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# Fabric and Garment Drape Measurement - Part 2

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**Abstract**

Fabric and garment drape were compared using an alternative drape measurement system based on an image analysis technique. Garment drape was investigated using dresses suspended on a mannequin. A graphical user interface was developed to carry out the image analysis and to calculate drape values identifying and determining 21 parameters. A range of fabrics including knitted, woven and nonwoven fabrics were compared in terms of FAST properties, drape coefficient and drape values. Visual assessment of the fabric range was carried out in terms of drape amount and preference. Low agreement was found between individuals with regard to preferred drape amount and high agreement with respect to actual drape amount. Nonwovens were found of better preference over some traditional fabrics. Most of the drape values of fabric and garment were found to have poor correlations.

*Keywords*: Drape; Fabric; Garment; Drape Values; Image Analysis

## 1 Introduction

Drape is one of the most important fabric properties and plays an important role in garment appearance. It is defined as "the extent to which a fabric will deform when it is allowed to hang under its own weight" [1].

It is a complex combination of a fabric's physical, mechanical and visual properties which can be evaluated either subjectively or objectively [2]. In 1950, a fabric research laboratory drapemeter (FRL) was developed to measure fabric drapeability objectively [3]. Studies and developments carried out by Chu *et al.* and Cusick are considered to be significant improvements for measuring fabric drapeability and the British standard of drape measurement is based on Cusick's findings [3-5].

Drape coefficient is the traditional parameter used to express the drapeability of fabrics and defined as the percentage of a paper ring (used to project/cast on the shadow of the draped sample) covered by the vertically projected shadow of the partially centrally supported circular sample on a circular disc with smaller diameter [1]. Some investigations have used the weight to express this percentage and others have used the area. Limitations in the traditional method (such as time consuming and errors dependant on operator) have encouraged researchers to seek

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alternative methods to investigate drape such as image analysis which showed good agreement with the drapemeter.

There have been several studies carried out to investigate drape using image analysis. In 1988 Collier *et al.* devised a drapemeter and a voltmeter to measure the amount of light blocked by the tested sample using a base of photovoltaic cells [6]. Typically, studies implementing image analysis in investigating drape are based on one of two approaches to analyze the captured image and calculate the DC%, the first approach uses the number of pixels occupied by the area of the supporting disc, shadow and the outer region [7-10]. The second approach disagrees with the accuracy of the first and instead uses the boundaries of the shadow cast to investigate the drape profile [11-15]. Much research has been carried out to investigate drape focused on: seeking reliable and representative drape parameters and formulas, factors affecting drape, its correlation with physical and mechanical properties, ease of analysing, predicting drapeability, static, dynamic and swinging motion drape. These have been described in Part 1 of this article [16].

During investigations into fabric drape, several parameters have been proposed such as: drape distance ratio [17], drape profile circularity (CIRC), number of nodes, mean node severity and variability of node severity [12] static and dynamic drape coefficients [13] wave amplitude, maximum, minimum, average and variance of amplitude, wavelength [18].

Few researchers have been concerned with investigating the form of the supporting body used to mount the fabric sample on. Most of the drapemeters used in these studies – even the apparel drape studies – were devised with a circular plate to mount the sample on.

Needless to say, if apparel fabric drape is to be investigated, the researcher should check if the supporting surface form and the performance of the fabric suspended on it matches the human body. Investigating apparel drape is completely different from furnishing textiles which may lend itself well to using the Cusick drapemeter.

Some studies employed garment on mannequin in investigations related to drape. Cui *et al.* studied the effect of fabric drapeability on girth ease allowance (GEA) of garment at waist, hip and bust [19]. Moreover, drape simulation studies have been investigating a reliable method for virtual presentation of garment drape. These were based on 3D scanning a garment, measuring its drape parameters followed by using alternative techniques and methods for reconstructing the drape profile [20].

In this study, we are concerned with investigating apparel drape on a suspended mannequin using image analysis. Garment drapeability was compared with fabric drapeability in terms of drape values measured for garment and fabric images. Moreover, nonwoven fabric drape for apparel use was investigated. Nonwovens are often used in the textile (apparel) industry whether as lining fabrics or disposable gowns for medical use. It is rare to find them in the apparel market as shell fabrics of a garment, top, skirt, etc. Their poor drape has been one of the reasons for that rare existence. Perhaps, it is one of the major nonwovens' drawbacks, which impedes using them in the apparel industry as shell fabrics. Therefore, it was considered essential to study and investigate this property, its measurement and its effect on garment appearance. It is proposed to compare the nonwoven drape behaviour with woven and knitted fabrics to help the understanding of nonwoven fabrics' behaviour.

The purpose of this study is to identify and determine an alternative method/system which would produce more dependable parameters than the extant traditional ones and would consequently give a better understanding of nonwoven materials for apparel. This system will use a dress on a mannequin, instead of a fabric on circular disc (traditional method), which would be more akin to the real apparel drape. A comparison between traditional and the new alternative methods was conducted.

# 2 Experimental

## 2.1 Materials

A group of traditional fabrics were used including two knitted fabrics and five woven fabrics. Their weights were suitable for making women's dresses. For nonwovens, it was observed in published literature that hydroentangled nonwoven fabrics have the lowest bending length, rigidity and shear rigidity and higher extensibility compared with other types of nonwoven fabrics (i.e. chemically and thermally bonded) in both machine and cross directions [21]. Based on this fact, this type of nonwoven fabric could be used in the apparel industry as light weight fabric. A range of 5 nonwoven fabrics (hydroentangled with polyamide and polyester based fibres) were provided by Freudenberg Nonwovens Company, their commercial name is Evolon (see Tables 1-3 for the description of the physical properties of each fabric group).

Table 1: Woven fabrics' physical properties

| Fabric Code | Structure | Weight (g/m$^2$) | Ends/cm | Picks/cm | Yarn details | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Warp | | Weft | |
| | | | | | Fibre type | Count (Denier) | Fibre type | Count (Denier) |
| W1 | Plain | 152 | 39 | 25 | viscose | 308 | viscose | 330 |
| W2 | Plain | 108 | 43 | 24 | viscose | 120 | viscose | 120 |
| W3 | Twill (warp faced) 3/1 | 158 | 44 | 27 | polyester | 180 | polyester | 337 |
| W4 | Plain | 105 | 41 | 25 | viscose | 120 | viscose | 120 |
| W5 | Plain | 250 | 26 | 24 | cotton | 276 | cotton | 298 |

Table 2: Knitted fabrics' physical properties

| Fabric Code | Gauge | Weight (g/m$^2$) | Courses/cm | Wales/cm | Yarn details | |
|---|---|---|---|---|---|---|
| | | | | | Fibre type | Count (Denier) |
| K1 | 28 | 260 | 28 | 16 | viscose | 120 D |
| K2 | 28 | 197 | 28 | 18 | viscose | 120 D |

Table 3: Nonwoven fabrics' physical properties

| Fabric code | Quality name | weight (g/m$^2$) | Treatment |
|---|---|---|---|
| N1 | Evolon | 100 | Not softened |
| N2 | Evolon 80 Soft | 80 | Softened |
| N4 | Evolon100 Soft | 100 | Softened |
| N5 | Evolon130 Soft | 130 | Softened |
| N6 | Evolon170 Soft | 170 | Softened |

## 2.2 Measurement of the Low Stress Mechanical Properties

The low stress mechanical properties of the three fabrics groups (woven, knitted and nonwoven) were measured to give clear identification of the fabrics and because of the high correlation between fabric drape behaviour and mechanical properties (specially bending and shear rigidity properties).

In this study, the FAST (Fabric Assurance by Simple Testing) system was chosen to measure the low stress mechanical properties as it is simple, available and has been used in many research studies. Using this system, three properties were measured on three devices and other properties were calculated from the measured values (see Table 4).

