Fabric objective measurements for commercial 3D virtual garment simulation

Abstract

Purpose – The aim of this paper was to explore the use of objective fabric parameters in 3-D virtual garment simulation.

Design Method – Two methods (FAST and Browzwear's fabric testing kit) of obtaining objective fabric measurements and the derived parameters for virtual garment simulation were studied. Three parameters (extension, shear and bend) were investigated to establish if the selected virtual software derived comparable parameters from the objective fabric measurements.

Findings – It was found that the conversion from the objective fabric measurement data to the required parameters for virtual simulation varied significantly. Manual analysis of the objective measurements showed the two test methods to be comparable for extension and shear parameters; However, some adjustment to the test method was required. The third parameter to be investigated (bending rigidity) concluded that the test methods and results obtained from the two different apparatus were not comparable and recommended further experimentation using a different testing technique.

Research limitations/implications – Future research should be conduct on a larger variety of fabrics ensuring comparable loads are used in the testing of the extensibility parameters. An expansion of this preliminary study should give more conclusive evidence of the trends observed.

Originality –Objective measurement of extension, shear and bend properties were investigated in relation to the derived parameters for a selected virtual simulation package. An understanding of such parameters will aid the general industry in adapting 3D virtual garment simulation as part of the standard product development process, resulting in a significantly shorter product development cycle.

Keyword – Fabric testing methods, FAST, Garment simulation, Objective testing, Textile parameters, Virtual simulation,

Paper type – Research paper

1.0 Introduction

In the last 25 years the landscape of the clothing industry has changed dramatically for many developed and developing economies. No longer are garments manufactured in specific local regions, in the twenty first century clothing and fashion is a complex global operation with sophisticated supply chains (Walter et al, 2009; Jones, 2002). Despite this transformation in the clothing industry it is reported that the apparel sector as a whole is lagging behind other manufacturing industries in its willingness to adopt new processes to aid product development, such as 3D virtual garment simulation (Goldstein, 2009; Hardaker and Fozzard, 1998). Although computation technologies for both garments and textiles have existed for a variety of years, various authors comment on the lack of their practical application and adoption within the clothing industry (Goldstein, 2009; Luible and Magnenat-Thalmann, 2007; Stylios, 2005; Xu et al., 2002; Hardaker and Fozzard, 1998). This is accredited to a variety of reasons including, setup costs, user expertise, technology limitations and accurate fabric simulation. However, in a competitive retail environment speed to market is crucial, the fast fashion phenomena has enabled retailers to react quickly to trends and significantly improve response times (Barnes and Lea-Greenwood, 2010; Sull and Turconi, 2008; Barnes and Lea-Greenwood, 2006; Hayes and Jones, 2006; Sheridan et al., 2006). In a rapid response environment the reduction of time in the developmental stages is essential.

Traditionally garment development begins with a 2D sketch accompanied with a selection of material samples, this is then interpreted into a 2D pattern by a skilled pattern cutter; each sample piece is then carefully cut from the designer's choice of fabric and manufactured into a sample or prototype garment. This often turns into a lengthily process as samples are fitted and re-fitted to live models to ensure a satisfactory fit is achieved prior to large scale production of the garment. Utilising 3D virtual garment simulation as part of the design development process would significantly reduce the time consuming sampling stages, since the end product could be viewed, assessed, modified and re-fitted without any actual cutting of fabric occurring. This would give the designer significant opportunity to experiment with stylelines, materials and seams before manufacturing begins resulting in a significantly shortened development process. Of course 3D virtual garment simulation offers benefits at the other end of the clothing spectrum, providing opportunities for niche and luxury custom made garments. A retail store could consist of a 3D body scanner linked to 3D virtual garment simulation software which is loaded with styles and fabrics. The consumer could contribute to the design by selecting from a library of styles, materials and colour. Once the customer is satisfied with the simulated garment the parameters would be sent to a local manufacturing establishment to enable the custom product to be realised.

So far the advantages of 3D virtual garment simulation have been highlighted in terms of the benefits to product development, speed to market and customisation of garments; but there are also significant opportunities for e-commerce in terms of interactive garment selection, whereby a garment could be purchased from a multimedia catalogue and viewed on a virtual body which is representative of the wearer (Volino and Magnenat-Thalmann, 2000). Stylios (2005) identified, geometrical reconstruction of real humans, digital cloning of the 3D face and body, virtual human locomotion, and cloth simulation as the four areas of research which could exploit global internet retailing. Communication is vital within the traditional garment product development processes, and much research has been done to explore the communication between the various parameters required for 3D virtual garment simulation (Goldstein, 2009; Volino and Magnenat-Thalmann, 2000) however, the commercial industry is slow to adapt this innovative technology. The most important problem is that there is a distinct difference in the simulation strata required. The graphics and animating community is interested to produce a nice animation but not necessarily real and hence do not use real fabric properties. Whilst the textile/material engineering community is interested to produce real simulation of garments using material properties so that what you see is realistic. The problem of course is that the latter have been battling over the years is to deal with no-linearities of the fabric which is difficult to define generically and to compute in real time, so all modern CAD packages assume some fabric properties and hence the 3D simulations are not realistic. Recently a company called Browzwear is offering a simple kit with which some fabric properties are being measured before a garment simulation is being produced. This concept is right and this paper investigates the effect of fabric objective measuring results obtained from different testing systems on the 3D virtual garment simulation, made by the Browzwear method.

2.0 Visualisation of garments

Luible and Magnenat-Thalmann (2007) acknowledged that the true representation of a virtual garment is dependent on two factors, precise computational models, and exact input of fabric parameters. The development of the microchip in the late 50s lead to an electronics revolution. Advancements in computer technology was built on developments in three fields: human-computer interface, which connected people to their machines; networking, which connected the machines together; but, most importantly the increased sophistication of the machines themselves. The first CAD/CAM tools for the fashion industry were introduced in the 70s. Despite other manufacturing and construction industries being quick to adopt and embed these tools within product design, the fashion industry suffered from independent systems being developments in two distinct areas which provided separate working environments for fashion design and pattern cutters (Hardaker and Fozzard, 1998). A divide that is even more apparent today with Adobe illustrator being one of the preferred softwares for designers; specialised 2D pattern preparation systems are offered by global leaders such as Gerber and Lectra which are the apparel industry standard; and sophisticated 3D virtual garment simulation software being introduced by a range of suppliers such as OptiTex, Browzwear and Lectra. Whilst the transition from 2D to 3D design occurred some 15 years ago in other manufacturing industries, modelling garments was inhibited by two factors, the accurate computer representation of the human form, and the realistic simulation of material drape (Goldstein, 2009; Protopsaltou et al., 2002).

