Comparison of Objective Measurement Methods of Fabric Tensile Properties for 3D Virtual Garment Software

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Background and Research Purpose: Amongst the emerging digital technologies, 3D virtual garment software is considered a groundbreaking technology, in particular, compared to the way of designing and developing products by converting the physical aspect into digital (Court, 2015; Mageean, 2019). In recent years, there has been a gradual increase in the exploration and adoption of 3D virtual garment simulation technology in the long-term strategic planning by fashion brands and retail companies such as Nike, Under Armour, VF Corporation, Target, Kohl's, Walmart, etc.

However, the validation of virtual fitting and drape is yet to be perfected (Kuijpers et al., 2020; Prah, 2017). Experts from industry and academia highlight an inconsistency amongst the fabric measurement methods and significantly varied simulation results of the same fabric between the different software providers. This demonstrates the need to standardize fabric measurements used in virtual software for more accurate simulation (Kuijpers et al., 2020). The accuracy of 3D virtual garment software depends on the computational algorithm of simulation software and the precision of fabric input parameters derived from the fabric's physical and mechanical properties (Luible & Magnenat-Thalmann, 2007; Sayem et al., 2010). As such, to digitize the mechanical and physical behavior of fabric material, some software providers employ independent systems that are also used for other regular textile testing. In contrast, a few software systems have developed their own testing instruments to support the software.

The fundamental fabric properties that can decide the drape of fabric in a 3D virtual garment software are thickness, bending, shear, tensile, and friction, and these can be acquired through objective fabric measurement methods (Kuijpers et al., 2020; Matusiak, 2017; Šarac et al., 2015). This study focuses on tensile and shear properties. Shear properties are defined as bias (45°) extension based on the same principle as the tensile test (Kuijpers et al., 2020). The study's purpose was to: (1) compare the principle, testing protocols, and SI unit for tensile and shear properties and (2) explore compatibility between the output data obtained from three types of fabric testing devices.

Objective measurement methods: For the experiments, 100% wool twill fabric was selected, and the tensile and shear properties of the fabric specimens were obtained through CSIRO FAST

system, CLO fabric kit, and MTS Q-test/5 Universal testing machine. CSIRO FAST system and MTS Q-test/5 universal testing machine can be classified as independent systems while the CLO fabric kit is a testing instrument composed as part of the software for creating a digital fabric library in CLO 3D software. Moreover, CSIRO FAST system and CLO fabric kit don't follow existing standards, whereas the MTS Q-test/5 Universal testing machine can conduct tests in compliance with ASTM D5034 (grab test), D5035 (strip test), and D4964 (elastic fabrics).

CSIRO FAST extension meter measured the extensibility (%) of fabric in the warp and weft directions under loads of 5 gf/cm, 20 gf/cm, and 100 gf/cm on each strip of fabric. It also measured the bias extensibility (%) of the fabric under a load of 5 gf/cm, and bias extensibility was used to calculate shear rigidity (N/m). Required fabric specimen size was 15cm by 5cm, and the measurement was repeated three times for warp and weft direction and six times for bias direction (Das & Alagirusamy, 2010). For measurement, the fabric specimen was placed between the jaws, securing the upper fixed clamping knob first, and then the specimen was hung through the lower moving jaws (under its own weight) and connected to the load cell.

CLO fabric kit's stretch test device measured the length of the stretch (mm) with the length ruler and applied force (kgf) with a digital force gauge installed onto the device. A fabric specimen of 22cm by 3 cm in size was placed on the fabric bed between the clamps. Subsequently, the fabric sample was manually extended by users by turning the knob from when the force gauge read 0.010. In any case, where the needle along the ruler was found to go past 1mm, the fabric was classified as high stretch fabric, and the first reading was considered to be the first established length value. In any case, where the needle along the ruler was at 1mm or less, the fabric was classified as low stretch fabric, and the resulting force value after stretching the fabric to 1 mm was considered to be the first round of the test. The test was conducted in a minimum of 3 sets and a maximum of 5 sets for a sample with the consistent increment of the first established length value. The CLO digital force gauge was found to have a threshold at 2 kgf, and warp, weft, and bias fabric samples were measured (CLO, 2019).

The MTS Q-test/5 Universal testing machine measured peak load and elongation by following ASTM standards, and current standards were used to test the breaking force by applying the maximum force to the material until it ruptured. This study followed the ASTM D5035 (strip test) standard under a load of 250 lb (113.4 kgf) throughout all assessments. A Fabric specimen of 1 inch by 6 inches was mounted lengthwise between the clamps with both 1-inch gripping area and the end of the specimen was automatically extended by a motor at a uniform speed until it broke. A force-elongation curve was generated in the software connected with the machine. The control panel software was found to have a good command of changing units of output data. The measurement was repeated five times for specimens with a warp, weft, and bias grainline.

Findings and Conclusion: Throughout all devices, fabric specimens in bias direction had the highest extensibility, which required the weakest loadcell for applying force. However, the breakage of bias fabric took the longest time due to the outstanding extensibility. The value of elongation of the MTS Q-test was not in the common range of that of the CLO and FAST system due to a huge difference in applied force. Fabric specimens in warp direction showed higher extensibility depending on the increase in loadcell compared to the weft direction. The CSIRO FAST system and MTS Q-test/5 Universal Testing machine applied tensility driven by force with a loadcell and motor, whereas the CLO fabric kit applied tensility driven by length extension.

Additionally, the MTS Q-test/5 Universal Testing machine obtained peak load and elongation when the fabric sample broke. In contrast, the calculation formula for generating data from the parameters in CLO3D was not inferred to be transparent. With unstandardized measurements and calculation principles, a threshold of loadcells, differing dimensions of fabric specimens, and differing SI units for defining the same property are derived as the relevant factors that impeded the convertibility and comparability of fabric properties between the software and devices. Correspondingly, commencing a discussion on raising the world's standards could be the first step to improve the fidelity and consistency of simulating 3D virtual garments across all the software providers. For future study, a larger number of fabric samples will be measured to analyze correlation factors between several objective measurement methods.

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