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RESEARCH ARTICLE

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An investigation on usability of 3D visualization and simulation programs in leather apparel

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ABSTRACT

Three-dimensional (3 D) visualization and simulation programs cannot be used in leather apparel companies prevalently due to the lack of leather material information in the databases. In this study, the properties of different types of leather and fabrics are determined with certain standards and alternatively with FAST (Fabric Assurance by Simple Testing) system, interpreted and defined in the database of Vidya 3 D program. The two-dimensional (2 D) garment patterns prepared in the Assyst CAD program were transferred to the 3 D program, and dress simulations were performed on the virtual mannequin by using the newly defined materials. The sewn dresses and simulations were evaluated by a jury considering similarity success. It has been found that Vidya 3 D program can simulate model and material behaviors realistically by using the data obtained from the FAST system, however, it does not demonstrate the drape parameter precisely, and the software should be improved for this direction.

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Leather; leather apparel; 3D simulation; leather mechanical properties; FAST system

1. Introduction

Three-dimensional (3 D) visualization and simulation programs are used in many areas such as virtual reality applications (VR), the movie industry, and computer games. Similar programs are also used in the textile industry. These programs enable transforming two-dimensional (2 D) designs and patterns created with computer-aided design (CAD) systems into 3 D realistic mannequins on computers.

According to the 3 D CAD system suppliers (Lectra, Gerber, Tukatech, and others), virtual prototyping and virtual try-on processes can drastically reduce product development time and cost. Virtual review and evaluation of fit with realistically simulated fabric behavior can enable faster detection of errors and earlier correction of design elements, material selection, and assembly (Sayem et al., 2010).

Once a garment is designed and its patterns are created with CAD systems in a 2 D platform, a physical prototype is produced with these parameters in a 3 D real world. After critics and regulations on the model, the batch production begins. Conversion of a 2 D design to a 3 D platform and prototype production can be time and money-consuming (Ork et al., 2017). Since companies can now decide whether or not to take a product to market using 3 D technology without a physical prototype, or fewer prototypes, the cost of rejecting a style (in terms of material, labor, and time) is significantly lowered (Iqbal, 2013).

Luible and Magnenat-Thalmann (Luible & Magnenat-Thalmann, 2007) described that the accuracy of virtual garment simulations is on the one hand dependent on precise computational models, and on the other hand on exact input parameters for a correct description of the fabric behavior. Analyzing the mechanical properties can enhance to determine the behavior of the fabrics during clothing exploitation (Tohidi et al., 2013).

The traditional method of fabric defining based on people's experiences and variable sensitivity is called subjective evaluation. To obtain information about physical parameters, textile materials are touched, tightened, hand-rubbed, etc. In the garment industry; professional and educated experts can distinguish fabric qualities. Predicting the fabric's behaviors by testing the relationships between feeling reactions and instrumental data is the primary goal of objective evaluation. Objective fabric characterization methods are related and measured to major mechanical properties to obtain comparable information about textiles (American Association of Textile Chemists & Colorists, 2002). The most well-known objective measurement methods such as Kawabata Evaluation System of Fabric Hand (KES-F), Fabric Assurance by Simple Testing (SiroFAST), PhabrOmeter®, etc. characterize the fabric hand indirectly by measuring certain mechanical fabric parameters. In the literature, several researchers used these systems in their studies (Akgul et al., 2021). KES-F is probably among the very few attempted to address the overall relationships between fabric sensory attributes and mechanical properties (Kawabata, 1980; Pan et al., 2019). The PhabrOmeter is one of the simplest methods for the measurement of resilience, softness, smoothness, drape, relative hand value, and wrinkle recovery properties (Iftikhar et al., 2019; Kan & Lau, 2018; Rous et al., 2018; Yim et al., 2017). Unlike the KES system,

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no attempt is made to separately measure individual fabric properties (such as bending, compression, tensile and surface properties) deemed to be associated with fabric sensory attributes (Pan et al., 2019). In FAST (Fabric Assurance by Simple Testing) method, the fabric of compression, bending stiffness, elongation elasticity, relaxation shrinkage, and higral expansion values are taken into consideration. The values obtained about all these factors are combined and a decision is made about the overall fabric. These evaluations are mostly made for clothing and woolen fabrics used in outwear (Coban, 1999; Gurarda, 2015).

Another material used for outwear is leather, which is preferred by those who want to reveal their style with its line and effect on people. It is an expensive and luxurious consumption product of ready-to-wear material. Because of that, leather garment manufacturers take a long way in the production process to eliminate the possibility of making mistakes. Preparation of leather garment collections requires careful cost calculations. In addition, many different losses are caused related to the structure of the production: from the design of the product to the packaging and delivery. Pattern making, which is one of the phases of leather garment production, takes the most time and causes the most loss of both labor and material in case of errors. Since leather is a valuable material, prototypes are prepared from unbleached plain fabric or imitation leathers to anticipate pattern errors and make corrections. When a prototype is finalized, one leather garment is produced from each size before batch production. Here again, there might be some errors due to material change. Regulations in leather products are very difficult because of the sewing holes. 3 D visualization and simulation programs can be used to skip these labor, material, and time-consuming steps, and companies can obtain simulations of the materials and clothes. One of them is the 3 D Vidya program produced by Assyst GmbH Company, but it is more specialized for fabric and there is only one leather material defined in the pre-installed material library of the program. However, an apparel leather company works with hundreds of types of leather and therefore they cannot effectively use the Vidya program and facilitate their works with the available library. These programs give a possibility to add new materials for users. Some data related to material properties are required while adding new materials into the library. If users want to achieve a realistic simulation; they have to enter many parameters into the program such as thickness, elongation at certain strength, bending stiffness, friction coefficient, and fold shape. Assyst has published a guidebook called "Vidya Software Package-Vidya Fabric Parameters" which includes methods for measuring and evaluating new material properties to be entered into the program, which works well with fabric material. Some modifications in the methods and interpretations in the results are needed to be made for the leather material.

In this study, both garment leathers and fabric materials were tested with the test methods described in the guidebook published by Assyst and alternatively with the FAST method. The material properties were interpreted and data were entered into the program by using the guidebook. After the patterns of the designed dress were created in the Assyst CAD system, the dresses have been simulated in the Assyst Vidya program by using these materials. Additionally, these dresses were sewn by using the same materials. Finally, simulation images and real products were compared by a 5-person jury, who are specialized in this field, and the data were interpreted according to the fuzzy logic method, which allows converting the voting results of the jury into numerical results (0-1), getting an average value, and then interpreting them by returning them to a quantitative result.

2. Materials and methods

2.1. Materials

Table 1 shows the properties of two different types of leather and fabric materials used in the study. The detailed photographs of these materials to be transferred to Vidya 3 D program are given in Figures 1–4.

The list of other materials and equipment used are given below:

- Heraeus Vötsch Climate Chamber
- FAST (Fabric Assurance by Simple Testing) measurement systems and SiroFast Software
- James Heal Drape Tester
- Assyst CAD GmbH (v.20.19.1.1102) pattern system and Lectra Alys 30 plotter
- Pfaff 1245 double toe leather upholstery sewing machine for sewing of leathers
- Global 3200 AUT sewing machine for sewing of fabrics
- Serafil Polyester 90 number sewing thread for sewing of leathers
- Saba[c] Polyester 120 number sewing thread for sewing fabrics
- Alvaform 01, 36 size female dummy
- Size Stream SS20 3D body scanner
- Canon EOS 70D DSLR camera
- Human Solutions 3D Vidya (v.20.19.1.35481) as the 3D visualization and simulation program.

2.2. Obtaining mechanical properties of leather and fabric materials

Conditioning and sampling: The leather test samples were conditioned according to TS EN ISO 2419 (TS EN ISO

Table 1. Material properties.