Modelling the human form or creating a life like avatar (virtual body) involves cross collaboration across many disciplines including, physics, mathematics, electronics and computer science (Wacker et al., 2005). The human body is a complex form and defining body shape requires the examination of; general anthropometrical classifications (somatotyping), the physical anatomical landmarking and the categorisations of body shapes (Protopsaltou et al., 2002). In recent years 3D body scanning data has contributed enormously to the development of virtual avatars and the study of this has been of significant interest to the apparel industry (Wang and Zhang, 2007; Xu et al, 2002; Stylios et al., 2001; Xu and Svinivasan, 1999; Kurokawa, 1997). A 3D scan can generate thousands of data points from the body and produces a raw image (3D point cloud) which can be used to create a static simulated human form (avatar). The animation industry has developed advanced knowledge to transform the raw data measured by the hardware into parameters suitable for virtual models with optical motions. This not only has huge benefits for the gaming industry but also for e-commerce as the virtual catwalk becomes a reality.

Garment design and realisation is a highly specialised domain which demands design creativity, an understanding of anthropometrics, skills of technical pattern making, knowledge of manufacturing techniques in addition to an appreciation of fabric science and performance. The relationship between clothing and textiles is of particular importance in 3D virtual garment simulation and much work has been done in the modelling of tactile materials (Stylios, 2005; Volino and Magnenat-Thalmann, 2005; Volino and Magnenat-Thalmann, 2000). Textile materials present particular challenges in virtual modelling due to their diverse properties. Fabrics range from rigid woven and knitted structures with limited drape (often used in outerwear) to ultra limp materials (such as chiffon); some knitted fabrics have distinct structural properties that can be engineered to interact like a second skin (particularly useful in sports attire), alternatively materials can be constructed to provide support or even compressive forces to the human form (developments include medical, underwear and sport applications). Modelling of tactile materials is complex due to the extensive spectrum of materials available to the modern designer which vary significantly in weights, thicknesses, aesthetic and functional properties, but more importantly these fabrics are difficult to define because they are viscoelastic and hence not linear. This has been one of the biggest stumbling blocks in advancing the 3D CAD simulation

During the last two decades the techniques to enable virtual simulation to occur have evolved significantly. Firstly in the field of graphics and animation which has enabled sophisticated virtual worlds to be created, and secondly in the textile/clothing engineering discipline interested in its utilisation as a design tool. The early works to simulate cloth appearance dates back to 1987 (Terzopoulos et al, 1987, 1989). When simulating fabric virtually an accurate reproduction of the mechanical behaviour is essential. This is particularly challenging in garment simulation when the fabric interacts with the body and other materials it may come into contact with. The mathematical basis of virtual garment simulation varies with the software design it is reported that finite elements have only a limited role and particle systems offer an easier way to perform cloth simulations (Volino et al, 2004). Real-time garment simulation presents challenges regarding the speed of mechanical computation and collision detection as the fabric comes into contact with the body (Volino et al, 2004, Fontana et al, 2005). The high efficiency and simplicity of particle grid systems makes them a suitable method for simulating fabric on real-time virtual bodies despite loss of accuracy through geometrical approximations and contextual simplifications (Volino et al, 2004). Both Optitex and Browzwear's V-stitcher use particle based systems to represent the mechanical behaviour of the fabric.

3.0 Objective fabric measurements

Virtual garment simulation software uses the data obtained from objective measurements of fabrics to simulate the appearance of a tactile material when modelled on an avatar. The Japanese made the first steps in the 1970s to standardise the objective handle of textiles with the introduction of the Kawabata evaluation system (KES-F). This system was said to provide the answer to earlier scientific citations which explored the mechanical properties of textile materials and their relationship to handle (Stylios, 2005). KES-F provided highly precise predictions of fabric handle and required significant expertise to use, thus it was limited to the cash rich giants and research establishments. After recognising the commercial limitations of the KES-F system which were mainly related to the cost of the equipment, the CSIRO association developed a simpler alternative which was termed FAST (fabric assurance by simple testing). The equipment was particularly geared to predicting the tailorabilty of wool fabrics and in comparison to the Kawabata system was relatively easy to use. Similar parameters are measured using each testing system; however, the principles applied vary significantly. KES-F provides complete stress-stain profiles for all the measured parameters, whereas, FAST only permits linear interpretation of the measured data. The advantages and disadvantages of each system are well documented by other authors (Luible and Magnenat-Thalmann, 2007; Stylios, 2005).

The current provision for objective testing is dominated by two test methods FAST and KES-F and even though these instruments are mature in research they are not extensively used in the industry. Much of industry still relies on subjective means of assessment, since the objective routes are considered to be time consuming and knowledge intensive in terms of analysing and understanding the data obtained. KES-F is in the main limited to scientific research and FAST although somewhat less expensive and simpler to use is still not fully adopted across the industry sector. Stylios (2005) acknowledged the need for alternative systems to be developed that are less expensive, less subjective (due to user error) and easier for industry to adapt into everyday use for a wide range of textile fabrics. A new device for measurement was developed and termed FAMOUS (fabric automatic measurement and optimisation universal system) this system had the benefit of all the tests being conducted automatically from the same sample, thus reducing the human error factor. Its developers make numerous claims; it significantly reduces cost and reproducibility increases (since only one system is required); it reduces the time taken to obtain data to approximately 5 minutes per sample; the complexity of taking the measurements and the analysis of the results is reduced since data is interpreted into a chart automatically; and it is suited to testing a wider range of fabrics. However, this system is still in the development stages and not currently available on the commercial market.

The textile and clothing manufacturing industries are experiencing a transformation into a demand driven, knowledge based, high technology industry (Walter et al., 2009). 3D virtual garment simulation will play an important part within apparel product develop in future years. Already there are many advanced systems on the market including Optitex’s 3D virtual clothing, Browzwear’s V-stitcher (3D fashion design) and Lectra’s Modaris 3D fit solution. Independent of the software utilised for the virtual simulation, all 3D virtual garment simulation software require the input of objective fabric measurements. Some software providers have developed their own measuring devices to obtain the required textile parameter specific to their application. Examples of these include Browzwear’s fabric testing kit and Optitex’s fabric testing utility. The fabric properties obtained vary depending on the system, but generally all devices include facilities for measuring tensile and bending properties. Other parameters such as surface properties, mass and thickness can be obtained either as part of the main testing process or extra testing instruments may be required. The cost of the specific testing equipment can be as little as £2,000 which is attractive to industry since the scientific alternatives are vastly expensive. There is a question of simplicity/low cost over data efficiency/high cost which needs to be examined.

