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STRUCTURAL CONSTRUCTS AND EASE REDUCTION TREATMENT INTERFACE RELATED TO CLING FIT

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Abstract:

Garment cling fit is a proximal fit that emphasizes close clinging contour lines of the apparel maintained by it on the human body in regular postures and while performing primary movements. To understand the nature of interface between ease reduction treatments and structural constructs, three-dimensional (3D) modeling of human body using body mapping concept and ease reduction treatment's role in explaining the garment strain patterns in cling fit conditions were investigated. We report the impact of ease reduction treatment that defines the proportions and measurements of the cling fit pattern with reference to human body surface profile.

Keywords:

Ease reduction treatment, cling fit, structural constructs, FSWL, cross contours, garment strain, in-plane fabric shear

1. Introduction

1.1 Fit

Fit is defined as a combination of the following five factors: ease, line, grain, balance, and set [1]. Ease and grain are determined at the pattern design stage, whereas the line of the form is expressed through the constructional lines. The three parameters ease, grain, and line of the form constitute the means to achieve set of the fabric planes on human body surface and balance. In the context of cling fit attributes, balance and line of the garment form are subject to the forces acting on it by the human body across various states of movement patterns and postures. The angles and postures subtended by each body segment are function of time and range of motion [2]. For an ideal fit, there should not be any garment slip and no parts of the garment may ride up or pull itself to one side at any contact area [3]. In this context, not only the cling fit garment as a form should be capable of straining itself and fit the human body shape cum surface profile but also should be capable of accommodating the skin expansions and musculature growth effected during postural changes and human body primary movements.

1.2 Representation of human body three-dimensional (3D) form in two-dimensional (2D) shapes

Hence, in order to produce an optimized contour fit pattern, linear measurements (1D) of anatomical landmarks and approximation of (2D) shape of key human body structural constructs serve as key inputs to achieve right pattern shape and its subsequent 3D form upon garment construction out of it [4]. In the contemporary scenario, 3D body modeling is carried out using Gregory patches modeling and spline curves surface modeling [5]. Meanwhile, the French curve considering its versatility in reproducing any surface profile of human body is used to deconstruct the 3D form and represent the same in 2D shapes with key anatomical/structural constructs. The French curve comprises a smoothed outline from its distant edge that compliments as a tangent to its curved semicircular profile at the opposite edge. In fact, it helps to produce concentric partial curves of varying radii from a specified point which is contrary to what Hu [6] claimed about them. It also helps to project human body 3D surface profile in 2D shapes by characterizing the various transverse/cross contour profiles at different elevations. The angular displacement and linear displacement of the undulating surfaces from a central reference line are also captured using French curve. Further by segmenting the 2D shapes along the complex curves of human body, we obtain the referential structural constructs like front waist shoulder line or the princess seam line which intersects and divides the body contours into a straight line and partial parabolic or quarter elliptical curvature at bust line elevation, waist line elevation, and hip line elevation. Since the primary part of scale referencing for all human designs is human body [7], it is also possible to mark other referential structural constructs like the back shoulder waist line, front waist hip line, and back waist hip line on the human body to serve as shape referencing structural constructs. Figure 1 is the representation of 3D human body as segmented shapes highlighting the cross contours, curves subtended by the cross contour lines, longitudinal referential constructs, and its outlines.

1.3 Fabric stretch property complimenting proximal fit

The amount of fabric stretched to fit the human body shape depends on the recovery properties of the fabrics. Fabrics with 15–30% elongation meet the many end uses of garments by means of reduced resistance to body movements in close fit conditions [8]. Further fabric stretch behavior is classified into two categories namely, ability to stretch – if the fabric has low resistance to stretch and high friction against the skin or fabric

