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A study on the Analysis of 3D Scanning of Knit Stitches and Modeling System

- Jersey, Rib, and Cable Stitches -

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Abstract

Since knitted textile products mostly do not require long span of time from the conception to the final products, they have lead the fashion trends during the recent decades. Developments in the textile engineering industries, and computer software and hardware industries have made the 3D virtual clothing software system easily accessible by the fashion/textile industry personnel. The simulated models of apparel products using the state-of-the-art virtual clothing systems are, however, not the replica of real-world garments. Moreover, the garments do not maintain fixed shapes during wearing. Deformations at low external stress lead to difficulties in predicting the behavior of the knitted garments. Therefore, there is a need to compare the differences in appearances, textures, or other related properties between simulated fabrics and actual fabrics. Three knit stitches including jersey, rib, and cable stitches are examined in this study. The differences between fluffy thick yarns and thin yarns are also compared using 3D scanning and surface reconstruction. Obtained three-dimensional data regarding the reconstructed knit specimens would help to build a data base for estimating the behavior of the 3D models of the knitted garments.

Key Words : 3D modeling, 3D scanning, Structured light, Knit stitch, Cable stitch

I. Introduction

Clothing customization process has been developed to meet the personalized need of the customer with the development in the textile machinery sector and computer hardware/ software sector. Demand for more personalized textile products is continuously rising. Trendy knitted products may well suffice the personal needs in terms of textile materials and constructions.

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Knitted products provide excellent comfort properties. Tactile and appearance properties are also important in all types of apparel fabrics.[1)] Knitting is the second most often implemented process after weaving process, which transforms yarns into fabrics.

The porosity of knitted fabrics is generally higher than that of woven fabrics. This characteristic comes from the structure of knit stitches. The loose structure of a knitted product differentiate itself from the woven fabric product in physical and mechanical properties and appearances.

Yarns comprising the knitted fabrics also play an important role in determining the comfort and tactile properties along with the physical and mechanical properties of the fabrics. Most of the knitted products made of flat untwisted filament yarns exhibit higher luster than those made of twisted cotton spun yarns do.

One of the recent studies simulates the knit stitches using a two-stage hybrid models consisting of sheet-level fabric simulation and relaxation based yarn-level simulation.[2)] In the yarn-level model, yarns are regarded as splines and the internal forces resist bending and intra-segment stretching.[3)]

However, the computer simulated models of textile fabrics or apparel products are not exact representations of real-world garments comprising soft and pliable textile materials. The garments may have several layers, wrinkles or folds which do not maintain fixed shape during wearing. Therefore, there is a need to compare the differences between simulated fabrics and actual fabrics.

3D surface reconstruction involves fitting of scanned data, filling of surface holes, and remeshing of existing models.[4)] The graphic process may utilize currently available utility programs, including MeshLab[5)], or ZBrush[6)]. Peirce[7)] presented a knit stitch model based on a geometric description. Kurbak et al. studied modeling of rib knitted fabric using 3DS-MAX computer graphics program.[8)]

Most of the textile testing schemes involve applying near-uniform deformation of the fabric specimen. Kawabata Evaluation System(KES)[9)] covers the comprehensive types of measurements, including tensile, bending, shearing, and compression.

A different measurement approach was reported by Miguel et al.[10)] They employed a vision system to recover the space-time geometry of the deforming cloth, which is then interpreted as a 3D image. The specimen is attached to a multitude of sensors and actuators. Pattern matching algorithm was utilized in detecting textile fabric pattern design or fault detection system.[11)]

In this study, three knit stitch types, and two knitting yarn types are employed. Knit stitch types include jersey(plain), rib, and cable stitches. Knitting yarns include thick bulky yarn type and thin yarn type. Jersey knit stitch is 3D modeled using a 3D CAD program in order to review the three-dimensional structure of the basic stitch together with the 2D rendering using a 2D textile design CAD program. Jersey, rib, and cable stitch knit specimens are 3D scanned using a structured light 3D scanner in order to review the three-dimensional surface shape and texture of the specimens.

II. Experiments

Plain knit stitches are 3-dimensionally modeled using a 3D CAD program based on a simple geometry model. Cable stitches are

2-dimensionally modeled using a 2D CAD program, dedicated for textile CAD design. Actual knit specimens of different stitch types are scanned using a structured light illumination and a CCD camera. The scanned images are analyzed using a 3D CAD program or an image analysis program.

