Journal of Fashion Business
Vol. 15, No. 6, pp.101~112(2011)

A Study on the 3D Scanning of Fashionable Textile Materials

- Ripple-finished Cotton Fabric and Shrink-proof Finished/Felted Wool Fabric -

Kim Jongjun
Prof., Dept. of Clothing and Textiles, Ewha Womans University, Seoul, Korea

Abstract

Three-dimensional(3D) virtual clothing simulation system may require the use of physical, mechanical, and configurational data in order to mimic the actual clothing with high degree of realism. Therefore the 3-dimensional scanning system based on optical methods was adopted to extract the 3-dimensional data of the fabric surface. In this study, the appearances of the 3-dimensionally transformed textile fabrics via several finishing procedures were investigated using a 3D scanning system. The wool gauze fabrics treated with the shrink-proof finishing and the felting process showed height changes up to 4.5mm. The 3-dimensional configuration may be objectively described by the use of mesh generation from the scanned output. The generated mesh information may further be utilized in the 3D virtual clothing simulation system for accurate description of the fashionable textile materials used in the simulation system.

Key Words : 3D scanning, ripple finishing, shrink-proofing, felting, wool.

I. Introduction

Domestic textiles and fashion industries have already globalized, thus establishing overseas production lines along with huge consumer markets of the textile products. At the same time, the design of fashionable textile materials requires outstanding ingenuity along with a variety of ingredients on top of the technological supports and marketing endeavors in order to lead the volatile yet huge global fashion markets.

Currently introduced textile finishing procedures include novel resin finishing methods, and diversified modification processes in order to endow the fabrics with novel functions and properties, which are not inherent to the original properties or functions of the traditional textile

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Corresponding Author: Kim Jongjun, Tel.+82-2-3277-3102, Fax.+82-2-363-3078
E-mail: jjkim@ewha.ac.kr

fabrics or fibers. The novel finishing procedures are being expanded to the sectors of bonding or coating processes, which encompass the nonwoven, flocking, and artificial leather industries. These novel textile finishing methods are regarded as indispensable tools to transform the traditional mass-production industries into the leading industries capable of creating new values of creativity in the textile products.

Recently, 3-dimensional virtual clothing systems[1~6] have emerged as a new sector supporting to the developments in textile and fashion industries. The system may also supply novel methods for planning of textile fabric, fabric trend study, apparel construction,[7] marketing, sales, communication, and design. Precise and accurate pattern making[8] is of pivotal importance in the apparel industry. In the 3-dimensional virtual clothing simulation system, the precision and accuracy of the supplied pattern data immensely affects the quality of simulated clothing products.[9,10]

With the advancement in the computer hardware, graphics researches, and 3-dimensional virtual clothing simulation systems, there has been a mutual enhancement in the degree of requirement for the realistic simulation in the software systems. On top of the implementation of the texture mapping techniques to make the simulation result visually pleasing, the behavior of the fashionable textile fabrics is closely simulated to mimic the actual movement of the clothing during the wearer's walking or turning action. At a certain point, however, the appearances of the creases or wrinkles generated around the bent area of the simulated clothing do not always look realistic to the sensitive eyes of the viewers. Therefore, it is necessary to actually measure the creases, drape contours, or the intentionally deformed finishing effects or textile effects,[11~13] including the seersucker patterns, large knit loops, plisse patterns with some degree of precision, even if the task is not trivial.

Since most of the textile fabrics are easily deformable with some degree of stiffness, drapable, stretchable, the appearances and behaviors of the actual clothing are not easily definable or described by one simple approach of the 3D virtual clothing system. In this study, the appearances of the 3-dimensionally transformed textile fabrics via several finishing procedures are studied by using a 3D scanning system.[14~16] The 3-dimensional configuration may be objectively described by the use of mesh generation from the scanning output. The generated mesh information may further be utilized in the 3D virtual clothing simulation system for accurate description of the fashionable textile materials used in the simulation system.