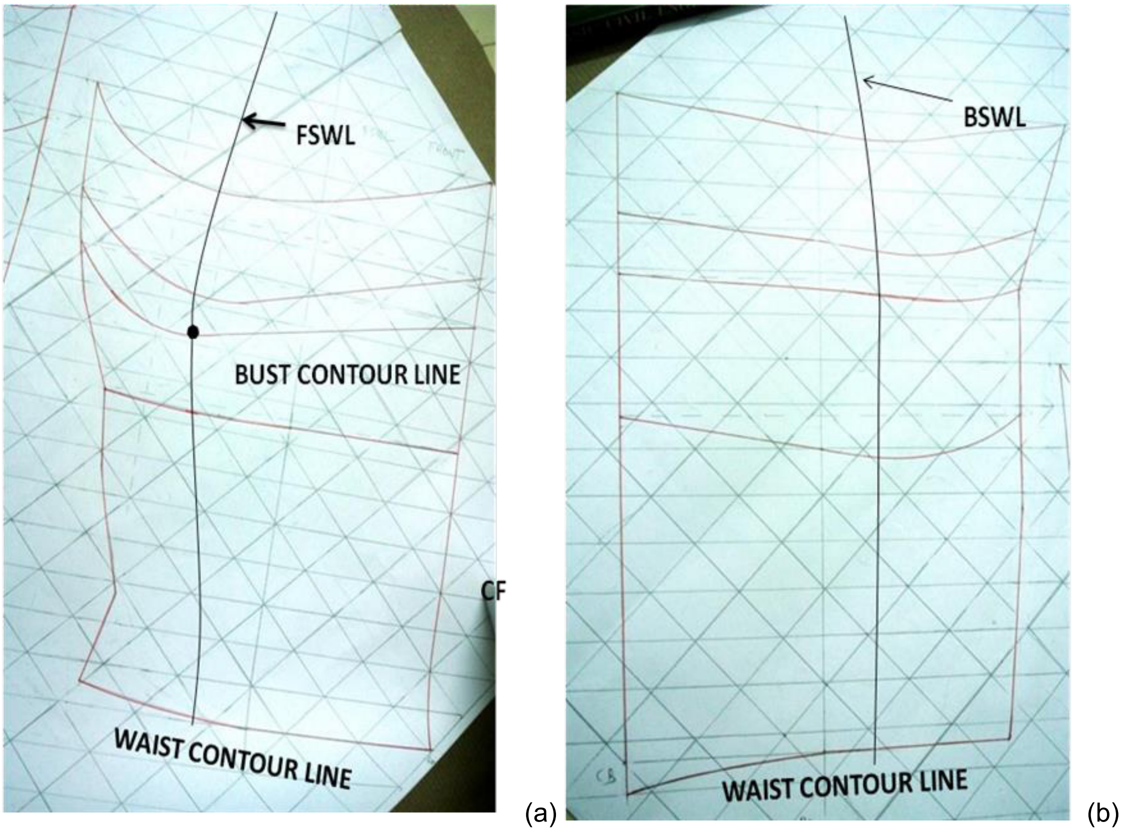


Figure 1. Segmented representation of top part of three-dimensional human body: (a) front and (b) back.

