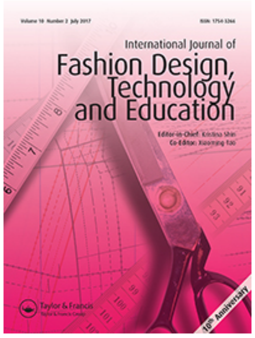

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Objective analysis of the drape behaviour of virtual shirt, part 2: technical parameters and findings

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ABSTRACT

Drape behaviour of virtual clothing can be expressed numerically using the technical parameters such as tension, stretch and pressure. This led to the development of an objective approach to analysing virtual fit of clothing, which has been discussed in this paper in context of a men's shirt by varying the ease at the chest area and changing the lengths. Avatars morphed with the measurements of M-sized British men derived from body scan data were utilised to simulate two different sets of pattern pieces (each set comprising 31 pairs of front and back panels with varying ease from 0.0 to 15 cm at the chest area at an interval of 0.5 cm) of sleeve-less men's shirt within two different CAD systems with consideration of FAST data of fabrics. Findings indicated that the change in tension, stretch and pressure followed a definite pattern when the ease at chest area was decreased or increased within the pattern pieces keeping the fabric properties unchanged. This has opened a new avenue for a more effective application of 3D simulation tools within the fashion-product-development process.

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KEYWORDS
Virtual shirt; drape behaviour; virtual fit; 3D CAD; tension map

1. Introduction

Existing literature (Kim, 2009; Lim, 2009; Kim & LaBat, 2013; Power, 2013; Power, Apeagyei, & Jefferson, 2011) hinted that only a subjective approach is not sufficient to take a conclusive decision on the state of virtual fit of clothing. This demands an objective approach to drape analysis with a potential application in clothing industry. Part 1 of this research discussed the avatar morphing and virtual simulation process of a sleeve-less men's shirt to facilitate an objective approach to drape evaluation. This part discusses the utilisation of tension, stretch and pressure mapping tools to identify the numerical values of these parameters and the trend of their change with the change of ease at the chest area of drafted pattern pieces of a men's shirt.

2. Virtual simulation and objective analysis

Once the simulation of all front and back pattern pieces of set A & B (31 pairs for each with varying ease starting from 0.0 to 15 cm at chest area at an interval of 0.5 cm as described in Section 2.2) were done on the avatars described in the Part 1 within the 3D window of both CAD software systems (hereafter mentioned as CAD system 1 and 2), the tension, stretch and pressure maps were initiated respectively in order to identify the numerical values of these parameters.

Tension (gf/cm), stretch (%) and collision pressure (dyne/cm^2) on the virtual clothing were analysed for each and every pairs of patterns in the CAD system 1. Amount of physical tension influencing the cloth was analysed in three ways, namely combined tension XY (gf/cm), tension X (gf/cm) in the warp direction and tension Y (gf/cm) in the weft direction. The tension scale in CAD system 1 uses the maximum and minimum values of tension of the particular fabric and garment in test. The colour band on the scale goes from blue through green and yellow to red where blue indicates minimum and red indicates maximum values of tension. Similarly, amount of fabric stretch is analysed in three ways, namely combined stretch XY (%), stretch X (%), that is, the expansion along the warp direction and stretch Y (%), that is, expansion along the weft direction were analysed. The stretch scale is also similar to tension scale in terms of colour coding. Additionally, the normal collision pressure (dyne/cm^2) at the contact point of virtual fabric and skin of the virtual mannequin was also analysed. The simulation tool was run for three times for each and every pair of pattern pieces to get a stable simulation before recording the values of tension, stretch

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and collision pressure. The maximum values were identified by moving the mouse pointer on the chest area covering both left and right sides of the chest up to the armhole.

In CAD system 2, tension (gr/cm) in fabric and pressure (gm/cm^2) exerted from the stretched garment on virtual body were analysed. In this system, the tension scale shows the intensity of the tension representing numeric values in gr/cm in colour codes from 0 (white) to 1000 (red). Similarly, the pressure scale represents numeric values in gr/cm^2 in colour codes from 0 (white) to 100 (red).

2.1. Simulation of pattern pieces of set A with longer shirt length

2.1.1. Results from CAD system 1

The maximum values of tension, stretch and collision pressure for 31 pairs of front and back panels with varying ease starting from 0.0 to 15 cm at chest area at an interval of 0.5 cm and with a shirt length of 78 cm are presented in Table 1. With a length of 78 cm, the shirt is constrained at both chest and hip areas when there is no ease at the chest. As the girth measurements of hip and chest of the avatar are similar, the tension shows a board red band on the hip and red to yellow band at the chest area (see Figure 1(a)). For the fabric properties considered in simulation, the maximum tension found on the garment was 44.67 gf/cm when there was no ease at the chest area, and this was found to be concentrated at the sides of the chest area underneath the armholes as well as on the hip area. In this case, the tension in fabric acts mainly in the weft direction as the weft tension was found significantly higher than the warp tension (see Table 1). As the pattern pieces started to include ease at the chest area, the maximum tension also started to fall down. Up to 2 cm ease, a drastic reduction of tension was seen for an increase of every 0.5 cm of ease. When the ease was between 2 and 7.5 cm, a gradual decrease in tension over the virtual fabric took place as can be seen in the Figures 1 and 2 and in the Table 1.

However, when the ease was between 7.5 and 15 cm, the maximum tension in virtual fabric did not vary significantly as it is shown in the Figure 2 and Table 1.

Unlike tension, the stretch in virtual fabric was found to be working at the middle of the chest and maximum stretch was found 1.61% when there was no ease in the chest area of garment. As the ease began to increase, the value of maximum stretch began to decrease, and started to spread towards the upper chest area (see the Figure 3(c)–(e)). It is evident from the Figure 4 and Table 1 that stretch in virtual fabric is mostly active in the weft direction. Similar to the phenomenon of tension distribution described earlier, the maximum stretch in virtual fabric also experienced a drastic reduction with the increase of ease up to 2 cm as it is evident in the Figure 4 and Table 1. When the ease was increased gradually from 2 to 7.5 cm, a gradual decrease in stretch in the virtual fabric took place as it can be seen in the Figure 4 and in the Table 1.

However, when the ease at chest was between 7.5 and 15 cm, the maximum stretch in virtual fabric did not vary significantly, which can be seen in the Figure 4 and Table 1.

