ANALYSIS OF A FABRIC DRAPE PROFILE

Tatjana Šarac, Jovan Stepanović and Nenad Ćirković

Faculty of Technology, Leskovac, Bulevar oslobodjenja 124, Universiity of Niš, Serbia,
tangerine.art83@gmail.com

Abstract: *Draping is an important factor in presenting the aesthetics and functionality of textile materials and products. Drape coefficient was used as a numerical indicator of drapery of textile materials. Most authors considered drape coefficient as insufficient parameter for describing the complexity of the concept of drapery, because the two fabrics can have the same drape coefficient and completely different configuration of a drape profile, due to different structural and mechanical properties. The use of software allows measuring many parameters. With the help of these parameters we can explain the drape profile. One of these parameters is circularity, or CIRC, which is a measure of drape profile roundness. This paper investigates the connection between the drape coefficient and circularity in different profiles configuration depending on the structural characteristics of fabrics. The aim of this paper was to study the parameters of drapery that give a better description of the drape profile.*

Keywords: *draping, drape coefficient, circularity, density, structural characteristics, fabric.*

1 INTRODUCTION

The ability of material to drape is a property that undoubtedly defines the qualitative characteristics of the fabric and design of clothing products. Contemporary fashion trends and modern technologies impose increasingly requires to the textile industry. New and functional textile materials, modern methods of making clothes, competition in the world of fashion and clothing are the factors that impose fashion and clothing industry to make constant changes and to adjust to the market requirements.

Draping is an important factor in presenting the aesthetics and functionality of textile materials and products. Generally, draping can be described as a phenomenon of the formation of folds when the fabric is loaded with its own weight without the influence of external forces. Drape coefficient was used as a numerical indicator of textile materials drapery. Drape coefficient describes any deformation between the deformed and not deformed part of the fabric. It is calculated in a percentage as a measure of projected surface of draped fabric and surface uninformed part before draping [1, 2]:

$$DC = \frac{Sp - \pi r_1^2}{\pi r_2^2 - \pi r_1^2} \tag{1}$$

where: *DC* - drape coefficient

S_p – projected surface of draped fabrics, including part covered by horizontal disc, mm^2

r_1 – the radius of the horizontal disc, mm

r_2 –, the radius of the sample before drape, mm

Drape coefficient is often quoted in the literature as insufficient parameter to describe the complexity of the concept of drape. Thus, for example, two fabrics can have the same drape coefficient and completely different profiles or configuration of drape, different structural and mechanical properties. In addition drape coefficient, to describe the drape concept is often used: the minimum and maximum amplitudes, which represent the minimum or maximum distance from the center of the circle to the outline of the profile of the draped sample, and the number of folds [3, 4].

In recent years, various computer softwares were applied for digital determination of the drape coefficient [5]. The photo of a drape profile is captured with a digital camera, and then the captured image is automatically processed to obtain the final image which is adjusted for subsequent analyzes. Using a variety of software enables measurement of many parameters which can explain drape profile. One of these parameters is the drape profile circularity, or *CIRC*. It is a measure of the roundness of a drape profile, as a drape profile shape is closer to form a perfect circle its value is closer to 1 and vice versa [6, 14, 15]. CIRC can be calculated as follows:

$$CIRC = 4\pi \cdot \frac{A}{P^2} \tag{2}$$

where: *A* - surface area of a profile of draped part of sample, *P* - perimeter of the area of draped part of the sample.

2 EXPERIMENTAL

2.1 Materials

For the purpose of draping tests were used different types of raw cotton type fabrics for different end uses (for shirts, dresses, blouses, suits, trousers, work clothes, uniforms). Table 1 shows raw fabrics formed on the same basis in plain weave which differ in density of weft threads. Table 2 shows raw fabrics formed on the same basis in five-wire satin weave but with different linear density of weft threads. Tables 3 and 4 show raw fabrics with different weave and raw material composition.

Table 1 Characteristics of cotton fabrics in plain weave with different weft thread densities

	Sample code	Linear density [tex]		Thread density [cm^{-1}]		Unit weight [g/m^2]	Crimp coefficient		Fabric thickness *h* [mm]
		warp $T_{t,wa}$	weft $T_{t,we}$	warp d_{wa}	weft d_{we}		warp K_{uwa}	weft K_{uwe}	
1	I1	18.52	23.5	37	18.5	127.32	1.184	1.0634	0.45
2	I2	18.52	23.5	36.5	20.5	124.57	1.1742	1.042	0.4
3	I3	18.52	23.5	36.5	21	130.74	1.1544	1.068	0.43
4	I4	18.52	23.5	36.5	23	135.62	1.0574	1.1881	0.41
5	I5	18.52	23.5	37	28	159.01	1.206	1.162	0.39
6	I6	18.52	23.5	37	29	160.57	1,1821	1.164	0.37
7	I7	18.52	23.5	37.5	32	162.65	1.192	1.0633	0.38

