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Evaluating Material Parameter Influence on Drapability Using VStitcher †

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Abstract: The goal of 3D simulation in the apparel industry is highly relevant in terms of sustainability, as the realistic visualization of textile drape and the drapability of textile surfaces plays a crucial role in reducing textile waste and optimizing resource use. It is a matter not only of generating photo-realistic images in 3D garment simulations, but also of making reliable predictions about the physical behavior of textile materials in order to achieve realistic outcomes. The prerequisite for 3D garment simulation is the correct application of standardized simulation programs, which is rarely accomplished in practice because the providers of 3D simulation software do not disclose their simulation algorithms, making accurate analysis difficult. In this study, an objective image comparison is carried out using the VStitcher simulation program as an example, which allows an assessment of the value of the relevant material parameters. A drape test is used as a validation method and the drape coefficient is calculated. Depending on the material and parameter settings, drape coefficients between 0.1 and 10% and between 0.7 and 70% are determined. By modifying the bending stiffness, the drape coefficient increases the most. By systematically varying and comparing these parameters, a deeper understanding of their influence can be obtained. The most significant effect on the drape coefficient (DC) is seen with increased bending stiffness, while changes in thickness, elongation, and shear stiffness have a minimal effect. Increased fabric thickness has a greater effect on appearance than on deformation. The digital parameters affect the simulation in much the same way as the physical textile parameters affect the real material. With VStitcher, the desired fabric changes are more effectively achieved by adjusting the bending stiffness and mass per area, while changes in thickness, elongation, and shear stiffness have little effect.

Keywords: drapability; drape coefficient; Cusick drape test; VStitcher simulation; physical behavior of textiles; 3D apparel simulation; apparel sustainability; textile waste reduction; 3D fabric simulation; VStitcher

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1. Introduction

The importance of garment simulation in the apparel industry is constantly increasing, and if the three-dimensional representation accurately reflects reality, it could transform the apparel industry [1]. Especially in the area of fit analysis and optimization, 3D garment simulation has the greatest potential for optimizing development processes and conserving resources. The realistic representation of textile surface structures in 3D simulations as a function of fabric properties remains a fundamental challenge, since small deviations in the fabric parameters can have a significant impact on the accuracy of the simulation results, which requires precise characterization and calibration of the fabric used [2,3]. The apparel industry utilizes diverse 3D simulation software, including solutions from vendors such as Opitex's "3D Runway Designer", Browzwear's "V-stitcher", Lectra's "3D-Fit", and Technoa's "i-Designer". Among these, Browzwear's VStitcher is particularly widely adopted. In addition, achieving realistic simulations in the apparel industry remains a challenge, as there are still significant differences between real and simulated garments.

Deformation behavior is an important factor in the selection of fabrics for the development of apparel products, as it affects the appearance and fit on the body, and realistic 3D simulations of garments that accurately reflect fabric parameters can lead to more efficient design processes, reduced waste, and improved longevity of garments, ultimately contributing to greater sustainability in the apparel industry [1,2]. Factors such as deformation behavior are generally divided into textile drape and drapability, both of which have a strong impact on the quality of the product as they determine how the fabric falls and conforms to the body. This is important because achieving accurate simulations of these behaviors ensures a higher quality product in terms of fit, comfort, and esthetics, reducing the need for physical prototypes and minimizing waste [4]. Generally, the deformation behavior can be described by the following parameters: drape coefficient (DC), Drape Distance Ratio (DDR), Fold Depth Index (FDI), Node Number (NN) and mechanical properties [5,6]. The drape coefficient (DC) is the ratio of the projected area of a fabric sample to its undraped area, minus the area of the supporting disk, while the Drape Distance Ratio (DDR) measures the reduction in the annular portion due to draping. The number of nodes (n) is determined by counting the folded apexes formed over the disk, and the Fold Depth Index (FDI) indicates the sharpness of these nodes [5,6]. The drape of the fabric is critically influenced by parameters such as mass per area, thickness, bending, elongation, and shear. Additionally, weave type and the linear density of the warp and weft significantly affect the fabric's behavior and are considered essential for simulation purposes [7–10]. By gradually changing one of the parameters while keeping the other parameters and the resulting drape coefficients constant, conclusions can be drawn about their influence on the simulation.