Code	Material	Construction	Thickness (mm)	Mass per unit area (g/m^2)	Area (dm^2)	Cr_2O_3 (%)	Ends/cm	Color
DM-1	Leather	Chromium tanned Tunisian Sheep	0.97	264	46.5	2.8	–	Black
DM-2	Leather	Chromium + vegetable tanned Tunisian Sheep	1.18	447	55.7	0.9	–	Brown
KM-1	Fabric	97% cotton + 3% lycra	0.43	191	–	–	30	Navy blue
KM-2	Fabric	95% polyamide + 5% lycra	0.82	268	–	–	40	Black

Figure 1. DM-1 Texture image (reptile pattern printed finish).

Figure 2. DM-2 Texture image.

Figure 3. KM-1 Texture image.

Figure 4. KM-2 Texture image.

2419 Leather, 2012), at 23 ± 2 °C temperature and 50 ± 5% relative humidity for 48 h; the fabric samples were conditioned according to TS EN ISO 139 (TS EN ISO 139 Textiles, 2008), at 20 ± 2 °C temperature and 60 ± 4% relative humidity for 24 h. Samplings from leathers and fabrics for all tests were done according to TS EN ISO 2418 (TS EN ISO 2418 Leather – Chemical, 2017) and TS EN 12751 (TS EN 12751 Textiles, 2002) standards respectively.

Mass per unit area: Grammage of leather and fabric samples were measured by using TS ISO 3801 (TS ISO 3801 Textiles, 2015) standard.

FAST System (Fabric Assurance by Simple Testing): The thickness of the materials was measured in the FAST-1 (Compression meter) system at two different loads (2 g/cm^2 and 100 g/cm^2). Bending lengths (mm) and bending values (µN.m) of the materials were obtained using the FAST-2 (Bending meter) system. By using FAST-3 (Extension meter) system, the extensibility of the materials was measured under three different loads (5, 20, and 100 g/cm) (De Boos & Tester, 1994). Our investigations and observations showed that the results and test methods of the FAST system performed better for the input data of the Vidya 3d Program, especially for leather.

Measurement of fold shape and volume: Samples were cut in accordance with TS 9693 (TS 9693, 9693, 1991) Textiles the Assessment of Drape of Fabrics standard. In the James Heal drapemeter device, the samples cut as a circle were placed between the horizontal disks with a diameter of 18 centimeters, and freely draped sample folded around the disc supporting the sample from below. Photographs of these cases were taken by using a DSLR camera. Then, the draping views of the samples in the photos were matched with the sample templates in the material entry of the Vidya 3 D program (Figure 5).

Measurement of dynamic friction coefficient: Frictorq (Fabric Friction Tester) device developed in Minho University, Portugal was used to measure the friction coefficient of materials. The device gave the dynamic friction coefficient (µ) of the material surfaces.

2.3. Preparation of two-dimensional (2 D) garment patterns

The dress patterns to be used in the study were created in the two-dimensional environment using the Assyst CAD system according to the Müller pattern system. Measurements were determined on a 36 size dummy female

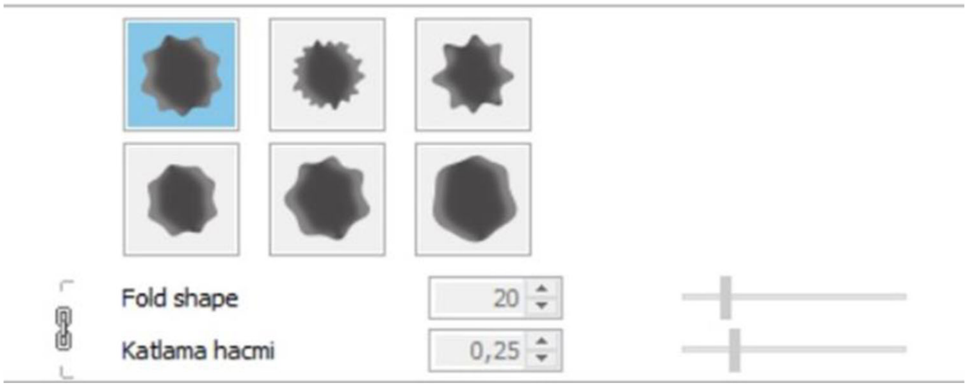

Figure 5. Folding shapes and volumes in Vidya 3 D program.

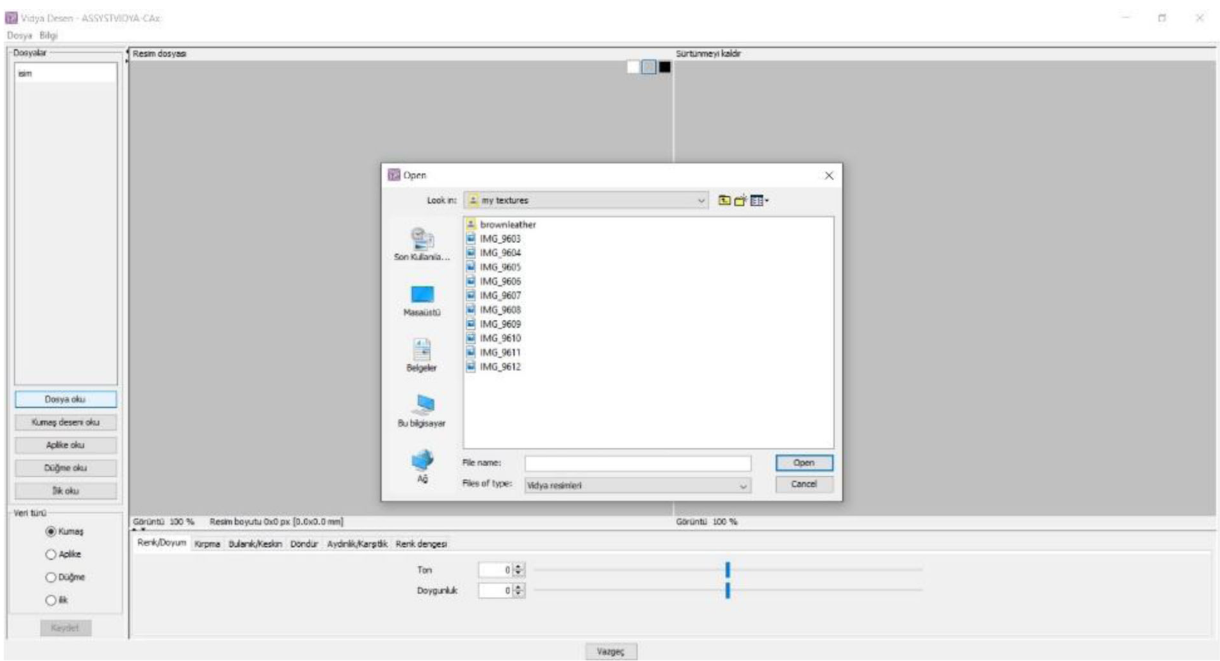

Figure 6. Vidya texture - File reading screenshot.

mannequin (Alvaform 01). The patterns which have been made ready for production were drawn on paper by using Lectra Alys 30 plotter. Then, the paper was cut with scissors, and dress patterns were obtained.

2.4. Sewing of dresses

The pieces obtained from leather materials were sewn by using Serafil polyester 90 thread and Pfaff 1245 double toe leather upholstery sewing machine. The pieces of fabric materials were sewn by using the Saba[c] polyester 120 thread and Global 3200 AUT sewing machine. The reason for choosing different sewing machines is the behaviors of the materials at the sewing stage due to their structural differences. In the sewing process, the fabric material shows less friction as it passes under the presser foot of the machine so that it slips, but the leather material does not easily slip off due to its surface structure or the formation of a surface texture from the finishing process.

