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COMPARATIVE ANALYSIS OF VIRTUAL 3D SIMULATIONS OF GARMENTS WITH DIFFERENT CAD 3D PROGRAMMES BASED ON METHODS FOR MEASURING FABRIC PROPERTIES

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Abstract: *Studies have shown the various shortcomings of the measurement devices used by existing garment simulation software to measure the low-stress mechanical properties of fabrics. Technical limitations, different working principles, the size of the samples, lack of interchangeability of the software, high prices and limited availability are just some of these limitations. This makes it difficult to compare simulation results from different software tools. From a practical point of view, the use of conventional low-stress mechanical properties assessed by conventional measuring devices available in most laboratories is highly desirable for the evaluation of fabric parameters required by garment simulation software. This paper investigates the suitability of currently available common measuring devices to determine fabric parameters such as extensibility, bending and shear rigidity for accurate 3D virtual garment simulation. For this study, two linen-cotton fabrics with significantly different plain and satin weaves were prepared and their mechanical properties were evaluated at low loads using the FAST measurement system and conventional test equipment according to corresponding ISO test methods. The capability of the use of conventional equipment for accurate simulations was analysed by comparing simulations of a flared skirt using two CAD 3D systems, Modaris and OptiTex, and two real skirt prototypes differing by fabric weave. The results of the study show that the simulations of the appearance of the skirt are quite similar for both testing methods used to determine the low-stress mechanical properties of fabrics. Among the software investigated, Modaris appears to be least sensitive to the method and the type of fabric used. The appearance of the simulated and the real skirts differs slightly for both analysed fabrics, especially in the depth of the folds regardless of CAD software used.*

Keywords: *Low-stress mechanical properties, Modaris, OptiTex, Virtual 3D garment simulation*

1. INTRODUCTION

Among the emerging digital technologies, 3D virtual clothing software is considered a breakthrough technology, especially when compared to the way products are designed and developed by transforming the physical aspect into a digital one [1]. In recent years, fashion brands and retailers such as Nike, Under Armour, VF Corporation, Target, Kohl's, Walmart, etc. have increasingly explored and utilised 3D virtual clothing simulation technology as part of their long-term strategic planning. However, the validation of virtual fitting and draping still needs to be perfected [2, 3]. Experts from industry and science point to the inconsistency of measurement methods for fabrics and the significantly different simulation results of the same fabric from different software providers. This shows that the fabrics measurements used in virtual software must be standardised to enable more accurate simulation [2]. The accuracy of the 3D virtual garment software depends on the calculation algorithm of the simulation

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software and the precision of the input parameters for the fabric, which are derived from the physical and mechanical properties of the fabric [4]. To digitise the mechanical and physical behaviour of textiles, some software providers use independent systems that are also used for other regular textile tests. In contrast, some software systems have developed their own test instruments to support the software. The basic fabric properties that can decide the drape of the fabric in a virtual 3D garment software are thickness, bending, shear, tensile and friction, and these can be captured by objective fabric measurement methods [2, 5, 6].