The collision pressure between the virtual fabric and virtual body followed a similar trend with the increase of ease in the chest area of the virtual garment. However, the collision pressure was found to be active mainly around the armhole and neck areas (Figure 5). A rapid decrease in pressure took place with gradual increase of ease from 0 to 2 cm, a gradual decrease in pressure took place when the ease increased gradually from 2 to 7.5 cm; and when ease at chest area was between 7.5

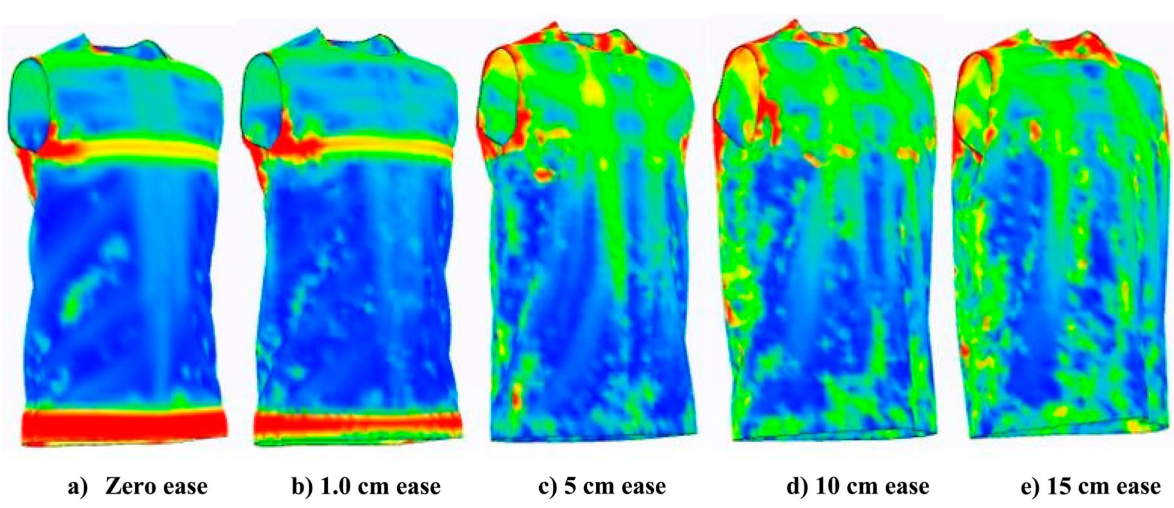


Figure 1. Tension maps on the virtual shirts from longer pattern pieces.

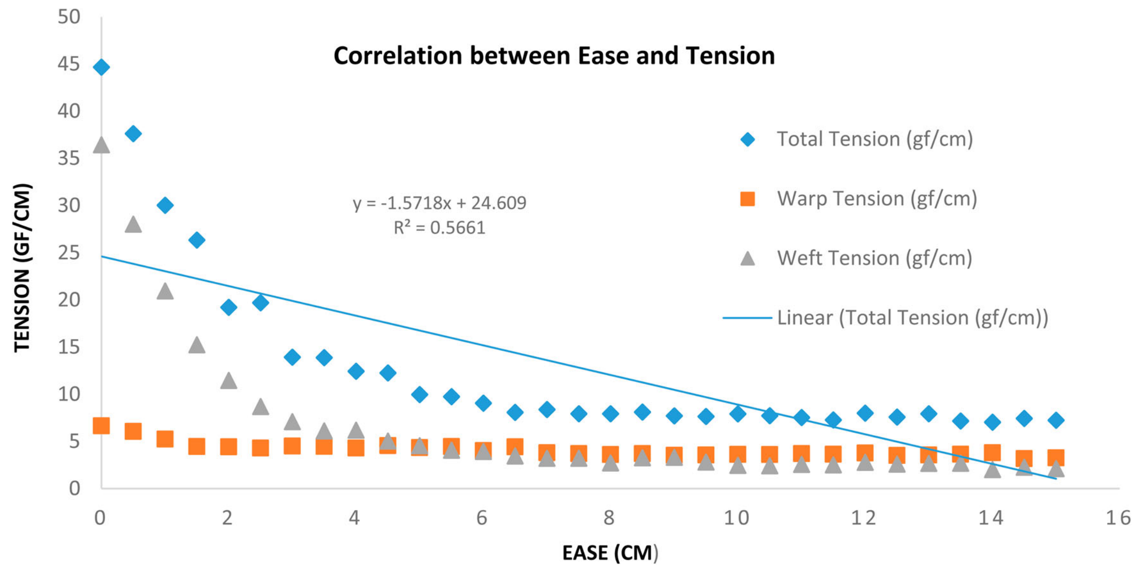


Figure 2. Correlation between ease in pattern and tension in virtual fabric in the longer shirts.

and 15 cm the collision pressure did not seem to change significantly, which is visible in the Figure 6 and Table 1.

It is apparently clear from the above-mentioned findings that any change in the chest ease from 0 to 2 cm in men's shirt influenced the mechanical behaviour of virtual drape most significantly and any change in ease between 7.5 and 15 cm does not affect the mechanical behaviour of virtual drape in any notable way.

2.1.2. Results from CAD system 2

The CAD system 2 used in this research does not provide any numerical value of fabric tension and pressure very precisely, rather provides a range with the help of colour coding. A close look on the tension scale and tension distribution found predominant yellow vertical and horizontal lines at the side to middle areas of the chest when the ease was between 0 and 2 cm, as can be seen

Table 1. Values of tension, stretch and collision pressure in simulated longer shirts.