Table 4: The measured and calculated low stress mechanical properties using the FAST system

| Measured properties | Symbol | Direction | Unit |
|---|---|---|---|
| Bending length | BL | L, C, bias | mm |
| Extensibility | E at 5, 20, 100 gf/cm | L, C, bias | % |
| Thickness | T at 2 and 100 gf/cm$^2$ | No direction | mm |
| Calculated properties | | | |
| Bending rigidity | BR | L, C, bias | $\mu$Nm |
| Bending modulus | BM | L, C, bias | Kg/cm$^2$ |
| Formability | FR | L, C, bias | mm$^2$ |
| Shear rigidity | G | No direction | N/m |
| Surface thickness | ST | No direction | mm |

The standard sample size stated in the FAST system manual 5 × 13 cm was used in all tests (thickness, bending length and extensibility).

All tested samples in this study were conditioned in a standard atmosphere: 60 ± 2% relative humidity and 20 ± 2°C according to the British Standard (BS EN 20139: 1992 ISO 139: 1973).

## 2.3 Samples

In fabric drape investigation, specimens of 30 cm diameter cut from fabric free from creases; at least 5 cm was left between the sample and the selvedge for all tests.

In garment drape study, an A line shift dress pattern (size 12) was used to cut dresses from the 12 fabrics tested in this study (see Fig. 1). All dresses were cut in the fabric lengthwise direction.

One centimetre seam allowance was applied in all the dresses. An invisible zip was sewn in the back opening. The centre back seam was stitched from the lowest end of the dress to the zip. In the woven and knitted dresses seam binding was used to finish the neck.

## 2.4 Measurement of Fabric Drape Coefficient

A Cusick drapemeter was used to measure fabric drape coefficient. Three fabric samples were conditioned in a standard atmosphere before testing as specified in BS 1051, i.e. a relative humidity of 65 ± 2% and a temperature of 20 ± 2 °C. A draped fabric was captured from above the drapemeter using a digital camera. Each sample was tested with its face upwards and turned upside down to measure its reverse. These two measurements were repeated twice to obtain 3 face and 3 back shadows for each sample. Nine face and nine back shadows were obtained for three different samples. The Drape Coefficient (DC) was calculated using Eq. (1):

$$\mathrm{DC} = \frac{\mathrm{M2} \times 100}{\mathrm{M1}} \tag{1}$$

where: M1 is the original paper ring number of pixels, M2 is the shaded area number of pixels.

## 2.5 Image Analysis of Fabric and Garment Drape

Images used in measurement of the drape coefficient which were taken for circular fabric samples were analysed in a fabric drape investigation using image analysis. However, these produced filled solid shapes.

For garment images, a mannequin of size 12 was used for suspending the dresses. Photos were taken for each dress on this mannequin from below. Pictures captured were converted into black and white images using Photoshop software. It was very important to adjust each image to be 1:10 scale of the original image with resolution 100 pixel/cm. This specification is necessary to obtain accurate results later when an image is processed.

Each processed image passed through the following procedures in order to obtain the values calculated in this study:

A monochrome (black and white/binary) image was converted into a polar plot ($\theta$, r), as the discrete points making up the image's contour were converted into polar coordinates, where the X-axis presented the angle $\theta$ of each point in degrees (from 0° to 360°) from the horizontal line passing through the centre, and Y-axis presented distance r of each point from the centre, in centimetres.

The polar plot was converted into Cartesian plot (x, y), where x was the angle of each coordinate's position and y was the radius. This plot was called the shape signature as it presented the original distinctive wave of each image.

The ideal (reconstructed) wave shape was recomposed from the determined average wave values measured; namely wave length, amplitude and height.

A Fast Fourier transform (fft) was performed to convert the original Cartesian plot into a frequency domain.

In this study, twenty one shape parameters were selected as drape values. These were subdivided into four groups: the first group was the "Basic drape shape characteristics"; the second group was the “wave measurements”, the third was “wave analysis” and the last one was “Fourier”.

In the “Basic drape shape characteristics” group, the general shape properties were measured including:


Fig. 1: Dresses tested in the visual assessment (real garments)

• Perimeter (P): This is the length of the processed shape outline measured in centimetres [22, 23].

• Area (A): This is the amount of space inside the boundary of the shape measured in centimetres square [22].

• Circularity (CIRC): This is a measure of shape complexity and sharpness (see Eq. (2))

$$\mathrm{CIRC} = 4\pi \mathrm{A}/\mathrm{P}^2 \tag{2}$$

where: A is the area and P is the Perimeter. can take a value in the range 0 to 1, where CIRC = 1 for a perfect circle and tends towards 0 for more complex profiles. This parameter showed strong correlation with the traditional drape parameter (Drape coefficient) [12]. It was decided to use it in this study as an alternative for drape coefficient as the latter is not applicable to garment images.

It is noteworthy that another complexity shape parameter Area/ Perimeter (A/P) was found to have strong correlation with circularity ($r_{\text{Dress images}}=0.96$, $p< 0.00001$ and $r_{\text{Fabric images}} = 0.995$, $p < 0.00001$). The A/P parameter showed negative/reverse relation with drapeability as this ratio increased with low drapeable samples. However the Circularity was used for its advantage in being compared with a perfect circle.

• Symmetry: This is the reflection symmetry which measures the degree of two halves of a shape identical over the vertical axis (Y) for Left/Right symmetry and over the horizontal (x) axis for Front/Back symmetry. Symmetry ranges between 0 (completely asymmetrical halves) and 1 (identical symmetrical parts) [22].

• Number of peaks: This is the number of peaks/ nodes making up the original wave of the shape signature. The threshold of Peak-Trough distance/length stated in Shyr el al's study which was found reliable to determine the number of drape wave peaks 0.3 cm was applied to detect the peak number [24].

In the "Wave measurements" group: the average, maximum, minimum and variation of single waves constituting the wave shape were computed. This was based on two successive peaks making up a single wave in the entire wave representing the original shape. According to this the calculations were conducted as follows:

• Wavelength (WL) (degrees): This is a measure of the distance between repetitions of a shape feature. In this study the distance between two successive peaks was used, expressed in degrees of a circle (from 0° to 360°). It was calculated as in Eq. (3) [25]:

$$\mathrm{WL_i} = \mathrm{Peak_i} - \mathrm{Peak_{i+1}} \tag{3}$$

• Wave height (H) (cm): One of the drape shape parameters indicating the wave distance / displacement / elevation from the centre of the supporting body. This was measured as in Eq. (4).

$$\mathrm{WH_i} = \frac{\mathrm{Peak_i} + \mathrm{trough_i}}{2} \tag{4}$$

where: $\mathrm{Peak_i}$ and $\mathrm{trought_i}$ are two successive peaks and troughs. Each peak and trough was measured from the x axis [26].

• Wave amplitude (WA) (cm): One of the drape shape parameters indicating the size and magnitude of change in the oscillating fabric edge. Peak-to-trough amplitude is the change between peak (highest amplitude value) and trough (lowest amplitude value) (see Eq. (5)).

$$\mathrm{WA_i} = \frac{\mathrm{Peak_i} - \mathrm{trough_i}}{2} \tag{5}$$

Each peak and trough was measured as its distance from the x axis [27]. This is a measure of wave depth with respect to the relation between peak and trough.

The reason for selecting this combination of shape parameters (wave amplitude, length and height) was that these are the essential parameters to represent/draw any wave.

In the "wave analysis" group, the following drape shape parameters were calculated:

• AM/WH: This is the ratio of wave amplitude to wave height [28], calculated as in Eq. (6).

$$\mathrm{AM/WH} = \frac{(\mathrm{Hmax} - \mathrm{Hmin})/2}{\mathrm{WH\,A}} \tag{6}$$

where: H Max and H Min are maximum and minimum radii respectively, WH A is the wave height average.