Table 2 Characteristics of cotton type fabric in five-thread satin weave with different weft linear densities

	Sample code	Fiber composition [%]		Linear density [tex]		Thread density [cm^{-1}]		Unit weight [g/m^2]	Crimp coefficient		Fabric thickness *h* [mm]
		warp	weft	warp $T_{t,wa}$	weft $T_{t,we}$	warp d_{wa}	weft d_{we}		warp K_{uwa}	weft K_{uwe}	
1	II1	100 Co	100 Co	13.54x2	19.55	43	36	185.65	1.1172	1.0931	0.54
2	II2	100 Co	50/50 Pes/Co	13.54x2	25.04x2	42	32	303.95	1.206	1.0415	0.65
3	II3	100 Co	100 Co	13.54x2	11.13x2	43	31	204.36	1.1164	1.0776	0.53
4	II4	100 Co	33/67 Pes/Co	13.54x2	14.62x2	41	33	228.56	1.1575	1.0368	0.55
5	II5	100 Co	67/33 Pes/Co	13.54x2	14.34x2	41	34	231.21	1.1742	1.03	0.56
6	II6	100 Co	100 Co	13.54x2	24.37	44	35	226.23	1.1152	1.0945	0.56
7	II7	100 Co	33/67 Pes/Co	13.54x2	35.85	43	34	266.14	1.176	1.06	0.59
8	II8	100 Co	50/50 Pes/Co	13.54x2	29.86	42	31	229.36	1.1604	1.052	0.55
9	II9	100 Co	67/33 Pes/Co	13.54x2	20.75x2	43	33	280.76	1.188	1.04	0.61
10	II10	100 Co	67/33 Pes/Co	13.54x2	34.73	40	33	244.6	1.154	1.0435	0.56
11	II11	100 Co	100 Co	13.54x2	17.28x2	46	33	268	1.157	1.086	0.64

Table 3 Characteristics of fabric 50/50% Pes/Co with different weaves

	Sample code	Linear density [tex]		Thread density [cm^{-1}]		Unit weight [g/m^2]	Weave	Crimp coefficient		Fabric thickness *h* [mm]
		warp $T_{t,wa}$	weft $T_{t,we}$	warp d_{wa}	weft d_{we}			warp K_{uwa}	weft K_{uwe}	
1	III1	36.9	28.27	44	27	241.76	panama 3/1	1.1227	1.0328	0.6
2	III2	36.9	28.27	47	26	241.26	warp rib 3/1	1.166	1.0118	0.57
3	III3	36.9	28.27	46	20	221.46	plain	1.115	1.03	0.48
4	III4	36.9	28.27	45	22	231.41	weft rib 3/1	1.1406	1.0699	0.52
5	III5	36.9	28.27	46	22	231.31	weft rib 2/2	1.134	1.0606	0.46
6	III6	36.9	28.27	46	26	245.9	cross twill	1.1450	1.0458	0.53
7	III7	36.9	28.27	45	28	243.65	warp rib 2/2	1.1507	1.0178	0.53
8	III8	36.9	28.27	47	28	243.28	panama 2/2	1.1326	1.036	0.52
9	III9	36.9	28.27	45	27	248.11	twill 2/2	1.1485	1.0421	0.53
10	III10	36.9	28.27	45	26.5	248.93	twill 3/1	1.1535	1.0317	0.5

Table 4 Characteristics of cotton fabrics with different weaves

	Sample code	Linear density [tex]		Thread density [cm^{-1}]		Unit weight [g/m^2]	Weave	Crimp coefficient		Fabric thickness *h* [mm]
		warp $T_{t,wa}$	weft $T_{t,we}$	warp d_{wa}	weft d_{we}			warp K_{uwa}	weft K_{uwe}	
1	IV1	10.84x2	19.98x2	42	32	228.83	twill 4/1	1.2	1.0693	0.61
2	IV2	10.84x2	19.98x2	41.5	31	222.05	twill 3/2	1.1504	1.0673	0.57
3	IV3	10.84x2	19.98x2	42	30	212.72	five-thread satin	1.1343	1.076	0.57
4	IV4	10.84x2	19.98x2	40	33	213.8	mixed panama	1.1816	1.0308	0.64
5	IV5	10.84x2	19.98x2	41	33	210.65	panama 3/2	1.1584	1.0427	0.6
6	IV6	10.84x2	19.98x2	42	31	213.86	panama 3/1	1.1445	1.0096	0.66
7	IV7	10.84x2	19.98x2	39	32	221.97	mixed panams	1.207	1.0217	0.59
8	IV8	10.84x2	19.98x2	43	23	193.38	warp rib 3/2	1.0851	1.124	0.47
9	IV9	10.84x2	19.98x2	44	23	185.52	warp rib 4/1	1.0693	1.099	0.51