SL	Ease (cm)	Total tension (gf/cm)	Warp tension (gf/cm)	Weft tension (gf/cm)	Total stretch (%)	Warp stretch (%)	Weft stretch (%)	Normal collision pressure (dyne/cm^2)
1	0.0	44.67	6.65	36.44	1.61	0.36	1.58	23,418.47
2	0.5	37.63	6.06	28.02	1.37	0.30	1.21	15,190.94
3	1.0	30.03	5.24	20.94	1.12	0.25	0.91	8726.25
4	1.5	26.35	4.46	15.24	0.85	0.24	0.66	5111.96
5	2.0	19.21	4.42	11.45	0.82	0.27	0.50	4785.74
6	2.5	19.69	4.30	8.68	0.66	0.20	0.38	3607.90
7	3.0	13.92	4.50	7.08	0.54	0.23	0.31	3263.47
8	3.5	13.87	4.48	6.10	0.51	0.25	0.26	2727.94
9	4.0	12.44	4.29	6.18	0.48	0.22	0.27	1904.85
10	4.5	12.26	4.55	5.03	0.41	0.21	0.22	1825.78
11	5.0	9.96	4.35	4.54	0.34	0.21	0.20	1805.99
12	5.5	9.74	4.45	4.06	0.30	0.22	0.18	1728.21
13	6.0	9.06	4.03	3.92	0.32	0.23	0.12	1186.52
14	6.5	8.08	4.42	3.44	0.28	0.23	0.12	1055.20
15	7.0	8.38	3.80	3.20	0.27	0.23	0.11	774.33
16	7.5	7.93	3.70	3.20	0.27	0.21	0.12	782.00
17	8.0	7.93	3.60	2.71	0.25	0.25	0.11	782.89
18	8.5	8.11	3.70	3.26	0.28	0.26	0.14	753.78
19	9.0	7.71	3.52	3.31	0.26	0.18	0.14	698.97
20	9.5	7.64	3.56	2.8	0.24	0.2	0.1	666.53
21	10.0	7.92	3.63	2.46	0.22	0.17	0.08	690.50
22	10.5	7.72	3.60	2.41	0.22	0.18	0.11	592.00
23	11.0	7.53	3.70	2.55	0.25	0.18	0.11	722.82
24	11.5	7.28	3.64	2.5	0.24	0.18	0.11	577.92
25	12.0	8.00	3.77	2.77	0.26	0.19	0.12	633.55
26	12.5	7.58	3.51	2.58	0.24	0.18	0.09	653.28
27	13.0	7.94	3.56	2.66	0.27	0.18	0.11	653.40
28	13.5	7.17	3.64	2.67	0.26	0.17	0.11	660.38
29	14.0	7.03	3.80	2.00	0.24	0.18	0.09	696.97
30	14.5	7.43	3.17	2.26	0.25	0.17	0.1	601.89
31	15.0	7.25	3.26	2.10	0.24	0.16	0.1	634.51

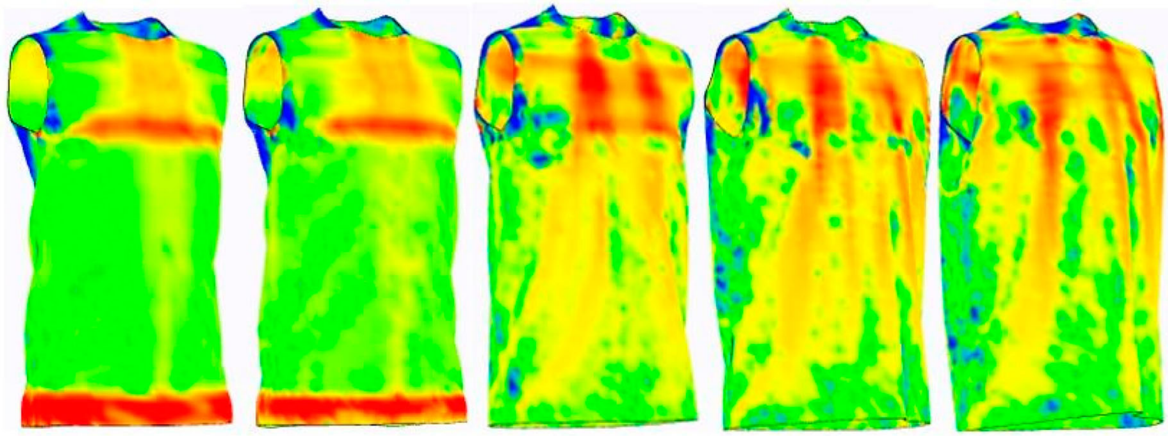


Figure 3. Stretch maps on the simulated shirts from longer pattern pieces.

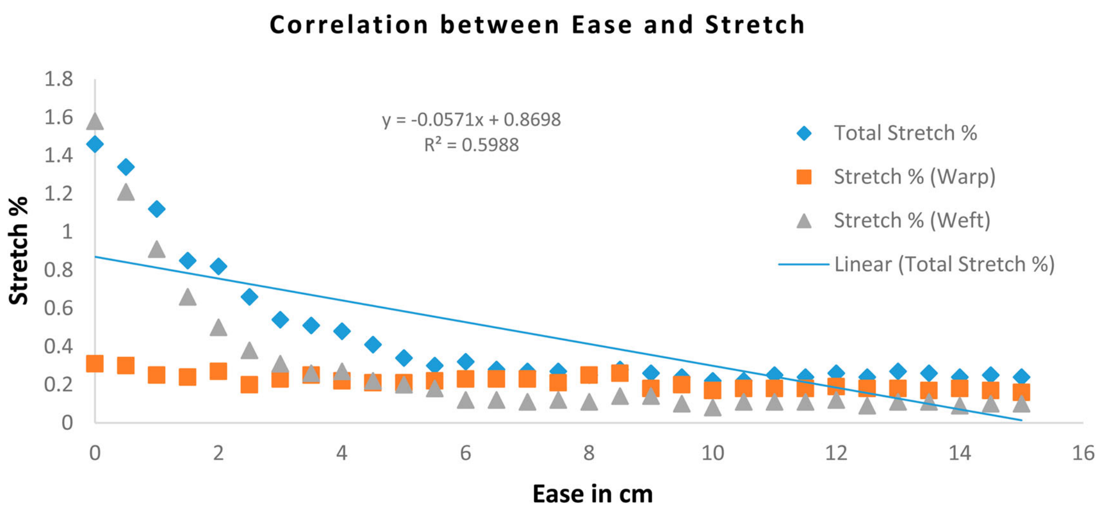


Figure 4. Correlation between ease and fabric stretch in the longer shirts.