This paper focuses on the drape coefficient as a numerical indicator of wrinkling during textile draping. Three different cotton fabrics in plain, twill, and satin weave were tested. In the test series, the value of the textile physical fabric parameters was analyzed in the simulation. The results of the draping tests were implemented in the VStitcher simulation program, which was used to analyze the simulation. In this study, the effects of various fabric parameters on the drapability of textiles were investigated using the simulation program VStitcher. The results show that increased bending stiffness has a significant influence on the drape coefficient, while changes in thickness, elongation, and shear have only minimal effects. The aim of this study was to evaluate the influence of different parameters on the virtual drape coefficient and to determine which parameter has the biggest impact on the virtual textile drape. By systematically varying and comparing the material parameters, a deeper understanding of their influence can be gained. This study emphasizes the importance of the textile physical material parameters for the simulation.

2. Textile Drape

Textile drape describes the ability of fabrics to deform three-dimensionally under their own weight. It has a significant influence on the esthetics and functionality of textiles [11]. It cannot be considered in isolation, but must be viewed in conjunction with mechanical fabric parameters such as bending stiffness, elongation, and shear stiffness. These, in turn, depend on the type of fiber, the construction properties of the fabric, and the finishing methods used [12]. The textile drape plays an important role in the development of apparel [5]. It can be quantitatively evaluated with the help of parameters such as the drape coefficient and the drape spacing ratio. These parameters are determined and analyzed using digital image processing techniques. The results can provide the apparel industry with important findings to support simulation-based product development and to improve communication within the product development process [5]. The textile drape is determined using a drape test.

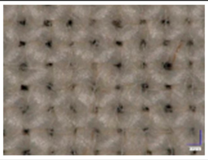
While the bending stiffness measurement only records the two-dimensional deformation of textiles, the drape test makes it possible to analyze the three-dimensional formation of folds [13]. This produces a drape image that can be visually assessed and described by specifying the number of pleats, the shape of the pleats, and the orientation of the pleats. A numerical analysis of the textile drape is carried out by determining the drape coefficient (DC). It describes the extent of the crease formation, provides an objective evaluation of the textile drape [12], and is the difference between a deformed and a non-deformed surface of the textile fabric. The percentage ratio of the projected area of the draped fabric to the undeformed area of the fabric before draping is the basis for calculating the DC [14]. A low DC indicates a fabric that deforms easily, while a higher DC indicates less deformation [15]. It should be noted that the DC alone is not sufficient to fully describe the appearance of a draped fabric. Due to various geometric factors, such as the number of knots and the curvature of the draped fabric, fabrics with the same DC can still look different [6,16]. The Cusick drape tester was developed to determine the drape coefficient [2]. In an analog procedure, the shadows of undraped and draped fabric are projected onto a round piece of paper, drawn, and cut out. The ratio of the masses of the cut-out papers is then formed and the draping coefficient is calculated [17]. Nowadays, image processing technologies are mainly used to capture the shadows as a digital image, which is used for computer-aided processing of the data. In addition to the DC, other parameters, such as the Drape Distance Ratio (DDR), the amplitude, the Fold Depth Index (FDI), and the number of knots, can be determined for a more comprehensive understanding of the draping of fabrics [5,6,18,19]. These parameters provide a robust, multi-dimensional view of the drape behavior of a fabric and thus offer valuable insights for product development and production [5].

3. Materials and Methods

VStitcher is a 3D modeling software developed for pattern makers and technical designers by the software company Browzwear (Browzwear Solutions Pte. Ltd., version 2021.2.0 51910, Singapore, Singapore) and was used in this study. The digital ecosystem includes the Fabric Analyzer (FAB), a proprietary device for recording and digitizing the physical properties of fabrics [20]. Using the FAB makes it is possible to rationalize the design process and increase simulation accuracy [21]. A fabric analysis using the FAB was carried out on three test strips, which were cut in the warp direction, weft direction, and 45° direction. The physical analysis of the fabric consisted of determining the mass per unit area, thickness, bending stiffness, elongation, and shear stiffness [21]. The software used for the calculation of the drape coefficient was MATLAB (The MathWorks, Inc., version R2023a 9.14.0, Natick, MA, USA). The basis for the series of tests was a Cusick drape test, which was carried out in accordance with DIN EN ISO 9073-9 [7] and provided an image of the draping of the fabric and the draping coefficient. Table 1 shows the fabric properties of the three tested fabrics. Vizoo GmbH, Munich, Germany, was utilized to record the necessary textile physical fabric parameters using the FAB, and these parameters were provided digitally for use in the simulation (see Figure 1).

Figure 1. An illustration of the virtual drape test.