1. Knitted fabric specimens

Plain knit, the basic form of knitting, can be produced by using a flat knitting machine. It is often called jersey stitch. Rib stitch produces alternate rows of plain and purl stitches, resulting in pronouncedly textured vertical stripes. Cable stitch is formed by crossing one stitch over another. Two types of knit specimens are prepared, hand knitted and flat-bed knitted. Hand knit specimens are prepared using 25mm diameter knitting needles for thick plied knitting yarns made of fluffy wool fibers. Flat-bed knit specimens, made of thin knitting yarns, are obtained from a series of experimental products, published by knitting center of KITECH, at Dongdaemun Fashion Supporting subsidiary, prepared using a flat-bed weft knitting machine. Sample code for the former starts with H(Hand), and the code for the latter starts with F(Flat).

2. Thickness measurement

Thickness of knit specimen is measured using a thickness gauge based on the specification of KS K0506. For the rib and cable stitch specimens, thicker region of the specimen is selected for the measurement.

3. Knit stitch model simulation

Rhino3D(v4.0, and v2.0, Robert McNeel and Associates, U.S.A.)[12] was used to prepare a 3-dimensional knit stitch model of continuous monofilament yarn. Geometrical knit stitch structure is based on the Peirce model. The Peirce model is then ported to the Rhinolator plug-in program to generate a data set of x, y, z Cartesian coordinates. The data set represents the central axis of the geometrical knit stitch. Three-dimensional model of the knit stitch is then rendered with adjusted material transparency under an appropriate illumination condition. TexPro[13] was used to prepare a 2-dimensional knit stitch presentation with relatively realistic image of knitted product.

<Table 1> List of knit specimens with basic specifications

Knitting method	Yarn count	Fiber composition	Sample code	Stitch type
Hand knitting	Nm 1 4ply	Wool (100%)	HJ	Jersey
			HR	Rib(2x2)
			HC	Cable(3x3)
Flatbed weft knitting	Nc 30/2 4ply	Cotton/Acryl (50:50)	FJ	Jersey
			FR	Rib(3x3)
			FC	Cable(3x3)

4. 3D scanning and surface reconstruction

3D scanning of objects is implemented using a structured light scanning system, comprising a machine vision CCD camera and a projector. The lenses for the CCD camera are 6mm and 12mm focal length lenses. In order to adjust the size of the projected area, a suitable close-up lens is added in front of the projector. In order to get an accurate scanning result, calibration of the CCD camera should be performed prior to the structured light scanning. 3D reconstruction is implemented using a mesh reconstruction program(MeshLab).

III. Results and Discussion

1. Physical measurement result

As shown in <Table 2>, thickness values of hand knitted specimens are much higher than those of flatbed weft knitted specimens. Wales/inch and courses/inch values of hand knitted specimens are lower than those of flatbed weft knitted specimens.

2. Jersey stitch analysis

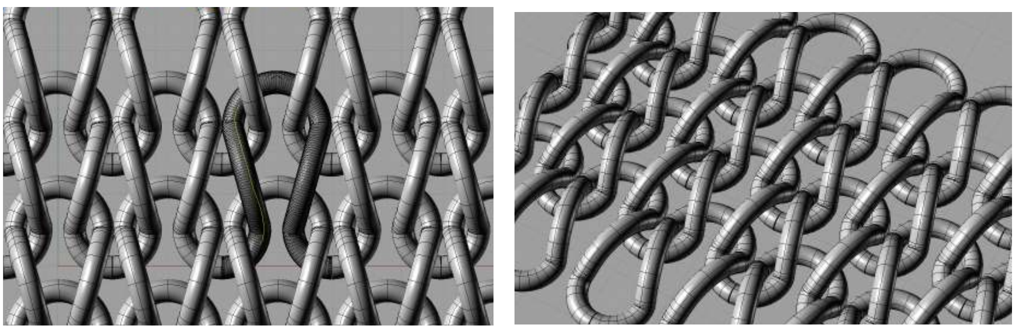
Jersey stitch is simulated based on the 3D CAD program, Rhino3D, as shown in <Fig. 1>.

Three-dimensional model of the jersey stitch is rendered with adjusted material transparency /reflectivity under an appropriate illumination condition.