The study by Kuijpers *et al*. [2] investigates different technologies to measure the most important fabric properties, bending, shear, tension and friction, which are essential for virtual garment simulations. Seven methods were investigated: KES, FAST, Fabric Touch Tester, CLO Fabric Kit 2.0, Browzwear Fabric Analyser (FAB), Optitex Mark 10 and the cantilever principle as well as tests with ZwickRoell systems and the fabric stiffness tester. FAB was tested on various fabrics, while others were evaluated by experts. The study shows that most methods measure similar properties with slight variations, but that there is often a lack of standardisation, clear test protocols and transparency in data processing. Further research by Kuijpers *et al*. [7] has shown the need to create a universal system for measuring, calculating and accurately specifying the mechanical properties of fabrics for virtual 3D prototyping of garments. 3D software providers must develop their systems to be compatible with this data. Compatibility should include both the input and the expected output. The study by Maksimović [8] also identified inconsistencies in fabric property measurements and simulation results in different 3D software packages used by fashion brands and pointed out the lack of standardisation of material testing methods and poor correlation between measurement data and simulation results for the same fabric. In the study by Jung and Istook [9] the tensile and shear properties of twill fabrics made of 100% wool were investigated using three fabric testing devices: FAST system, CLO fabric kit and MTS Q-test/5 universal testing machine, to investigate the testing principles, protocols and SI units and to evaluate the compatibility of output data from different devices. It was found that differences in load cell thresholds, specimen dimensions and SI units hinder the convertibility and comparability of data between devices and software. The study highlights the need for standardised measurement protocols to improve accuracy and consistency in virtual 3D garment simulations. Dai and Hong [10] address the current limitations in the accuracy of 3D simulation of garments with CAD systems and see the biggest challenge in the insufficient use of mechanical fabric parameters. They categorise these parameters into two main types: empirical parameters obtained from objective fabric measurements (FOM) and virtual parameters derived from simulations of draping tests. To improve the efficiency and precision of parameter acquisition for garment simulation, the report proposes the development of a fabric classification system based on a comprehensive database of objectively measured fabric parameters. Recently, Dominguez-Elvira *et al*. [11] proposed two novel learning-based methods for estimating the mechanical properties of fabrics using (1) manufacturer’s metadata (fabric family, density, composition, thickness) and (2) planar images of the textile as input. The evaluation using the Cusick drape test showed that the drape simulations of both methods agreed very well with the measurements of the fabrics on laboratory measuring devices.

The above studies have highlighted various shortcomings of the specific tools used by the existing simulation software, which makes it difficult to compare simulation results coming from different software tools. Technical limitations, different working principles, lack of interchangeability of software, high price, limited availability, lack of SI units are just some of these limitations. From a practical point of view, the use of conventional testing methods and instruments available in most laboratories is highly desirable for the evaluation of fabric parameters required by garment simulation software. Therefore, this article analyses the suitability of currently available measuring instruments to determine fabric parameters such as extensibility, bending and shear rigidity for a precise virtual 3D garment simulation. For this study, two linen-cotton fabrics with significantly different plain and satin weaves were prepared and their low-stretch properties were evaluated using the FAST measurement system and conventional test equipment according to various ISO test methods. The ability of the conventional equipment to provide accurate simulations was analysed by comparing Optitex and Modaris simulations of virtual 3D prototypes of an A-line skirt with real sewn skirts.

2. EXPERIMENTAL

2.1 Materials

For this study, two fabrics were produced on a Dornier industrial rapier weaving machine with a width of 1.6 metres. Cotton yarns 150 tex and linen yarns 40 tex were used in the warp and weft directions. The fabric count in weft and warp direction was 10 threads/cm and 18 threads/cm respectively, for both fabrics in plain weave 1/1 (FB1) and satin weave 4/1 (FB2). The fabrics FB1 and FB2 had a comparable thickness (1.11 mm and 1.44 mm) and mass per unit area (339.96 $g.m^{-2}$ and 354.92 $g.m^{-2}$). The physical parameters of the fabrics were measured as described in section 2.2.1 and are listed in Table 1.

2.2 Methodology

2.2.1 Determination of Fabric Physical Parameters

The fabric count in warp and weft direction was determined according to the standard ISO 7211/2: 1984 [12]. The fabric thickness was determined with a thickness gauge according to the standard ISO 5084:1996 [13] and the fabric surface mass according to the standard ISO 3801:1977 [14]. Prior to the test, the fabrics were air-conditioned for at least 24 hours in accordance with the ISO 139:2005 [15] standard.

2.2.2 Determination of the Low-stress Mechanical Properties by FAST

The low-stress mechanical properties of the fabrics, including weight, thickness, extensibility, shear, bending and compression properties were measured using the FAST measurement system [16]. The FAST extension meter was used to measure the extensibility (%) of the fabric in the warp and weft directions under loads of 4.91 $N.m^{-1}$, 19.62 $N.m^{-1}$ and 98.07 $N.m^{-1}$ on each fabric sample. In addition, the bias extensibility (%) of the fabric was measured under a load of 4.91 $N.m^{-1}$ and bias extensibility was used to calculate the shear rigidity ($N.m^{-1}$). The required size of the fabric sample was 5 cm x 15 cm, and the measurement was repeated for samples cut at 45° and 135° angles. For the measurement, the fabric sample was placed between the jaws and first fixed with the upper clamp, while the sample hung under its own weight through the lower movable clamp and was then fixed with the lower clamp. The measured low-stress mechanical properties of the fabrics were converted into the units of the OptiTex 3D software [17] and used to simulate the drape of the fabrics.