Table 1. Tested fabrics.

Code	Microscopic Photography	Weave Construction	Warp/Weft Thread Density per Centimeter	Mass per Unit Area (g/m²)	Composition
M05		Atlas Weave	36/25	144.3	100% cotton
M08		Plain weave	24/25	201.9	100% cotton
M15		Twill fabric	36/22	216.1	100% cotton

4. Results and Discussion

4.1. Virtual Simulation of Draping Behavior with VStitcher

The Cusick drape test was integrated into the VStitcher simulation system to simulate the virtual drape behavior. The test conditions were based on [DIN] [7] specifications in order to ensure comparable results. This concerned the geometries of the samples and test specimens, characteristic values for positioning and fixing the sample over the test specimen, camera and lighting settings, and specifications for rendering. A description of the test procedure ensures the reproducibility of the method.

4.2. Creating Grayscale and Binary Images and Calculating the Drape Coefficient Using MATLAB

There are various methods of calculating the drape coefficient, but an accurate and fast approach is to use an image analysis technique based on the number of pixels. This involves first converting the virtual drop images into grayscale and then into binary images. The grayscale value represents the brightness of a pixel, independent of the colors [21]. The threshold value is then determined, which defines the brightness at which the pixel color changes from black to white. By reducing the colors to black and white, the software can process these two colors as 0 and 1, respectively, and enable calculations based on the number of pixels. The software used was MATLAB (The MathWorks, Inc., version R2023a 9.14.0: Natick, MA, USA).

Intervals for calculating the modification values were defined on the basis of preliminary tests (see Table 2). Subsequently, only the value of one fabric parameter was modified in the test, leaving the other parameters constant.

Table 2. Calculation of the intervals for modifying the digital fabric parameters.

	Intervals	Plus	PlusPlus
Mass	50%, 100%	1.5	2
Thickness	200%, 400%	3	5
Bend	200%, 400%	3	5
Stretch	200%, 400%	3	5
Shear	400%, 800%	5	9

The virtual drape test is based on the Cusick physical drape test (DIN EN ISO 9073_9 [7]). The three fabrics to be tested are implemented in VStitcher using the digital data previously determined with the FAB. For image evaluation, it is important to ensure that the backing plate is visible, so the transparency of the fabrics is set to 50%. This does not affect the behavior of the fabric. In order to determine the value of the fabric parameters, the original digital fabric is duplicated and the material data of the duplicates are modified according to previously defined grade rules. The result is a case image for each fabric setting (see Figure 2).

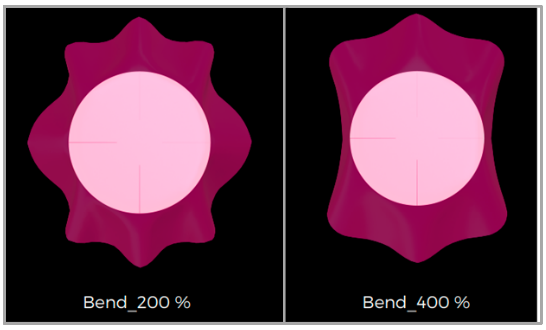


Figure 2. Example of drape test images with modified bending stiffness values.

4.3. Calculation of Draping Coefficients Using Matlab

The MATLAB scripts were used to first convert the colored images into grayscale images and then into binary images (black and white), and then to calculate the number of pixels for different objects: the circular disk that serves as a measurement reference, the non-draped fabric sample, and the draped fabric sample. The drapability coefficient was then calculated from the number of pixels of these individual objects. When processing the image files in MATLAB, file naming conventions needed to be defined and followed consistently; otherwise, the program would run incorrectly. The calculations were divided into three scripts (Table 3). The result of one script provided the input information for the next script.

Table 3. Script structure in MATLAB.

Order	Script	Allocation
1.	TexFall_AutoFolder	Creating a folder structure
2.	TexFall_Ref	Calculation of the circular disk
3.	TexFall_Fabric	Calculation of the drainage coefficient

In the TexFall_AutoFolder script, a folder structure was created to store the calculated values and images. In the TexFall_Ref script, the reference image of the circular disk was converted into a binary image (See Figure 3). The software interprets the white areas as objects and the black areas as background. This conversion enables the program to calculate the number of pixels of the circular disc by determining the number of white pixels. In addition, the diameter of the non-draped fabric sample is determined in the same program. TexFall_Ref thus provides the basis for the further steps of the area calculation in the project. In the TexFall_Fabric script, the case images generated in VStitcher were converted into binary images. The pixels were then calculated for the area of the draped fabric. The drape coefficient was calculated based on these results and the results from TexFall_Ref. All values and generated images were saved in the folder structure defined in the TexFall_AutoFolder script.