• WH/WL: This is the ratio of wave height to wavelength. This is a measure of drape fold severity [12]. It was calculated as in Eq. (7).

$$\mathrm{WH/WL} = \mathrm{Mean}(\mathrm{H_i}/\mathrm{L_i}) \tag{7}$$

where: $\mathrm{H_i}$ and $\mathrm{L_i}$ were each single wave height and length respectively.

In the "Fourier" measurements group, three parameters called fitness factors were used to investigate the reliability of using Fourier transformation to represent drape were calculated:

• Fourier (cm): This is the area under the frequency (Fourier) plot for the measured shape.

• Fourier/ Original (%): This is the ratio between areas under frequency and original curves.

• Dominant/Original (%): This is the ratio between areas under reconstructed and original curves.

A Graphical User Interface (GUI) called "Drape" was developed in MATLAB software to enable calculating the required drape parameters (see Fig. 2).

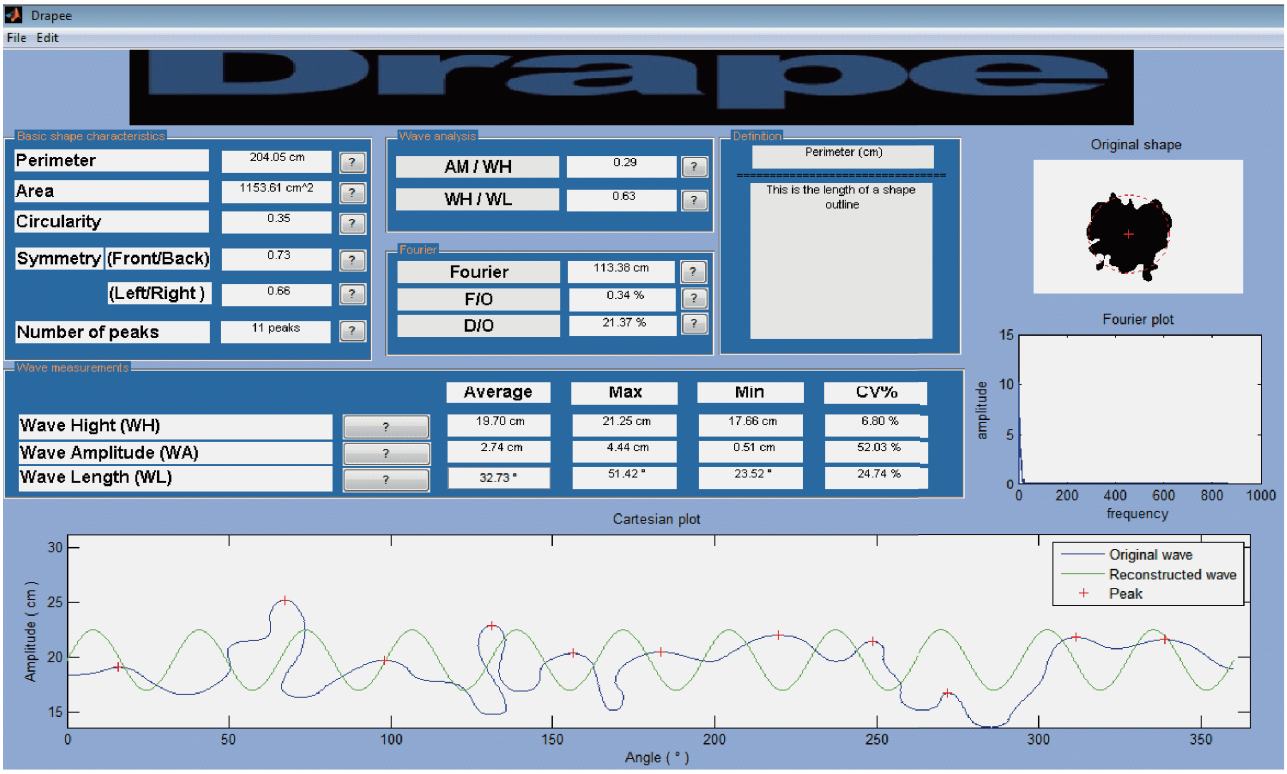


Fig. 2: The graphical user interface "Drape" (example of image processed)

## 2.6 Visual Assessment

Visual assessments of fabric and garment drape were carried out using an ordinal ranking method to compel each judge to prioritize items being assessed with respect to the property/attribute evaluated. Each judge was asked to order items being assessed according to the attribute tested.

#### 2.6.1 Physical Samples Assessment

In this test, a convenience sample of 20 students studying in the last year of the fashion design programme were the assessors. Prior to the test, "Drape" was defined to each judge to clarify the test and orient the judge. It was defined as the fabric's ability to deform and orient itself into graceful folds or pleats when it is suspended under its own weight [3, 29].

The fabrics were hung from one tip to allow them to make folds. Assessors were asked to order them from the most drape to the least. They were allowed to handle and touch the fabrics.

In the garment tests, 12 garments constructed from the fabrics used in the previous test were hung on 12 mannequins of the same size (12) in a line. The mannequins were arranged randomly in a row in front of the judge. First, each judge was asked to rank the dresses for drape amount and then to order them according to drape preferred.

Students were allowed to examine the dresses closely and touch them if necessary. Therefore, the evaluation process was dependant on visual and tactile senses which are usually used by apparel designers, makers and consumers in a drape assessment process.

#### 2.6.2 Images Analysis

In this test, 2 groups of black and white images for fabrics (Fig. 3) and garments (Fig. 4) were assessed. Fabric images were taken for the draped fabric on the Cusick drapemeter. Dress images were the ones taken for the dresses from underneath the mannequin when they were suspended. Even a cursory visual assessment by the reader nill make them realise that the drape characteristics of flat fabric samples bears little resemblance to drape on a body or mannequin.

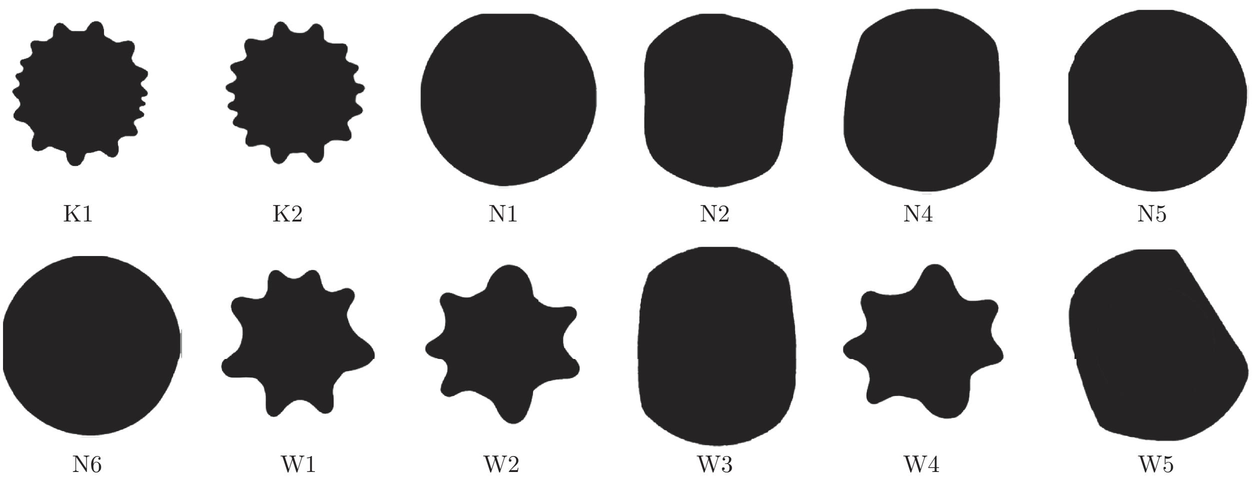


Fig. 3: Fabrics' images used for image analysis

Twenty individuals were asked to rank the images of each group for drape amount. They were asked to order the images from the most complex and deformed shape with the highest number of peaks to the lowest number of peaks.