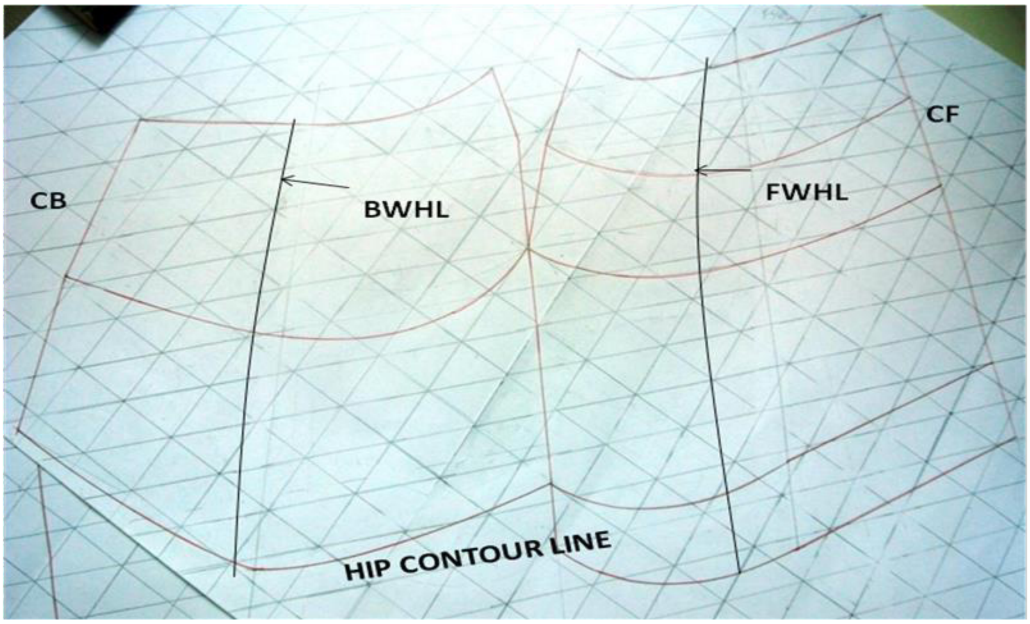


Figure 2. Segmented representation of bottom part of three-dimensional human body: back and front.

and tendency of fabrics to exert pressure and if fabric has both high resistance to stretch and high friction [8]. While in the case of non-stretch fabrics, pattern blocks using body darts to denote 3D form are incorporated to accommodate the movement [9].

1.4 Interface between human body shape profile and garment strain behavior

In previous research studies, studies emphasized ease reduction treatment as the major determinant for standardizing fit, and the geometrical profile of pattern was shaped by the primary 1D and 2D constructs of the human body: bust, waist, sleeve crown, etc. Studies also focused on optimizing the pattern profile geometry with minimum fabric displacement at rest [3]. However, to understand the complex relationship between seamless human body surface profile and pattern geometry profile under cling fit conditions in terms of garment's strain behavior, it is essential to investigate the impact of secondary human body constructs for example front shoulder waist line (FSWL) that is positioned at the complex curves of human body. These complex curves given their structural position where not only the cross contours exhibit a change in direction but the longitudinal lines also indicate a change in direction serve as principal stress-acting areas in cling fit conditions. As we interpret the geometry of the 3D human form, it is along this secondary construct FSWL the semielliptical cross contour smoothes out to a flat curve. This shape profile is analogous to the concept of involute of a composite shape. Hence, this secondary construct offers information about the human body surface geometry changes. Obtaining information about garment strain behavior at designated secondary constructs like FSWL, a complex curve shall provide us the inputs for better matching of stretch pattern geometry profile to human body surface profile. Furthermore, it will also help us in understanding the dynamic garment balance of cling fit expressed through in-plane shear and garment strain. In other words, the principal stress-acting complex curve along the FSWL behaves as a control point in modeling the deformation of 2D pattern shape for fitting 3D human forms under stretched conditions. It serves to explain the garment surface skew in state of cling fit.

2. Experiment

Hypothesis

To ascertain the relevance of ease reduction treatment in determining the internal proportions of garment pattern that consequently explains the local fabric strain pattern in the cling fit.

To represent in-plane fabric shear through the resultant shear force and shear angle measured at the principal stress acting area: FSWL.

2.1 Materials

Three types of warp knitted fabrics were chosen with three levels of blend proportions for polyester to spandex ratio. The higher the spandex percentage in blend proportions, higher is the fabric stretch ability. Under cling fit conditions, the fabric is stretched and deformed to fit the human body. Hence, this cling fit context underlines the requirement for uniform tension distribution along the fabric panels in the garment that is only fulfilled by elastic modulus of the fabric. Stable elastic modulus is taken care by the stretch recovery properties. The stretch levels of the chosen fabrics determined by ASTM D2594-2008 fall into three levels as follows: 61 & 50, 57 & 73, and 33 & 77. Furthermore, the warp knitted fabric weights fall into two categories as follows: 300 GSM and 180 GSM. Owing to its high density, the heavier fabric weight has higher modulus that necessitates the requirement for comparatively larger force in order to stretch or deform. However, as fabric thickness is also high for heavier fabric, it aids in deforming to cling fit state at small stretch ratios.