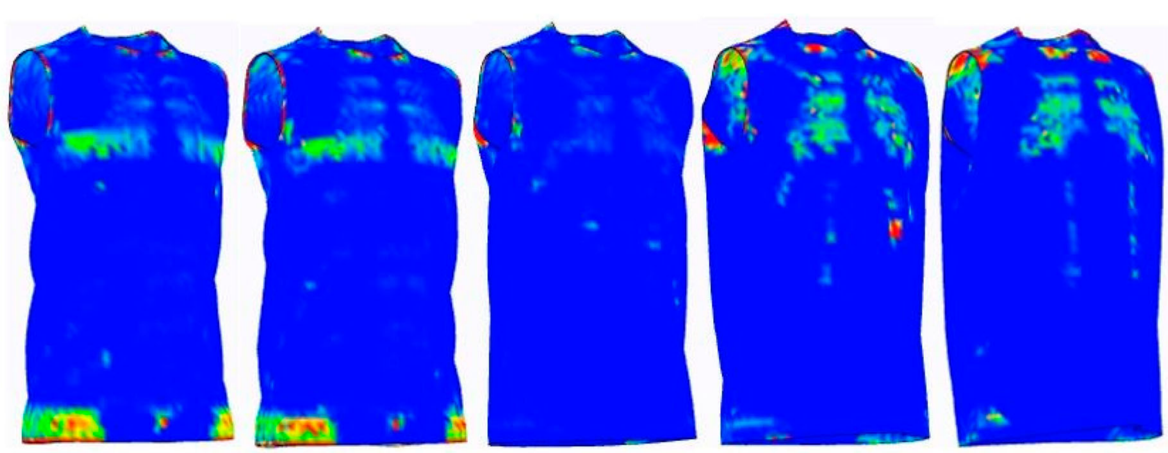


Figure 5. Collision pressure maps on the virtual shirt from longer patterns.

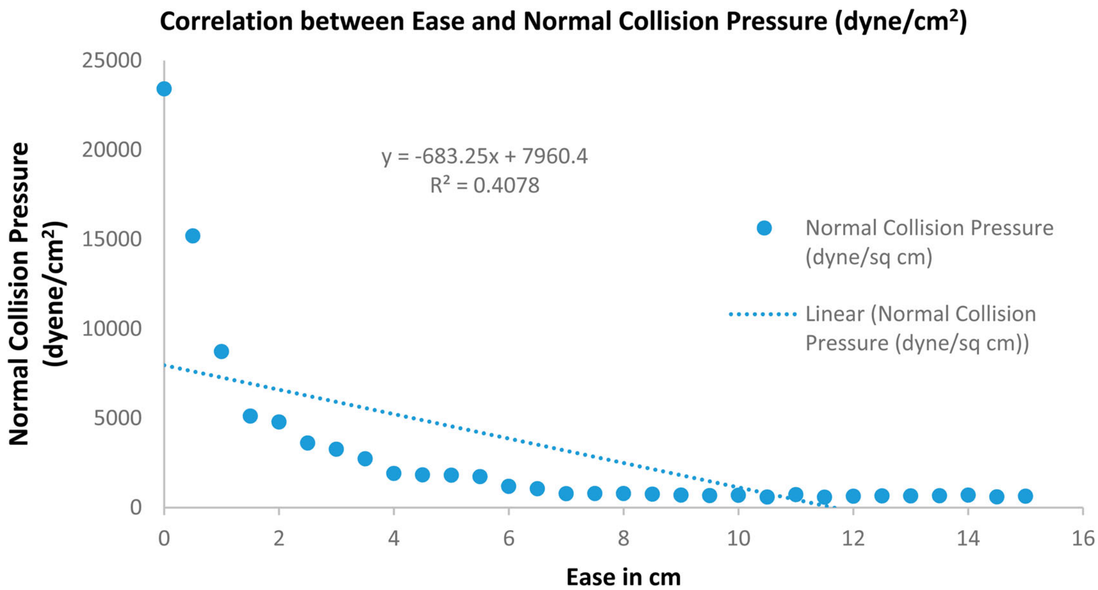


Figure 6. Correlation between ease and normal collision pressure in longer shirts.

in the Figure 7(a) and (b). According to the tension scale of CAD system 2, the yellow colour indicates a range of tension between 20 and 50 gf/cm. This supports the findings from the CAD system 1 described in the earlier section. As the ease in the chest area was increased, the intensity to yellow lines started to decrease and the intensity of green to blue lines started to increase. This indicated a decreasing trend of tension with the increase of ease in the chest area of a men's shirt. However, it was not possible to identify the fine changes in tension with the changes of ease at every centimetre interval.

The analysis of pressure of virtual fabric on the virtual body also showed that the side chest and hips are the most pressurised areas for this shirt with longer length when the ease is zero or very low at the chest area (see Figure 8). The maximum pressure was indicated by yellow colour within the CAD system 2, which referred to range of values between 5 and 20 gm/cm^2 (i.e. between 5000 and 20,000 dyne/cm^2). This, in general, supports the finding from the CAD system 1. As the ease decreased at the chest, the colour of pressure map on the virtual garment also got changed from yellow through green to blue. In the pressure scale, the colour band in blue to green zones indicates a range of pressure value between 0.5 and 1 gm/cm^2 (i.e. between 500 and 1000 dyne/ cm^2). This finding also correlates with the findings from the CAD system 1. However, a precise identification of pressure with the change of every centimetre of ease was not possible from the pressure map of CAD system 2.

2.2. Simulation of pattern pieces of set B with shorter shirt length

2.2.1. Results from CAD system 1

The maximum values of tension, stretch and collision pressure from simulated shirts from pattern pieces of set B with shorter lengths are presented in Table 2 and