In leather apparel, products are generally produced with a lining. In this study, the dresses were sewn without lining, because it is thought that it would be more literal and precise to observe the individual behaviors of the leather and fabric materials.

2.5. Simulation process

Transferring the material textures to the Vidya 3 D program: The transfers of the surface texture images of the materials were carried out with the "Vidya Texture" add-on of the 3 D Vidya program by uploading photos of each surface texture (Figure 6).

Scanning the dummy in 3 D: There are different sizes of virtual mannequins in the 3 D Vidya program, additionally, the users can use two methods to create their own virtual mannequins. The first method is the scanning of the dummy or human body in a cabin with a 3 D scanner and creating a virtual image on the computer screen. The second method is to create an avatar from the beginning by using

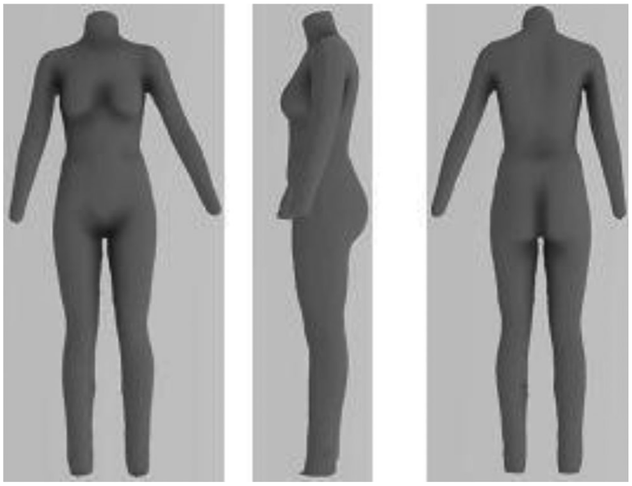

Figure 7. Front, back and side view of dummy transferred to Vidya program.

Table 2. Body measurements of the dummy.

	Measurements (cm)
Chest girth	84.5
Waist girth	67
Hip girth	93
Upper waist girth	70
Upper hip girth	83
Between neck-chest	26.5
Between neck-waist	41
Between waist-hip	22
Arm length	58
Shoulder to shoulder	38
One shoulder	12.5
Biceps girth	26
Wrist girth	16
Inner leg length	74
Upper leg girth	52
Knee girth	33
Calf girth	32

measures when a dummy or 3 D body scanner doesn't exist. In this study, Alvaform 01, 36 size female dummy mannequin was placed in the cabinet, scanned in Size Stream SS20 model 3 D body scanner, and transferred to the computer in three dimensions as a virtual mannequin (avatar) *via* Vidya 3 D avatar add-on. This file was saved to the 3 D Vidya program in the "obj" file format and displayed (Figure 7). Body sizes measured from Alvaform 01dummy are given in Table 2.

Entering the data obtained from the tests into the Vidya 3 D program: The data obtained from different materials by measuring in the FAST system are entered in the data entry spaces under the tab headings of the weft, warp, bias, and additional data in the Vidya 3 D program considering the guidebook published by Assyst Company.

Simulations of the clothes from each material in the Vidya 3 D program were created by using the prepared patterns, newly defined leather and fabric materials, and a 3 D mannequin. As shown in Figure 8, the material entry screen consists of four main headings as base data, extension behaviors, bending behaviors, and additional features.

All tests and comment results entered into the program under the four main headings mentioned above can be seen on the consolidated final screen. Necessary corrections can be made from the home screens with the four main titles as well as from this final screen. Figure 9 shows a screenshot of an example page of the final screen.

Process steps for simulation in Assyst CAD program: Some preparations are required to create simulations of the patterns created in 2 D CAD. The main steps of these processes are shown in Figure 10.

Simulation process in Vidya program: After pressing "Start" button in Assyst CAD program, Vidya 3 D visualization and simulation program is opened and the simulation process starts. The first screen is "Edit environment". In this step, the dummy to be used in the Avatar tab is selected which is the 36 size dummy file prepared for this study. Scene parameters are selected in the next step "Scene parameter" such as background, light direction, light settings, etc. After all, preparations are finished, the "Start" button is pressed (Figure 11).

2.6. Comparison of 3 D simulation images and real dresses

Considering the visual aesthetics and comfort properties of the products obtained in the study, each simulation image and the actual dresses were subjectively compared by the jury, who is an expert in 3 D visualization and simulation programs, according to the following features: Fit of the front side, Fit of the right side, Fit of the left side, Fit of the backside, Tension in different parts of the dress, Drapeability (Skirt side), Amount of drapes, Texture image, Appearance (General).

Methods that rely only on quantitative data, disabling decisions affected by personal experience and information; may not be enough to solve complex problems (Ofluoglu et al., 2017). Therefore, the fuzzy logic method, one of the artificial intelligence approaches developed by Zadeh (Zadeh, 1965), which reflects subjective decisions as numerical decisions, was applied for the mathematical modeling of subjective measurements. Each jury subjectively rated the "low", "medium", "good" and "very good" values between each dress and its simulation. Given votes are numerically collected and similarities were evaluated as: less 0.2; medium 0.4; good 0.6 and very good 0.8. Qualitative data was found by calculating the means of numerical data. These qualitative data provide information about the similarity of simulations and real dresses.

3. Results and discussion

3.1. Results from the FAST system

All the data of the materials obtained from the FAST system are given in Tables 3–6 below. When the values of DM-1 in Table 3 are examined, it is seen that the elongation percentages of the samples, which are taken in the vertical direction of the backbone of the leather, are higher than the samples taken in the horizontal direction. Mutlu (Mutlu et al., 2014), found and stated that elongation property changes directionally over the area of the sheep leathers,