II. Theoretical backgrounds

1. Ripple Finish of Cotton Fabrics

The principle of the ripple finish of cotton fabrics is based on the mercerization process. Mercer was the first to observe the caustic soda treatment of cotton, which led to the contraction of the length of fiber, increased the tensile strength and dye affinity.[17] One of the variety of the processes is the slack mercerization. Slack mercerization is a process of mercerizing the cotton fabric in absence of tension or under reduced tension. After washing, the cotton fabric remains in the shrunken state with subsequent development of high yarn crimp rate. This makes the fabric more stretchable. However, the luster is not increased during this slack process. The cross-section shape of cotton fiber becomes rounder by swelling. The solution of the caustic soda penetrates into the amorphous region of the cellulose fiber causing the swelling together with other physical and structural changes.

Ripple finishing, based on the mercerization process, changes the fabric surface appearance by adding ripples on the flat fabric. After printing the indalca paste containing caustic soda on the cotton fabric, contraction takes place in the printed area with no effect on the remaining intact area. The differences in the level of contraction in the cotton fabric result in the rippled sections and flat sections on the cotton fabric surface. The ripple finish process endows the flat cotton fabric with 3-dimensional appearance, thereby adding cool touch during hot and humid weather, allowing more room between the fabric and the skin surface and better breathability.

2. Felting and Shrink-proof Finishing of Wool Fibers/Fabrics

When wet wool fibers are subjected to mechanical action of compression and relaxation, there occurs the development of felting. Under the influence of appropriate temperature and alkaline solution, the felting phenomenon is accelerated. Individual wool fibers pack themselves closer together, and the soft and bulky structure of the original wool mass becomes a hard mass with tightly interlocked fibers. Felting of wool is both favorable and unfavorable. The shrinkage of wool product during its use is an unfavorable property. In order to prevent the shrinkage of the wool product, a shrink-proof finishing is required. The shrink-proof finishing is based on the reduction of the directional frictional effect(DFE) of the wool fibers. The finishing agents for the shrink-proof finishing are: dichloroisocyanuric acid(DCCA) and potassium permanganate($KMnO_4$).[18] The other finishing methods include corona discharge treatment and plasma treatment of the fabric. CSIRO(Commonwealth Scientific and Industrial Research Organisation) has developed the Chlorine-Hercosett Process, during which the surface of wool fiber is chlorinated under acidic condition. The application of Hercosett resin(polyamide-epichlorohydrin) provides the wool fiber surface with thin coating of the resin, thereby causing the reduction in the DFE and shrinkage of the fabric.

3. 3D Scanning

The 3D scanning system would serve as a good candidate in order to study the appearances of the fabric drape, creases or wrinkles, and intentionally deformed textile products such as seersuckers, plisse, ripple, and pleats. The 3D scanning system may be divided into two types: contact methods, and non-contact methods.

Since the fabric surfaces are mostly compressible and easily deformable, the contact method of describing the fabric objects is used in some limited area, where the contact pressure does not change the structural factors appreciably. Coordinate measurement machines (CMM) are prevalently employed in the contact method of 3D scanning.

Non-contact scanning allows relatively much faster scanning speed. With the advances in CCD(Charge Coupled Device) camera or sensors and projector technologies, recent optical scanners are achieving accuracies required for the reverse engineering. Structured-light 3D scanners are based on optical technologies.[19] They use projectors to cast fringe patterns or laser lines, and calculate the true shape of the physical object by reading the returned pattern.

Time-of-flight(TOF) type laser range finder (LRF) system scans its light source to the object, and measures the time for the light returns to the system, thereby calculates the distance between the system and the object. This type of system is mostly employed in measuring large structures, such as building or construction measurement.

White light scanning, or structured light scanning, method is used to describe a wide range of 3D scanning instruments. Its principle is to project a specified pattern of light and use CCD cameras to capture images of the object while the patterns are being projected on the surface of the object. In cases where multiple patterns or grids are projected on the object, the software refers to the shape changes in the known pattern as reference in order to analyze the measurements. In recent years, multiple-stripe laser triangulation methods have been developed to accurately interpret the complex patterns on the object.