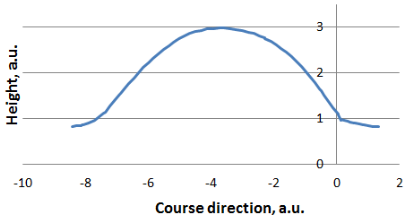
The yarn surface height profile of the 3D monofilament model is clearly shown in <Fig. 2a>. In order to plot the height profile, a dark polyline is drawn on the scanned knit stitch surface as shown in <Fig. 3>.

<Table 2> Measurement results

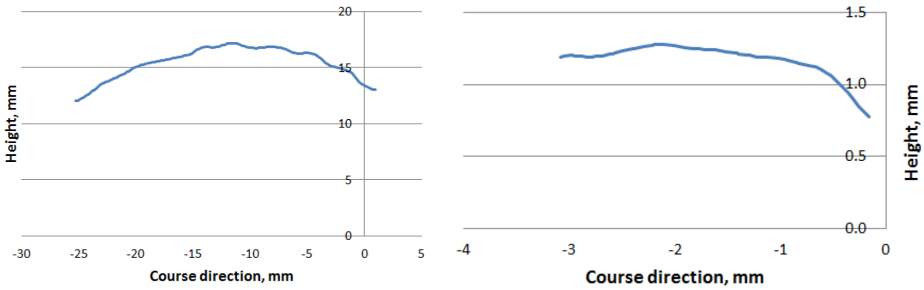
Knitting method	Sample code	Thickness, mm	Wales/inch	Courses/inch
Hand knitting	HJ	5.05	1.0	1.4
	HR	6.98	1.6	1.6
	HC	9.73	1.3	1.4
Flatbed weft knitting	FJ	0.93	7	10
	FR	1.85	13	16
	FC	1.62	12	12



<Fig. 1> Top and perspective views of 3D knit stitch model(jersey knit).

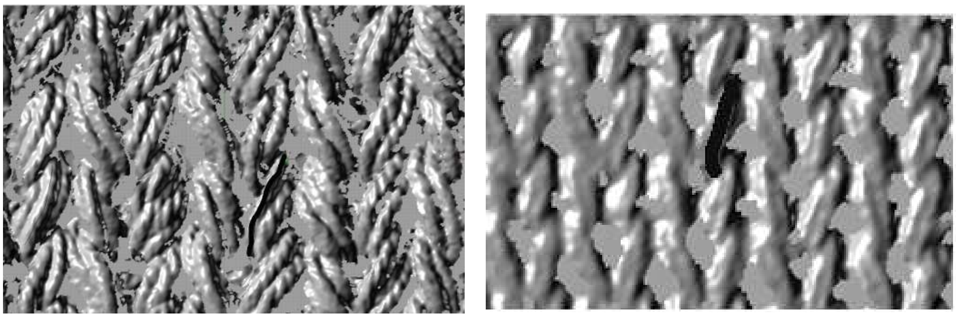


(a) 3D model of monofilament knit stitch (a.u.: arbitrary unit)



(b) 3D scanned height profile of HJ stitch (c) 3D scanned height profile of FJ stitch

<Fig. 2> Height profile of knit stitches, (a)3D model, (b) HJ, (c) FJ.



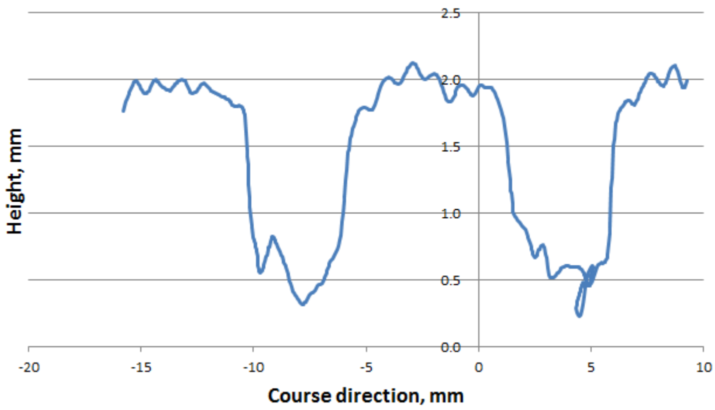
<Fig. 3> 3D scanned surface image of knit stitches, (a) specimen HJ, (b) specimen FJ.
(A polyline is drawn on the surface of the 3D scanned knit stitch.)