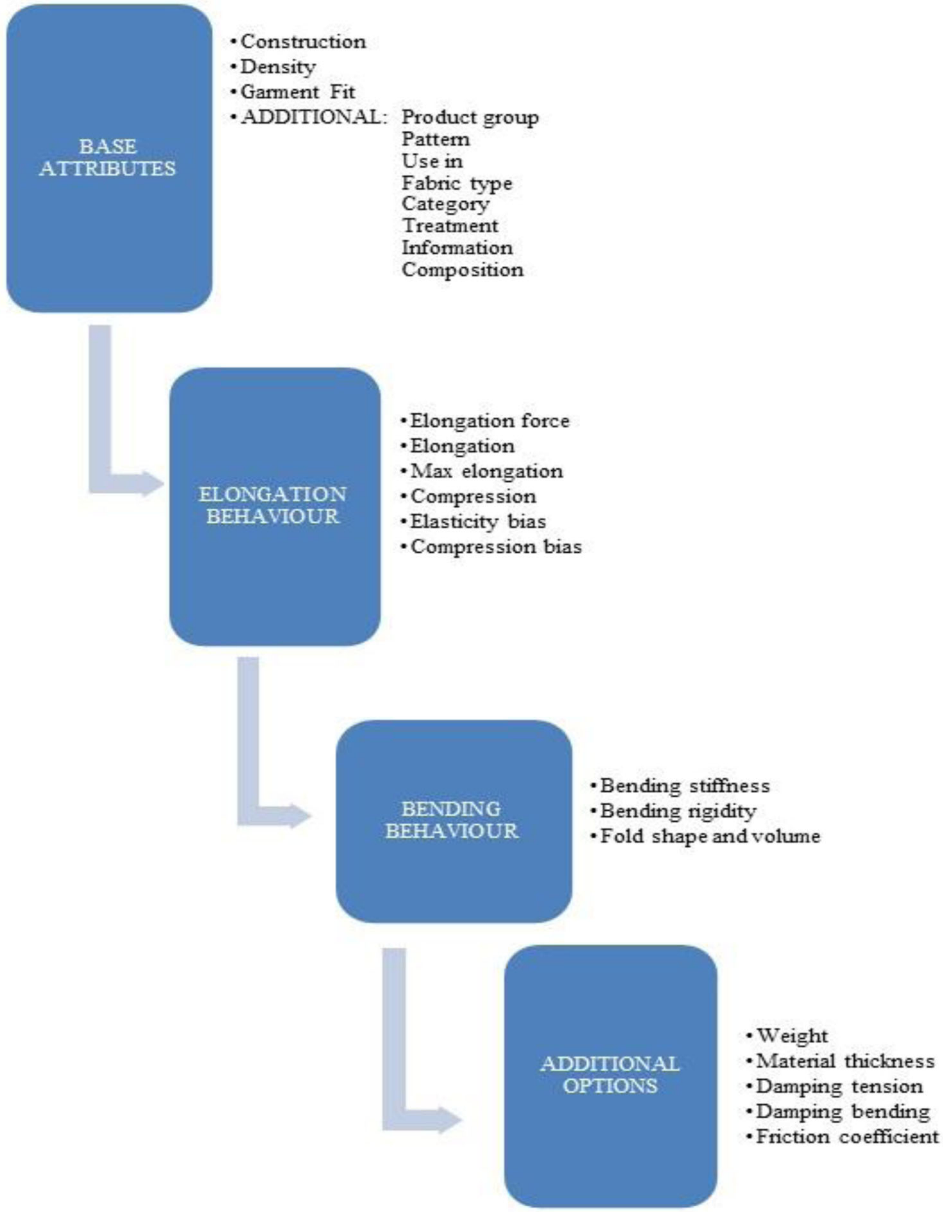

Figure 8. Steps for adding new material in Vidya 3 D Program.

due to leather is anisotropic material and its fibre bundles reportedly being oriented in different directions depending on the location on the skin (Conabere, 1944; Lin & Hayhurst, 1993). This difference in direction of fibre bundles reportedly affects some physical properties such as ultimate tensile strength and accounts for some of the variability observed in properties of finished leather (Conabere, 1944). As expected, the percentage of elongation increases as the applied force increases. Bending stiffness values of DM-1 were higher than fabric materials. The shear value defines the slip resistance of the material in the bias direction and his value is not used in the 3 D Vidya program, but it is included in the tables for information (this value is a parameter used for the material adding in some other 3 D visualization and simulation programs). The thickness and weight values are within the limits expected from the garment leather.

When the values of DM-2 in Table 4 are examined, a lower percent elongation value was obtained compared to DM-1. As in DM-1, when the applied force increases, the percentage of extension of DM-2 increases. Bending stiffness values were higher than DM-1, KM-1, and KM-2. The thickness and weight values are within the limits expected from the garment leather. Percentage of elongation, bending stiffness, thickness, and weight values are expected to be different than DM-1, because vegetable tanning agents are known to give a firmer behavior to the leather.

When the values of KM-1 shown in Table 5 are examined, a similar elongation value was obtained with leather materials. However, the percentage elongation value is noticeably less than KM-2. As in other materials, when the applied force increases, the elongation percentage value of KM-1 also increases. The bending stiffness values were also

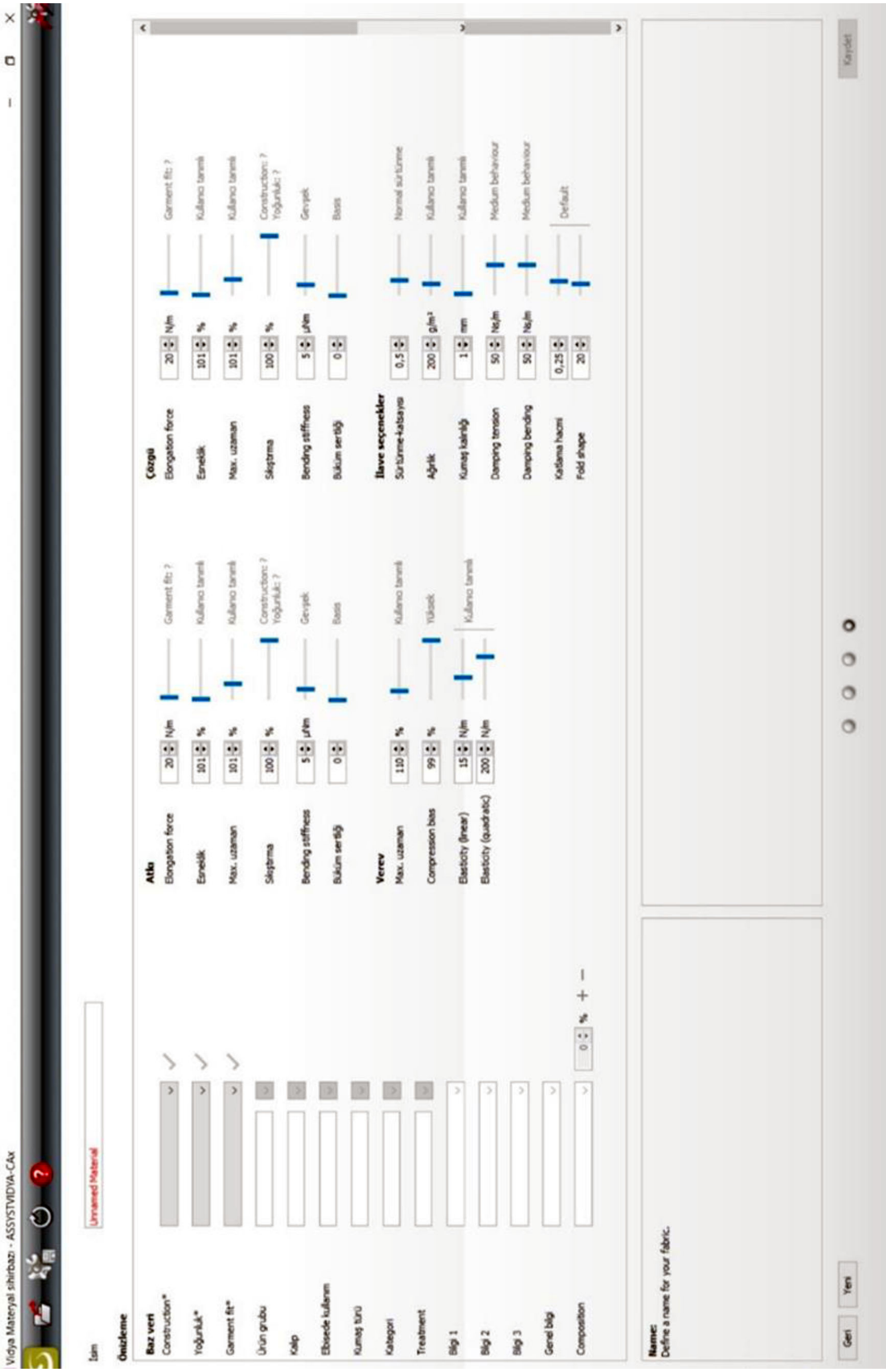

Figure 9. 3 D Vidya material wizard - Final screen.

lower than the leather materials. The thickness and weight values are within the limits expected from the garment fabric materials.

When the values of KM-2 in Table 6 are examined, a higher percentage elongation value was obtained compared to other materials in the study. The fact that it contains Lycra supports

Figure 10. The first step to define 3 D pieces (pattern).