3.1 Browzwear's Fabric Test Kit (FTK)

The Browzwear fabric testing kit (Figure 1A illustrates model FTK 1) is a single piece of apparatus that measures three parameters, bending, tensile and shear; although other parameters (mass and fabric thickness) are required to enable the data to be utilised in the 3D virtual garment simulation. Bending is defined in the FTK manual as 'the amount of cloth resistance to folding when applying an external force on a cloth'. Warp and weft fabric specimens are obtained, each specimen is clamped at one end and fed through a metal clip (Figure 1B). The fabric is pulled though the clip by moving the clamp, until the edge of the cloth is almost detached from the lower scale (bend scale). The lengths known as the distance and curved length are obtained (Figure 1C), the height is fixed at 2.7cm. This follows the cantilever principle of testing.

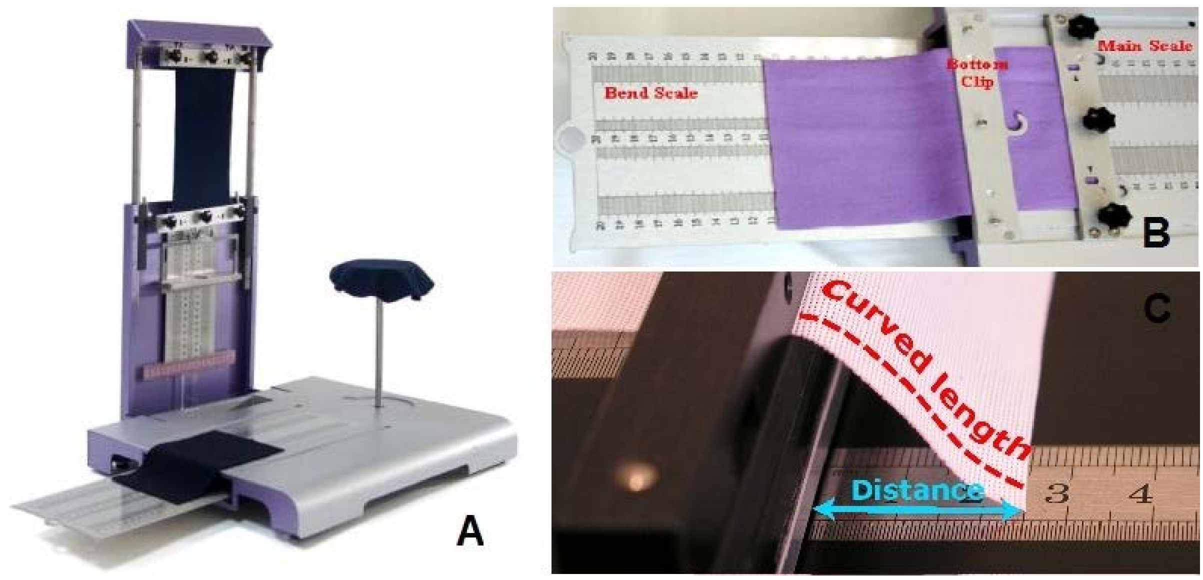

Figure (No.1)

(Browzwear manual: Fabric Physical Properties and Testing Methods)

In tensile tests a series of 5 weights (100g) are applied to a vertically mounted fabric in succession (Figure 2 illustrates the general principle). The fabric is clamped between two clips; the distance between the clips is measured. The top clip is then secured to a frame (FTK 1) and the fabric is allowed to hang freely, a second measurement is recorded), a succession of weights are then applied and the distance between the clips recorded manually using the mounted measuring device. This test is repeated for the weft, warp and bias of the fabric. Shear is measured by repeating the tensile procedure but the fabric sample is cut in the bias, a known concept that is also utilised by the FAST instruments.

Figure (No.2)

(Browzwear manual: Fabric Physical Properties and Testing Methods)

4.0 Experimentation

The properties of textile materials can be described as aesthetic or functional (mechanical and physical). Various authors have identified important functional properties as; surface contour, density, surface friction, flexibility, compressibility, elasticity, resilience and thermal attributes (Minazio, 1995; Kawabata, 1980; Lindberg et al., 1961; Peirce, 1930). The calculated standard fabric hand values are not of particular interest for 3D virtual garment simulation but the actual measured data is extremely important. This paper investigates if fabric objective measuring results obtained from two different testing systems affect the 3D virtual garment simulation. The selected 3D virtual garment simulation software was V-stitcher (from Browzwear), this was identified as a leader in the market (Gerber, 2011). Six polyester fabrics (Table 1) were tested for the properties of tensile (extensibility), shear rigidity and bending rigidity, using two different textile testing system (FAST and Browzwear's fabric testing kit). FAST was selected since it is simpler than the

KES-F and used commercially for obtaining objective fabric measurements. Browzwear's fabric testing kit was used because of its novelty and since the 3D virtual garment simulation software has a direct interface for the fabric parameters to be inputted and it is much simpler than FAST apparatus. The objective measurements obtained from each textile testing system were analysed and parameters were derived for the selected 3D virtual garment simulation software.

Fabric Identification	Fibre composition	Fabric Description	Fabric Mass
A	Polyester	weft knitted double pique	135 g/m^2
B	Polyester	weft knitted single pique	186 g/m^2
C	Polyester	tricot mesh	121 g/m^2
D	Polyester	weft knitted single pique	181 g/m^2
E	Polyester/elastane	weft knitted single jersey	190 g/m^2
F	Polyester	tricot mesh	91 g/m^2

Table 1

All the fabric testing has been conducted in accordance with each systems operating manual and sample size specification. The fabrics have been conditioned in accordance with the method described in BS 139 (2005) and all testing were performed in a standard laboratory environment. The analysis and discussion presented in this paper are based on an exploratory case to determine if fabric objective measuring results obtained from the two different testing systems affect the 3D virtual simulation. The three key parameters used for the 3D virtual simulation were tensile extension, shear rigidity and bending rigidity.

4.1 Fabric extensibility

Tensile tests are usually carried out to provide a measure of elongation under a given force. Both of the selected test systems measure the tensile property under a series of predetermined loads. FAST uses loads of 5gf/cm, 20gf/cm and 100gf/cm. The Browzwear's fabric testing kit offers a more simplistic approach using strain gauges for measurement. Five weights (100g, 200g, 300g, 400g and 500g) are hung from a vertically mounted sample and the user records the extensibility results. To enable a direct comparison of fabric extensibility data obtained from each system, a suitable load was determined covering the range of both instruments. The data obtained from the Browzwear's fabric testing kit was converted into a comparable unit and the selected load for comparison was deemed to be 20gf/cm. The derived extensibility data for the six fabrics indicated good agreement between the two test systems (Figure 3). The results obtained from FAST generally illustrate a slightly higher extensibility percentage in both the warp and weft directions, which may be accredited to the smaller specimen size. The correct tensile extensibility for Fabric E (single jersey with elastine) was not able to be measured by the FAST system, since the apparatus' maximum extension is 20%.