Since the 3D scanning is based on optical measurement, the shape of the knit stitch is not subject to any deformation during the measurement. The maximum value of the height profile of specimen HJ reaches 16.9mm, while the value of thickness measurement is 5.05mm. <Fig. 2> The maximum value of the height profile of specimen FJ reaches 1.27mm, while the thickness measurement of specimen FJ results in 0.93mm. The effect on the value of measured height or thickness due to the difference in the pressure is much larger in the case of HJ. As shown in <Fig. 2b>, the height profile looks more jagged compared to that of the monofilament type 3D model. It seems to be related to the 4-ply spun yarn structure comprising the HJ specimen. The height profiles, which correspond to the dark polylines drawn on the knit stitch of the reconstructed surface of 3D scanning, are obtained using 'PolylinePoints' function of Rhino3D.<Fig. 3>

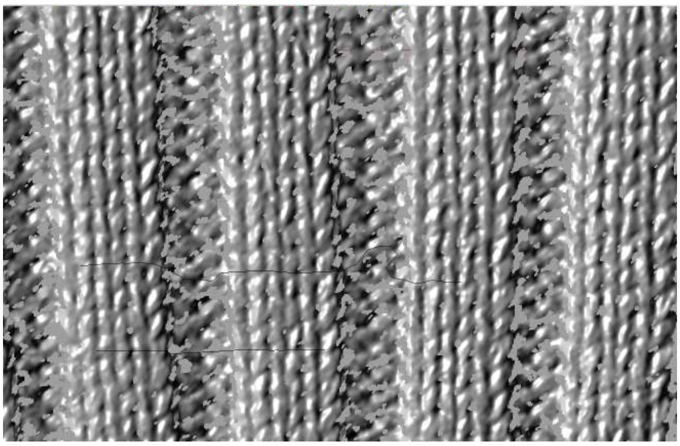
3. Rib stitch analysis

The height profile of the rib stitch specimen, FR, is shown in <Fig. 4> A polyline is drawn, along the course direction, on the surface of the 3D scanned image representing the height profile. <Fig. 5>

The height profile plot corresponds to the thickness data shown in <Table 2>. The average height values of left and center ribs are 1.94mm and 1.98mm respectively. The values almost coincide with the thickness value of 1.85mm with the small difference of 0.09~0.13mm, which may be attributed to the fact that thickness measurement requires compressional pressure during the measurement, therefore the measurement



<Fig. 4> Height profile of knit stitch, FR.



<Fig. 5> 3D scanned image of knit stitch, FR.

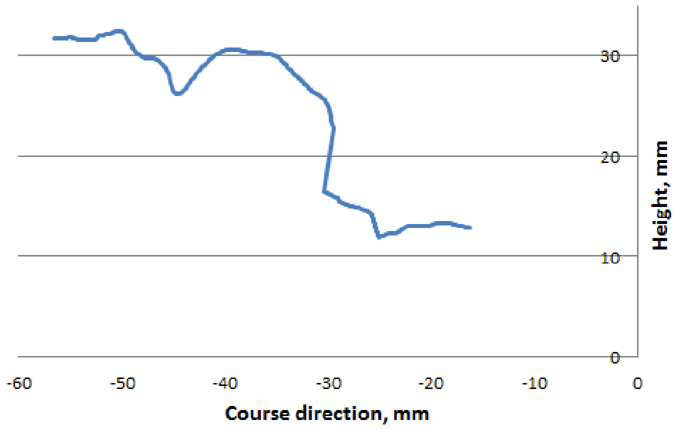
of thickness under compression gives lower value than the measurement result based on the optical 3D scanning scheme which does not require any pressure on the specimens.

The average value of height profile of a rib in HR specimen reaches almost 30mm.<Figs 6,7> The height value is different from the thickness measurement value of 6.98mm, due to the high yarn bulkiness and pressure effect during the thickness measurement.