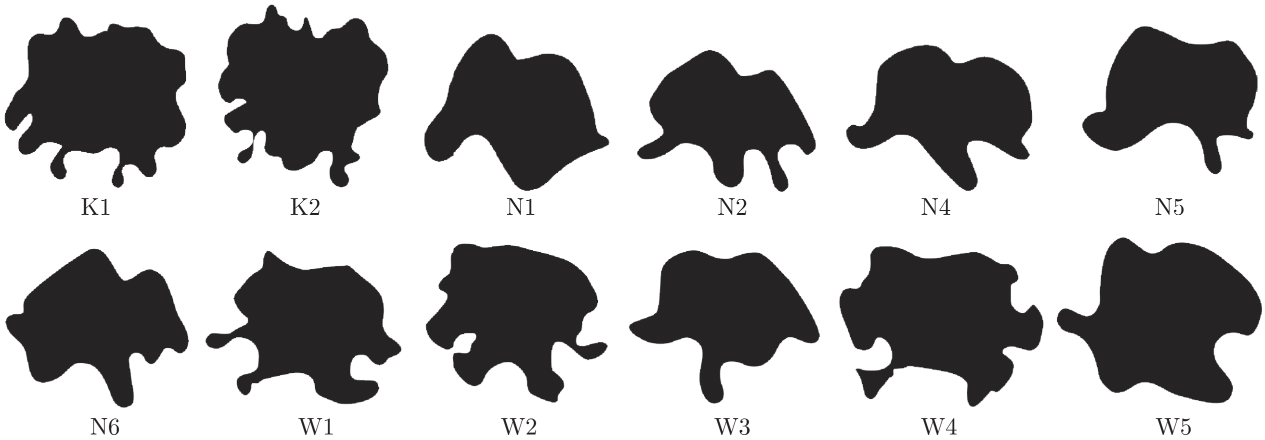


Fig. 4: Dresses' images used for image analysis

The collected ranks were analysed using the following procedures: Kendall's coefficient of concordance was computed as in Eq. (8) [30]:

$$\text{Kendall's W} = \frac{12\text{S}}{\text{r}^2\text{n}(\text{n}-1)(\text{n}+1)} \tag{8}$$

where: $\text{S} = \sum(\text{R}_\text{j} - \bar{\text{R}})^2$, $\text{R}_\text{j}$ = rank sum of each object/fabric, $\bar{\text{R}} = \frac{\text{r}(\text{n}+1)}{2}$, r = the number of observers, n = the number of fabrics. Because in this study $\text{n} > 7$, W was tested for statistical significance using Friedman's $\text{x}^2$ statistic. Friedman's $\text{x}^2$ statistic was obtained from W using the formula: $\text{x}^2 = \text{r}(\text{n}-1)\text{W}$. This quantity ($\text{x}^2$) follows a chi-square distribution with (n-1) degrees of freedom. $p$ value $< \alpha$ (significance level) shows the significance of W. If the $p$ value is less than the significance level, the null hypothesis is of complete independence of the rankings which is therefore rejected, and we conclude that there is a real measure of agreement among judges. A final overall ranking of the fabrics according to the average ranks could therefore be justified. If $\text{H}_0$ was rejected ($p$ value $< \alpha$ (significance level)), the fabrics average ranks could be used.

A multiple comparison test (MCT) was considered to determine where the differences among the populations' means are and as a Post-hoc test in order to decide which groups are significantly different from each other. It measures the difference between all possible pairs of fabric means. Bonferroni's method for MCT was selected because it could be used to control the family (experiment-wise) type 1 error rate in any multiple testing situation to $\alpha_{\text{family}}$.

This test performed more than one hypothesis test simultaneously. The null hypothesis was that each pair was equal. This was rejected if the absolute difference between any pair is higher than the test threshold or significant range. This significant range is called Least Significant Difference (LSD) and calculated as follows (some results were taken from the ANOVA table):

$$\text{LSD} = \text{t}_{\text{crit}}\text{S}_{\text{pooled}}\sqrt{\frac{2}{\text{K}}} \tag{9}$$

where: $\text{t}_{\text{crit}}(\alpha_{\text{Bonferroni}}, \text{df}_{\text{within}}), \text{S}_{\text{pooled}} = \sqrt{\text{RMS}}$, If the difference between two means of ranks was equal or greater than this critical value (LSD), we concluded that there was sufficient evidence that means of populations were different. A summary of visual tests carried out in this study is shown in Fig. 5.

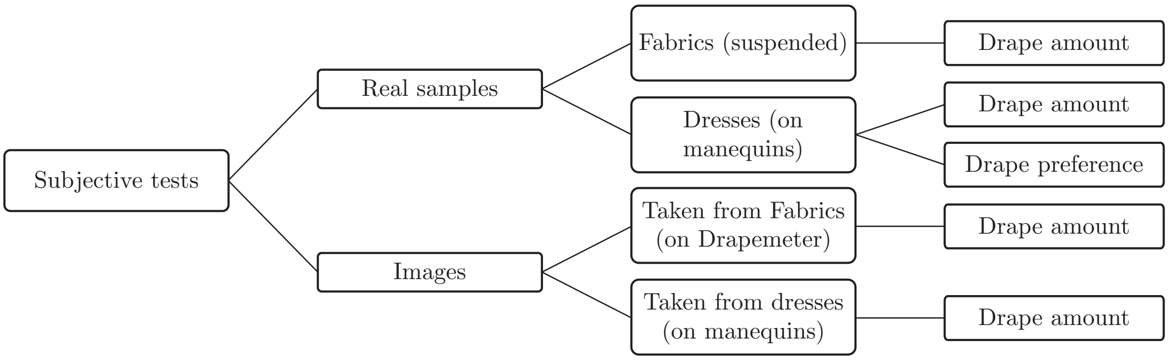


Fig. 5: Summary of visual tests conducted

# 3 Results and Discussion

## 3.1 Fabric Mechanical Properties and Drape Coefficient

The measured mechanical properties and drape coefficient values of the tested fabrics are presented in Fig. 7. This chart shows the relationships between weight, thickness, extensibility, shear rigidity, bending length, rigidity and modulus, formability and the drape coefficient of the fabrics tested both traditional and nonwoven fabrics. The traditional fabrics' (knitted and woven) maximum and minimum values of the measured mechanical properties are determined and connected to make a shaded area. This shaded area shows the limitations of their measured properties and would help identify the difference between nonwoven and traditional fabrics in terms of physical and mechanical properties and the drape coefficient.

The traditional fabrics have similar or higher weights than the nonwoven fabrics, as one of the nonwovens (N2) has lower weight than the lowest traditional fabric with a weight of 25 g/m$^2$. Two Nonwovens (N1 and N4) had lower insignificant weight than traditional fabrics with 5 g/m$^2$.

The Thickness at 2 gf/cm$^2$ (T2) and 100 gf/cm$^2$ (T100) of nonwovens is at the high range of the traditional fabrics. However, the surface thickness values of the nonwovens are in the low range of the traditional fabrics. This means that there is similarity between nonwovens and traditional fabrics with respect to T2, T100 and ST.

At the lowest load of extensibility (5 g/cm), the nonwovens were inextensible and at the lowest end of the E5 range of the traditional. However, the highest end of the traditional fabrics reached around 8%. In E20 test, the group of nonwovens still in the lowest range of extensibility of the traditional fabrics, only N1 was still inextensible and out of the traditional fabrics range. In E100, the nonwovens group had lower E values than the traditional fabrics.

The shear rigidity of the nonwovens, W3 and W5 had infinite shear rigidity, which means that they were unable to shear.