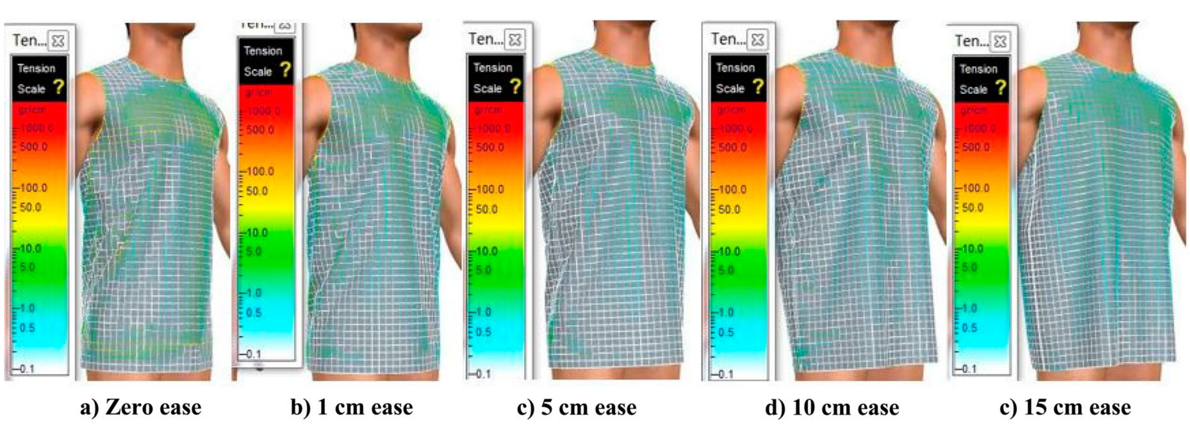
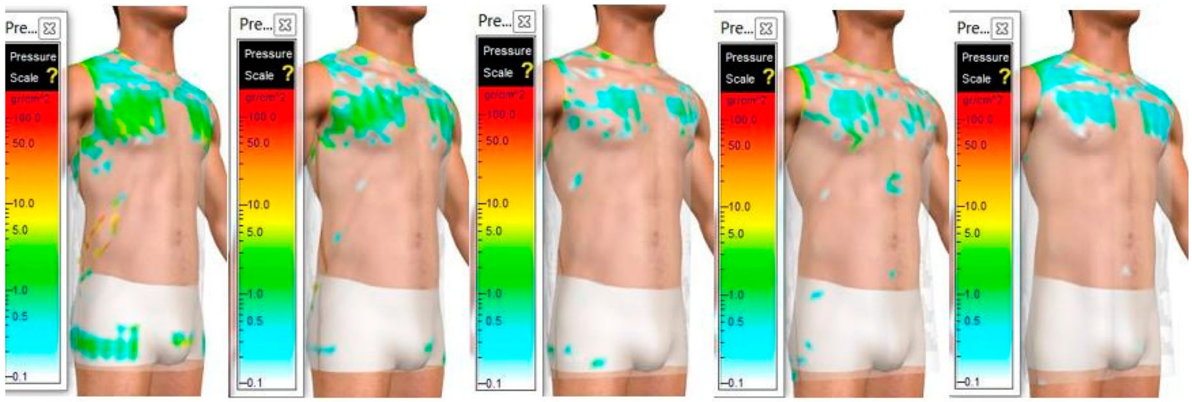


Figure 7. Tension maps on longer shirt from CAD system 2.



a) Zero ease b) 1.0 cm ease c) 5 cm ease d) 10 cm ease c) 15 cm ease

Figure 8. Pressure maps on longer shirt from CAD system 2.

Figures 9–14. It can be seen in the Figure 10 and Table 2 that the shirt length significantly influenced the tension in fabric. With a length of 58 cm the shirt is only constrained at the chest area; and when there is no ease in chest the maximum tension was found 35.46 gf/cm, which is over 20% lower than the maximum tension in longer shirt discussed in the Section 2.1.1. However, the pattern of change in maximum tension with the change in chest ease was similar to the tension phenomenon in the longer shirt described in the Section 2.1.1. A rapid reduction of tension with the increase of ease from 0 to 2 cm was experienced as it can be seen in the Figure 10 and Table 2. Tension in fabric decreased gradually up to an ease of 7.5 cm at the chest area; however, when the ease was between 7.5 and 15 cm, the maximum tension in virtual fabric did not vary significantly as it is shown in the Figure 10 and Table 2.

Unlike tension, the stretch in virtual fabric was found to be working mostly at the middle of the chest and maximum stretch was found 1.58% when there was no ease in the chest area of garment. As the ease began to increase, the value of maximum stretch began to

Table 2. Values of tension, stretch and collision pressure in simulated shorter shirts.

SL	Ease (cm)	Total tension (gf/cm)	Tension (Warp)	Tension (Weft)	Total stretch %	Stretch % (Warp)	Stretch % (Weft)	Normal collision pressure (dyne/cm^2)
1	0	35.46	4.26	16.03	1.58	0.22	0.69	10,403.17
2	0.5	28.05	3.55	14.21	0.96	0.26	0.62	7673.68
3	1.0	25.16	3.55	11.18	1.03	0.22	0.48	5461.59
4	1.5	20.65	3.40	9.38	0.57	0.19	0.41	5088.83
5	2.0	17.92	4.10	7.74	0.55	0.22	0.34	4284.66
6	2.5	14.80	3.70	6.80	0.56	0.18	0.29	3995.30
7	3.0	14.72	3.53	5.65	0.54	0.18	0.24	3262.79
8	3.5	11.58	3.74	4.57	0.42	0.19	0.20	2881.68
9	4.0	10.07	3.28	4.07	0.33	0.16	0.18	3241.46
10	4.5	10.47	3.02	4.19	0.33	0.16	0.18	2540.67
11	5.0	10.34	3.79	4.50	0.36	0.17	0.19	2552.25
12	5.5	9.39	3.02	4.07	0.32	0.13	0.19	1669.16
13	6.0	10.01	3.33	3.72	0.23	0.22	0.18	977.92
14	6.5	9.80	2.85	3.98	0.20	0.22	0.17	1028.25
15	7.0	8.93	4.77	2.84	0.23	0.24	0.13	814.76
16	7.5	8.21	3.75	2.52	0.20	0.20	0.11	860.17
17	8.0	8.12	4.14	2.02	0.21	0.21	0.08	964.29
18	8.5	8.31	4.83	2.45	0.26	0.23	0.13	764.71
19	9.0	8.04	4.65	2.36	0.26	0.24	0.12	740.55
20	9.5	8.36	4.24	2.42	0.25	0.24	0.10	706.16
21	10.0	8.38	4.54	2.80	0.23	0.22	0.09	664.57
22	10.5	7.69	4.20	3.20	0.24	0.21	0.13	845.05
23	11.0	8.17	4.53	2.99	0.25	0.23	0.11	693.15
24	11.5	8.39	4.83	2.61	0.26	0.25	0.10	640.10
25	12.0	8.07	4.77	2.84	0.26	0.23	0.13	585.25
26	12.5	8.17	4.55	3.16	0.23	0.23	0.12	627.13
27	13.0	7.34	3.95	2.99	0.23	0.20	0.13	574.35
28	13.5	7.68	4.15	2.65	0.24	0.22	0.13	609.21
29	14.0	7.10	3.78	2.87	0.21	0.19	0.12	592.15
30	14.5	7.37	4.07	2.90	0.23	0.21	0.12	590.25
31	15.0	7.34	3.99	2.53	0.22	0.20	0.12	632.39