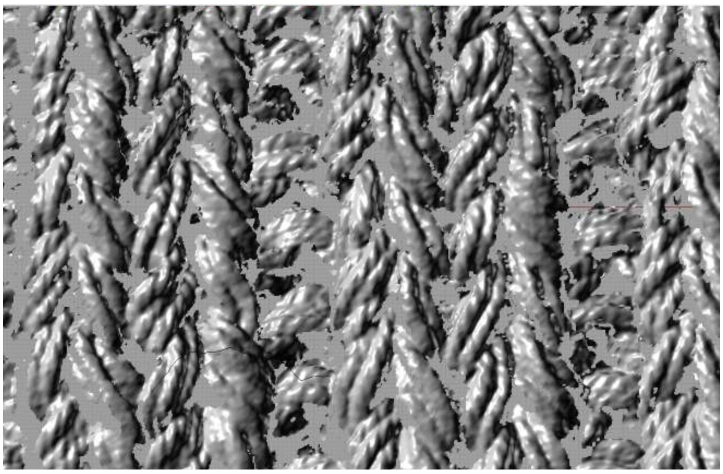
4. Cable stitch rendering and measurement

2-dimensional rendering of the cable stitch is shown in <Fig. 8>, using a textile CAD program, TexPro.

In <Fig. 8> and <Fig. 9>, the images of simulated and actual knit specimen look relatively similar, except for the dark holes due to yarn over-stretching in the simulated one,



<Fig. 6> Height profile of rib stitch, HR.



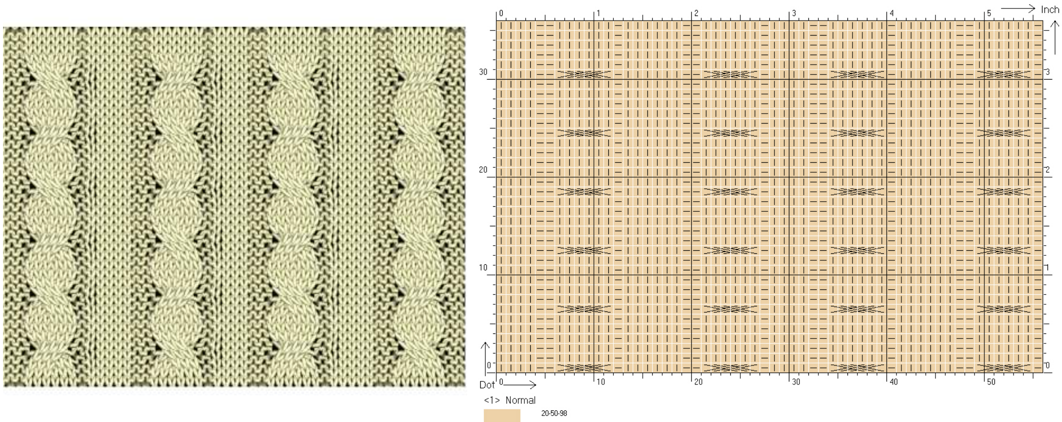
<Fig. 7> 3D scanned image of rib stitch, HR.

and irregular spacings between cables or other stitches, possibly due to the tension adjustment, in actual cable specimen. The 2D simulated image does not contain any 3-dimensional information. For the preparation of <Fig. 9>, no special tension adjustment of the actual knit specimen was applied.

Since the 3D jersey stitch model, shown in <Fig. 1>, is based on the continuous monofilament yarn, it differs from the simulated image shown in <Fig. 8>, which is based on spun yarn appearance. As shown in these comparisons, the 3D model may offer ample information regarding 3-D simulation of textiles.

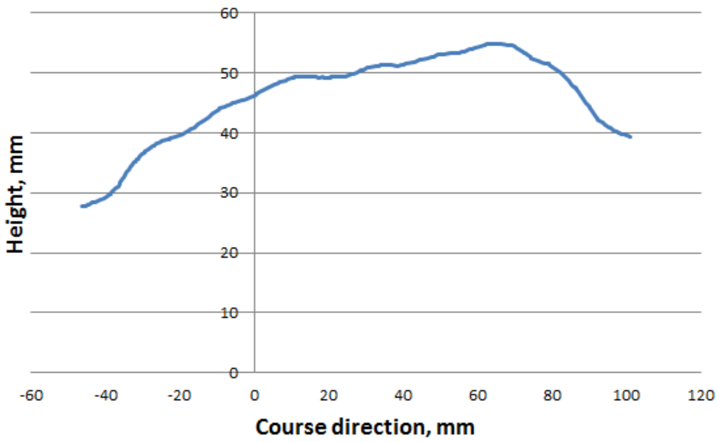
<Fig. 10> shows the height profile of cable stitch specimen, HC. The height reaches almost 55mm, while the thickness value shown in <Table 2> is 9.73mm. As stated previously, this large difference is due to the high bulkiness of yarn and the thickness measurement pressure scheme. <Fig. 11>