2.2.3 Determination of the Low-stress Mechanical Properties of Fabrics by Conventional Testing Instruments

The extensibility of the fabric (%) in warp and weft direction under loads of 4.91 $N.m^{-1}$, 19.62 $N.m^{-1}$ and 98.07 $N.m^{-1}$ was measured with an Instron device according to the standard EN14704-1:2005 [18]. Therefore, five samples of 5 cm x 30 cm were prepared in the weft, warp and bias directions. The samples were placed between the jaws of the tensile tester with a gauge of 100 mm and extended at a constant speed of 30 mm/min. Each sample was subjected to three consecutive load/unload cycles up to 0.245 N (E5), 0.98 N (E20) and the last of 4.9 N (E100). The bias extensibility (%) of the fabric under a load of 4.91 $N.m^{-1}$ (EB5) was also measured and used to calculate the shear rigidity G (N/m) according to the equation G=123/ EB5 [16]. The bending rigidity B (μNm) of the fabric was determined according to the cantilever principle (ISO 9073-7:1995) [19].

2.2.4 Development of Skirt Prototypes and Simulation in Modaris/Optitex Software

Two prototypes were produced for a half-circle skirt in the same size 38, which differ in the type of fabric (FB1 and FB2). Software from Modaris [20] and OptiTex 3D [17] was used for virtual 3D prototyping by using low-stress mechanical properties measured with FAST and conventional testing instruments. Simulations and images of the real prototypes were compared with each other. The virtual 3D body model and the size 38 mannequin from the HOGENT Smartfit database [21] was imported into both software.

3. RESULTS AND DISCUSSION

3.1 Fabric Properties Measured by FAST Measuring System and Conventional Equipment

The results of the different fabric properties measured according to the FAST and the alternative ISO method are summarised in Table 1 for both fabrics in plain weave (FB1) and satin weave (FB2). The results show no significant differences between the thickness of both fabrics measured with the two methods. The extensibility results measured with the two methods differ for both fabrics, FB1 in plain weave and FB2 in satin weave. The differences in extensibility results are observed at loads of 4.91 $N.m^{-1}$ and 19.62 $N.m^{-1}$ for the FB2 fabric. The extensibility at these loads is higher when measured with conventional equipment. The difference in extensibility of the fabrics at a load of 98.07 $N.m^{-1}$ is similar for both measurement methods. However, the extensibility of the FB1 fabric measured with the FAST method is higher in both the warp and weft directions than in the conventional test. The difference is observed in the warp direction for the FB2 fabric. The bending rigidity B of both fabrics was comparable in the warp direction regardless of the test method, but unexpected large differences were observed in the weft direction. Characteristic differences were found between the values of shear stiffness G for the two test methods used and for the two fabrics. In general, it was difficult to measure the extensibility E5 with the Instron dynamometer regardless of the fabric direction because the load very low required (5 gf/cm= 0.245 N) is difficult to be set on this device, which is equipped with a heavy load cell of 1 kN. The fabric FB1 in plain weave had a higher weight, a lower thickness and extensibility E100 and above all an expected higher bending and shear rigidity than the fabric FB2 in satin weave.