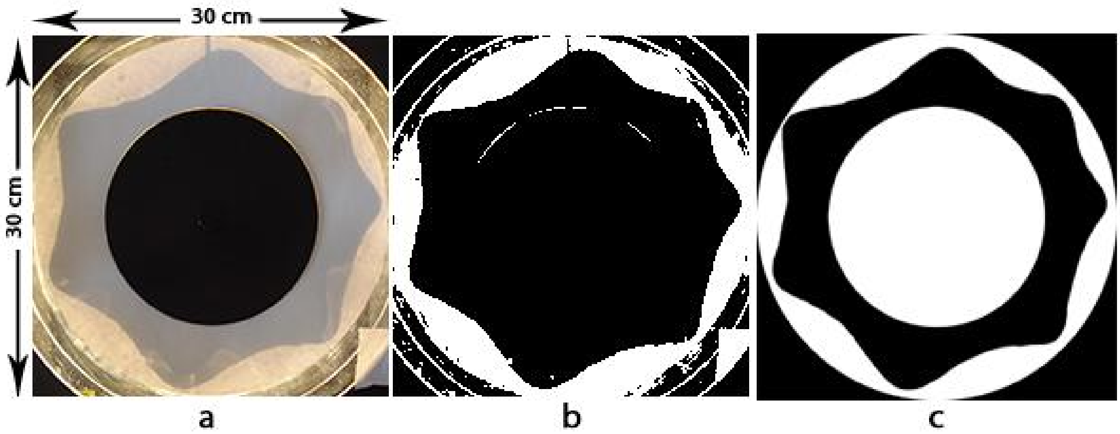

Figure 1 Image processing using Adobe Photoshop: a) cutting and calibration of the image, b) setting the threshold between black and white, c) cleaned image draped sample

2.2 Methods

Determination of drape parameters is carried out on a standardized test device drape tester James H Heal & Co, model 665, according to British standard BS 5058.

For all fabric samples is determined drape coefficient (*DC*), the maximum amplitude (*Amax*) and the minimum amplitude (*Amin*), the number of folds (*n*) and the circularity of a drape profile (*CIRC*).

This experimental method means that circular fabric sample 30 cm in diameter, hangs on a circular disk 18 cm in diameter. The sample with diameter of 36 cm can be used for rigid fabrics if their *DC*% s greater than 85% in fabric sample with a diameter of 30 cm, while in the case of soft fabric can be used 24 cm diameter sample, if their *DC*% in 30 cm diameter fabric sample is less than 30% [6].

However, if would be used a different diameter of fabric samples for this study, the obtained results of drape coefficient could not be in correlation with other parameters of the fabrics, because increasing of draped part of the sample reduces the drape coefficient, so all the fabric samples were tested with a diameter of 30 cm, regardless of the results of drape coefficient which were less than 30% or greater than 80%.

Drape coefficient values were obtained by digital method. By this method, the drape profile of a sample is recorded with digital camera which is mounted on the stand above the drape meter at a certain height so that it covered the top panel of the device, then the resulting image is being processed in software Adobe Photoshop (Figure 1). First is carried out cutting and calibration of the image (Figure 1a), then the image is processed to set the threshold between black and white (Figure 1b). Then it is necessary to clean the image, where on black surface white pixels are removed, and the black pixels on white surface (Figure 1c). Image becomes black - white, and then the surface can be easily marked and number of pixels can be calculated. Adobe Photoshop contains tools for easy and accurate recalculation of pixels in any marked area. The minimum and maximum amplitudes also were measured using pixels measuring the distance from the centre of the circle to the outline of draped profile. All researches were performed under the same conditions.

3 RESULTS AND DISCUSSION

In Tables 5-8 are given the values of the test results of drape coefficient, the minimum and maximum amplitude, the number of folds and drape profile circularity.