In the case of cable stitch specimen FC, the ‘PolylinePoints’ function does not work well as expected due to the poor 3D scanned image. This seems to be caused probably by the poor structured light resolution adjustment during the

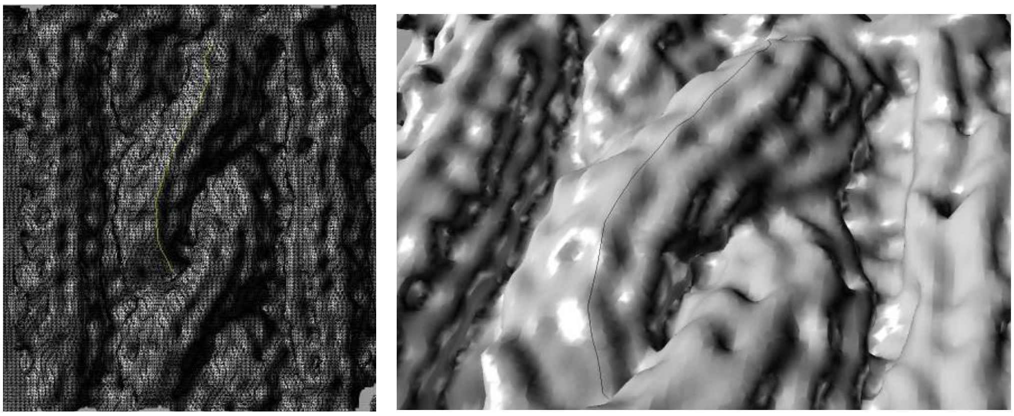


<Fig. 8> 2-dimensionally simulated image of cable stitch and its corresponding knitting structure mark(TexPro-based).

<Fig. 9> Actual image of cable stitch knit specimen, FC.



<Fig. 10> Height profile of cable knit stitch, HC.


(a) Top view (meshes) (b) Perspective view (enlarged)

<Fig. 11> 3D scanned image of cable knit stitch, HC.

3D scanning. For this reason, the result is not reported in this study.

IV. Conclusions

Developments in the computer graphics sectors and textile science sectors have made 3D virtual clothing software system easily accessible by the textile industries. However, the computer simulated models of textile fabrics or apparel products are not exact representations of real-world garments comprising soft and pliable textile materials. The garments do not maintain fixed shapes during wearing. Deformations at low external stress lead to difficulties in predicting the behavior of the knitted garments. Therefore, there is a need to compare the differences between simulated fabrics and actual fabrics.

Three knit stitch types, and two knitting yarn types are three-dimensionally examined through

3D modeling and 3D scanning in this study. The following results are obtained:

1. Since the 3D scanning is based on optical measurement, the shape of the knit stitch does not deform during the measurement. Therefore, the maximum value of the height profile of specimen HJ reaches 16.9mm, while the thickness measurement results in 5.05mm. In the case of knit specimen FJ, the height/thickness difference between the measurement methods is relatively small compared to the case of the specimen HJ. This seems to be related to the differences in the fluffiness of the yarns for the knit specimens.

2. In the case of rib stitch analysis, the height profile values almost coincide with the measured thickness value of 1.85mm with the small difference of 0.09~0.13mm for the FR specimen. The average height profile value of rib in HR specimen reaches almost 30mm. The height value is different from the thickness value of 6.98mm, due to the high yarn bulkiness and the pressure effect during the thickness measurement.

3. The 2D rendering of cable stitches look relatively similar under visual observation, except for the hole size due to the depiction of overly extended stitch and irregular regions. This might be adjusted by applying proper tension in the actual knit specimen. In the case of HC specimen, the height profile value reaches almost 55mm, while the measured thickness value is 9.73mm. As stated previously, this large difference is due to the high fluffiness of yarn and the thickness measurement pressure scheme.

From the 3D scanning and subsequent reconstruction of the surface of the actual knit specimens, detailed three-dimensional information is obtained. The three-dimensional data of the reconstructed knit specimens would help to build a data base for estimating the behavior of the 3D models of the knitted garments Further study would possibly complement the performance and applicability of the 3D virtual clothing simulation software system.

We hope these three-dimensional information regarding the surface contours and textures of easily deformable knit products may bridge the gaps between the real textile materials and the appearances and textures of the virtual 3D clothing models.

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