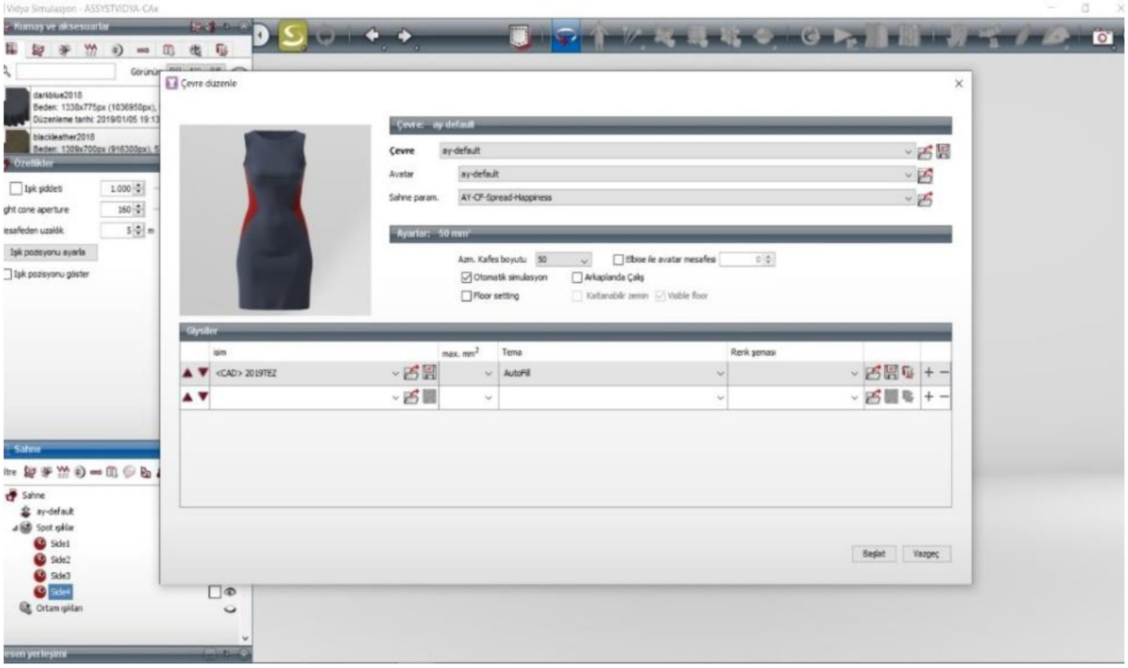

Figure 11. 3 D Vidya start settings.

Table 3. Results from DM-1 Chrome black garment sheep leather.

		1			2			Mean		
		Perpendicular (Warp)	Horizontal (Weft)	Bias	Perpendicular (Warp)	Horizontal (Weft)	Bias	Perpendicular (Warp)	Horizontal (Weft)	Bias
Elongation (%)	5 g/cm	0.8	0.7	0.8	0.8	0.5	0.5	0.8 ± 0.05	0.6 ± 0.15	0.7 ± 0.15
	20 g/cm	2.4	2.1	2.5	2.8	1.4	1.6	2.6 ± 0.15	1.8 ± 0.70	2.1 ± 0.45
	100 g/cm	9.1	6.6	10.1	12.6	5.5	9.8	10.9 ± 1.25	6.1 ± 3.55	10.0 ± 0.13
Bending Stiffness (µN.m)		28.8	39.0	–	24.5	43.1	–	**26.7 ± 5.05**	**41.1 ± 9.30**	–
Shear (N/m)			160.4			273.3			**216.9**	
Compression *Thickness (mm)	2 g/cm^2		0.99			0.97			**0.97 ± 0.04**	
	100 g/cm^2		0.76			0.72			**0.74 ± 0.03**	
Mass per unit area (g/m^2)					264.0				**264.0 ± 0.13**	

Table 4. Results from DM-2 Chrome + vegetable brown sheep leather.

		1			2			Mean		
		Perpendicular (Warp)	Horizontal (Weft)	Bias	Perpendicular (Warp)	Horizontal (Weft)	Bias	Perpendicular (Warp)	Horizontal (Weft)	Bias
Elongation (%)	5 g/cm	0.4	0.4	0.7	0.5	0.6	0.7	0.5 ± 0.01	0.5 ± 0.05	0.7 ± 0.01
	20 g/cm	1.7	1.3	2.3	1.5	1.9	2.2	1.6 ± 0.20	1.6 ± 0.20	2.3 ± 0.01
	100 g/cm	8.6	6.0	9.1	6.5	7.3	10.0	7.6 ± 1.30	6.7 ± 0.40	9.5 ± 0.47
Bending Stiffness (µN.m)		75.6	56.9	–	89.5	79.7	–	**82.6 ± 9.35**	**68.3 ± 4.90**	–
Shear (N/m)			175.7			175.7			**175.7**	
Compression Thickness (mm)	2 g/cm^2		1.22			1.15			**1.18 ± 0.04**	
	100 g/cm^2		1.03			0.97			**1.00 ± 0.03**	
Mass per unit area (g/m^2)					447.0				**447.0 ± 0.34**	

this phenomenon. As the force applied increases like other materials, the percentage of elongation of KM-2 material also increases, even under 100 g/cm load almost approached the measuring device limit. The bending stiffness values were lower than the leather materials. The thickness and weight values are within the limits expected from the garment fabric materials.

Generally, when looking at the values, the percent elongation values of DM-1 were higher than DM-2. In fabric

Table 5. Results from KM-1 97% cotton + 3% lycra content dark blue fabric.

		1			2			Mean		
		Perpendicular (Warp)	Horizontal (Weft)	Bias	Perpendicular (Warp)	Horizontal (Weft)	Bias	Perpendicular (Warp)	Horizontal (Weft)	Bias
Elongation (%)	5 g/cm	0.4	0.3	1.4	0.6	0.3	1.4	0.5 ± 0.05	0.3 ± 0.15	1.4 ± 0.01
	20 g/cm	1.7	0.6	5.7	1.9	0.5	5.7	1.8 ± 0.55	0.6 ± 0.70	5.7 ± 0.01
	100 g/cm	8.5	2.2	17.5	7.5	2.1	17.2	8.0 ± 3.15	2.2 ± 2.70	17.3 ± 0.15
Bending Stiffness (μN.m)		6.6	14.5	–	6.3	15.1	–	**6.5 ± 3.95**	**14.8 ± 4.40**	–
Shear (N/m)		91.1			85.8				**88.5**	
Compression Thickness (mm)	2 g/cm^2	0.43			0.43				**0.43 ± 0.01**	
	100 g/cm^2	0.32			0.33				**0.32 ± 0.01**	
Mass per unit area (g/m^2)				191.0					**191.0 ± 0.05**	

Table 6. Results from KM-2 95% polyamide + 5% lycra content black fabric.