III. Experimentals

1. Fabric Specimens

<Table 1> shows the specifications of the fabric specimens. Cotton fabric and wool gauze fabric specimens were prepared for the ripple finishing and shrink-proof finishing with subsequent felting process.

2. Finishing Methods

1) Ripple Finishing of Cotton Fabric Specimen

500 gram of 25% NaOH aqueous solution was prepared for the ripple finishing of cotton fabric specimen. As a thickening paste for the subsequent silk printing, 20 gram of indalca powder was added to the prepared NaOH solution to obtain adequate viscosity for the silk printing, with subsequent stirring.[20] The pattern of the silk screen had crossings of vertical and horizontal lines. The mixture of NaOH aqueous solution was poured on the surface of silk screen for the cotton fabric printing, and spread evenly by using a rubber blade. Treated fabric was then dried under a room condition. Dried fabric was rinsed thoroughly with running water, and neutralized in an 1.0% acetic acid aqueous solution bath, with additional rinsing.

2) Shrink-proofing Finishing and Felting of Wool Fabric Specimen

As a shrink-proofing agent, syntha R-BAP was employed in the shrink-proofing treatment of the wool gauze fabric. Sodium alginate(empirical formula: $NaC_6H_7O_6$) was used as a thickening agent. Sodium bicarbonate($NaHCO_3$) was used as a neutralizing agent. The paste of 4% sodium alginate powder(2.4 gram) was prepared in 57.6 ㎖ of distilled water. The paste was then mixed with the shrink-proofing agent solution, containing 12㎖ of syntha R-BAP, 3.0 gram of sodium bicarbonate and 120㎖ of distilled water.[18] The paste of thickener and the shrink-

<Table 1> Fabric specifications.

Fabric specimen	Thickness, mm	Weight, g/m^2
Cotton fabric	0.21	75
Wool gauze fabric	0.27	78

proofing agent solution were mixed thoroughly. The mixture was then printed on the wool gauze fabric using a round sponge stamp. The treated fabric was dried and cured in a hot-air oven of 110℃ for 20 minutes. The cured wool fabric was then subject to a felting process until desired degree of felting of the untreated wool section was accomplished in a soap solution bath at the temperature of 60℃.

3. Measurement of Thickness and Dimensional Changes

1) Thickness measurement

The thickness of the fabric specimen was measured using a thickness gauge conforming to the specification of the KS K0506.

2) Optical microscopy

An optical microscope with a CCD camera was used to observe and record the fabric appearance changes. For the illumination, transmissive or incident light was used under the microscope.

3) 3D Scanning using Structured Light

Structured-light based 3D scanning system was employed to measure the 3-dimensional change of the cotton and wool fabric specimens. The 3D scanning system comprises a video projector, a CCD camera or an equivalent device, a PC, and a set of supporting mounts or brackets. The 3D scanning system was calibrated using a calibration plate with suitable dimension of interest.

Prior to the scanning of treated fabric specimens, a preliminary examination of a few simple objects with known dimensions, mounted on a flat panel, was implemented in order to verify the accuracy of the 3D scanning system. The objects included a semi-circular cross-section wooden bar, a triangular cross-section wooden bar, and a flat steel plate with known height values.

The treated fabric specimen was mounted on a flat panel, and placed vertically in front of the 3D scanning system. The CCD camera was interfaced to a PC, which controlled the projector and the camera. The fabric specimens were mounted on a black foam board by using double-stick tapes.

The scanned result was saved as OBJ (Wavefront .obj file: a 3D geometry definition file format developed by Wavefront Technologies) file format. The OBJ file was then imported into a NURBS-based CAD software, Rhino3D.21) A polyline was drawn on the mesh object of interest, using the Polyline-On-Mesh built-in function. After the polyline was successfully constructed, Polyline-Points script was loaded in order to export the coordinate values, x, y, z, as a text file format. The coordinate values, x, y, z, were finally imported into MS Excel spreadsheet software to analyze the height values along the x-axis of the scanned fabric specimen.