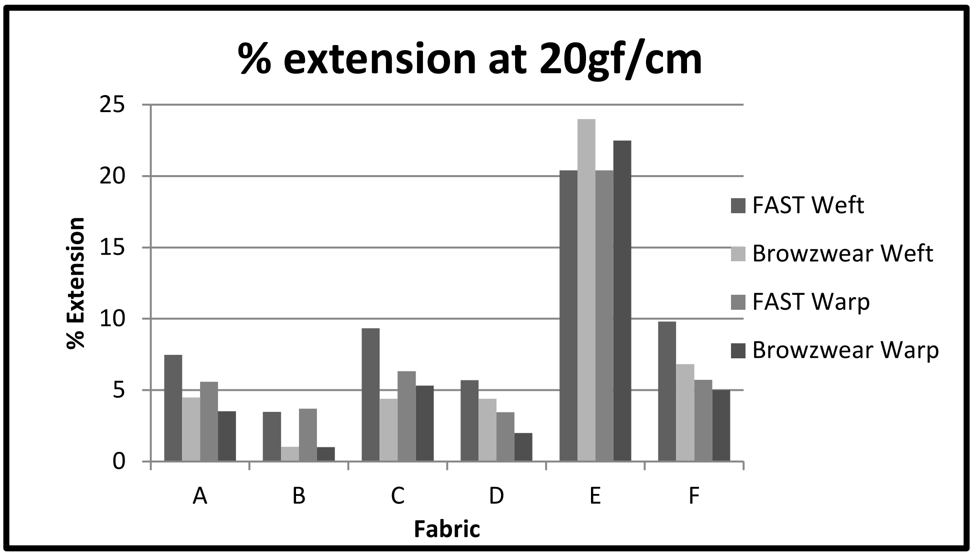

Figure (No.3)

In order to make the tensile parameters suitable for 3D virtual garment simulation software a mathematical description of the measured data is required. The data for warp extensibility obtained from both testing systems for two fabrics (A and B) is presented in Figure 4 as a linear interpretation at the maximum loads. It should be acknowledged that the derived parameters are only as accurate as the range of measured data. For the purpose of comparison only the warp extensibility was used since the majority of fabrics weft extensibility at a load of 100 gf/cm were outside the limits of FAST apparatus. From the results obtained it can be concluded that for all fabrics (under 20% extensibility) and at low loads under 25gf/cm the difference between the two testing systems was insignificant. However, should the derived linear results be extended to predict extensibility under larger loads the differences between the two test methods may be higher.

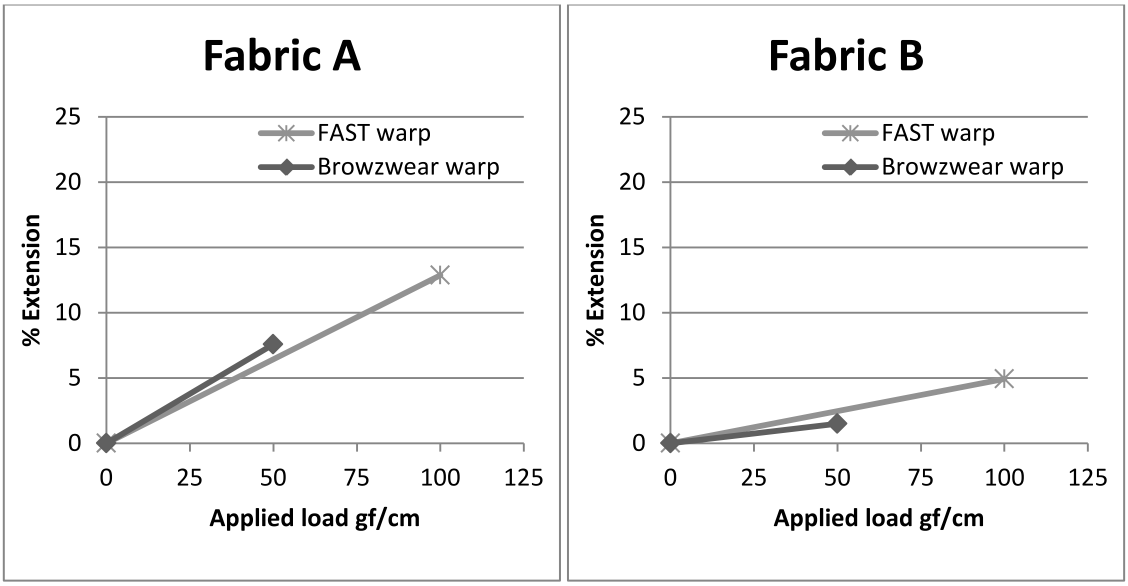

Figure (No.4)

Figure 5 illustrates the derived virtual parameters obtained using the FAST converter and the V-stitcher physics calculator (the two stage approach required to convert the experimental data into the required parameters for simulation). Extensibility was expressed as stretch rigidity (N/m) in the selected 3D virtual garment simulation software. Low values indicate a high level of stretch and high values denote fabrics with low extensibility. The derived parameters obtained during the conversion of the FAST data are compared to those derived from the Browzwear data and are generally found to show good agreement between the two testing methods (mean differences were found to be weft: 82.42 and warp: 25.82 N/m) ; with the exception of fabrics B and D. This is due to the nature of the knitted specimens and many of the results for weft extensibility at maximum load (100gf/cm) are outside the limit of the FAST testing equipment. When the derived textile parameters were applied to a basic T-shirt garment and modelled virtually no significant difference was observed for any of the six fabrics between the two testing systems in terms of visual appearance or fit (assessed through a pressure mapping function).