The FAST bending properties i.e. BL, BR, BM and FR were investigated. Two nonwoven fabrics, N1 and N6 had higher BL than the range determined for the traditional fabrics. The bending rigidity of N6 was higher than the traditional range. In the BM test, N1 had a higher value than the traditional range. N4, N5, and N6 had similar FR to traditional fabrics.

The DC (as the traditional drape parameter) was investigated in order to study the nonwovens tested drapeability and compare it to the traditional fabrics range. Two fabrics (N2 and N4) from the five nonwovens tested had DCs at the high range of the DC of the traditional fabrics. Three nonwovens (N1, N5, N6) had DCs higher than the traditional fabric limitations. This means that N2 and N4 had similar drapeability to some traditional fabrics with low drapeability.

The mechanical properties which would make the three nonwovens N1, N6 and N5 out of the traditional fabrics' drape limitations were investigated. N1 had W, FR, BM, BL and E100 out of the traditional range, N5 had only the E100 value out of the traditional range, N6 was differing in (T2, BL, BR and E100). Therefore, the increased DC would be as result of the increased BL, BR, BM, and/or the reduced FR and E100.

Generally, the twelve fabrics tested seem to be categorized into two groups K1, K2, W1, W2, and W4 and the other group including W3, W5, and nonwovens. Their DCs range were 11.65 - 35.27% and 79.63 - 98.66% respectively. Therefore, we could say that we have a group of fabric with good drapeability (GD) and another one with low drapeability (LD) (see Fig. 6).

With respect to the LD fabric group, three sub groups existed. These were $W5_{DC} < N2_{DC} < N4_{DC} < W3_{DC}$. The second group was ($N5_{DC} < N6_{DC}$), however the third group included only N1. From these subgroups, two nonwoven fabrics tested (N2 < N4) had lower DC 30 than one woven fabric W3. W5 had an insignificantly lower DC30 than N2 (the highest drapeable nonwoven) with around 3%. Therefore, we could conclude that though the nonwovens had generally higher DC (lower drapeability) than some types of traditional fabrics, they could have similar drapeability to certain types of traditional fabrics.

N2 (80 $g/m^2$) and N4 (100 $g/m^2$ softened) were the most drapeable within the nonwovens group. N5 and N6 had lower drapeability than (N2 and N4) and N1 was the lowest in drapeability. The difference between N1 and N4 in DC (which had the same weight with different treatments, the first is not softened and the second is softened) shows the effect of the softening treatment on fabric drapeability. As the softened one is more drapeable than the unsoftened.

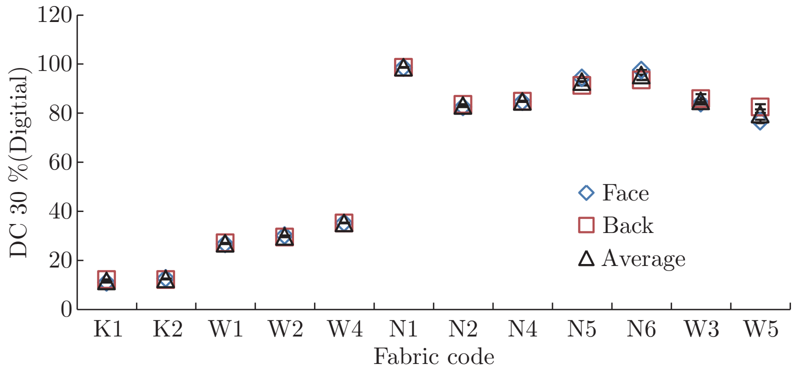


Fig. 6: The drape coefficient measured using 30 cm diameter by the digital method

## 3.2 Node Severity/Size (NS30)

The severity degree of the node defined as the ratio of the node's height to its width was investigated. The difference between the node severity/size in the three groups of fabrics is noted and the knitted fabrics had small nodes compared with the other two groups. The two measured knitted fabrics had similar node sizes.

The woven fabrics (W1, W2, W4) had approximately medium similar node sizes. Their node sizes are in between the knitted, and (nonwoven, W3, W5) fabric groups but more resemble the knitted fabrics than the nonwovens and W3 and W5.

The nonwovens and W3 and W5 fabrics have the largest node sizes (in other words they had long wavelength with short wave amplitude). Generally, N1, N5 and N6 have insignificant or nonexistent nodes. However, N2, N4, W3 and W5 have similar large nodes.

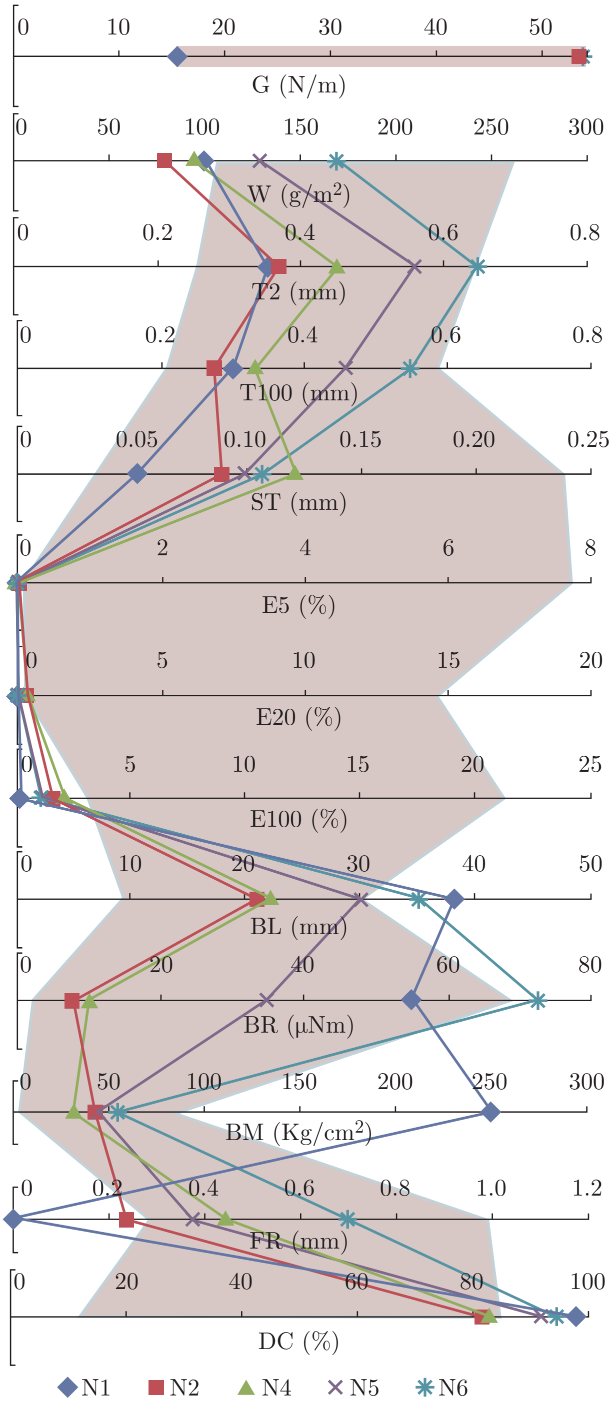


Fig. 7: Correlations between traditional fabrics and nonwovens' measured properties (the shaded areas are for the traditional fabrics)

## 3.3 Node Orientation (NO30)

The nodes constituting the drape profile orientation and position with regard to the lengthwise and crosswise directions of the fabric measured were studied. The two knitted fabrics tested had similar node orientation and distribution, the face and back drape profiles were similar also. However, smaller nodes were located in the crosswise direction than lengthwise direction.

There was similarity between the three tested fabrics (W1, W2, W4) and between their face and back as well. The nodes were approximately regularly distributed around the periphery of the tested samples.

In the low drapeable fabrics group (nonwovens and W3 and W5), N2, N4, W3 and W5 included considerable nodes in the lengthwise direction.