2.2 Methods

Ease reduction treatments

In each ease reduction treatment, the pattern length was kept same as the body section length considering the human movement patterns and the fact that when the garment layer is closest to the body will follow the body contours and the length shall be higher than the one of a semifitted garment [10]. Meanwhile, pattern width is reduced systematically as per the three methods explained below to fulfill the cling fit attributes. Thus, three different treatments represented by three ease reduction concepts were applied across three different fabric types: A, B, and C in singlet garment form. A real model close to UK size 10 with slightly bigger bust size and hip measurements was chosen for the experimental study. The pattern reduction amount was calculated through the method proposed by Watkins [11] with a slight modification; pattern ease reduction is applied only across the width. Across the ease reduction treatments, the internal proportional distribution of pattern segments at the intersection of FSWL and bust contour line varies from one ease reduction treatment to another. Furthermore, stretch reduction factor for each fabric is intentionally kept well within the elastic limits where linear relationship between stress and strain existed.

3. Results and discussion

3.1 Relevance of ease reduction concept in determining the garment strain pattern

The fabric surface is marked by grid lines spaced one inch apart in both vertical direction and horizontal direction. The perimeter of two adjacent one square inch grids adjoining the

Table 1. Fabric parameters

S. no	Fabric	Composition		GSM	Stretch			
		Polyester	Spandex		Wale direction	Recovery (after 1 min)	Course direction	Recovery (after 1 min)
1.	A	91%	9%	300	61.2%	84.2%	50%	84.2%
2.	B	81.5%	18.5%	180	57.2%	84.2%	73.2%	92.1%
3.	C	84.8%	15.2%	180	32.8%	89.5%	77.2%	89.5%

Table 2. Ease reduction treatments

S.	Ease reduction parameters	E1			E2			E3		
1.	Stretch reduction factor	100/(100+stretch reduction%)			100/(100+stretch reduction%)			100/(100+stretch reduction%)		
2.	Total width way reduction amount	WRF at CF = (WRF/4) WRF at SS = [(WRF/4)´3]			Ease reduction amount distributed equally and applied at both the sides of X coordinates			WRF at CF = (WRF/4) WRF at SS = [(WRF/4) ´3]		
3.	Additional relaxation amount	Nil			Nil			[(WRF/4)´3] ´ contour suppression relaxation factor (0.5) Contour suppression relaxation factor = 100/(100+waist to hip difference in percentage) = 0.5		
4.	Proportional distribution of half body torso at the intersection of FSWL and bust contour line between CF and side seam	A	44%	56%	A	36%	64%	A	41%	59%
		B	45%	55%	B	34%	66%	B	42%	58%
		C	45%	55%	C	33%	67%	C	43%	57%

Note: A, B, and C represent the following three fabrics: fabric A, fabric B, and fabric C.
FSWL, front shoulder waist line.

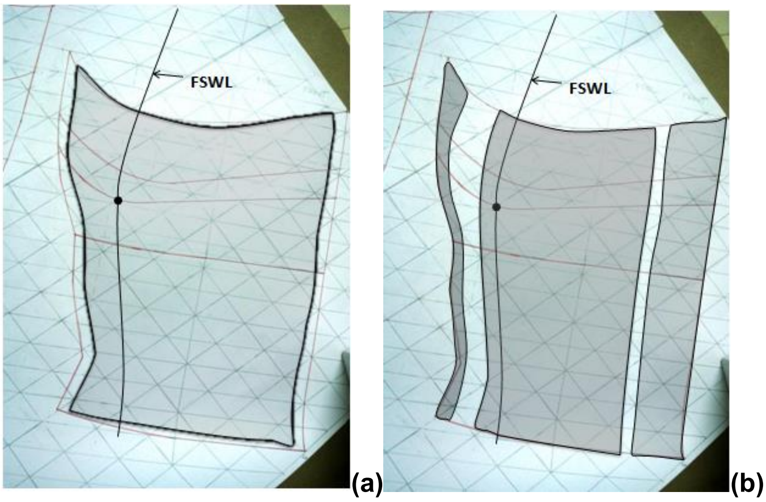


Figure 3. Ease reduction treatments: (a) ease reduction treatment 1 and (b) ease reduction treatment 2.