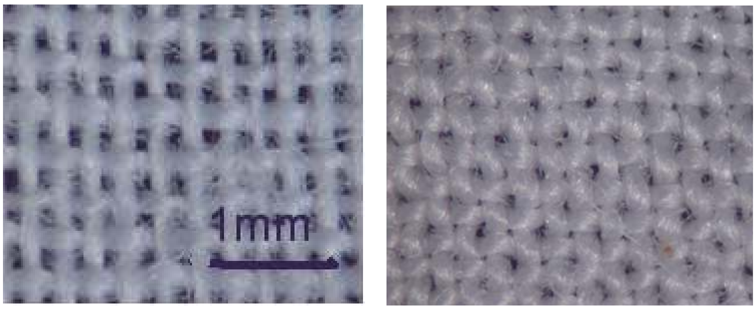
Ⅳ. Results and Discussion

1. Microscopy Observations and Thickness Changes

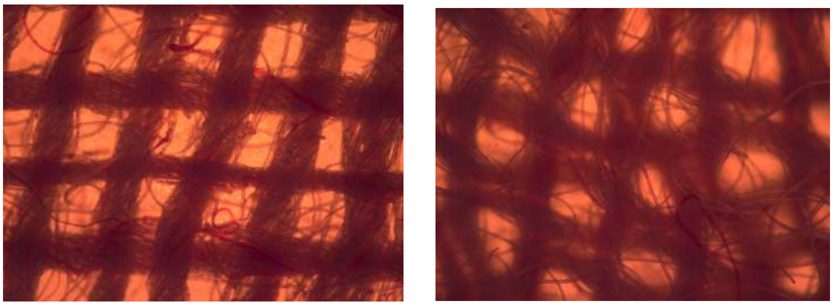
As shown in <Figure 1>, the cotton yarns in the treated fabric specimen shows appreciable amount of contraction due to the ripple finishing process compared to those the control fabric(untreated cotton). The spacing between the yarns also decreased due to the contraction of the yarns by the strong alkaline treatment. The property changes are due to the less closely-packed fine structure of the unit cell of cellulose II.

<Figure 2> shows the changes in wool gauze fabric specimen due to the shrink-proof finishing and subsequent felting process. The yarns in the shrink-proof finished wool sections do not show any development of the entangled felted fibers around the warp or filling yarns, while those in the untreated wool sections show many entangled fibers with the yarn configurations appreciably displaced due to the contractions and entanglements by the DFE of projecting scales on the wool fibers.

<Table 2> shows the thickness changes of the fabric specimens due to the treatment methods. The thickness of the ripple-finished cotton fabric is 0.27mm, while that of the control cotton fabric is 0.21mm, indicating the thickness increase due to the contraction by the structural change incurred by the NaOH solution infiltrated into the amorphous region of the cellulose molecular chains. The thickness of the shrink-proof finished section of the wool gauze fabric is 0.31mm, while that of felted only section without shrink-proof treatment is 0.65mm with an increase of 0.38mm, compared to that of control specimen. This thickness change clearly explains the effect of felting which accompanies the entanglement of fibers around the yarns, and the disoriented and contracted yarns in the felted wool section of the specimen. Compared to the thickness of control



<Figure 1> Photographs of the cotton fabric specimens.
(left: control, right: ripple finished, 100x)



<Figure 2> Photographs of the wool gauze fabric specimens.
(left: felted area with shrink-proof treatment,
right: felted area without shrink-proof treatment, 100x)

wool gauze fabric, 0.27mm, that of shrink-proof finished section does not show much of increase.