N1, N5 and N6 did not seem to generate significant nodes as N2, N4, W3 and W5 which means they were not considered to produce nodes but sometimes stick out in the lengthwise direction.

## 3.4 Selection of "Basic Drape Shape Parameters"

Area (A) and Perimeter (P) are considered general shape descriptors. However, Circularity is a shape complexity descriptor calculated using A and P. One of this study purposes is to suggest/introduce alternative shape parameters which could present drapeability and another aim is to study the correlation between these parameters in order to find out the parameters highly correlated with drape.

Correlation coefficients between three measured parameters: Perimeter, Area and Circularity measured for fabric images are presented in Table 5. Correlation coefficients between three measured parameters: Perimeter, Area and Circularity measured for dress images are presented in Table 6.

Table 5: Correlation coefficients between three measured parameters: Perimeter, Area and Circularity measured for fabric images

| | Perimeter | Circularity | Area |
|---|---|---|---|
| Perimeter | 1 | - | - |
| Circularity | 0.48 | 1 | - |
| Area | 0.62 | 0.98 | 1 |

Table 6: Correlation coefficients between three measured parameters: Perimeter, Area and Circularity measured for garment images

| | Perimeter | Circularity | Area |
|---|---|---|---|
| Perimeter | 1 | - | - |
| Circularity | -0.47 | 1 | - |
| Area | 0.07 | 0.84 | 1 |

The correlations in the above tables show that, however Circularity is calculated from A and P it is only strongly correlated with the A (in both cases fabric and dresses images with r=0.98 and 0.84 respectively). However the correlations between A and P were moderate in fabric images and no correlation in the dress images (r=0.07). The correlation between Circularity and Perimeter was weak in both fabric and dress images.

In investigating the correlation between drape values from fabric and dress images, however, it was expected that Circularity and Area to give similar correlations. It was found that Circularity had r=0.91 and Area had r=0.64 (which is weaker than the first). This means that Circularity parameter is similar for fabric samples but the area was not.

## 3.5 Correlation between Drape Coefficient and Drape Values Measured for Fabrics on Drapemeter

The correlations between the drape values measured using "Drape" GUI and drape coefficient values measured previously in this study were investigated, see Table 7 for the significant correlations found.

Table 7: Significant correlations between Drape coefficient and Drape values

| | Circularity | Peaks number | WH/WL | F/O | D/O | Perimeter | Sym (R-L) |
|---|---|---|---|---|---|---|---|
| $r$ | 0.99 | -0.96 | -0.83 | -0.65 | -0.64 | 0.62 | 0.57 |
| $R^2$ | 0.97 | 0.91 | 0.69 | 0.42 | 0.41 | 0.38 | 0.33 |

DC was dependant on area ratio which means that the Area parameter was completely consistent with DC. Another two very strong correlations were found between the DC and each of Circularity ($R^2$ = 0.97) and Number of Peaks ($R^2$ = 0.91). Good reverse correlation was found between DC and WH/WL (measure of node severity), as node severity decreases with increased DC (decreased drapeability). F/O, D/O and Perimeter were found with significant weak correlations with DC $R^2$=0.42, 0.41 and 0.38 respectively. Symmetry (R/L) had the least significant correlation $R^2$=0.33.

This means that Area>Circularity>Peaks number>WH/WL were alternative predictors for drape coefficient, however the area was the best alternative.

## 3.6 Correlation between Fourier Parameters and Fabric and Garment Drapeability

The correlation between Fourier parameters including Fourier, F/O and D/O and drapeability in terms of images drape ranking were investigated for fabric and garment images (see Table 8).

There were found two significant correlations. These were Fourier (Garment images) and D/O (fabric images). The strongest correlation found is for D/O (fabric images).

In the garment drapeability, negative significant correlation was found between Fourier and drape ranks. This means that Fourier increase as the drape decreases. However, F/O and D/O were found with insignificant correlations coefficient and coefficients of determination close to Zero which means that these two parameters were not able to predict garment drape.

Correlations between Fourier parameters of garment and fabric images were investigated. The following correlation coefficients and coefficients of determinations were found.

Table 8: Correlation coefficients and coefficients of determination between Fourier parameters and drapeability

| | Garment | | Fabric | |
|---|---|---|---|---|
| | r | $R^2$ | r | $R^2$ |
| Fourier | -0.68 | 0.46 | -0.46 | 0.22 |
| F/O | -0.43 | 0.19 | -0.53 | 0.28 |
| D/O | 0.38 | 0.15 | -0.78 | 0.61 |

Table 9: Correlation coefficients and coefficients of determination between Fourier parameters of fabric and garment images

| | r | $R^2$ |
|---|---|---|
| Fourier | 0.36 | 0.13 |
| F/O | 0.34 | 0.12 |
| D/O | -0.19 | 0.04 |

From the correlations above, it was found that the correlations were insignificant and had R2 close to zero. This means that Fourier parameters calculated for fabric drape are not garment drape predictors. This indicates that the extant conventional methods for measuring drapeability based on using flat fabrics is not correlated with garment drape.

## 3.7 Correlation between Fabric and Garment Drape Values

In this study, two groups of samples (fabrics and dresses) were analysed. Each group included 12 samples. Five photos were taken for each sample. Fabrics were captured on a Cusick Drapemeter and the dresses were photographed from underneath the mannequin used. Each image was processed using a "Drape GUI" to obtain the drape values proposed. The results of each test (image) were exported to Excel software to calculate the average of each parameter from the five replicas captured (see Table 10 for garment drape values measured).

The correlations between fabric and garment drape values resulting from the image analyses were investigated.

Table 11 lists the Correlation coefficients and coefficients of determination calculated for the 12 fabrics and their correspondent dresses ranked from the strongest to the weakest.

It is evident from

Table 11 that just 4 drape values (from the fabric and dress images) namely Circularity, Peak number, Area and Perimeter from the 21 drape values measured had significant correlations.

The highest correlation is for the Circularity with $R^2$=0.84 followed by moderate $R^2 = 0.69$ for the number of peaks. However the Area and the Perimeter have weak correlations with 0.41 and 0.37 coefficients of determination respectively. Circularity and number of peaks were always considered as traditional parameters for fabric drapeability. It is believed that these two parameters characterize only the overall degree of drapeability not are highly/significantly correlated with drape profile parameters. This would explain the reason for insignificant and weak correlations between the rest of the drape values measured for fabrics and dresses which are responsible for establishing drape shape. The drape shape parameters are highly dependent on the fabric form and supporting body. Therefore, it would not be reliable to predict garment drape shape using the drape shape values measured for fabrics.

## 3.8 Visual Assessment

Drape amount of fabrics and garments and their images was assessed visually using panels of judges. Drape preference of garments was assessed as well.

It is evident that Kendall's W coefficients for fabric drape amount, garment drape amount, fabric drape amount (images), garment drape amount (images), and garment drape preference tests were significant $p$ value $\leq 0.0001$.

The assessment of fabric drape amount using any method and material (fabrics or their images, garments or their images) produced high and consistent agreement between judges. Kendall's W coefficients (of drape amount) $W \geq 0.82$ were much higher than W=0.22 for garment drape preference assessment. This means that there was a significant low agreement between judges with regard to garment drape preference.

Methods of evaluating drape amount used were ranked from the highest to the least agreement as follows: Garment (images) > Fabric > Fabric (images) > Garment.

It was found that all correlations were high and significant $r \geq 0.83$, $p < 0.01$. The highest correlation was between fabric and garment (real) drape amount $r = 0.98$, $p < 0.01$ ($R^2 = 0.96$).

The average ranks of garment drape preference was correlated positively with fabric drape amount assessed using any of the four methods, $r \geq 0.78$, $p < 0.01$ ($R^2 \geq 0.6$). This means that highly drapeable garments were preferred by judges over low drapeable fabrics. This preference was consistent with the fashion trend of highly drapeable fabrics/garments.