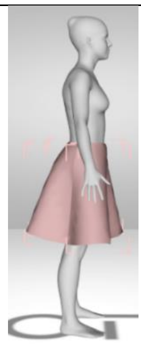
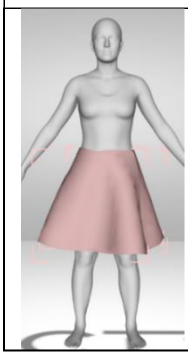
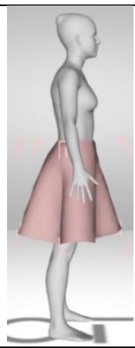
Table 1. Low stress properties of the fabrics FB1 and FB2 with plain and sating weave measured the FAST and corresponding ISO test

Fabric property	Device	Test method	Label	Unit	FB1 (plain)		FB2 (satin)	
					warp	weft	warp	weft
Weight	Balance	ISO 3801	W	$g.m^{-2}$	354.92 ±2.8		333.96 ±1.7	
Thickness	FAST-1	FAST	T100	mm	1.00 ±0.02		1.22 ±0.01	
	Thickness gauge	ISO 5084	T		1.12 ±0.01		1.44 ±0.01	
Extensibility under load 4.91 $N.m^{-1}$	FAST-3	FAST	E5	%	0.03 ±0.06	0.00 ±0.0	0.13 ±0.06	0.03 ±0.06
	Instron	EN14704			0.09 ±0.01	0.07 ±0.03	1.09 ±0.77	0.39 ±0.2
Extensibility under load 19.62 $N.m^{-1}$	FAST-3	FAST	E20	%	0.13 ±0.06	0.03 ±0.06	0.4 ±0.01	0.3 ±0.26
	Instron	EN14704			0.15 ±0.02	0.11±0.04	1.3 ±0.75	0.47 ±0.19
Extensibility under load 98.07 $N.m^{-1}$	FAST-3	FAST	E100	%	0.87 ±0.12	0.20 ±0.10	1.6 ±0.01	0.73 ±0.15
	Instron	EN14704			0.41 ±0.05	0.15 ±0.06	2.03 ±0.75	0.67 ±0.17
Bending rigidity	FAST-2	FAST	B	μN.m	201.42 ±3.59	285.55 ±1.02	111.29 ±3.44	135.16 ±4.47
	Cantilever	ISO 9073			213.42 ±28	190.98 ±4	88.86 ±22	65.43 ±9
Shear rigidity	FAST-3	G=123/EB5 (bias)	G	$N.m^{-1}$	738.00 ±0.04		60.49 ±0.19	
	Instron				2928.57		200.98	

3.2. Influence of the Fabric Properties on the Simulations with Modaris and OptiTex Software and the Real Prototype

The simulations with the Modaris software of the skirt made of the fabric FB1 (plain weave) showed similarities when FAST and conventional test instruments were used to evaluate the properties of the fabric at low load (Table 2). This can be attributed to the agreement found between the properties of fabric FB1 measured with FAST and conventional test instruments (Table 1). Nevertheless, the simulated skirts are not very similar to the real prototype (Table 4), regardless of the test method used and the product view. The differences are clear in the simulation of the number of folds of the skirt and in the simulation of the side seams. The real skirt has three folds on the front and two folds in the simulation, while the number of folds on the back is consistent. The biggest difference can be seen in the simulation of the side seam, which forms an inner fold, while the real skirt has an outer fold.

Table 2. Simulation with Modaris software of fabric FB1, measured with the FAST measuring system and conventional test instruments

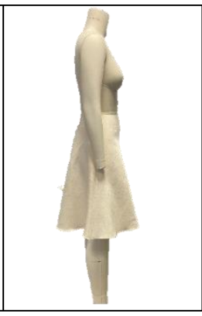
MODARIS – FAST measuring system					
Front view	**¾ Left**	**Left view**	**Right view**	**¾ Right**	**Back view**
					
MODARIS - conventional testing instruments					
					

The simulations with the OptiTex software of the skirt made from the fabric FB1 (plain weave) showed differences when FAST and conventional test instruments were used to evaluate the properties of the fabric at low load (Table 3). The difference is mainly seen in the shape of the folds on the front and back of the skirt. The latter can be attributed to the different values of elongation E100 and shear rigidity G, which depend on the method used to measure the mechanical properties at low loads (Table 1). The comparison of the simulated skirts with the real skirt also showed differences (Tables 3 and 4). The simulated skirt with Optitex 3D-FAST has two folds on the front, similar to the simulated skirt with Modaris-FAST, while only one central fold is formed on the back of the skirt. The simulation of the back of the skirt with OptiTex 3D conventional testing instruments shows two folds, which are also present in the real skirt and in the simulated skirt with Modaris software for both measurement methods. One advantage of the simulation with the OptiTex software is that it can emphasise the side seams (outer folds), which are similar to those of a real skirt.