		1			2			Mean		
		Perpendicular (Warp)	Horizontal (Weft)	Bias	Perpendicular (Warp)	Horizontal (Weft)	Bias	Perpendicular (Warp)	Horizontal (Weft)	Bias
Elongation (%)	5 g/cm	1.6	1.1	1.1	1.7	1.6	1.4	1.7 ± 0.25	1.4 ± 0.05	1.3 ± 0.15
	20 g/cm	7.1	4.2	4.2	7.6	5.6	4.6	7.4 ± 1.465	4.9 ± 1.00	4.4 ± 0.17
	100 g/cm	21.3	19.3	20.8	21.2	21.3	21.0	21.3 ± 1.00	20.3 ± 0.05	20.9 ± 0.07
Bending Stiffness (μN.m)		12.7	16.0	–	12.1	13.9	–	**12.4 ± 1.65**	**15.0 ± 0.90**	–
Shear (N/m)		108.6			86.8				**97.7**	
Compression Thickness (mm)	2 g/cm^2	0.82			0.82				**0.82 ± 0.01**	
	100 g/cm^2	0.75			0.75				**0.75 ± 0.01**	
Mass per unit area (g/m^2)				268.0					**268.0 ± 0.19**	

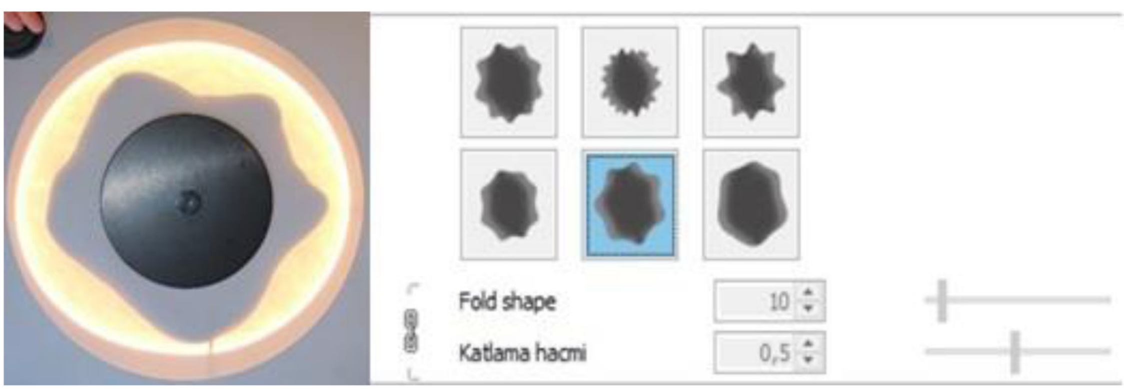

Figure 12. DM-1 Chrome black garment sheep leather - Folding shape and volume.

materials, it is seen that KM-2 has more elongation value than KM-1. It is known that the chrome tanning material and lycra material give flexibility to the materials. In the bending stiffness parameter, DM-2 was the material, which showed the most hardness, and, on the contrary KM-1 was the easiest to bending.

Normally, the leather materials produced to be garment have the thickness and weight values close to the fabrics. However, fabric and leather materials, which have different thickness and weight properties, were chosen intentionally to obtain the simulations of the garments which were made of different materials.

3.2. Results of the folding shapes and volumes of the samples

The photos of the bending folds when the samples are folded and the screenshots of the options of this parameter in the 3 D Vidya program are shown in Figures 12–15.

3.3. Results of friction coefficient of samples

Dynamic friction coefficients of the materials (separately from the up-grain and back- flesh sides) are shown in Table 7. The purpose of entering the friction coefficient in the 3 D Vidya program is that the friction between the mannequin and garment is determining the fit of the garment. Since the friction between the mannequin and the garment is in question, the friction coefficient values on the back of the fabrics and the flesh of the leathers are selected and entered into the program. Friction coefficients of leather materials were found around 0.6 and fabric materials were around 0.4. The reason why the friction coefficients of the leather are higher than the fabric materials is the coarse fiber network on the flesh side of the leather.

3.4. Comparison of three-dimensional simulation image and real clothes

The photographs of the 3 D dresses created in the real world and Vidya Program sewed from all materials are given from the front, back, left and right sides in Figures 16–19.

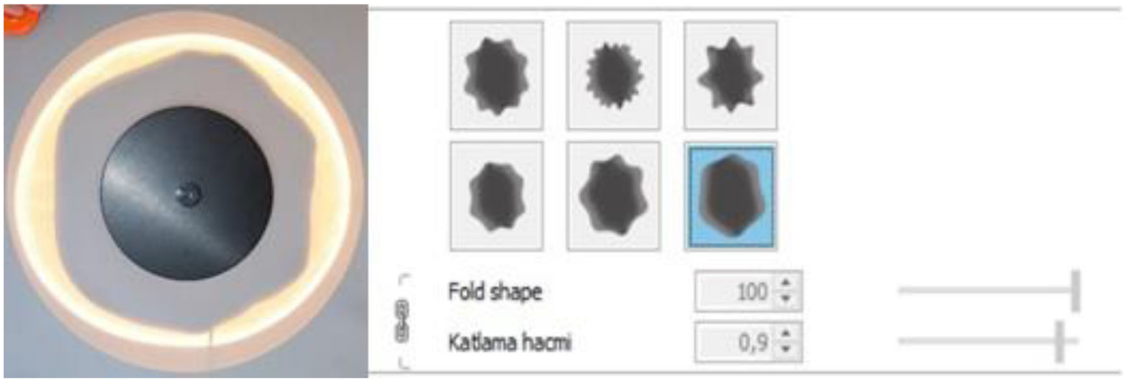

Figure 13. DM-2 Chrome + vegetable brown sheep leather - Folding shape and volume.

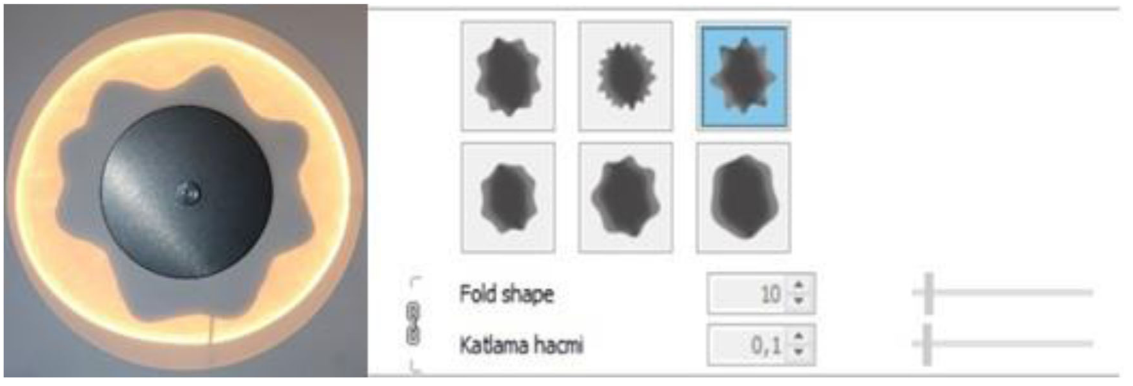

Figure 14. KM-1 97% cotton + 3% lycra content dark blue fabric - Folding shape and volume.

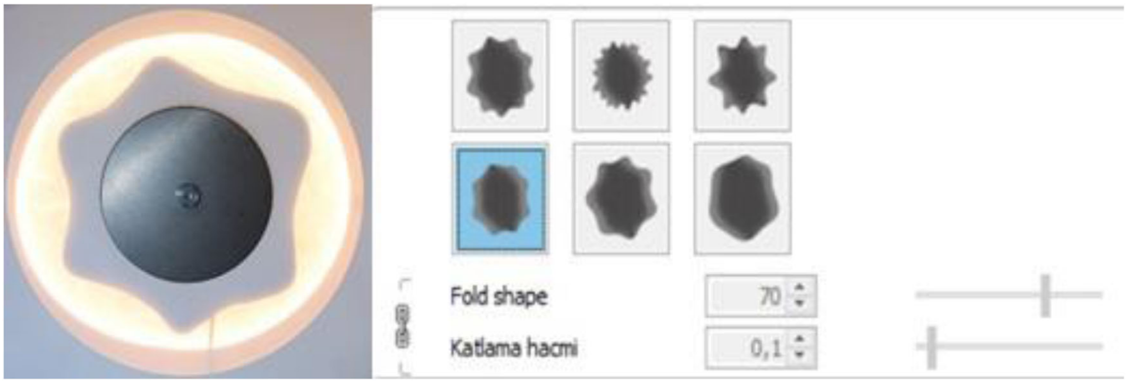

Figure 15. KM-2 95% polyamide + 5% lycra content black fabric - Folding shape and volume.

Table 7. Dynamic Friction Coefficient Values (μ).