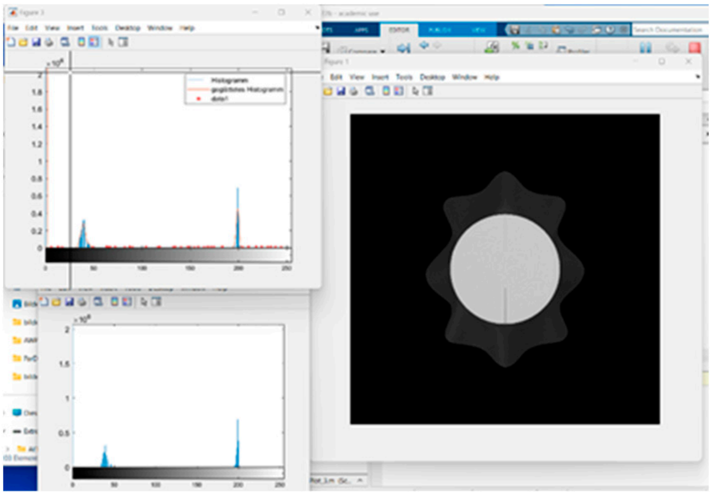
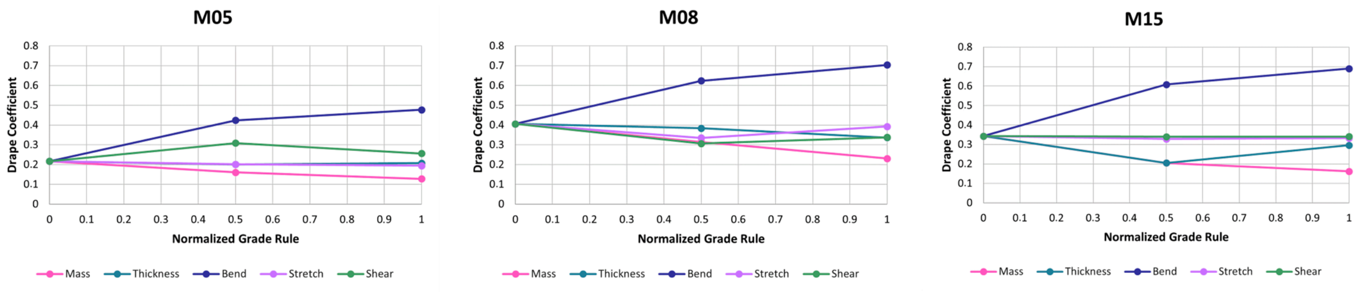


Figure 3. Image processing—converting color images into grayscale and binary images.

The drape coefficients determined were plotted in diagrams against the respective fabric parameters. For comparability, the values for the fabric parameters were normalized to the maximum. Figure 4 shows a comparison of the parameters for each fabric.



(**a**) (**b**) (**c**)

Figure 4. The drape coefficients of the samples: (**a**) M05; (**b**) M08; (**c**) M15. The diagrams show the drape coefficients for each fabric with different parameters.

The most significant change in the drape coefficient can be seen when modifying the bending. For material M05, the drape coefficient increases from 0.2 or 20% to 0.5 or 50%; for material M08, from 0.4 or 40% to 0.7 or 70%; and for material M15, from 0.35 or 35% to 0.7 or 70%. The influence of the parameters mass, thickness, elongation, and shear on the drape coefficient is much less pronounced. The drape coefficient is least influenced by the modification of the parameters corner, elongation, and shear. The effect of the mass per area parameter on the drape coefficient is also low, but a clearer trend can be seen than with the previously mentioned parameters. The heavier the fabric, the lower the drape coefficient. The biggest effect on the drape coefficient is the change in bending stiffness. The graphs of all fabrics show a significantly higher drape coefficient when the bending stiffness is increased.