Table 3. Simulation with OptiTex 3D software of fabric FB1, measured with the FAST measuring system and conventional testing instruments

OPTITEX 3D – FAST measuring system					
Front view	¾ Left	Left view	Right view	¾ Right	Back view
					
OPTITEX 3D - conventional testing instruments					
					

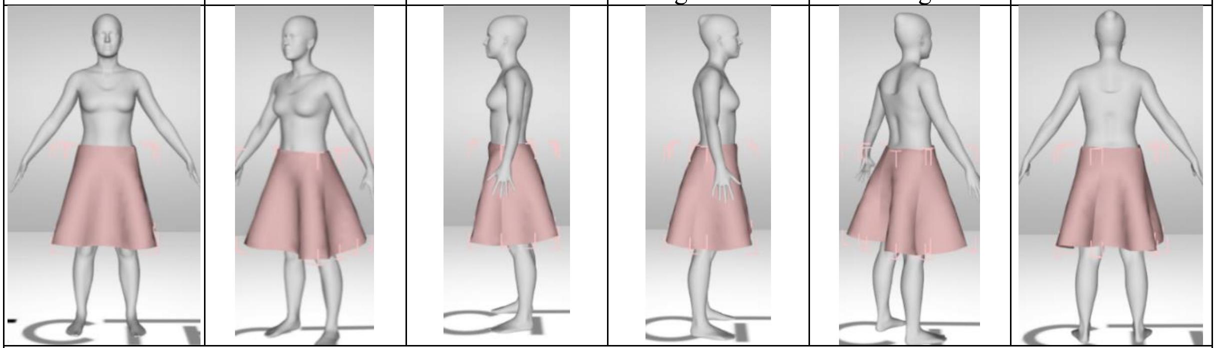
Table 4. Photos of the real prototype in fabrics FB1 and FB2

FB1					
Front view	¾ Left	Left view	Right view	¾ Right	Back view
					
FB2					
					

The comparison of the simulated skirts (Modaris) between the measured mechanical properties using both methods and real skirts for the satin fabric FB2 showed many similarities (Tables 4 and 5). This agreement is quite unexpected considering the differences between the low-stress mechanical properties measured with the FAST measuring system and the conventional test instruments.

Table 5. Simulation with Modaris software of fabric FB2, measured with the FAST measuring system and conventional testing instruments

MODARIS – FAST measuring system					
Front view	¾ Left	Left view	Right view	¾ Right	Back view