Table 3. Key garment measurements after ease reduction treatment application for fabric A @ 30%, fabric B @ 45%, and fabric C @ 50%

S. no	Anthropometric points	E1A	E2A	E3A	E1B	E2B	E3B	E1C	E2C	E3C
1.	Armscye depth	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5
2.	Bust	65	65	73	58	58	69	56	56	67
3.	Waist	57	52	57	50	47	50	48	45	48
4.	Hip	73	71	77	66	64	72	64	61	70

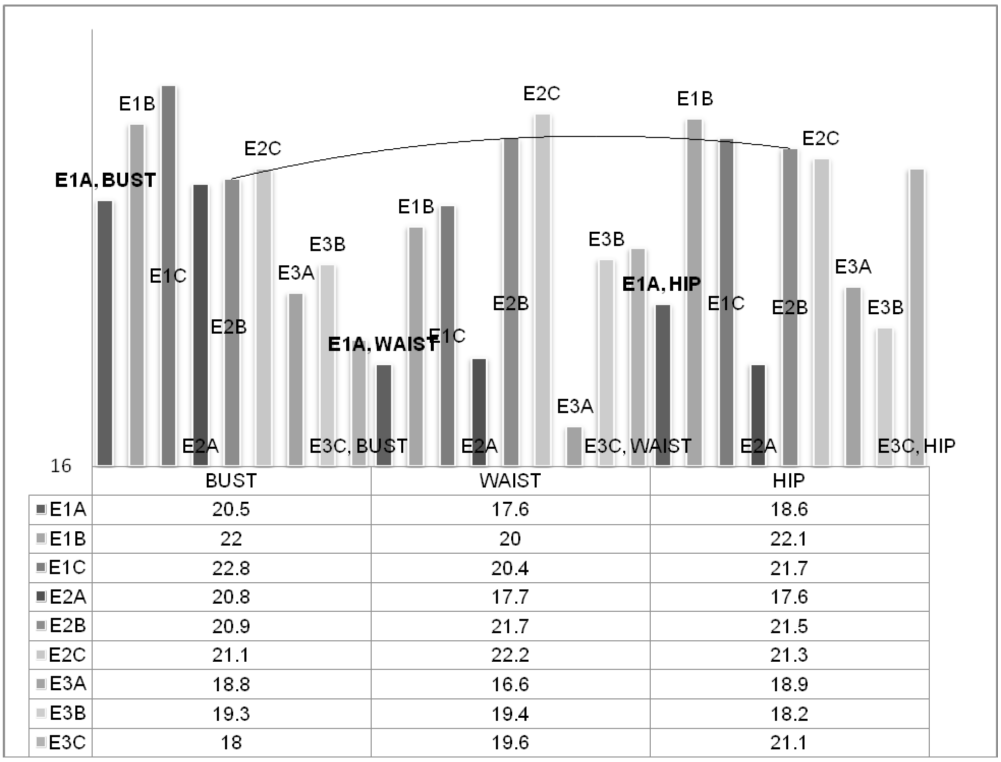
Note: From the final measurements of the garment, it could be seen that for all the ease reduction treatments effected on fabrics B and C, the stretch ratio of the garment is high. In other words, garments made of fabrics B and C should stretch and deform more to fit the body.

Figure 4. Proportional distribution of pattern segments at the intersection of front shoulder waist line and bust contour line.

intersection of FSWL is measured to reflect upon the nature of strain, as these two adjacent grid's angles and distortion profile are larger in values and act as sites of principal stress in the singlet garment. Higher the strain, larger is the perimeter of the adjacent grid squares and higher is the distortion. They are also located along the most complex curve of human body where we witness the presence of hills, arcs, and undulating curves located along the same line. The horizontal grid lines and vertical grid lines take the shape of distorted profile due to deflections the fabric undergo at the hills and undulating areas of the human body surface profile (Figure 5). As a result of this, the arc constituted by the transverse reference contour lines marked in the singlet garment deviate from the original position of the reference cross contours indicated on the developed 2D layout.