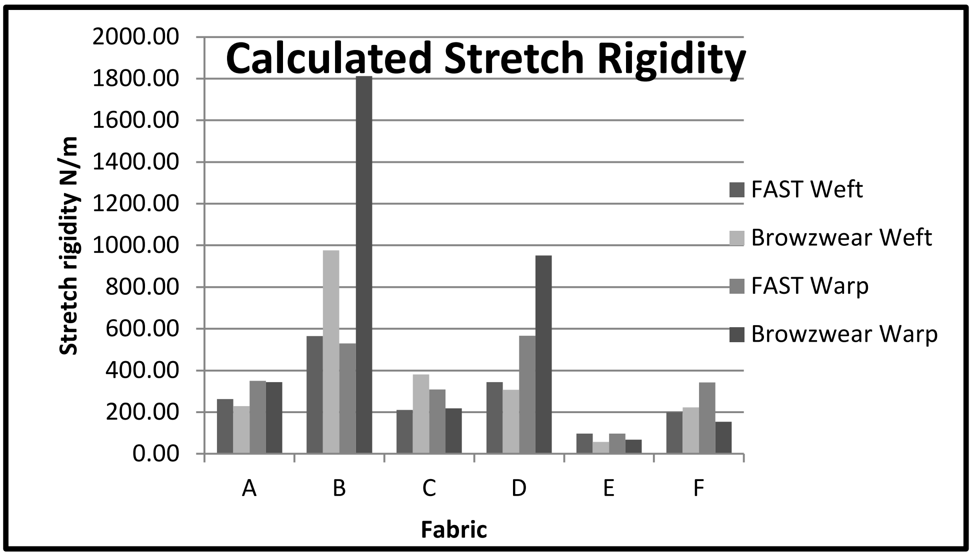

Figure (No.5)

4.2 Shear Rigidity

The shear and stretch properties have been combined into one calculation within the V-stitcher software and since FAST calculates shear rigidity using bias extensibility under one load this was not deemed to be an issue. The virtual parameters derived using the V-stitcher physics calculator and FAST converter expressed shear as shear rigidity (N/m) and fabric linearity. Fabric linearity was defined as the percentage of extension where the fabric becomes less elastic, typically low values will yield fabrics which are less elastic; and higher values will yield fabrics which have higher elasticity levels. What was interesting from the derived parameters was the large variation between the results obtained from the FAST and the Browzwear fabric testing systems (mean difference between the two instruments ranged from 0.4 - 377.34 N/m). Further analysis revealed that this could be directly accredited to the FAST testing method, which calculates shear rigidity from a single force of 5 gf/cm from the combined bias specimens (cut at 45° and 135°). In contrast the Browzwear method obtains the data from a range of forces equivalent to 10, 20, 30, 40, 50 gf/cm cut from specimens obtained at the bias of 45° only. The exact calculation used to obtain the shear rigidity was not visible within the V-stitcher software so it was difficult to ascertain how the shear rigidity results were derived. The results obtained using Browzwear fabric test kit were recalculated manually using data from combined bias specimens of 45° and 135°. The manual calculated data illustrated better agreement with the parameters obtained from the FAST textile testing system – the difference averaged to 8.54 N/m for the six fabrics (Figure 6). The shear rigidity textile parameters obtained through the V-stitcher converter were applied to a basic T-shirt garment and modelled virtually (based on data obtained from 45° bias only using Browzwears testing kit and average of 45° & 135 ° for FAST data). Interestingly when the shear rigidity values were inputted into V-stitcher the converted stretch values were reduced slightly however, it was recommended by the software providers that the stretch parameters and shear values are inputted simultaneously prior to conversion. Initially there was insignificant difference observed visually in terms of how the garment draped in the 3D environment (Figure 7). However, when the pressure map function was applied in some cases a very significant difference in fit became apparent (Figure 8).

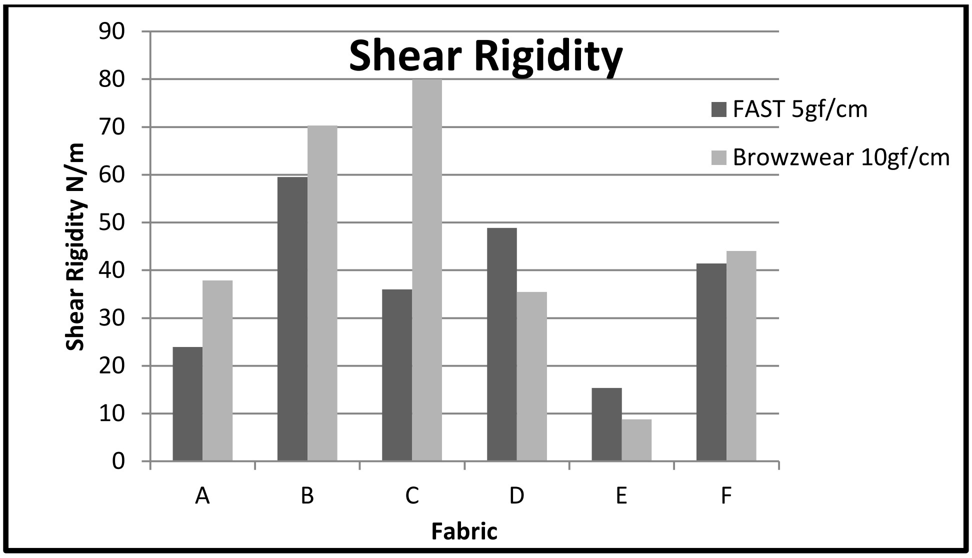

Figure (No.6)

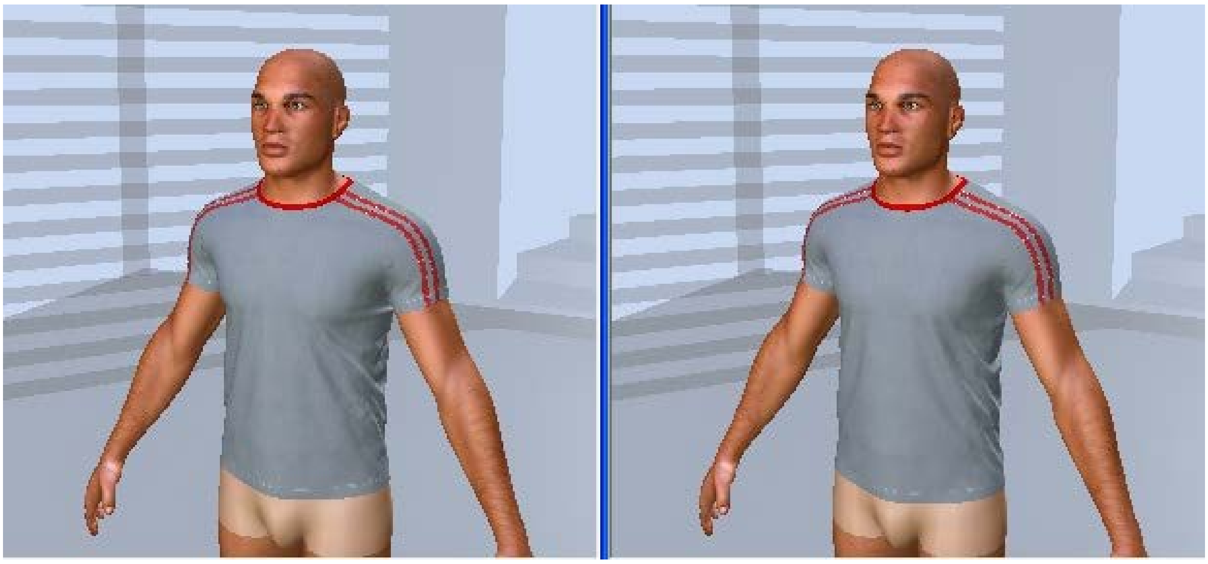

Figure (No.7)