MODARIS - conventional testing instruments

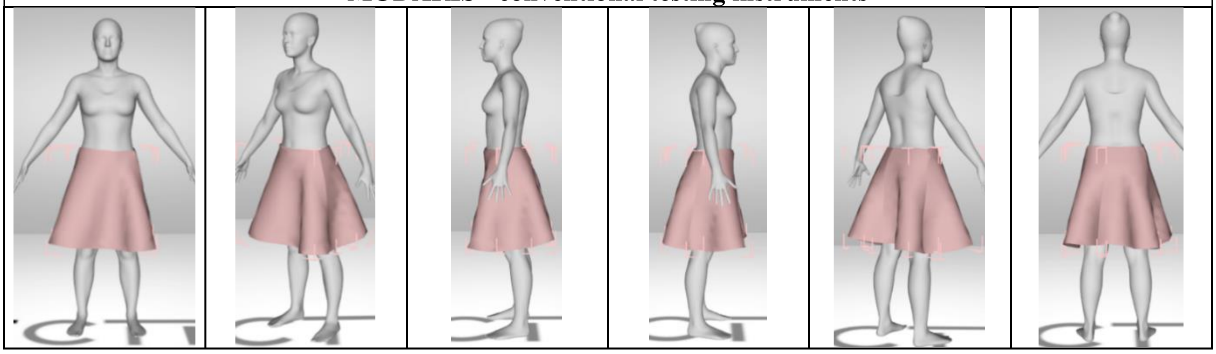
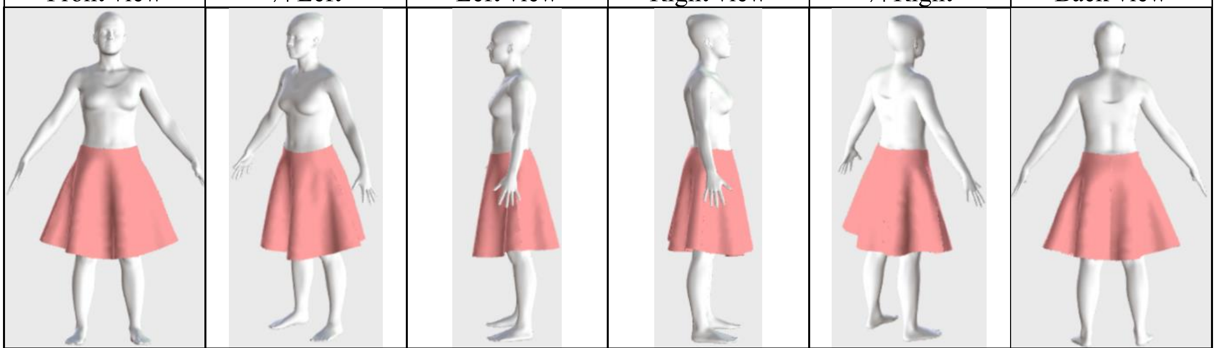
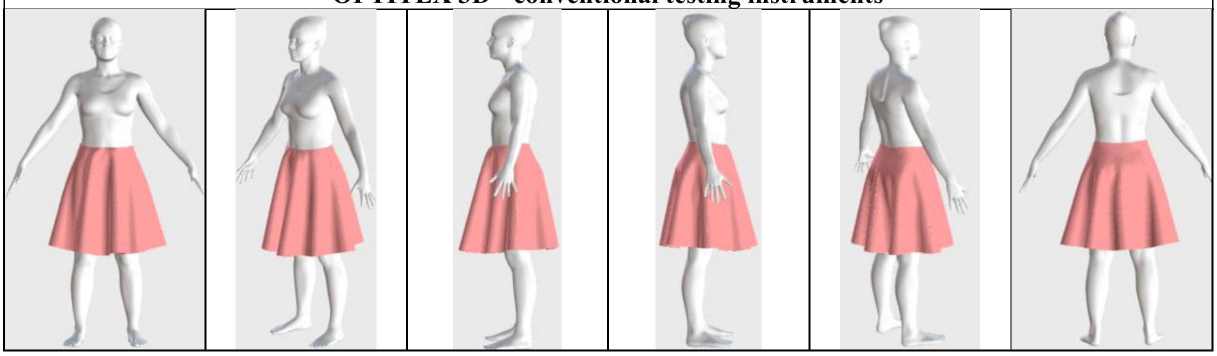


Table 6. Simulation with OptiTex 3D software of fabric FB2, measured with the FAST measuring system and conventional testing instruments

OPTITEX 3D – FAST measuring system					
Front view	¾ Left	Left view	Right view	¾ Right	Back view



OPTITEX 3D - conventional testing instruments



The simulation with the OptiTex 3D software for the satin fabric FB2 showed significant discrepancies between the methods for measuring the low-stress mechanical properties, as well as in comparison to the simulation results with the Modaris software and the real prototypes of the skirts.

5. CONCLUSIONS

This research derives the need for a new garment design by using virtual 3D prototyping and measuring methods of low-stress mechanical properties that enable the creation of realistic virtual 3D prototypes. The methods used demonstrate the advantages and disadvantages of the low-stress mechanical property measurement methods required for virtual 3D simulation and real-world simulations of garments. The research should be extended to test more textiles with different mechanical properties and to vary the simulation parameters in order to obtain the most realistic simulations of garment prototypes.

