PRESSURE AND COMFORT PERCEPTION IN THE SYSTEM “FEMALE BODY-DRESS”

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Abstract:

The three-dimensional (3D) Garment virtual technology is expected to help the designers to turn own trends and ideas into the creative samples more quickly with 3D simulation and the visualization of the pressure values and stress points where the fabric might be too tight against the body. The aim of this study is to present the wearer perceptions of woven fabric in 22 anthropometrical points located on the women torso, which can then be helpful to accurately predict the ease and tightness of a garment in 3D Garment virtual try-on system.

For establishing the common principles joining the eases value designed on pattern block and the pressure perception in the system “body-dress”, we took the experiment with the women using Flexiforce Sensor® and ELF® system concerning the woman dresses with sleeve-in as the basic garment category. The objective pressure measured on seven levels of woman torso wearing the dresses designed by different ease distribution. All points and levels of the pressure measuring reflected to the daily movements, and the results obtained were compared with the corresponding subjective comfort perception from the wearer. The relationship between the ease values designed on 2D pattern and the pressure perception from the wearer were analysed to supply the theoretical reference for 3D virtual try-on system improvement.

Keywords:

Woman torso, pressure, comfort perception, dress, pattern block, ease, 3D virtual try-on

1. Introduction

Three decades ago, three-dimensional (3D) try-on technology was only used to visualize the styles in the fashion industry by a few adventurous manufactures. At present, the improved 3D technology includes the tools that respond to the challenges in the apparel market: cost reduction, enhanced creativity, and improved communication. It is now been recognized by the industry that the 3D technology at the design stage can help reduce the cost and time-to-market, contributing to a more efficient and profitable process by reducing the number of samples required and their associated costs. However, the maturing clothing industry emphasis more on clothing fitting, comfort and fabric characters for 3D try-on technology improvement, although until recently it has proven very difficult to predict the fabric properties accurately and view the effect of fabric on the body. Therefore, the study of apparel comfort has been upgrade from a single physiological subject to the complex of physics, physiology, and comfort psychology, which became a relatively new field considering the apparel comfort perception as a dynamic and mechanics interaction between the clothes and the human body [1].

Predecessors already explored a comfort perception with tight underwear and knitwear. Ikuta [2] studied the basic underwear comfort perception in different sizes and found that the smaller size is the hotter human body perceived, which makes people feel tight and easy to be sweating. Makabe [3] found that the

human body will have uncomfortable perceptions when the pressure is over 4–5.33 kPa through the experiment with different styles, structures and materials of girdle. Later, they [4] continued the research about the girdle and found the pressure in waist impact by covering area, breathing, and movement: the wearer had comfort perception when the pressure was 0–1.47 kPa, they have endurable perception when the pressure turned to 1.47–2.46 kPa, and uncomfortable when the pressure was over 2.46 kPa. Japanese scientists [5] tested the pressure on different levels of a human body and founded that people endure the pressure in the front of shank from 0 to 2.452 kPa; furthermore, the front is more sensitive than the back. Recently, some scientists have improved the technology of pressure measurement by using a manikin [6] and a knitting material [7].

However, the lack of woven materials between the explored objects limited the 3D virtual try-on technology as the following problem unsolved: while daily movements happening the ease values designed in the pattern block (a front, a back, a sleeve) are influenced on the human body sizes as the body shape is changing; in this way, the inherent ease will end use in some places and formed the pressure to human body [8]. Thus, the changing ease value is the basic aspect, which has to be concerned for the improvement of 3D virtual try-on technology. Simulation of knitwear in recent 3D try-on system simply shows the pressure where the apparel contacts with the human body in a constant standing posture, which limited the availability of the simulation results. Therefore, the main goal of our research

is to provide more data that could be realized for the 3D virtual try-on, which will be based on the experiment using woven fabrics, and to improve the interactive links in designing system “body–clothes”.

2. Shape changing of a human body

Taking “body–clothes” as a system, in which an interaction occurs with surroundings in physical, physiological, neurological, and psychological aspects, we could explain what “the pressure perception of textile” is and how it happens. When tactile receptors located in clusters in human skin are stimulated or squeezed by clothes or in some other way, the layers rub against each other, causing an electrical nerve impulse to be generated. There are approximately 17,000 mechanoreceptors in the skin, comprising Meissner’s corpuscles, Merkel disks, Ruffini endings, and Pacinian corpuscles, and they are differentiated into grades depending on their receptive fields and the speed and the intensity with which they adapt to static stimuli. The receptors that sense touch are most often in the skin of fingers and lips [9].