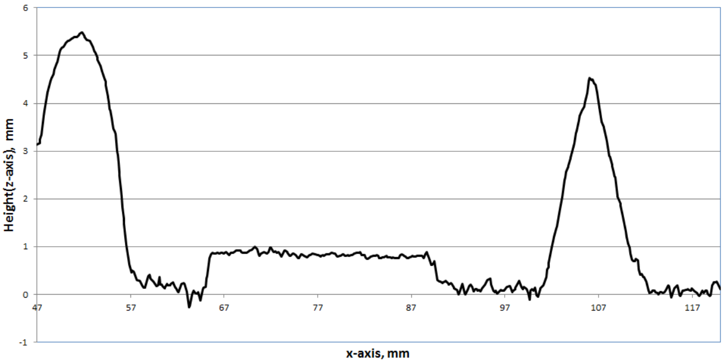
2. Height Profile Analysis of Samples of Known Dimension

<Figure 3> shows the height profile of the three known samples of semi-circular, triangular, and flat cross-section bars. As shown in <Table 3>, the height differences ranges from -0.1mm to 0.3mm. The 0.3mm difference for the triangular shape may be due to the steep angle of the tip of the sample. The resulting consequential accuracy level seemed to be relatively satisfactory.

3. Analysis of 3D Scanning Measurement of Cotton Fabric Specimen

<Figure 4> shows a photograph of the cotton fabric specimen, treated with the ripple-finishing paste. It can be seen in the photograph that there are small squares. They show irregular wavy structures inside the square shapes, with the treated parts showing clearly flat structure due to the shrinkage. Dye affinity of the treated area increased due to the fine structural changes of the cellulose molecules.

<Figure 5> shows the rendered image of 3D scanned cotton fabric specimen, where the two separate lines represent the results of Polyline-On-Mesh function in Rhino3D software



<Figure 3> Height profile from 3D scanning measurement.

<Table 3> Comparison of height measurement using 3D scanning.

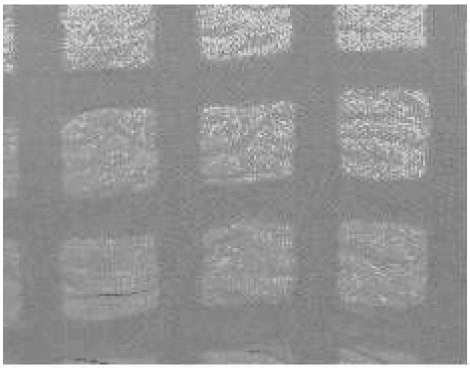
Sample for Measuring Height	Height(A), mm	3D Scanned Height(B), mm	Height Difference (A-B), mm
semi-circular cross-section bar	5.40	5.40	0.00
triangular cross-section bar	4.80	4.50	0.30
flat steel plate	0.70	0.82	-0.12

program on the fabric mesh object. The z-axis points toward the viewer's view point starting from the paper's plane.

<Figure 6> shows the height profile values plotted against the y-axis of the rendered image of 3D scanned cotton fabric specimen. The height profile values of the regions containing wavy squares were in the range from 1.3mm to 2.5mm, while those of the contracted flat sections range from 1.6mm to 1.9mm. The relatively wide range of height profile values is an objective indication of the 3-dimensional deformation of the cotton fabric, which adds interesting feature to the mass-produced flat textile fabrics.

4. Analysis of 3D Scanning Measurement of Wool Gauze Fabric Specimen

<Figure 7> shows a photograph of the wool gauze fabric specimen, which is treated with the shrink-proofing agent and subjected to subsequent felting procedure. There are rows of three or four round shaped shrink-proof finished