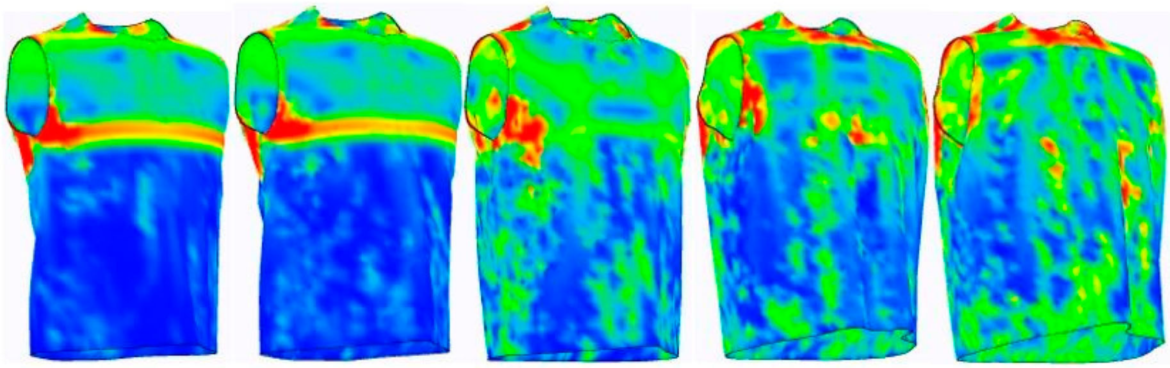


Figure 9. Tension maps on the virtual shirts from shorter pattern pieces with varying eases.

decrease, and started to spread towards the upper chest as it can be seen in the Figure 11(c)–(e). It is evident from Figures 11 and 12 and Table 2 that the stretch in virtual fabric was mostly active in the weft direction. Similar to the phenomenon of tension distribution described earlier, the maximum stretch in virtual fabric also fell drastically with the increase of ease up to 2 cm as it can be seen in the Figure 11 and Table 2. When the ease was increased gradually from 2 to 7.5 cm, a gradual decrease in stretch in the virtual fabric took place, which is evident in the Figure 12 and in the Table 2.

However, when the ease at chest area was between 7.5 and 15 cm, the maximum stretch in virtual fabric did not vary significantly, as it is shown in the Figure 12 and Table 2.

The maximum collision pressure between the virtual fabric and virtual body with the shorter shirts was found remarkably lower than that of the longer shirts. However, it followed a similar trend with the increase of ease in the chest area of the virtual garment. The collision pressure was found to be active mainly around the armhole and neck areas. A rapid decrease in pressure took place with gradual increase of ease from 0 to 2 cm; and a gradual decrease in pressure took place when the ease was increased from 2 to 7.5 cm; and when the ease at chest area was kept between 7.5 and 15 cm the collision pressure did not seem to change significantly as it can be seen in the Figure 14 and Table 2.

It is apparently clear from the above-mentioned findings that any change of chest ease in men's shirt from 0 to 2 cm influences the mechanical behaviour of virtual drape most significantly; and any change in ease between 7.5 and 15 cm does not affect the mechanical behaviour of virtual drape in any notable way.

2.2.2. Results from CAD system 2

As the CAD system 2 does not provide any numerical values of fabric tension and pressure very precisely, it was not possible to identify the fine changes in tension with the changes of ease at every 0.5-cm interval. When looked very closely on the tension scales and

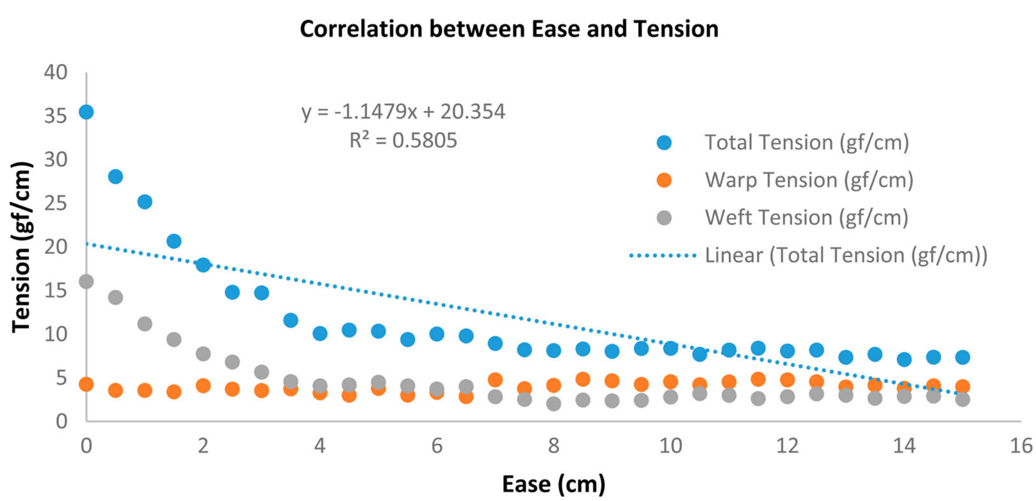


Figure 10. Correlation between ease in pattern and tension in virtual fabric of the shorter shirts.

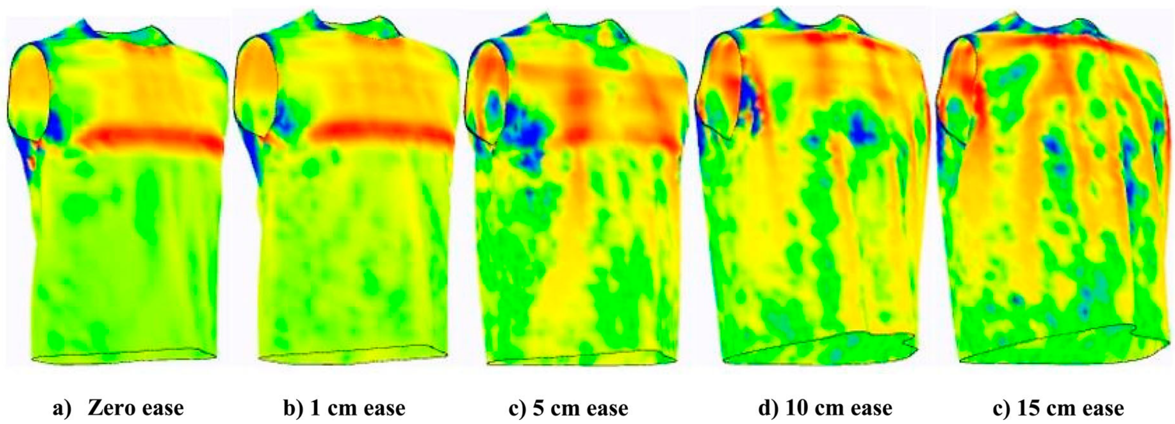


Figure 11. Stretch maps on the simulated shirts from shorter pattern pieces.