Clothes act on human body in two main forms: by the weight of materials and by the tension generated due to the material deformation, which press the human skin. For the curved part of the human body, these two kinds of pressure may exist. While for the flat part, it will be one of the two forms under normal circumstances [10]. Moreover, the human body constitutes in more than one way in different places: the shape and size of the bone, muscle thickness, degree of compression, and elastic modulus will also affect the pressure [11]. Meanwhile, the skin will produce different degrees of deformation and displacement, which result in the partial pressure distribution changes. Kirk and Ibranim measured the elongation of the human skin under different states of motion; this approach provides an important reference for calculating the relationship between pressure and skin elongation [12].

As described above, the changing of posture and the action will cause skin deformation in different places on human body, so it is necessary to consider both good-fitting and movement comfort to learn the volume of skin changes in different

directions for apparel design. From ergonomics knowledge, the human body surface characters and how the skin area changed with four change rate types were acquainted [13]. Among them, the elbow, the bust and the side of torso, the abdomen, and the area from the back blade to waist level have the greatest changes. The knee area and foot changed a little. After all, the upper part (limbs and torso) varies more than the down; besides, the surface changing has a close relationship with joint rotation in shoulder, elbow, hip, and knees.

3. Object of exploration

The woman dress was selected from all kinds of clothes. Typical woman dress (made from woven fabric and designed with right ease values) will not influence the human haptic perceptions much in stable standing posture. But in cases of daily movements, the pressure will strengthen on some points though the motion range will not be as gymnastic sport. According to the evident fact that the human body shape and the skin surface are changeable, taking the basic points of human body [14] as the reference, 22 points that are required to be tested for pressure and comfort perception were selected (Table 1) and the corresponding places of these points were shown with different sights of woman torso (Figure 1).

4. Experiment

4.1 Materials and methods

Apparel ease refers to the air gap between the human body and the clothes, which has been proved to influence the design theory [8,15]. In our research, the woven material selected belongs to the plus-ease situation (opposite to minus-ease materials such as knitting). We used two methods of pressure application. First, the belt was made of common cambric (80% polyester and 20% cotton) with the hook & loops instead of full dress, and simultaneously they were also marked with the length scale that helped the adjustment for testing the comfort perception on different points. Secondly, the full dresses were prepared with different ease volumes to find out how the main ease combinations affected the comfort perception.

Table 1. Points chosen on woman torso for measuring pressure and testing the comfort perception.

Point number	Point name	Point number	Point name
P 1	Neck root side	P 12	Front under BP on under-bust level
P 2	Neck root back	P 13	Under-bust level side
P 3	Arm root front	P 14	Back under scapular on under-bust level
P 4	Arm root back	P 15	Front under BP on stomach level
P 5	Upper arm side	P 16	Side on stomach level
P 6	Upper arm front	P 17	Back under scapular stomach level
P 7	Upper arm back	P 18	Front under BP in waist level
P 8	Elbow	P 19	Side on waist level
P 9	Bust	P 20	Back under scapular on waist level
P 10	Side point in bust level	P21	Front under BP on abdomen level
P 11	Back under scapular on bust level	P22	Back under scapular on abdomen level

Figure 1. Anthropometrical points for measuring pressure and testing the comfortable perceptions.

Flexi Force device (Figure 2) that has a sensor with good flexibility and high accuracy is the instrument for measuring pressure; with the ancillary ELF system in computer, the pressure measurements are promptly recorded. While the experiment was combined with movement in different postures, the clear plastic has been used to keep sensor on points, so that the pressure will be positioned at the exact point even with movement (Figure 3).

However, pressure parameters in daily dress are generally below 1960 Pa and they will not exceed above 10 kPa (10,000 Pa); in common situations, the pressure range should be from 0 to 10 kPa at least. Therefore, for adjusting the system pressure sensitivity and texting range to better match with our experiment, debugging of the device was prepared as the manufacturer suggested. After repeating the testing for 25 times, the accuracy had met the experimental requirements and the accuracy displayed in ELF system.

For controlling the error of measurements, the experiment for device definition was completed before starting the main experiment. The pressure was measured 12 times one after another in low, middle, and high areas of the measuring range, which correspond to the three levels of comfort perceptions. Through the average value and dispersion analysis, the random error statistics were done and the results are shown in Figure 4. The vertical axis describes the error values, and the horizontal axis indicates the number of times the pressure was measured (2, 3, 4 ¼ 12 times). The results illustrated that the error will be below 15% in both cases (the level of probability is $p = 90\%$ and 95%) after measuring six times. Therefore, in this research, each measurement at the same point has been repeatedly measured for six times for each point, which ensures the accuracy of the result.

4.2 Experiment with testing belts

As mentioned above, in the beginning the belts were prepared for testing pressure and comfort perception experiment. For bust, waist, and hip level, the belt width was 5 cm; for neck, shoulder, and arm the width was 2 cm (narrow in contrast to be adapted to physical characteristics of human body). The

Figure 2. Instrument of experiment.

