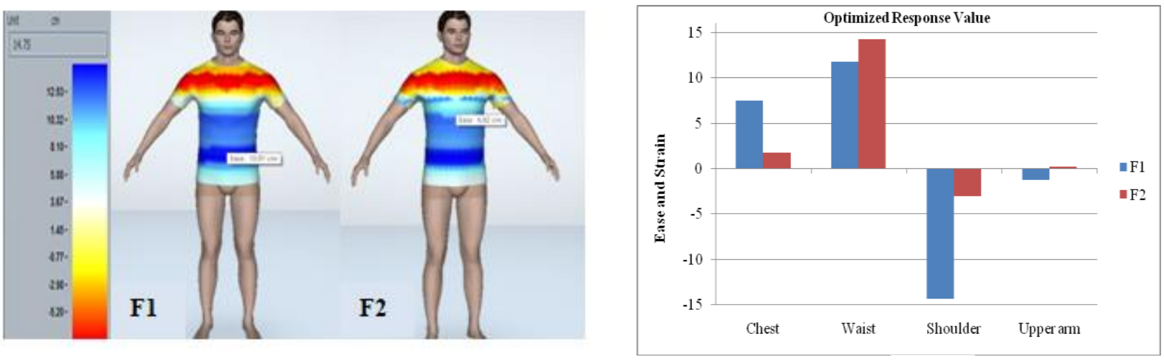


Figure 4. Subjects rating value



(a)

(b)

Figure 5. a) Virtual simulation of F1 and F2 fabrics and b) optimized values

4. CONCLUSION

The experimental investigation was conducted on a virtual platform by changing the pattern parameters and the strain and ease values for both F1 and F2 knitted materials in the critical fit zones. The key conclusions are summarized as follows:

- The influence of pattern design parameters has significant effects on the fit zone of the chest region for both fabric garments due to the shaping of the pattern, but the quantum of ease reduction is much higher for F2 fabric garments due to the influence of fabric properties.

- The shoulder fit zone exhibits strain for both styles, which is much higher for F1 compared to F2 due to the influence of the shear properties of the fabric. In the upper arm, minimum ease has been obtained for F2 due to the higher compression resiliency properties of the fabric.

- The desirable percentage for optimized pattern parameters for both styles is obtained above 80%; the low stress mechanical properties of knitted fabrics and pattern design variables make a significant contribution to the apparel fit, which is exactly quantified in the virtual fit. As the garments are also developed and evaluated with the actual subject, there are significant differences in the fit of the actual garment made from the optimized design data for both materials, and F2 outperforms F1 due to better handle and elongation properties.

- The optimization of pattern parameters and finding of ease reduction makes a significant contribution to the reduction of fabric waste in the apparel industry for mass production. This finding also helps the customized garment development based on fabric properties in the segment of digital marketing of apparel products on the online platform.

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