REFERENCES

[1] Court, F., *Op-Ed | Embracing Digital is a Matter of Survival*, 2015, accessed 22.5.2025, available at: https://www.businessoffashion.com/opinions/technology/op-ed-embracing-digital-is-a-matter-of-survival/
[2] Kuijpers, S.A.A.M., Luible-Bar, C., Gong, R.H., *The Measurement of Fabric Properties for Virtual Simulation – A Critical Review,* In: IEEE Industry Connections (IEEE-IC), 25 Feb. 2020, 1-43, https://ieeexplore.ieee.org/servlet/opac?punumber=10570385
[3] Prahl, A., *3D Digital Technologies: Material Focus. Innovation in Textiles*, December 2017, accessed 22.5.2025, available at: https://www.innovationintextiles.com/3d-digital-technologies-material-focus/
[4] Sayem, A.S.M., Kennon, R., Clarke, N., *3D CAD Systems for the Clothing Industry*, In: Int. J. Fash. Des. Technol. Educ., 2010, 3*,* 2, 45–53, https://doi.org/10.1080/17543261003689888
[5] Matusiak, M., *Influence of the Structural Parameters of Woven Fabrics on their Drapeability*, In: Fibres Text. East. Eur., 2017, 25, 1, 56–64, https://doi.org/10.5604/12303666.1227883
[6] Šarac, T., Stepanović, J., Demboski, G., Petrović, V., *Fabric Draping and Cotton Fabric Structure Relation Analysis*, In: Advanced Technologies, 2015, 4, 1, 84-88, https://doi.org/10.5937/savteh1501084S
[7] Kuijpers, A.A.M., Geelhoed, M.W., Crietee, M.A., *The Future of Fabrics: Digital Fabric Roadmap*, Modint, 2021, available at: https://www.modint.nl/nieuws/digital-fabric-roadmap-katalysator-wereldwijde-samenwerking-virtual-design/
[8] Maksimović, N., *Methods to Digitizing Physical Properties of Fabric for Virtual Simulation*, In: Tekstilna industrija, 2020, 68, 3, 36-43, https://doi.org/10.5937/tekstind2003036M
[9] Jung, U., Istook, C., *Comparison of Objective Measurement Methods of Fabric Tensile Properties for 3D Virtual Garment Software*, In: International Textile and Apparel Association Annual Conference Proceedings, 2020, 77, 1, https://doi.org/10.31274/itaa.12158
[10] Dai, X., Hong, Y., *Fabric Mechanical Parameters for 3D Cloth Simulation in Apparel CAD: A Systematic Review*, In: Comput. Aided Des., 2024, 167, 103638, https://doi.org/10.1016/j.cad.2023.103638
[11] Dominguez-Elvira, H., Nicas, A., Cirio, G. *et al.*, *Practical Methods to Estimate Fabric Mechanics from Metadata*, In: Comput. Graph. Forum, 2024, 43, e15029, https://doi.org/10.1111/cgf.15029
[12] ISO 7211-2:2024 Textiles – Methods for Analysis of Woven Fabrics Construction. Part 2: Determination of Number of Threads per Unit Length
[13] ISO 5084:1996 Textiles – Determination of Thickness of Textiles and Textile Products
[14] ISO 3801-1997 Textiles – Woven Fabrics – Determination of Mass per Unit Length and Mass per Unit Area
[15] ISO 139:2005. Textiles – Standard Atmospheres for Conditioning and Testing
[16] De Boos, A.G., Tester, D.H., *SiroFast: Fabric Assurance by Simple Testing: A System for Fabric Objective Measurement and Its Application in Fabric and Garment Manufacture*, CSIRO Division of Wool Technology Geelong, 1997
[17] OptiTex, Pattern Design Software (PDS) 2D. Accessed 26.5.2025, available at: https://optitex.com/
[18] EN 14704-1:2005 Determination of the Elasticity of Fabrics – Part 1: Strip Tests
[19] ISO 9073-7:1995-Textiles — Test Methods for Nonwovens – Part 7: Determination of Bending Length
[20] Lectra. Modaris. Accessed 26.5.2025, available at: https://www.lectra.com/en/fashion/products/modaris
[21] HOGENT Smartfit. Belgian Anthropometric Research. Accessed 26.5.2025, available at: https://smartfit.be/home-en.html