The comparison of this current study with previous research highlights the pivotal role of bending stiffness in influencing the drape coefficient of textiles. Specifically, our findings demonstrate significant increases in the drape coefficient for materials M05, M08, and M15, particularly with increased bending stiffness. The results of this study align with the findings of Kim and Lee (using CLO 3D design software, CLO Virtual Fashion Co., Ltd., V.7.1), as well as those of Kyosev, both of which identified that modifying bending stiffness has the most significant impact on the drape coefficient [22,23]. Pabst et al. further support this conclusion, asserting that bending stiffness is likely the most critical parameter for characterizing a specific textile [24]. Moreover, Morooka and Niwa, along with Matsudaira and Yang, emphasize the close correlation between mechanical properties, such as bending stiffness, bending hysteresis, weight per unit area, shear stiffness, and shear hysteresis, and the drape coefficient [25,26].

This current study aligns with the findings of Niwa and Seto, who noted that the combination of bending hysteresis and weight per unit area significantly affects the drape coefficient [27]. While other factors like mass, thickness, elongation, and shear were examined, their influence on the drape coefficient was less pronounced. This reflects prior research highlighting the predominant influence of bending stiffness and surface mass. The results of this study using VStitcher software and virtual drape tests corroborate these earlier studies, confirming that bending stiffness and mass are crucial determinants of the drape coefficient in both real and simulated scenarios. In this study, VStitcher software was used, yielding comparable results regarding bending stiffness, which reinforces the importance of this parameter in both real and virtual fabric simulations. However, these findings are crucial for the textile and apparel industry, as they provide valuable insights for designing textiles with optimal drape characteristics, improving overall garment quality and performance. This study has certain limitations, primarily due to the examination of only three different textiles. The complexity of textiles, independent of a large number of varying factors, such as fiber material, yarn construction, and textile structure, presents inherent challenges. Moreover, factors such as finishing processes, textile aging, and others previously mentioned, such as bending stiffness and mass per unit area, could also play a significant role in influencing the outcomes for the simulation of textile drape. Consequently, the results must be interpreted with caution, keeping in mind the multifaceted nature of textile materials.

5. Conclusions and Outlook

This study provides insights into the handling of textile physical parameters in VStitcher. It demonstrates that digital parameters affect the VStitcher simulation in much the same way as physical textile parameters affect the actual fabric. The desired changes in fabric behavior are best achieved by modifying bending stiffness and mass per area, while changes in thickness, elongation, and shear stiffness have a minimal effect. Notably, changes in thickness primarily affect visual appearance rather than deformation. Future research should expand the dataset to include additional parameters such as fold characteristics for more comprehensive conclusions. Standardization of testing using the Fabric Analyzer (FAB) for VStitcher is recommended to ensure traceability and comparability, ultimately improving the understanding and optimization of simulation algorithms and highlighting the importance of physical textile parameters.

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References

1. Cheng, Z.; Wu, X.; Kuzmichev, V. Research on the Accuracy of Clothing Simulation Development: The Influence of Human Body Part Characteristics on Virtual Indicators. *Appl. Sci.* **2023**, *13*, 12257. [CrossRef]
2. Rudolf, A.; Zadravec, M.; Stjepanovič, Z. Investigations Regarding the Effects of Simulating Parameters During 3D Garments' Drape Simulations. *Fibres Text. East. Eur.* **2016**, *24*, 143–150. [CrossRef]