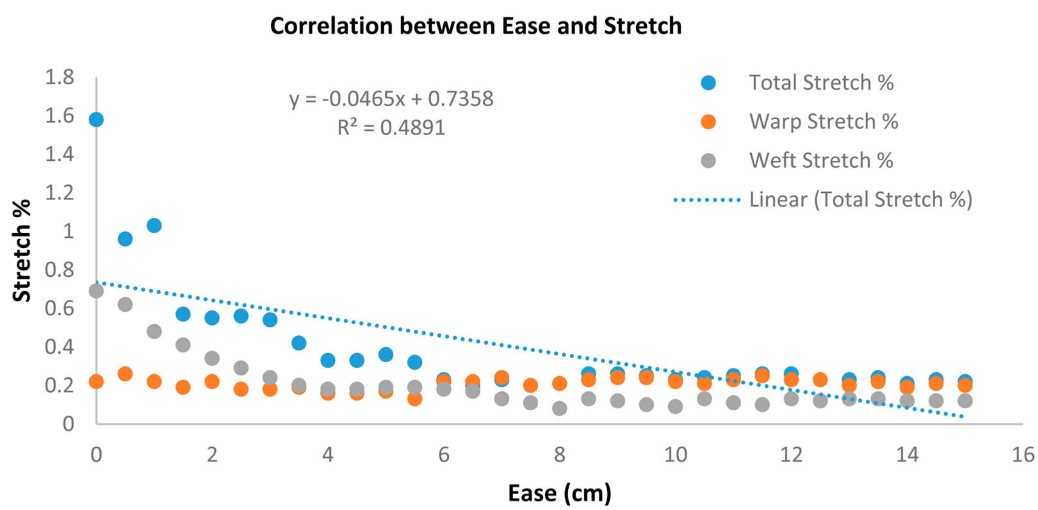


Figure 12. Correlation between ease and fabric stretch in the shorter shirts.

distribution of tension on the virtual shirts, predominant yellow vertical and horizontal lines at the side to middle areas of the chest were identified when the ease was between 0 and 2 cm (see Figure 15(a) and (b)). When the ease in the chest area was increased, the intensity to yellow lines started to decrease and the intensity of green to blue lines started to increase. This indicated a decreasing trend of tension with the increase of ease in

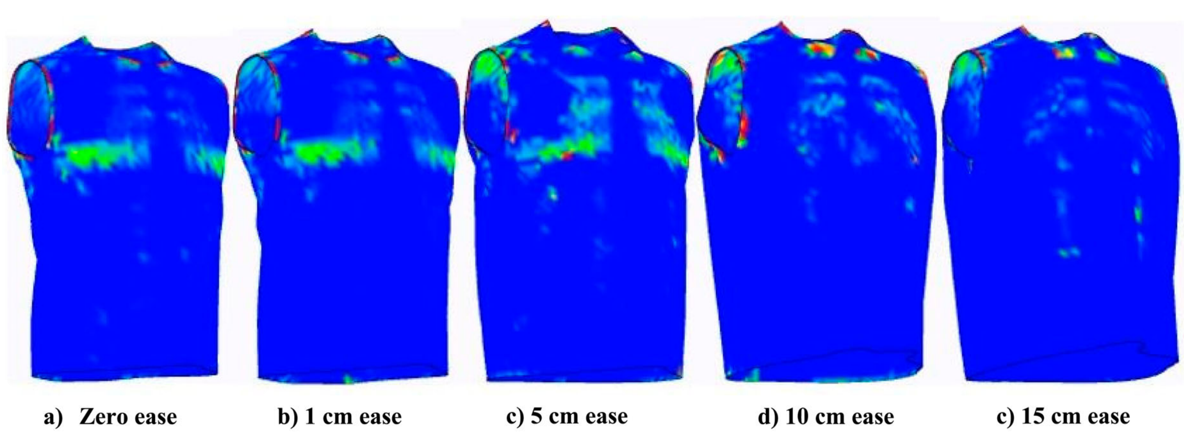


Figure 13. Collision pressure maps on the virtual shirt from shorter patterns.

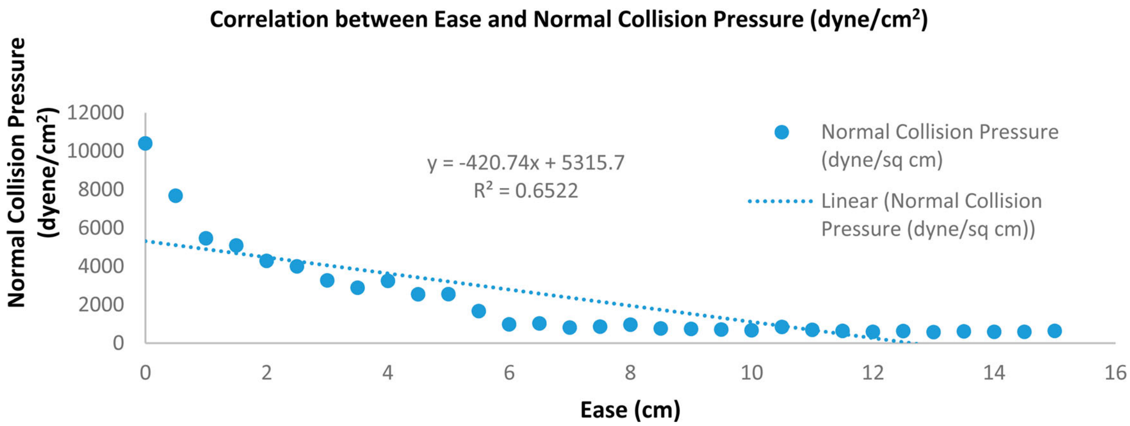


Figure 14. Correlation between ease and normal collision pressure in shorter shirts.