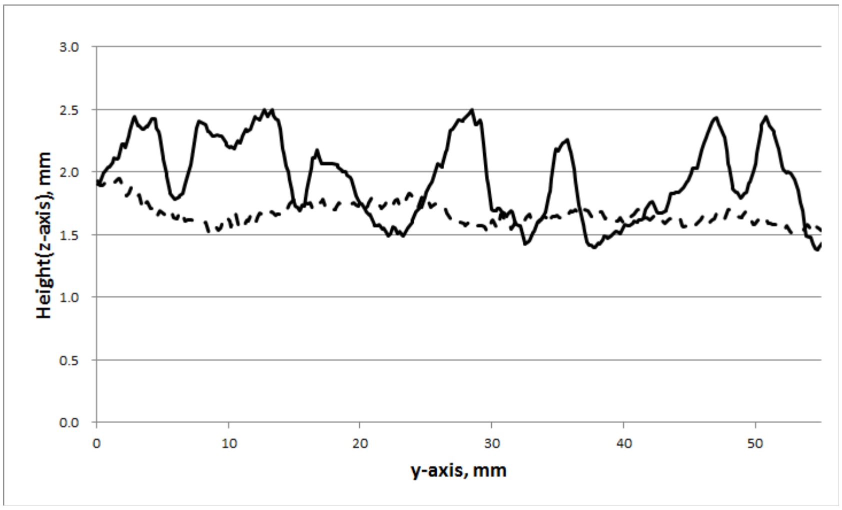
<Figure 4> Photograph of the cotton fabric specimen.

<Figure 5> Rendered image of 3D scanned cotton fabric specimen.
(Two lines represent the results of Polyline-On-Mesh function on the fabric mesh object.)

parts in a row, which have irregular wavy structures inside the circular shape, with the remaining parts showing clearly felted flat structure.

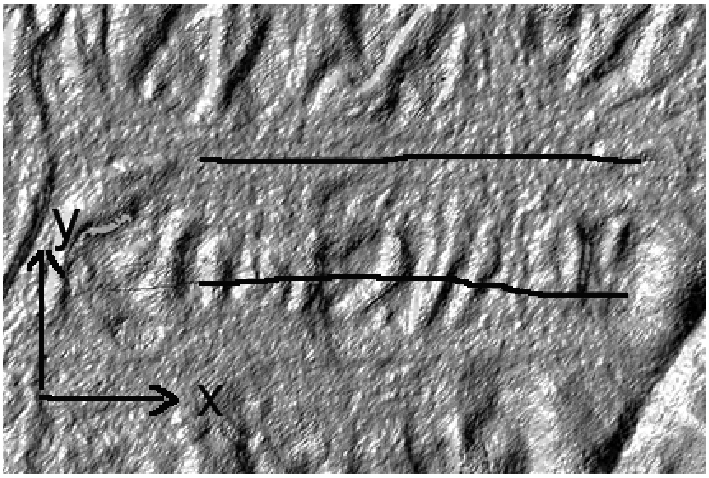
<Figure 8> shows the rendered image of 3D scanned wool gauze fabric specimen, where the two separate lines represent the results of Polyline-On-Mesh function in Rhino3D software program on the fabric mesh object. The z-axis points toward the viewer's view point starting from the paper's plane.

<Figure 9> shows the height profile values

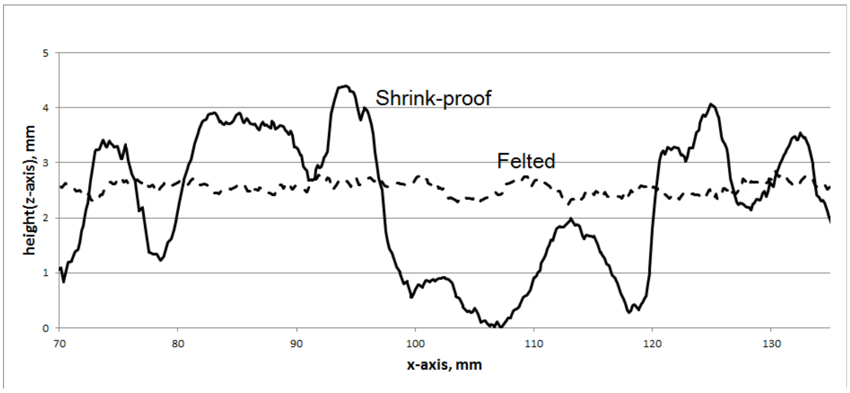


<Figure 6> Height profile from 3D scanned cotton fabric specimen.