Figure 3. Method of fixing the sensor.

pressure was examined as the belts were tightened up every 0.5-cm interval.

However, the tolerance relationship between the human body and the clothes will change during daily movements; the action comes through the sport of joint and cause the shape changed in partial body [12]. According to the discipline of adult joint activities angle range [7] and daily movement, the experimental action angle was determined (Table 2).

Figure 4. Error after different measured times from low to high testing area of the device ($p = 90\%$ and 95%).

Table 2. Main activities range of adult joint and angle for experiment.

Places	Joint	Action	Angle (°)	Angle range (°)	Comfortable angle range (°)	Experiment angle (°)
Head and torso	Neck	Yield and Bow	-35 to 40	75	12–26	-35
		Left and right crooked	-55 to 55	110	0	+55
Torso	Bust Waist	Bend forward and backward	-50 to 100	150	0	+80, -10
		Bend left and right	-50 to 50	100	0	+40
Forearm and upper arm	Elbow	Bending, stretch	0 to 145	145	10–85	+145
Arm and torso	Shoulder	Inward swing and outward swing	-30 to 180	210	0	+170
		Up swing and down swing	-45 to 180	225	15–35	+15
		Front swing and back swing	-40 to 140	180	40–90	+140, -40

Experiment done with the belts helped to understand how the woman torso perceived pressure in various points and levels (Figure 5). Ten typical postures in daily movement were selected for experiment “belts-body”, e.g. arm front bending, waist front bending, sitting and legs apart (as getting out from the car), and one leg lifting (as going up the stairs).

For the purpose of obtaining results more adaptive and preventive, three volunteers with the same or similar size (height is 160 cm, bust girth is 84 cm) took part in the experiment.

4.3 Experiment with dress samples

Dress tolerance changed as the human body moves in a daily live, e.g. the dress will generate the deformation of the skin around the arm and in back if we move our arms forward; the bust level will be lifted up as well as all levels below. Therefore, the above experiment with the belt must be continued by real dress for the complex deformation to happen during the choosing actions. Thus,

in the second step, the dresses were made with different eases to bust and waist girths; in this way, the relations existing between the ease values in the dress and the corresponding comfort perception were expected to be seek out. Fit-style dress refers to the bust ease volume varying from 4 to 10 cm and good-fit dress from 2 to 4 cm [9], and the ease to waist girth has the minimum as same as to bust. Intervals were 2 cm in bust girth and 1 cm in waist girth according to the reference of the standard industrial error tolerance. Other parameters of the dress – shoulder width, waist height, dress length (100 cm), and bust dart angle (10°) – were kept stable as in typical woman pattern block (Table 3).

The pattern were built on the basis of typical woman block up and down, and the eases altered as size increased: on bust level, the ease averagely distributed between three parts of the front and the back (bust width, armpit width, and back width); whereas on waist level and hip level, the eases averagely distributed between two parts – the front and the back (Figure 6).

Figure 5. Experiment postures with the belt.

As the first attempt for dress pressure experiment, the samples were designed without the sleeves and collars. Eight postures for the dress experiment were as same as in the previous experiment (Figure 7).

4.4 Results and discussion

Twenty-two testing points in the experiment were divided into nine levels, which help us to establish a systematic observation for the result as shown in Table 4, which describes how the eases and the pressure influence the comfort perceptions.

In pattern design, the ease value should be at least over the endurable grade value to promote the pressure that could be barely afford for human body. We used the bar graph to show how the woman bodies perceived the pressure on different levels in a more exactly the same way. For the reason that the levels or girths may include two or three points and they perceive the pressure in different manners, the comfortable perception grades in the same level have overlapping area, which is also marked in the picture (Figure 8).

It indicated that the comfortable grade areas were clear in most of them; in other cases, the down level of one grade was almost over the average value of the previous or at least equal. Additionally, the pressure on each of the horizontal position and the degree of pressure perception were ready for the observation. For example, below the bust, waist, and abdomen levels, the pressure values for comfortable perception were

Table 3. Main eases for dress samples.

Sample	Ease to body sizes (cm)		
	Bust girth	Waist girth	Hip girth
1	2	2	2
2	4	3	4
3	6	4	6
4	8	5	8
5	10	6	10

Figure 6. Dress pattern for sample cutting and ease changing.

Figure 7. Experimental postures with the dress.

Table 4. Eases and pressure ranges with the comfort perceptions.