	Up-Grain Side	Back- Flesh Side
DM-1 Chrome black garment sheep leather	0.44	**0.59**
DM-2 Chrome + vegetable brown sheep leather	0.39	**0.64**
KM-1 97% cotton + 3% lycra content dark blue fabric	0.17	**0.38**
KM-2 95% polyamide + 5% lycra content black fabric	0.29	**0.35**

When the success of the dress images obtained by simulating the patterns, which were created in Assyst CAD program, in 3D Vidya program are examined; the following general results were obtained:

- It is seen that the armhole, which is one of the problems encountered especially in the pattern-making phase, is simulated harmoniously with the body of the virtual mannequin.
- The fitting of the coupe pieces seen in almost every jacket and dress model in the leather garment is important and the chest coupes starting from the armpit have been successfully simulated by adapting to the body of the virtual mannequin.

Figure 16. Images of real (left) and virtual 3 D dresses (right) of DM-1.

- Similarly, the coupes on the back of the garment ensure that there is no pot and no gap at the waist of the garment. In the waist part of simulated clothes, there is no pot and gap.

As seen in Table 8, where the scores of all materials are given by the juries, the simulation created from KM-1 with 0.70 points has the best similarity in the general average. Secondly, there is a simulation image created from KM-2 with 0.60 points. When looking at the fabric materials, it is seen that they provide a good resemblance. DM-1 takes third place in similarity by taking 0.52 points. The simulations created from these three materials are in the "good" category. DM-2, which shows a weaker similarity, is in the "middle" category with 0.47 points. This result can be considered normal, since the DM-2 has less bending, more weight, and thickness, and Vidya 3 D software visualization and simulation program is mainly for fabric materials.

Table 8 which shows the scores that correspond to the evaluation criteria between 3 D simulations and real dresses, has been transferred to the graphs in Figure 20 for easier visual evaluation. It is seen that the green bar representing KM-1 shows high values compared to the values created by the scores of other materials, and the purple bar representing KM-2 has the second highest rating, but only in the third place in the criterion of "Fitting of left side". It is seen that the blue bar representing DM-1 ranks third in five criteria, while the red bar representing DM-2 only passes the DM-1 scoring in the criterion of " Fitting of right side".

Looking at the results in general, it can be said that simulations can be created as real-like in 3 D Vidya program, but the draping on the skirt side does not show the reality.

4. Conclusion

In line with the demand from customers for personal and special fashion products, it is observed that the interest in 3 D virtual clothing simulation is increasing all over the world. 3 D clothing simulation is used for many areas like virtual fashion shows, online fashion communities, virtual trials of clothes, and more. However, the most important criteria of these simulations is that they are realistic or not.

Figure 17. Images of real (left) and virtual 3 D dresses (right) of DM-2.

It can be said that the more accurate the material properties are, the more realistic the simulation is. In order to achieve real-life experience, the mechanical properties of the materials must be defined precisely in the program.

In this study, three important points were emphasized. The first is to measure the required mechanical properties of textiles and leather materials in 3 D visualization and simulation programs with special test methods for users. As known, the test standards of fabrics and leather materials differ from each other. For this reason, all standards in the guidebook created for the test methods published by Assyst can't be used for the leather material. Many methods in this guidebook are similar to the Kawabata test method, and this method is both expensive and requires much effort therefore the FAST system has been preferred accordingly. This method provides more cost-effective, less labor-intensive, and faster results. Due to these advantages, FAST system was used for the leather and textile materials selected within the scope of this study. In particular, the elongation data provided more realistic images in simulation according to the results obtained by using the method in the guidebook created by the company.

The second point is the interpretation of the data according to the program and comparison with the material database. Almost all fabric types are found in the database of the program and the characterization of these fabrics is almost similar. In contrast, leather material behavior varies as expected because variables such as the type of raw skin/hide, chemicals used in leather production, mechanical processes, processing type, etc. cause the manufactured leather to vary widely in many aspects. These variables also make the leather distinguish from each other. When looking at the program database, there is only one type of leather material and also when looking at a leather apparel industry, production is made with thousands of leather types, and therefore, the company can never have a realistic simulation in the 3 D Vidya program because the material they use will not be in the database.

The third one is the comparison of the simulations and real products. Within the scope of the study; the dress model, which shoulder - chest - waist fits to the body and

Figure 18. Images of real (left) and virtual 3 D dresses (right) of KM-1.

has drape below the waist, was selected and patterns of this design were created in Assyst CAD. Simulation images of the dresses were obtained using the data of each leather and textile material, and the dresses were sewn by using both materials. In the last step of the study, simulations and real dresses were compared according to the factors chosen by the experts in this field.

The results obtained and observed within the scope of this study are as follows:

In terms of the usability of the 3 D visualization and simulation program in leather apparel companies, no studies have been found in the literature. As a result of this study, it was first investigated that data could be obtained from leather materials by using appropriate test systems measuring different fabric behaviors and used in the simulation program.

As a result of the evaluations of 3 D simulations prepared with two different leather and fabric materials made by the jury according to the criteria determined by using the fuzzy logic method, KM-1 showed the closest similarity between prepared 3 D simulations and dresses. KM-2 was second with a slight difference. It was predictable that the fabric materials would give good similarity results. When the 3 D simulations and dresses prepared with leather materials were examined, DM-1 showed close to a good similarity, and DM-2 showed moderate similarity results. It is seen that the FAST method is successful in measuring the mechanical properties of the leather, but it requires more comments and experience when transferring this data to the 3 D Vidya program. The Vidya program is software designed for fabric materials and this can be explained as the reason why the property of the leather material is not very successful on the drape parameter.

In real life situation, a sample is sewn before starting mass production in a leather apparel company. Due to the cost of the leather, this sample is sewn by using the unbleached plain fabric first. If there is any rejection/objection from the customer or the designer, it is unstitched. If there is an error in the pattern, measurements, or sewing, they are prepared and sewn again. If the sample is approved, this time a sample is sewn by using the leather material. If the customer or designer does not approve, the leather material is completely discarded and wherever the mistake is made, this step is corrected and the garment is

Figure 19. Images of real (left) and virtual 3 D dresses (right) of KM-2.

Table 8. Comparison chart of Vidya 3 D and real images.

	DM-1	DM-2	KM-1	KM-2
Fitting front part	0.44	0.44	0.68	0.60
Fitting right part	0.52	0.56	0.64	0.60
Fitting left part	0.64	0.56	0.68	0.60
Fitting back part	0.56	0.52	0.76	0.60
Tightness of different parts of the dress	0.56	0.56	0.72	0.64
Drapeability (Skirt part)	0.44	0.36	0.68	0.52
Amount of drape of the skirt	0.44	0.36	0.76	0.52
Texture appearance	0.52	0.32	0.72	0.68
Appearance (General)	0.56	0.56	0.68	0.60
Mean	**0.52**	**0.47**	**0.70**	**0.60**

produced again using new leather material. To avoid waste of time, labor, and money; leather apparel companies can buy 3 D visualization and simulation programs and obtain realistic simulations after applying the test methods mentioned in this study on their own materials. In this way, leather apparel companies can instantly see the pattern errors and the incompatibility between the garment and the material; and provide significant savings in terms of both time and cost of leather. At the same time, it is added to the mentioned savings that sample controls, which are made by the long-distance/overseas customers visiting the company, can now be made both quickly and without transportation costs by sending the simulation image to the customer *via* email.