In garments made from fabric A across all ease reduction treatments, the perimeter of two adjacent grids on either side of the intersecting FSWL at bust contour line, waist contour line, and hip contour line witnessed comparatively lower values *as its stretch ratio is low.* The garment's cross contour lines at waist and hip for ease reduction treatment 1 and ease reduction treatment 2 exhibited large deflected curve profiles. The dipping trajectory of the curve indicates high amount of distortion and strain. Owing to the ease reduction treatment 1 impacts on fabrics B and C, the perimeters of the two adjacent grids intersecting FSWL recorded higher values in the range of 22.0 and 22.8 (Table 4) at the bust contour line. Meanwhile, due to ease reduction treatment 2 impacts on fabrics B and C, and smaller perimeters in the range of 20.9 and 21.1 (Table 4) were recorded at the bust contour line indicating lower strain compared to ease reduction treatment 1. Although the bust measurements on the finished garment were same for

Table 4. Perimeter of adjacent grid squares for each ease reduction treatment.



	BUST	WAIST	HIP
■ E1A	20.5	17.6	18.6
■ E1B	22	20	22.1
■ E1C	22.8	20.4	21.7
■ E2A	20.8	17.7	17.6
■ E2B	20.9	21.7	21.5
■ E2C	21.1	22.2	21.3
■ E3A	18.8	16.6	18.9
■ E3B	19.3	19.4	18.2
■ E3C	18	19.6	21.1

Note: All the measurements are in centimeter.

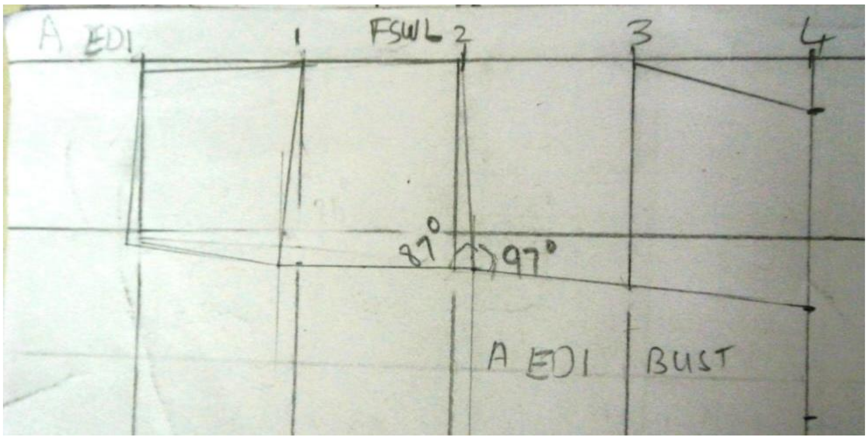


Figure 5. Traced example of bust contour line deflection at the intersection of front shoulder waist line.

both E1 and E2 at the given stretch levels for fabrics B and C, the relatively smaller strain pattern at the bust contour line is witnessed in ease reduction treatment 2. As expected, the ease reduction treatment 3 that had additional ease at the bust contour also recorded lower values for the perimeters of adjacent grids across both fabrics B and C: 19.3 and 18, respectively (Table 4).

At the waist zone, the perimeters of adjacent grids along the intersection line were higher in ease reduction treatment 2 for fabric B (21.7) and fabric C (22.2) compared to ease reduction treatment 1 for fabric B (20) and fabric C (20.4) (Table 4). This is attributed to the lower waist measurements of the finished garments in ease reduction treatment 2. At the hip zone, no significant difference existed between the ease reduction treatment 1 and ease reduction treatment 2. Ease reduction treatment 3 recorded minimum perimeters for the adjacent grids located at the intersection of FSWL and contour lines across all three zones: bust, waist, and hip for fabrics B and C. This owing to the slightly lower strain levels that is attributive of relaxation factor added at bust and crotch in it.