Comfortable perceptions and pressure values Levels on body	Ease values, cm, influenced on the comfort perception			Pressure, Pa		
	Comfortable	Endurable	Uncomfortable	Comfortable	Endurable	Uncomfortable
1. Neck root girth	≥ 3	2 to 2.5	≤ 1.5	1039 $\pm$ 97	1402 $\pm$ 8	2097 $\pm$ 346
2. Around arm root	≥ 2	0.5 to 1.5	≤ 0.5	1107 $\pm$ 10	1301 $\pm$ 56	1745 $\pm$ 86
3. Upper arm girth	≥ 2	1 to 1.5	≤ 1	1190 $\pm$ 179	1491 $\pm$ 91	2090 $\pm$ 454
4. Elbow girth	≥ 6	3.5...5.5	≤ 3	2870 $\pm$ 355	5776 $\pm$ 2775	9466 $\pm$ 490
5. Bust girth	≥ -0.5	-1 to -1.5	≤ -2	1303 $\pm$ 196	1509 $\pm$ 238	1823 $\pm$ 155
6. Under bust girth	≥ 2.5	1.5 to 2	≤ 1	1133 $\pm$ 123	1348 $\pm$ 90	1472 $\pm$ 125
7. Stomach girth	≥ 2	1 to 1.5	≤ 0.5	1110 $\pm$ 21	1247 $\pm$ 70	1423 $\pm$ 100
8. Waist girth	≥ 1.5	0 to 1	≤ -0.5	1017 $\pm$ 68	1058 $\pm$ 66	1197 $\pm$ 9
9. Abdomen girth	≥ -0.5	-1 to -2	≤ -2.5	910 $\pm$ 17	1032 $\pm$ 8	1221 $\pm$ 77

Figure 8. Pressure and comfort perceptions in different places.

Table 5. Eases and comfort grade in woman dress.

Ease to bust/waist (cm)	Pressure value (Pa)							
	Around arm		Bust level			Waist level		
	P3 (front arm root)	P4 (back arm root)	P9 (bust point)	P10 (side point under arm)	P11 (back point under scapular)	P18 (front point under BP)	P19 (side point under arm)	P20 (back point under scapular)
2/2	1203	1477	1935	1393	1814	682	1158	1203
4/3	1168	1425	1948	1356	1747	610	907	1216
6/4	1050	1362	1203	1271	1684	407	789	1070
8/5	992	1268	988	1233	1546	400	516	1003
10/6	915	1136	944	1173	1507	342	484	947

similar, but the waist level was with border blur field, which represent that the same pressure force on waist level may produce more diverse perception level.

Thereafter, the pressure measurements with the dresses made with different bust and waist eases were taken and the results are shown in Table 5. In this manner, the comfort grade was given.

According to the experimental results, Figures 9 and 10 show the bust and waist level pressure diversification at different points. As in the bust level, the “bust point” pressure declined more rapidly than the remaining areas if the ease to bust girth increased from 4 to 10 cm (Figure 9a). In the waist area, all diagrams have the similar trends (Figure 9b).

The pressure grades in different places of each level on the cross-section “body–clothes” are shown in Figure 10. Dress sections were combined with the body sections to indicate the ease changing and be arranged as the order in Table 3 (from minimum ease to maximum). It contained the most common and essential areas where the women might have uncomfortable perceptions in daily actions, which indicated the pressure grades with different colours.

Simultaneously, the comfort grade from the front, back, and profile sight was represented (Figure 11). With dress eases varying from minimum to maximum, the pressure on woman torso varied in different areas. For example, on bust point, the pressure turned from high to low while the ease increased, whereas on the back of bust level, the pressure remained at a high degree.

However, in every physical level, the woman torso could have different perceptions in front, side, or back with the same ease volume. Thus, the results in the figures provide us more details about pressure indexes in each level. Through the pressure map and the comparison of pressure ranges about the comfort perceptions in different levels shown in Table 2, the minimum value of ease that would make woman perceive comfortable or at least endurable could be seized.

5. Conclusions

In this study, we established the basic database of investigating the eases values for describing the pressure comfort perception of woman torso wearing a dress made of woven material during

Figure 9. Relations between the eases and the pressure in system “body–dress” on bust level (a) and waist level (b).

Figure 10. Ease change and pressure on bust, waist, and around the arm in daily movement.

Figure 11. Dress pressure in daily movement.

the situations that slippage happened in daily movement has been taken into account. Research includes two aspects: (1) initial ease values in “belts-body” system, which represented the subjective comfort perception with the objective pressure indexes in different points and levels; and (2) final ease values of “dress-body” system. We proposed the way for the pressure scale indication which express the maximum possible pressure. These results can be utilized to improve the existing GSAD.

However, the limitation of fabric species and structural complexity in this investigation restrict the practicality and systematic integrity, which can be improved further in the future by:

- Increasing the number of fabric species to analyse how the fabric properties influence the pressure in the “body–dress” system.
- Developing the dress constructure including the sleeves and the collars, which will influence the dress possibility to move around the body under daily movements.

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