(Images simulated using Browzwear's V-stitcher software)

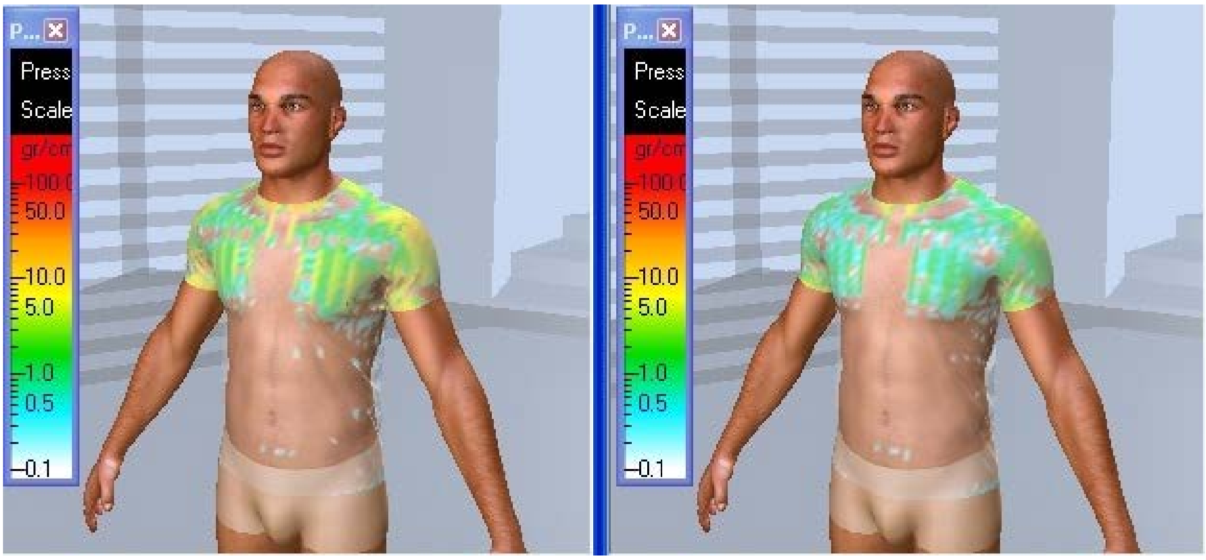

Figure (No.8)

(Images simulated using Browzwear's V-stitcher software)

4.3 Bending Rigidity

Both fabric test systems use the cantilever principle to obtain the bending length under the fabrics own weight. Utilising the mass of the material, bending rigidity was calculated based on the relationships established by Peirce (1930). The derived parameters for the six fabrics (expressed as dyne per cm) obtained using the converter functions within V-stitcher varied significantly (mean difference between the two instruments ranged from 5.57 – 61.93 dyne/cm). The difference in the results could be accredited to the different sample size used to obtain the data. FAST measured the length of the overhanging fabric inclined at an angle of 41.5° automatically, whereas the Browzwear kit relies on three manual measurements being obtained; the length of the fabric overhanging; the horizontal distance from the support; and the support height. Through manual calculation the angles obtained utilising the Browzwear test kit were derived and are illustrated in Table 2. Despite the significant difference (in the results obtained for bending rigidity from the two test systems it was observed that the 3D virtual garment simulations did not appear to be significantly affected (although it is acknowledged that this may be due to the fabric types selected). The pressure mapping function however showed some significant differences similar to the simulations illustrated in Figure 8, which suggest that the objective measuring results obtained from different testing system do have some affect on the fit parameters, but further experimentation would be required to verify this. Interestingly the images simulated using the shear rigidity and bending rigidity data show very little difference in the virtual garment simulation and fit.

Fabric	Weft θ	Warp θ
A	50.20	61.08
B	48.49	47.98
C	61.86	36.50
D	54.65	37.99
E	56.31	32.21
F	61.99	36.50

Table (No.2)

Further investigations revealed that there is some incompatibility of the units read by the instruments and that the conversion of the commercial software cannot convert the units which produces problems in comparison of the simulations.

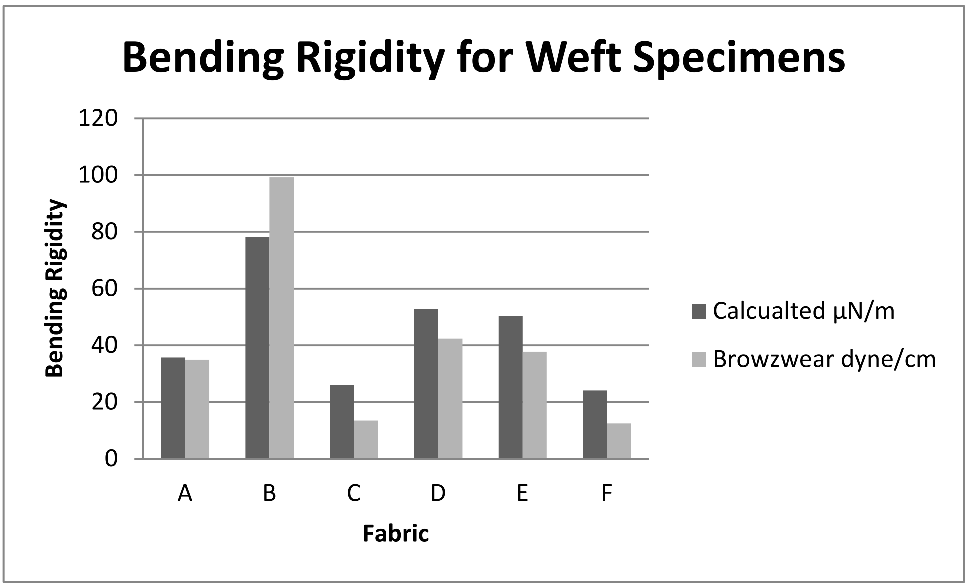

Figure (No.9)