The drape amount assessment using garment images was found to be the highest $W = 0.933$ and had high correlation with other methods applied. Therefore, it was found that according to this test average garment drape amounts were ranked as follows: K2 > K1 > W4 > W2 > W1 > N2 > N6 > W3 > N4 > N5 > W5 > N1.

It was decided to investigate how these ranked garments were different from each other, as two fabrics or more could be ranked for example as the first and the second, however there might be no significant differences between them and they could be ranked in one group with similar drapeability.

Bonferroni's method for multiple paired comparison was used to compare pairs of fabrics using their resulting least significant difference. The underlined groups in Table 12 refer to fabrics with insignificant differences.

Table 10: Garment drape values measured

| | Perimeter | Circ | Area | Peaks | Sym (F-B) | Sym (R-L) | WH A | WH Max | WH Min | WH CV | WA A | WA Max | WA Min | WA CV | WL A | WL Max | WL Min | WL CV | A/ WH | WH/ WL | Fourier | F/O | D/O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K1 | 218.67 | 0.36 | 1353.13 | 10 | 0.63 | 0.59 | 21.17 | 23.02 | 18.53 | 0.08 | 2.93 | 5.55 | 1.35 | 0.44 | 59.77 | 302.27 | 20.15 | 1.07 | 0.29 | 0.66 | 123.28 | 0.003 | 0.2 |
| K2 | 199.66 | 0.34 | 1076.78 | 11.8 | 0.73 | 0.64 | 19 | 21.29 | 16.18 | 0.09 | 2.56 | 4.55 | 0.48 | 0.55 | 30.63 | 48.49 | 14.86 | 0.33 | 0.31 | 0.72 | 120.77 | 0.004 | 0.22 |
| N1 | 185.15 | 0.54 | 1480.76 | 5 | 0.59 | 0.56 | 23.57 | 26.02 | 20.57 | 0.11 | 5.25 | 9.29 | 3.28 | 0.46 | 95.16 | 202.45 | 51.96 | 0.45 | 0.4 | 0.33 | 110.67 | 0.003 | 0.25 |
| N2 | 166.02 | 0.42 | 1008.38 | 6.4 | 0.74 | 0.6 | 18.83 | 21.4 | 16.69 | 0.1 | 3.88 | 6.02 | 1.76 | 0.4 | 57.26 | 111.05 | 25.7 | 0.56 | 0.33 | 0.45 | 114.8 | 0.005 | 0.31 |
| N4 | 186.77 | 0.47 | 1314.32 | 5 | 0.74 | 0.65 | 21.77 | 24.52 | 18.98 | 0.11 | 5.09 | 7.49 | 2.46 | 0.39 | 73.2 | 115.89 | 39.88 | 0.44 | 0.36 | 0.37 | 104.55 | 0.003 | 0.24 |
| N5 | 185.65 | 0.55 | 1513.1 | 6 | 0.72 | 0.58 | 23.57 | 26.88 | 20.66 | 0.1 | 4.06 | 7.91 | 0.58 | 0.65 | 60.69 | 93.23 | 24.11 | 0.44 | 0.34 | 0.52 | 100.02 | 0.003 | 0.24 |
| N6 | 188.1 | 0.54 | 1513.09 | 6.6 | 0.78 | 0.56 | 22.82 | 24.86 | 19.83 | 0.09 | 3.66 | 7.42 | 1.27 | 0.66 | 54.86 | 90.37 | 25.97 | 0.43 | 0.33 | 0.52 | 101.15 | 0.003 | 0.24 |
| W1 | 197.68 | 0.36 | 1117.6 | 7.4 | 0.71 | 0.76 | 20.15 | 21.98 | 18.38 | 0.07 | 3.83 | 6.3 | 0.69 | 0.53 | 48.86 | 95.18 | 31.27 | 0.53 | 0.36 | 0.5 | 129.1 | 0.004 | 0.22 |
| W2 | 192.98 | 0.36 | 1070.75 | 6.2 | 0.72 | 0.61 | 18.83 | 20.42 | 17.16 | 0.06 | 4.28 | 6.17 | 2.22 | 0.37 | 58.29 | 117.09 | 33.23 | 0.51 | 0.34 | 0.38 | 109.8 | 0.004 | 0.23 |
| W3 | 187.9 | 0.52 | 1461.67 | 4.8 | 0.7 | 0.42 | 22.66 | 25.22 | 19.94 | 0.1 | 5.57 | 7.92 | 3.72 | 0.32 | 79.2 | 123.22 | 43.98 | 0.4 | 0.36 | 0.36 | 113.32 | 0.003 | 0.23 |
| W4 | 186.8 | 0.4 | 1115.44 | 6.6 | 0.69 | 0.67 | 19.72 | 21.98 | 18.15 | 0.07 | 3.1 | 5.24 | 0.62 | 0.54 | 73.63 | 204.91 | 20.28 | 0.72 | 0.27 | 0.49 | 113.19 | 0.004 | 0.23 |
| W5 | 187.61 | 0.52 | 1460.25 | 5 | 0.77 | 0.43 | 22.84 | 25.77 | 20.86 | 0.09 | 4.98 | 6.55 | 3.55 | 0.25 | 95.9 | 222.43 | 46.31 | 0.56 | 0.33 | 0.34 | 100.12 | 0.003 | 0.24 |

Table 11: Correlation coefficients and Coefficients of determination between parameters measured for fabrics and dresses tested

| | r | $R^2$ |
|---|---|---|
| Circularity | 0.91 | 0.84 |
| Peaks number | 0.83 | 0.69 |
| Area | 0.64 | 0.41 |
| Perimeter | -0.61 | 0.37 |
| WH/WL | 0.55 | 0.30 |
| WH A | -0.44 | 0.20 |
| WA Max | -0.36 | 0.13 |
| Fourier | 0.36 | 0.13 |
| WH Min | -0.34 | 0.12 |
| WA CV | -0.34 | 0.12 |
| WH Max | -0.34 | 0.12 |
| F/O | 0.34 | 0.12 |
| WA Min | 0.32 | 0.10 |
| WL A | 0.29 | 0.09 |
| Sym (R-L) | -0.27 | 0.07 |
| AM/WH | -0.25 | 0.06 |
| WA A | 0.23 | 0.05 |
| D/O | -0.19 | 0.04 |
| Sym (F-B) | -0.14 | 0.02 |
| WL Min | 0.12 | 0.01 |
| WH CV | 0.11 | 0.01 |
| WL Max | -0.11 | 0.01 |
| WL CV | -0.02 | 0.00 |

Table 12: Grouping of fabrics with similar drape amount assessments

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K2 | K1 | W4 | W2 | W1 | N2 | N6 | W3 | N4 | N5 | W5 | N1 |

At the 0.0008 level of significance, the groupings imply that there is insufficient evidence to conclude that the mean of garments' drape amount in each group: (W4, W2 and W1), (N2 and N6), (W3 and N4) differ. This means that there is similarity between the drape behaviour of fabrics in the previous assigned groups. However, there was sufficient evidence to conclude that the population means of drape amount of these groups are different from each other.

In this study, it is important to recall the results of Kendall's coefficient of concordance computed for garment drape preference, Kendall's W was 0.22, $p \leq 0.0001$. This means that there was a significantly low agreement between judges for drape preference. This means that there was inconsistent evaluation for drape preference, as a low drapeable garment which was preferred by some judges was not preferred by others. This illustrates the unnecessary desire of a high drapeable fabric for making garments as low drapeable fabrics were preferred by some judges.

In this study, we used the average rank values to study drape preference of fabrics assessed. It was found that there was strong positive correlations r $\geq$ 0.78, p $>$ 0.05 between drape amount rankings and drape preference. This means that a highly drapeable fabric was preferred.