3. Tu, Y.-F.; Kwan, M.-Y.; Yick, K.-L. A Systematic Review of AI-Driven Prediction of Fabric Properties and Handfeel. *Materials* **2024**, *17*, 5009. [CrossRef] [PubMed]
4. Gereke, T.; Huynh, T.A.M.; Sennewald, C.; Cherif, C. 12—Modeling and simulation of the 3D interlock woven fabric forming. In *Advanced Structural Textile Composites Forming*; Wang, P., Hamila, N., Eds.; Woodhead Publishing Series in Composites Science and Engineering; Woodhead Publishing: Sawston, UK, 2025; pp. 329–353. [CrossRef]
5. Šarac, T.; Stepanovic, J.; Ćirković, N. Analysis of a Fabric Drape Profile. *Vlak. Text.* **2018**, *25*, 27–34. Available online: https://api.semanticscholar.org/CorpusID:219939083 (accessed on 20 September 2024).
6. Hamdi, T.; Ghith, A.; Fayala, F. Study of the Relationship between the Drape and Characteristics of Fabric Using Graphic Methodology and the AHP Method. *Fibres Text. East. Eur.* **2021**, *29*, 37–45. [CrossRef]
7. *DIN EN ISO 9073-9*; Textiles—Test Methods for Nonwovens—Part 9: Evaluation of Textile Drape Including Drape Coefficient. DIN Deutsches Institut für Normung e.V.: Berlin, Germany, 2008.
8. Matusiak, M. Influence of the Structural Parameters of Woven Fabrics on their Drapeability. *Fibers Text. East. Eur.* **2017**, *25*, 56–64. [CrossRef]
9. Al-Gaadi, B.; Göktepe, F.; Halász, M. A new method in fabric drape measurement and analysis of the drape formation process. *Text. Res. J.* **2012**, *82*, 502–512. [CrossRef]
10. Duong, P.D.; Phuong, L.T.T.; Phan, D.N.; Thang, V.T. Correlation between material properties and actual—Simulated drape of textile products. *Results Eng.* **2024**, *22*, 102077. [CrossRef]
11. Sukendar, D.; Totong, T.; Putra, V.G.V. Study of Fabric Movement and Influenced of Drape Measurement Based on Image Processing Using Matlab. *J. Phys. Conf. Ser.* **2019**, *1381*, 12011. [CrossRef]
12. Kenkare, N.; May-Plumlee, T. Evaluation of drape characteristics in fabrics. *Int. J. Cloth. Sci. Technol.* **2005**, *17*, 109–123. [CrossRef]
13. Lojen, D.; Jevšnik, S. Some Aspects of Fabric Drape. *Fibres Text. East. Eur.* **2007**, *15*, 39–45. Available online: https://api.semanticscholar.org/CorpusID:136726980 (accessed on 21 September 2024).
14. Süle, G. Investigation of bending and drape properties of woven fabrics and the effects of fabric constructional parameters and warp tension on these properties. *Text. Res. J.* **2012**, *82*, 810–819. [CrossRef]
15. Plattürk, G.G.; KiliÇ, M. Measurement of Fabric Drape by the Methods Based on Image Analysis. *Tekst. Ve Mühendis* **2014**, *21*, 31–45. [CrossRef]
16. Hamdi, T.; Ghith, A.; Fayala, F. Study of Drape Parameter usind Image Analysis. *Int. J. Eng. Sci. Technol.* **2013**, *5*, 1456–1464.
17. Sanad, R. Fabric and Garment Drape Measurement—Part 1. *J. Fiber Bioeng. Inform.* **2012**, *5*, 341–358. [CrossRef]
18. Behera, B.K.; Pattanayak, A.K. Measurement and modelling of drape using digital image processing. *Indian J. Fibre Text. Res.* **2008**, *33*, 230–238.
19. Memon, H.; Chaklie, E.B.; Yesuf, H.M.; Zhu, C. Study on Effect of Leather Rigidity and Thickness on Drapability of Sheep Garment Leather. *Materials* **2021**, *14*, 4553. [CrossRef]
20. Papachristou, E.; Anastassiu, H.T. Application of 3D Virtual Prototyping Technology to the Integration of Wearable Antennas into Fashion Garments. *Technologies* **2022**, *10*, 62. [CrossRef]
21. Reumann, R.-D. *Prüfverfahren in der Textil- und Bekleidungstechnik: Mit 105 Tabellen*; Springer: Berlin, Heidelberg, 2000; ISBN 3-540-66147-6.
22. Kim, J.H.; Lee, J.S. Investigating parameters affecting the real and virtual drapability of silk fabrics for traditional Hanbok. *Fash. Text.* **2024**, *11*, 21. [CrossRef]
23. Kyosev, Y. Material description for textile draping simulation: Data structure, open data exchange formats and system for automatic analysis of experimental series. *Text. Res. J.* **2022**, *92*, 1519–1536. [CrossRef]
24. Pabst, S.; Krzywinski, S.; Schenk, A.; Thomaszewski, B. Seams and Bending in Cloth Simulation. In Proceedings of the Workshop on Virtual Reality Interactions and Physical Simulations, Grenoble, France, 13–14 November 2008. Engineering, Materials Science. [CrossRef]
25. Morooka, H.; Niwa, M. Relation between drape coefficients and mechanical properties of fabrics. *J. Text. Mach. Soc. Jpn.* **1976**, *22*, 67–73. [CrossRef]
26. Matsudaira, M.; Yang, M. Some features of the static and dynamic drape behaviour of polyester-fibre Shingosen fabrics. *J. Text. Inst.* **2000**, *91*, 600–615. [CrossRef]
27. Niwa, M.; Seto, F. Relationship between drapability and mechanical properties of fabrics. *J. Text. Mach. Soc. Jpn.* **1986**, *39*, 161–168. [CrossRef]