Considering these factors, it is believed that this study will make important contributions to the literature and future studies about the leather material, and it will be an occasion for leather apparel companies to take one step ahead with cost/time saving, innovative production, and

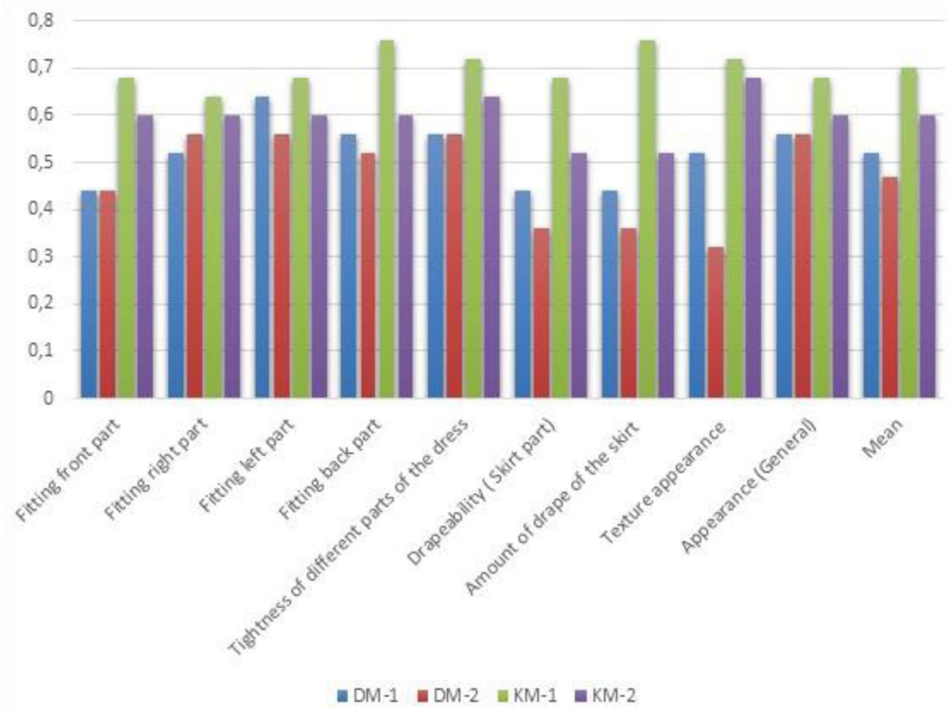

Figure 20. Scores of the similarities between dresses and 3 D simulation.

mercantilism by using 3 D visualization and simulation programs in the tough competition of companies.

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References

Akgul, E., Kizilkaya Aydogan, E., & Sinanoglu, C. (2021). Investigation of different denim fabrics with fabric touch tester and sensory evaluation. *Journal of Natural Fibers*, Published Online, 18 Feb. https://doi.org/10.1080/15440478.2021.1881687

American Association of Textile Chemists and Colorists. (2002). AATCC Technical Manual. https://www.aatcc.org.

Coban, S. (1999). Genel Tekstil Terbiyesi ve Bitim Islemleri. Ege Universitesi Tekstil ve Konfeksiyon Arastirma Uygulama Merkezi, Izmir.

Conabere, G. O. (1944). The fundamental structure of hides, skins and leather. *Journal of the International Society of Leather Trades' Chemists*, *28*(12), 270–280.

De Boos, A., & Tester, D. (1994). *SiroFAST – A system for fabric objective measurement and its application in fabric and garment manufacture*. CSIRO Textile and Fibre Technology.

Gurarda, A. (2015). Konfeksiyon işlemleri ile kumaş özellikleri arası ndaki ilişkinin incelenmesi. *Tekstil ve Mühendis*, *22*(99), 41–50.

Iftikhar, F., Ali, Z., & Hussain, T. (2019). Influence of yarn count and cover factor on mechanical, comfort, aesthetic and hand properties of ladies' summer apparel fabrics. *Journal of Natural Fibers*. Published Online, 19 Nov. https://doi.org/10.1080/15440478.2019.1692322

Iqbal, M. A. 2013. *Virtual product development and management opportunities in fashion industry* [Master thesis]. Tampere University of Technology. 3 October, 2012.

Kan, C. W., & Lau, T. C. (2018). Use of softener in home laundering of cotton fabric – hand feel value measurement by PhabrOmeter. *Fibers and Polymers*, *19*(10), 2203–2207. https://doi.org/10.1007/s12221-018-8442-2

Kawabata, S. (1980). *The standardization and analysis of handle evaluation* (2nd ed.). The Textile Machinery Society of Japan.

Lin, J., & Hayhurst, D. R. (1993). Constitutive equations for multi-axial straining of leather under uni-axial stress. *European Journal of Mechanics A/Solids*, *12*(4), 471–492.

Luible, C., & Magnenat-Thalmann, N. (2007). Suitability of standard fabric characterisation experiments for the use in virtual simulations. In *Proceeding of Autex 2007 Conference*. Finland, June.

Mutlu, M. M., Ork, N., Yegin, O., et al. (2014). Mapping the variations of tensile strength over the area of sheepskin leather. *Annals of the University of Oradea Fascicle of Textiles. Leatherwork*, *15*(1), 157–162.

Ofluoglu, P., Ork, N., & Mutlu, M. M. (2017). The best supplier selection by using analytic hierarchy process (AHP) and fuzzy comprehensive evaluation (FCE) methods: An example of a Turkish leather apparel company. *Tekstil ve Konfeksiyon*, *27*(4), 326–333.

Ork, N., Mutlu, M. M., & Pamuk, O. (2017). Material testing for 3D visualization and simulation programs in leather apparel. In H. Karavana, A. Yorgancioglu, & E. Onem (Eds.), *Proceeding of IV International Leather Engineering Congress* (pp. 93–98). Ege University Engineering Faculty Leather Engineering Department.

Pan, N., Lin, C., & Xu, J. (2019). A new method for measuring fabric drape with a novel parameter for classifying fabrics. *Fibers*, *7*(8), 70. https://doi.org/10.3390/fib7080070

Rous, M. A., B., M., E., L., & J., I. (2018). Handfeel of single jersey fabrics as assessed by a new physical method. *Journal of Fashion Technology & Textile Engineering*, *s4*, 4–8. https://doi.org/10.4172/2329-9568.S4-006

Sayem, A. S. M., Kennon, R., & Clarke, N. (2010). 3D CAD systems for the clothing industry. *International Journal of Fashion Design,* *Technology and Education*, *3*(2), 45–53. https://doi.org/10.1080/17543261003689888

Tohidi, S. D., Jeddi, A., & Nosrati, H. (2013). Analyzing of the woven fabric geometry on the bending rigidity properties. *International Journal of Textile Science*, *2*(4), 73–80.

TS 9693. (1991). *Textiles the assessment of drape of fabrics*. Turkish Standard Institute.

TS EN 12751 Textiles. (2002). *Sampling of fibres, yarns and fabrics for testing*. Turkish Standard Institute.

TS EN ISO 139 Textiles. (2008). *Standard atmospheres for conditioning and testing*. Turkish Standard Institute.

TS EN ISO 2418 Leather – Chemical. (2017). *Physical and mechanical and fastness test - Sampling location*. Turkish Standard Institute.

TS EN ISO 2419 Leather. (2012). *Physical and mechanical tests - Sample preparation and conditioning*. Turkish Standard Institute.

TS ISO 3801 Textiles. (2015). *Woven fabrics - Determination of mass per unit length and mass per unit area*. Turkish Standard Institute.

Yim, K. Y., Yang, R. H., Kan, C. W., Ng, S. P., & Lam, J. K. C. (2017). Analysis of fabric handle of warp knitted fabrics by PhabrOmeter system. *AATCC Review*, *17*(6), 36–41. https://doi.org/10.14504/ar.17.6.4

Zadeh, L. A. (1965). Fuzzy sets. *Information and Control*, *8*(3), 338–353. https://doi.org/10.1016/S0019-9958(65)90241-X