The fabrics were ranked as follows from the most preferred to least: W1 $>$ W2 $>$ W4 $>$ K2 $>$ K1 $>$ N2 $>$ N6 $>$ N4 $>$ W5 $>$ W3 $>$ N1 $>$ N5.

It was required to investigate the significance of the difference between them. Paired comparison tests were carried out by calculating the absolute difference between the average rank values of each pair. The underlined groups in Table 13 refer to fabrics with insignificant differences.

Table 13: Grouping of fabrics with similar drape preference assessments

| W1 | W2 | W4 | K2 | K1 | N2 | N6 | N4 | W5 | W3 | N1 | N5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| — | — | — | — | | | | | | | | |
| | — | — | — | — | | | | | | | |
| | | | — | — | — | — | | | | | |
| | | | | — | — | — | — | — | — | | |
| | | | | | | | | — | — | — | — |

At 0.0008 significance level, the groupings imply that we have sufficient evidence to conclude that (W1 was preferred to K1), (W4 preferred to N6), (K2 preferred to W3) (N2 preferred to N1) and (N4 preferred to N5), in other words that their populations means are different.

With respect to nonwoven fabrics, two traditional fabrics W5 and W3 were less preferred than three nonwoven fabrics (N2, N6, N4). Two nonwoven fabrics were least preferred by the observers (N1, N5).

This means that the drapeability of nonwovens can be preferred to traditional fabrics. In addition to the results some nonwovens had higher drapeability than some traditional fabrics; it was found that they were preferred as well. These results recommend adapting nonwovens in clothing industry for making drapeable garments.

# 4 Conclusions

The drape coefficients (traditional drape parameter) of the tested fabrics were measured using manual and digital (image analysis) and were found highly correlated. The number of nodes was correlated with the drape coefficient negatively and strongly. Some nonwoven fabrics produced the highest DC, and the least and largest node numbers and sizes respectively (if any existed) compared with some traditional fabrics. The nonwoven fabrics vastly differ from some traditional fabrics with regard to fabric drapeability but are similar to others. The knitted fabrics had the highest drapeability.

An alternative drape measurement system was developed consisting of a suspended mannequin to hang the garment measured and a digital camera to capture a photo for the garment hung from below. A graphical user interface was developed to calculate drape values of flat fabrics on drapemeter and garments on mannequin images to assess drapeability using an image analysis technique. It was found that drape shape parameters of garment could not be predicted using corresponding fabric drape shape parameters. This means that textile engineers and scientists working on drape measurement and simulation have to measure drape shape properties for garment on mannequin rather than flat fabric supported on circular disc.

The usefulness of this research is that it challenges the use of flat fabric measurements of drape properties. It is suggested that as fabrics in garments are never draped in this manner then we need to seek a more suitable measurement system. An alternative has been suggested, evaluated and though more studies are required, a considerable degree of success has been achieved.

# References

[1] British Standards Institution. Method for the assessment of drape fabrics. London: Brtitish Standard Instituition; 1973.

[2] Fan J, Yu W, Hunter L. Clothing appearance and fit: science and technology Cambridge: Woodhead Publishing in association with The Textile Institute; 2004.

[3] Chu CC, Cummings CL, Teixeira NA. Mechanics of Elastic Performance of Textile Materials: Part V: A Study of the Factors Affecting the Drape of Fabrics -The Development of a Drape Meter. TEXT RES J. 1950; 20(8): 539-48.

[4] Cusick GE. The dependence of fabric drape on bending and shear stifness J TEXT I T. 1965; 56(11): 596-606.

[5] Cusick GE. The measurement of fabric drape. J TEXT I. 1968; 59(6): 253-60.

[6] Collier BJ. Measurement of fabric drape and its relation to fabric mechanical properties and subjective evaluation. CTRJ. 1991; 10(1): 46-52.

[7] Vangheluwe L, Kiekens P. Time dependence of the drape coefficient of fabrics. INT J CLOTH SCI TECH. 1993; 5(5): 5-8.

[8] Ruckman JE, CHENG KB, Murray R. Dynamic drape measuring system. INT J CLOTH SCI TECH. 1998; 10(6): 56.

[9] Uçar N, Kalaočlu F, Bahtiyar D, Blaç OE. Investigating the drape behavior of seamed knit fabrics with image analysis. TEXT RES J. 2004; 74(2): 166-71.

[10] Kenkare N, May-plumlee T. Fabric drape measurement: A modified method using digital image processing. JTATM. 2005; 4(3 spring): 1-8.

[11] Jeong YJ. A study of fabric drape behaviour with image analysis Part I: Measurement, characterisation, and instability. J TEXT I. 1998; 89(1): 59-69.

[12] Robson D, Long CC. Drape analysis using imaging techniques. CTRJ. 2000; 18(1): 1-8.

[13] Matsudaira M, Yang M, Kinari T, Shintaku S. Polyester "Shingosen" fabrics characterized by dynamic drape coefficient with swinging motion. TEXT RES J. 2002; 72(5): 410-6.

[14] Behera BK, Mishra R. Objective measurement of fabric appearance using digital image processing. J TEXT I. 2006; 97(2): 147-53.

[15] Mizutani C, Amano T, Sakaguchi Y. A new apparatus for the study of fabric drape. TEXT RES J. 2005; 75(1): 81-7.

[16] Sanad R, Cassidy T, Cheung V. Fabric and Garment Drape Measurement - Part 1. Journal of Fiber Bioengineering and Informatics. 2012; 5(4): 341-58.

[17] Jeong YJ. A Study of Fabric-drape Behaviour with Image Analysis Part I: Measurement, Characterisation, and Instability. J TEXT I. 1998; 89(1): 59-69.

[18] British Standards Institution. Textiles. Test methods for nonwovens. Determination of drapability including drape coefficient. London: British Standards Institution; 2008.

[19] Cui F-F, Zhang X, Wang L-S Study of the Relationship between Jacket- Business Wear Fitness and Fabric Drape. In: Y L, YP Q, XN L, JS L (eds) The 3rd International Symposium of Textile Bioengineering and Informatics; May 28-30, 2010; 2010. 1299-306.

[20] Jiang J-F, Zhong Y-Q, Wang S-Y, Li D Sketch-Based Drape and Wrinkles for Virtual Skirt. In: Y L, YP Q, XN L, JS L (eds) The 3rd International Symposium of Textile Bioengineering and Informatics; May 28-30, 2010; 2010. 1113-7.

[21] Saleh SSE-DS. Low stress mechanical properties of hydroentangled fabrics Leeds: The University of Leeds; 2003.

[22] Costa LdF, Jr RMC. Shape analysis and classification: Theory and practice Boca Raton: CRC Press; 2000.

[23] Haidekker MA. Advanced biomedical image analysis Chichester: Wiley; 2011.

[24] Shyr TW, Wang PN, Lin JY. Subjective and objective evaluation methods to determine the peak-trough threshold of the drape fabric node. TEXT RES J. 2009; 79(13): 1223-34.

[25] Jevšnik S, Žunič-Lojen D. Drape behaviour of seamed fabrics. Fibers Polym. 2007; 8(5): 550-7.

[26] Pandurangan P, Eischen J, Kenkare N, Lamar TAM. Enhancing accuracy of drape simulation. Part II: Optimized drape simulation using industry-specific software. J TEXT I. 2008; 99(3): 219-26.

[27] British Standards Institution. Textiles. Test methods for nonwovens. Determination of drapability including drape coefficient. London: BSI; 2008.

[28] Sharma KR, Behera BK, Roedel H, Schenk A. Effect of sewing and fusing of interlining on drape behaviour of suiting fabrics. INT J CLOTH SCI TECH. 2005; 17(1-2): 75-90.

[29] British standards Institution. Method for the assessment of drape fabrics. London: BSI; 1973.

[30] Leaf GAV. Practical statistics for the textile industry. Part 2. Manchester: Textile Institute; 1987.