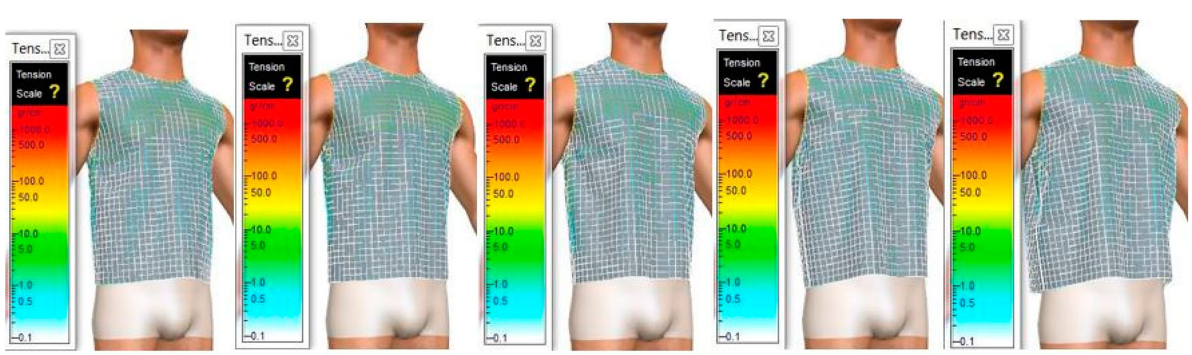
the chest area of a men's shirt. However, the value of yellow to dark yellow zone indicates a range of tension between 20 and 50 gf/cm, which covered the values of individual tensions at every 0.5 up 2 cm found in the CAD system 1.

The pressure maps (see Figure 16) of the shorter shirts showed that the sides of the chest are the most pressurised area for shorter shirt when the ease is zero or very low at the chest area. The maximum pressure was indicated by yellow colour within the CAD system 2, which referred to range of values between 5 and 20 gm/cm^2 (i.e. between 5000 and 20,000 dyne/cm^2). This, in general, supports the finding from the CAD system 1. As the ease decreases at the chest, the colour of pressure map on the virtual garment also changes from yellow through green to blue. In the pressure scale, the colour band between blue and green zones indicates a range of pressure value between 0.5 and 1 gm/cm^2 (i.e. between 500 and 1000 dyne/cm^2). Findings from the CAD system 1 also showed that the collision pressure with the simulations of shorter shirt also lied within this range when the ease at chest ware was between 7.5 and 15 cm. However, a precise identification of pressure with change of every centimetre of ease was not possible, which is mentioned in the Section 2.1.2.

3. Discussion

Objective evaluation of the drape behaviour of virtual garment will be beneficial to the fit technician for taking decision on the acceptance of pattern pieces in the situation of changing ease or design. The numerical values of fabric tension, stretch and pressure can be taken into consideration while altering the ease and design in pattern pieces to achieve the required fit sought by the designers and customers. It has been found that the change in tension, stretch and pressure followed a definite pattern when ease was decreased or increased within the pattern pieces keeping the fabric properties unchanged. It has also been seen that the change in shirt length keeping all other design parameters unchanged also affected the mechanical behaviour of the drape of virtual clothing.

The properties of a 100% cotton poplin fabric was utilised for the simulation part of this research. If the same experiments are repeated with the mechanical properties



a) Zero ease b) 1.0 cm ease c) 5 cm ease d) 10 cm ease c) 15 cm ease

Figure 15. Tension maps on shorter shirts from CAD system 2.

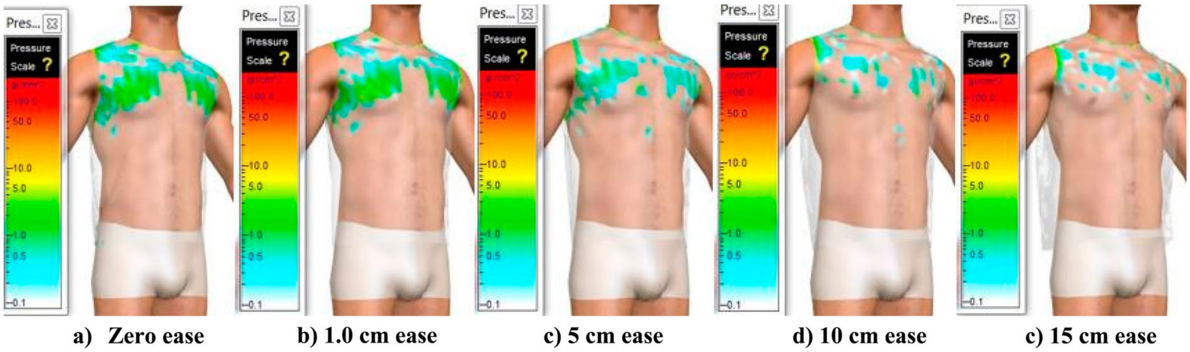


Figure 16. Pressure maps on shorter shirts from CAD system 2.

of different fabrics, a clear correlation between the change of fabric properties together with the change of ease in pattern pieces and the drape behaviour of virtual clothing could be visualised. Thus, it would really be helpful for the garment technicians while taking decision on the change of ease in pattern or alteration of pattern with the change of fabrics.

4. Conclusion

Although the tools for virtual prototyping and fit analysis have been available on the market for more than a decade now, they have not found any notable application within the industry yet, especially at the manufacturer's end. One of the main reasons behind this is the non-availability of a well-accepted protocol or guideline for fit analysis using such tools. It has been mentioned by several researchers (Kim, 2009; Kim & LaBat, 2013; Lim, 2009; Power, 2013; Power et al., 2011) that only visual analysis of virtual fit of clothing is solely not enough for use in the process of decision-making on the acceptance or rejection of virtual prototype, or altering pattern pieces to achieve desired fit in the virtual and ultimately in the physical prototypes. This research took an objective approach to analyse the drape behaviour of virtual shirts using three technical parameters. It has been found the drape behaviour of virtual fabric can be numerically identified, and it follows a specific pattern of change when the ease and length of garments are changed in the 2D pattern pieces. This provides an opportunity of combining the objective approach of fit analysis with the traditional subjective one to make the virtual fit analysis process more effective and reliable. If the fabric parameters are known, it will then be possible to predict the change in drape and fit of virtual garment if the ease and design need to be altered in the 2D pattern pieces. Moreover, this will make the available virtual fit tools for meaningful and useful to the designers, fit technicians and pattern cutters in the industry.

Disclosure statement

No potential conflict of interest was reported by the author.

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