<Figure 7> Photograph of the wool gauze fabric specimen.
(Rows of almost round shapes with irregular
waves are shrinkage-proof finished sections)



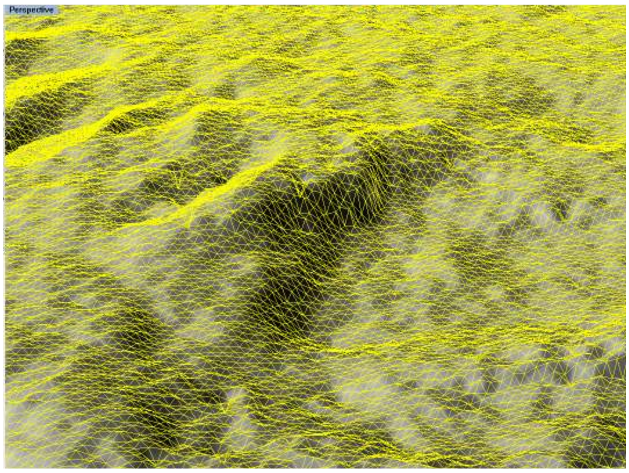
<Figure 8> Rendered image of 3D scanned wool gauze fabric specimen.
(Two lines represent the results of PolylineOnMesh
function on the fabric mesh object.)



<Figure 9> Height profile from 3D scanned wool gauze fabric specimen.

plotted against the x-axis of the rendered image of 3D scanned wool gauze fabric specimen. The height profile values of the shrink-proof finished sections of the wool fabric range from almost 0mm to 4.5mm, while those of the felted sections range from 2.3mm to 2.8mm. The wide range of height profile values is an objective indication of the 3-dimensional deformation of the flat wool fabric, which adds interesting feature to the mass-produced textile fabrics.

<Figure 10> shows the triangular mesh surface constructed from the OBJ file taken using the 3D scanning system. The number of mesh objects may further be reduced to alleviate the CPU processing and memory burden in the 3D virtual clothing simulation software system. With the configurational mesh data base of the fashionable textile materials, the 3D virtual clothing simulation system would accomplish the realism of the virtual clothing.



<Figure 10> Perspective view of the triangular mesh surface of the wool gauze fabric treated with the shrink-proof finishing.

V. Conclusion

Currently introduced textile finishing procedures include a variety of resin finishing methods, and diversified modification processes in order to endow the fabrics with novel functions and properties, which are not inherent to the original properties or functions of the traditional textile fabrics or fibers. Therefore, some of the surface contours of the fashionable textile products are deviated from the flat structures. It is necessary to consider these configurational changes in order to increase the realism of the 3D virtual clothing simulation systems introduced recently to the textile and fashion industries.

1. The change in the surface height of fabric specimens may be measured accurately in the order of less than 1.0mm under the specific experimental settings of the 3D scanning system used in this study. Even though highly transparent material or sheer textile fabrics may not be accurately measured, the configurations of employed cotton and wool gauze specimens were measured without much of a difficulty.

2. The cotton fabrics treated with the sodium hydroxide solution paste showed good amount of 3-dimensional variations on the otherwise flat surface. The range of height level change was at least 1.2mm.

3. The wool gauze fabrics treated with the shrink-proof finishing and the felting process showed height changes up to 4.5mm. If this type of pronounced surface features is possibly incorporated into the 3D virtual clothing simulation systems, the degree of realism attained by the final simulation would be highly increased.

The measured configurational values of the cotton, wool, and other finished fabrics may further be used for the 3D virtual clothing mesh adjustment, which would increase the degree of realism and sophistication of the static or dynamic virtual clothing prepared by the 3D virtual clothing simulation system.

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Received Sept. 29, 2011
Revised Nov. 21, 2011
Accepted Nov. 28, 2011