5.0 Discussion

The work presented in this paper is motivated by a commercial 3D virtual garment simulation software which has for the first time incorporated simple but nevertheless fabric measurement instruments. The study goes further to investigate these instruments and in doing so it has analysed six fabrics to determine if fabric objective measurement results obtained from this system and FAST affect the 3D virtual garment simulation. It must be pointed out that since the instruments in question are simple and do not determine frictional characteristics of the fabric, true 3D simulation of fabric drape may be still some way away, however the realisation that even simple fabric properties are necessary along with fabric simulation software should be commended. The three key parameters used for the 3D virtual garment simulation were tensile extension, shear and bending rigidity. A two stage approach was required to convert the fabric data obtained from the FAST textile testing system. Initially it was converted into equivalent values to those derived from the data obtained from the Browzwear testing kit. The converted values needed to be noted manually and then inputted directly into the fabric parameter function within the V-stitcher software. This was a laborious task since it involved inputting and re-inputting many values, with obvious opportunity for user error, problems with unit incompatibility were recognised. The derived parameters obtained during the conversion of the FAST data were compared to those derived from the Browzwear data. The results for extensibility show good agreement between the two objective textile testing systems; with the exception of fabrics B and D. Interestingly these two fabrics were of similar structure type (single bed knits with floats) and significantly different to the other specimens. It appears that the structure and the finish (Fabric B is printed on one side) had a significant effect on the extensibility of the fabric; however this does not explain the vast differences between the values derived from the data obtained from the FAST and the Browzwear test systems. Further experimentation would be required to determine if this discrepancy was down to experimental error, or due to the structure of the fabric. Surprisingly the 3D virtual garment simulations appeared remarkably similar despite many of the results for weft extensibility at maximum load (100gf/cm) being outside the scope of the FAST testing equipment. This either suggests that the selected software is sophisticated enough to interpret the limits of the FAST testing system, or that it may not be sensitive enough to alter its output. Although these exploratory results show that for the limited number of specimens tested, fabric extensibility data obtained from the two systems do not affect the 3D virtual garment simulation, a further and more extensive study needs to be carried out. Further to this, it would be beneficial if further work was undertaken to explore fabric with extreme properties such as extensibility, recovery and hysteresis.

When the initial shear parameters obtained through the V-stitcher converter were applied to a basic T-shirt garment and modelled virtually (based on data obtained from 45° bias only using Browzwears testing kit and the average of 45° and 135 ° for FAST data) initially there was no significant visual difference observed in terms of how the garment draped in the 3D virtual environment. This was unsurprising when comparing to other studies utilising 3D virtual garment simulation which have acknowledged that since the forces involved in shear are small in some garments it has a negligible effect on the simulation and pressure mapping (Luible and Magnenat-Thalmann, 2007). However, when the pressure map function was applied to the 3D virtual garment simulation it was observed that there was some difference in fit. This is surprising given the findings of prior studies, however, this could be a result of the differences in the testing experimental procedure. Rowe's (2005) investigation found the bias direction to have a direct effect on the results obtained for extensibility and shear. Further analysis with more fabrics would need to be conducted using data calculated from a combination of the two bias directions at comparable loads. Further to this it should be noted that the exact calculation used to obtain the shear rigidity was not visible within the V-stitcher software so it was difficult to ascertain exactly how the shear rigidity results are derived. It appears that the V-stitcher converter calculates shear rigidity and expresses this as N/m, this data was then converted into shear rigidity again expressed as N/m, but the values are completely different. Interestingly when the shear values are inputted into V-stitcher converter the converted values are reduced slightly, again there is no explanation for this but it does not appear to have any significant effect on the 3D virtual garment simulation produced, again one may suspect lack of high precision.

Despite the significant difference in the results obtained for bending rigidity from the two test systems again it was observed that generally the 3D virtual garment simulation did not appear to show any significant visual affect. This suggests that again the software is either sophisticated enough to interpret the results obtained from the two selected testing systems, or it is so simple that it cannot differentiate, despite the differences within the respective test methods. It is observed that further analysis of the derived parameters was prevented since the algorithms to model the fabric parameters in the 3D virtual garment simulation were not available: again the garment simulations using the shear rigidity and bending rigidity data (obtained from FAST) show very little difference in the 3D virtual garment simulation and fit.

6.0 Conclusion

This paper presented the findings of an exploratory case in which commercial software incorporates fabric measurement for 3D garment simulation. This, however simple and recognising limitations of not measuring frictional parameters which are important for non-linear 3D modelling, is a commendable way forward with CAD companies helping in design, product development, manufacturing and retailing. The study went on to investigate the differences of the Browzwear instrument with the FAST system and in turn their effect in relation to garment simulation. Six knitted fabrics recognising their difficulties were measured compared and interpreted. Three key parameters (extensibility, shear rigidity and bending rigidity) were investigated. Despite the significant differences in test methods being utilised by the two selected system the 3D virtual garment simulations appeared consistent. It should be acknowledged that some of the selected fabrics results for weft extensibility at maximum load (100gf/cm) were outside the scope of the FAST testing equipment. However, the 3D virtual garment simulations appeared unaffected by this, raising questions of either sophistication or simplicity. It is suggested that significantly more investigations are needed to verify these results, with more fabrics and including hysteresis measured by KES-F and/or FAMOUS. Further to this, the findings of this exploratory study appear to suggest that despite the consistency in the 3D virtual garment simulation, there may be some difference expressed through fit using the pressure mapping function, which appear to highlight some visual differences between the objective fabric measurements obtained from the selected two testing systems.

It should be acknowledged that whilst the results presented in this paper are not conclusive they identify shortcomings in utilising objective measurements in garment simulation and highlight the difficulties faced by industry in terms of the usability of parameters derived from various methods and systems and that simplicity may have a price to pay in terms of accuracy. However, if each software provider introduces their own textile testing method to obtain fabric parameters specific to their software simulation it will need standardisation. It is predicted that 3D virtual garment simulation will play an important part in apparel product development in future years. However, at the moment an advanced knowledge of textile physics is required to interpret the calculated parameters required for 3D virtual garment simulation. It is unlikely that a user of 3D virtual garment simulation will acquire a knowledge of all the testing systems and methods of obtaining textile parameters from the available systems. Therefore, there is the danger of inputting data without fully understanding the limits of the system and this may result in inaccurate fitting and draping leading to extreme compression garments for underwear and sports applications being uncomfortable and non-aesthetic in draping of apparel. There is the requirement to simplify and standardise the procedure for obtaining and calculating textile properties into the required parameters for 3D virtual garment simulation. Enormous progress has been made in 3D virtual garment simulation in recent years, however, more transparency is required from the 3D virtual garment simulation software providers regarding the calculations which convert the objective test data from one test system to another, to enable comparisons of the data on which the 3-D virtual garment simulation is based. However, it is encouraging that 3D virtual garment simulation providers have recognised the importance of utilising fabric objective measurements and are actively developing alternative textile testing systems which are significantly less expensive and simpler but attention should be paid on accuracy of defining fabric behaviour. Friction is a problem that makes fabrics useful to wear in clothing, this produces hysteresis effects which need to be taken into account if we are to define their real 3D state. There is much work to be done in the area of 3D virtual garment simulation, this paper has identified areas for further research and has explored commercial instruments and software used by industry.