3.2 Principal in-plane fabric shear

As the fabric is stretched to fit the body, the amount of bending of the grain line along the garment length and the deflections of the cross grain line in *Y* axis serves to depict the fabric in-plane shear during wear. Identifying the ease reduction treatment that induces minimal fabric shear upon wear would act as a measure of optimum fit. Meanwhile, in the assessment of garment cling fit, zones encompassing the complex curves produce maximum strain on the fabric indicating combined action of tension forces and bending moments. In other words, human body form acts as the load and the extended zones of the fabric indicate displacement. Hence, the fabric in-plane shear (Figure 6) is computed from the resultant shear force affected by the bending of grain line along FSWL and cross grain deflections at the hip contour line.

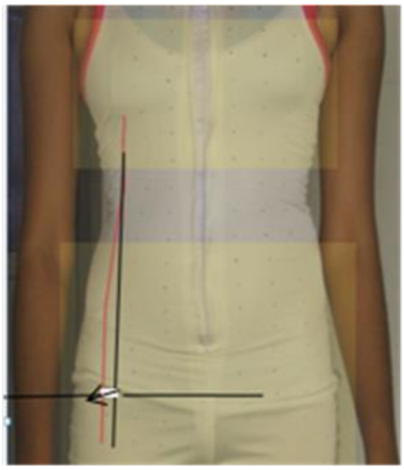
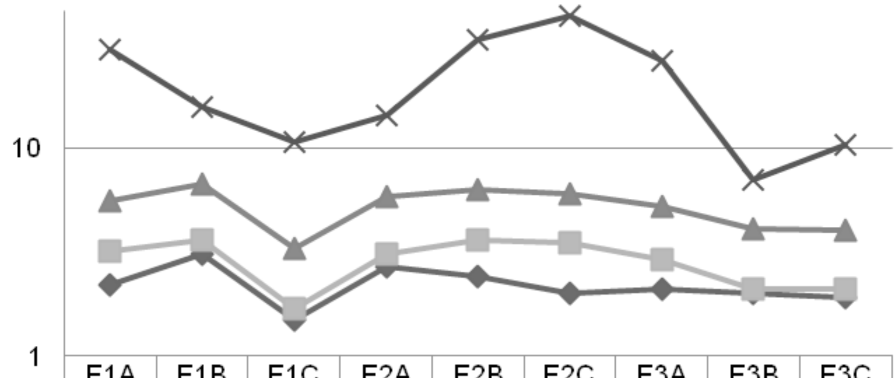


Figure 6. The resultant shear force and shear angle.

To understand the nature of in-plane shear of the garment surface across cross contour lines and structural constructs: FSWL, we employ the principle proposed by Moseley [12] that is “if the mass be bent throughout its whole length every transverse section of it will thus be made to intersect in the new position which it is thus made to take up”. So, the garment’s cross grain deflections at the hip contour line takes an arc-like shape that dips down at the side seam side of the garment. For fabrics B and C, the fabric in-plane shear angle corresponding to ease reduction treatment 2 is many times higher in the range of 36.9° and 20.8° (Table 5) when compared to fabric in-plane shear angle measured in other ease designs. High fabric in-plane shear angle reflects not only steeper slope of the cross grain at the hip contour line but also at the waist contour line. Thus, higher fabric shear angle indicates higher amount of in-plane shear, whereas for ease reduction treatment 3 across fabrics B and C, the fabric shear angle is very low in the range of 2.9° and 6.3° (Table 5). The fabric shear angle corresponding to fabric A across ease reduction treatment 1 and ease reduction treatment 3 also recorded higher values in the range of 24.2° and 20.8° *due to higher deformation of fabric plane withdrawn from its thickness (Table 5).*