Reference List

Barnes, L. and Lea-Greenwood, G. (2006), “Fast fashioning the supply chain: shaping the research agenda”, *Journal of Fashion Marketing and Management*, Vol. 10 No. 3, pp. 259-271.

Barnes, L. and Lea-Greenwood, G. (2010), “Fast fashion in the retail store environment”, *International Journal of retail distribution Management*, Vol. 38 No. 10, pp. 760-772.

BS 139 (2005), “Textiles. Standard atmospheres for conditioning and testing”, *British Standards.*

BS 3356 (1990), “Determination of bending length and flexural rigidity of Fabrics”, *British Standards.*

Fontana, M., Rizzi, C. and Cugini, U. (2005), “3D virtual apparel design for industrial applications”, *Computer-Aided Design*, Vol. 37 pp 609–622.

Goldstein, Y. (2009), Virtual Prototyping: from concept to 3D design and prototyping in hours, Walter, L. et al. (Ed.), *Transforming clothing production into a demand-driven, knowledge-based, high-tech Industry*, Springer, London.

Hardaker, C.H.M and Fozzard, G.J.W. (1998), “Towards the virtual garment: three-dimensional computer environments for garment design”, *International Journal of Clothing Science and Technology*, Vol. 10 No. 2, pp. 114-127.

Hayes, S.G. and Jones, N. (2006), "Fast fashion: a financial snapshot", *Journal of Fashion Marketing and Management*, Vol. 10 No. 3, pp. 282-300.

Jones, R.M. (2002), *The apparel industry*, Blackwell Science, UK.

Kawabata, S. (1980), "The standardization and analysis of hand evaluation (2nd Edition)", *The Textile Machinery Society of Japan, Osaka.*

Kurokawa, T. (1997), "Measurement and description of human body shape and their applications", *Journal of the Society of Instrument and Control Engineers*, Vol. 36 No. 2, pp. 77-83.

Lindberg, J., Behre, B., and Dahlberg, B. (1961), "Mechanical properties of textile fabrics, Part III: Shearing and buckling of various commercial fabrics", *Textile Research Journal*, Vol. 31 No. 2, pp. 99-122.

Luible, C. and Magnenat-Thalmann, N. (2007), "Suitability of standard fabric characterisation experiments for the use in virtual simulations", MIRA Lab, University of Geneva, Switzerland. *Proceedings: Autex 2007 Conference*, Tampere, Finland, *June 2007.*

Minazio, P.G. (1995), "FAST – Fabric assurance by simple testing", *International Journal of Clothing Science and Technology,* Vol. 7 No. 2/3, pp. 43-48*.*

Peirce, F.T. (1930), "The handle of cloth as a measurable quantity", *Journal of the Textile Institute,* Vol. 21 No. 9, pp. 377-416*.*

Protopsaltou, D., Luible, M.A. and Magnenat-Thalmann, N. (2002), "A body and garment creation method for an internet based fitting room", MIRA Lab, University of Geneva, Switzerland. *Proceedings: Computer graphics International. Springer pp. 105-122.*

Rowe, H.D. (2005), "The effect of sample direction on shear rigidity values using objective measurement techniques" *Proceedings of The 84th Textile Institute World Conference,* Raleigh, North Carolina.

Stylios, G.K. (2005), "New measurement technologies for textiles and clothing", *International Journal of Clothing Science and Technology*, Vol. 17 No. 3/4, pp. 135-149.

Stylios, G.K., Han, F. and Wan, T.R. (2001), "A remote online 3-D human measurement and reconstruction approach for virtual wearer trials in global retailing", *International Journal of Clothing Science and Technology*, Vol. 13 No. 1, pp. 65-75.

Sheridan, M., Moore, C. and Nobbs, C. (2006), "Fast fashion requires fast marketing: the role of category management in fast fashion positioning", *Journal of Fashion Marketing and Management*, Vol. 10 No. 3, pp. 301-15.

Sull, D. and Turconi, S. (2008), "Fast fashion lessons", *Business Strategy Review*, Vol. 19 No. 2, pp. 4-11.

Terzopoulos, D., Platt, J.C., Barr, H. and Fleischer, K. (1987), “Elastically deformable models”, *Proceedings SIGGRAPH'87, Computer Graphics*, Vol. 21 No. 4, pp. 205-214.

Terzopoulos, D. and Fleischer, K. (1988), “inelastic deformation: viscoelasticity Plasticity, Fracture”, *Proceedings SIGGRAPH'88, Computer Graphics*, Vol. 22 No. 4, pp. 269-278.

Volino, P. and Magnenat-Thalmann, N. (2000), *Virtual Clothing*, Springer, London.

Volino, P., Cordier, F. and Magnenat-Thalmann, N. (2004), “From early virtual garment simulation to interactive fashion design”, *Computer-Aided Design*, Vol. 37 pp. 593-608.

Volino, P. and Magnenat-Thalmann, N. (2005), “Accurate garment prototyping and simulation”, *Computer-aided design and applications*, Vol. 2 No. 5, pp. 645-654.

Wacker, M., Keckeisen, M. Kimmerle, S. Straber, W. et al. (2005), “Simulation and visualisation of virtual textiles for virtual try-on”, *RJTA,* Vol. 9 No. 1, pp. 37-47.

Wang, J.P. and Zhang, W.Y. (2007), “An approach to predicting bra cup dart quantity in the 3D virtual environment”, *International Journal of Clothing Science and Technology*, Vol. 19 No. 5, pp. 361-373.

Walter, L., Kartsounis, G. and Carosio, S. Ed. (2009), *Transforming clothing production into a demand-driven, knowledge-based, high-tech Industry*, Springer, London.

Xu, B. and Svinivasan, S.V. (1999), “A 3D body imaging and measurement for apparel customization”, *Journal Of Textile Institute,* Vol. 90, No. 2, pp. 104-120.

Xu, B., Huang, Y., Yu, W. and Chen, T. (2002), “Body scanning and modelling for custom fit garments”, *Journal of Textile and Apparel, Technology and Management*, Vol. 2 No. 2, pp. 1-11.