Table 5. Magnitude of resultant shear force and shear angle



	E1A	E1B	E1C	E2A	E2B	E2C	E3A	E3B	E3C
✕ Magnitude of shear angle	24.2	9.1	7.4	8.5	26.6	36.9	20.8	2.9	6.3
▲ Magnitude of the resultant shear force	2.4	3.1	1.6	2.7	2.7	2.5	2.3	2	1.9
■ Cross grain deflections in Y direction at hip contour line.	1	0.5	0.2	0.4	1.2	1.5	0.8	0.1	0.2
◆ Grain line bending along FSWL in X co-ordinate direction between bust and hip along FSWL.	2.2	3.1	1.5	2.7	2.4	2	2.1	2	1.9

4. Conclusion

From the studies conducted, we ascertain that the ease reduction treatment not only determines the internal proportions of garment pattern from the manner the reduction amount is deployed in 2D pattern layout but also significantly affects the garment strain pattern at the principal stress-acting areas along the human body structural constructs: FSWL. *This is predominantly apparent across garments made from fabrics B and C whose stretch ratio is higher. In other words, there exists a linear relationship between medium weight high stretch fabrics and in-plane fabric shear.* Hence, maintenance of right shape profile along the structural constructs of human body where we witness complex shapes is deemed critical in achieving cling fit attributes provided the stretch reduction factor is kept within the threshold elastic limits.

Further high in-plane fabric shear measured through computing resultant shear force and shear angle along the structural construct: FSWL underscores the need for accommodating additional fullness between waist and hip zones that elicit pattern making knowledge. Rather, high in-plane fabric shear produces variations in fabric plane density that are direct implications of the strain levels experienced at the corresponding zones in the human body.

The findings of this study are limited to a specific body shape; hour glass figure shape and silhouettes resembling singlet and body suits. Further study is required for grading the sizes and morphing the shapes of segmented representations pertaining to other body shapes, which shall use 3D scan data for human body.

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References

[1] Yu, W. (2004). Subjective assessment of clothing fit. In Fan, J., Yu, W., Hunter, L. Clothing appearance and fit: science and technology (pp. 31). Woodhead (Cambridge).

[2] Tozeren, A. (2000). Human body structure. In Human body dynamics – Classical mechanics and human body movement (1st eds.) (pp.4). Springer Newyork (Newyork, USA)

[3]. Watkins, PA (2008). Stretching performance. In Proceedings of the conference on Extreme fashion: pushing boundaries of design, technology and business, (pp. 115). Centre for Learning and Teaching in Art and Design (CLTAD), Web site: https://iffti.com.bh-in-10. webhostbox.net/downloads/ papers- presented/ix.../2.5.

[4]. Cottle, F. S., Ulrich, P. V., Teel, K. P. (2018). Framework of understanding somatological constructs relative to the fit of Apparel. Retrieved August 3, 2018; from Rick.cottle@ mtsu.edu; 1-615-494-8752; www.mtsu.edu

[5] Zhang, J. (2017). Study on 3D modeling and patern making for upper garment (pp. 17). Doctoral dissertation. Retreived July 20 2018; Web site: https://soar- ir.repo.nii.ac.jp/

[6]. Hu, H. S. (1985). Design Philosophy Statement and Design Work. 07,08 Magenta, International Design Review (pp. 35–37). Mexico.

[7] Aspelund, K. (2015). Principles of designing. In Aspelund, K. Designing: an introduction (pp. 108). Bloomsbury (UK).

[8] Li, Y., Dai, X. Q. (2006). Clothing comfort and compression therapy. In Li, Y., Dai, X. Q. (Eds.), Biomechanical engineering of textiles and clothing (1st ed.) (pp.152). Woodhead (Cambridge, England).

[9] Dove, T. (2016). Stretch to fit – made to fit. International Journal of Fashion Design, Technology And Education, 9(2), 115-129.

[10] Fasanella, K. (1998). Improving product quality. In The entrepreneur's guide to sewn product manufacturing (3rd ed.) (pp.171-173). Apparel Technical Services (USA).

[11] Watkins, P. A. (2011). Designing with stretch fabrics. Indian Journal of Fibre & Textile Research, 36, 366-379.

[12] Moseley, H. (1847). A treatise on mechanics, applied to Arts: including Statics and Hydrostatics (3rd ed.) (pp.112). John, W. Parker (London).