Table 5 Test results of cotton fabric drape in plain weave with different weft thread densities

	Sample code	*DC* [%] on the face of the fabric	*DC* [%] on the back of the fabric	*DC* [%]	Minimum amplitude A_{min}	Maximum amplitude A_{max}	Number of folds *n*	Drape profile circularity *CIRC*
1	I1	48.16	47.95	48.06	10.33	14.46	8	0.3035
2	I2	53.21	51.62	52.42	10.74	14.44	7	0.3387
3	I3	51.76	50.88	51.31	10.53	14,47	7	0.3309
4	I4	57.15	57.24	57.19	10.86	14.56	8	0.3733
5	I5	64.7	63.36	63.53	11.44	14.77	7	0.4161
6	I6	68.71	66.46	67.59	11.6	14.71	7	0.4391
7	I7	73.22	70.53	71.87	11.99	14.84	7	0.4578

Table 6 Test results of cotton type fabric drape in five-thread satin weave with different weft linear densities

	Sample code	*DC* [%] on the face of the fabric	*DC* [%] on the back of the fabric	*DC* [%]	Minimum amplitude A_{min}	Maximum amplitude A_{max}	Number of folds *n*	Drape profile circularity *CIRC*
1	II1	44.44	41.56	43	9.34	14.44	7	0.2676
2	II2	76.49	62.91	69.7	11.12	14.84	7	0.4437
3	II3	45.76	42.89	44.33	9.91	14.18	8	0.2783
4	II4	52.81	46.43	49.62	10.14	14.41	7	0.3159
5	II5	57.8	50.58	54.19	10.42	14.69	7	0.3486
6	II6	50.29	46.02	48.15	9.57	14.57	7	0.3466
7	II7	64.56	54.99	59.77	9.9	14.84	6	0.3909
8	II8	62.16	53.47	57.81	10.15	14.77	6	0.3758
9	II9	72.94	62.08	67.51	11.27	14.94	6	0.4341
10	II10	58.34	52.2	55.27	9.57	14.85	6	0.3661
11	II11	57.52	50.03	53.78	10.43	14.53	7	0.3469

Table 7 Test results 50/50 % Pes/Co fabric drape in different weave

	Sample code	*DC* [%] on the face of the fabric	*DC* [%] on the back of the fabric	*DC* [%]	Minimum amplitude A_{min}	Maximum amplitude A_{max}	Number of folds *n*	Drape profile circularity *CIRC*
1	III1	75.55	77.7	76.63	11.15	15.07	5	0.4866
2	III2	75.13	73.83	74.48	11.52	14.94	6	0.4728
3	III3	79	81.7	80.35	11.99	15.02	5	0.5039
4	III4	87.69	89.22	88.45	13.45	15.06	-	0.5861
5	III5	90.1	87.89	89	13.59	15.09	-	0.5419
6	III6	80.73	76.46	78.6	12	15.05	6	0.4927
7	III7	79.16	79.85	79.5	12	15.14	5	0.4984
8	III8	82.63	81.39	82	12.53	15.12	6	0.5072
9	III9	85.77	84.59	85.15	12.75	15.23	-	0.5225
10	III10	82.77	76.85	79.81	12.16	15.06	6	0.4983

Table 8 Test results of cotton fabric drape in different weave

	Sample code	*DC* [%] on the face of the fabric	*DC* [%] on the back of the fabric	*DC* [%]	Minimum amplitude A_{min}	Maximum amplitude A_{max}	Number of folds *n*	Drape profile circularity *CIRC*
1	IV1	62.82	53.34	58.07	10.67	14.7	7	0.3746
2	IV2	65.57	62.53	64.05	11.52	14.64	7	0.4183
3	IV3	66.79	56.7	61.75	10.85	14.65	7	0.4039
4	IV4	63.35	64.5	63.93	11.19	14.67	7	0.4145
5	IV5	59.76	57.62	58.69	10.63	14.58	7	0.3802
6	IV6	62.35	63.73	63.04	11.02	14.75	7	0.4104
7	IV7	65.61	65.71	65.66	11.34	14.73	7	0.4291
8	IV8	57.39	60.72	59.06	11.3	14.47	7	0.3891
9	IV9	64,57	62.49	63.53	11.33	14.6	7	0.4141

Figure 2 shows the relation between drape coefficient and drape profile circularity of cotton fabrics in plain weave (to see changes in drape coefficient depending on changes in weft threads density) and Figure 3 shows the relation between drape coefficient and drape profile circularity of cotton types fabric in satin weave (to be noticed changes in drape coefficient depending on changes in weft linear density). Figures 4 and 5 show the dependence of the drape coefficient and drape profile circularity in fabrics blends 50/50% Pes/Co and 100% cotton fabrics with different weaves applied.

The graphs show that there is a good correlation between drape coefficient and drape profile circularity. The best relation is observed in the fabric where the weft density is changed, r^2 = 0.9919 (Figure 2), and the lowest correlation is with the fabric 50/50 Pes/Co, r^2 = 0.8222 (Figure 4). Determination coefficient in cotton fabrics is (Figure 5) je r^2 = 0.9817, and in cotton types fabrics with changes in weft linear density is r^2 = 0.944 (Figure 3).

According to the graphs, this dependence of drape coefficient and circularity can be represented by regression equation of general form, ie:

$$DC = a + b \cdot CIRC \quad (3)$$

where the coefficients *a* and *b* are given in Table 9.

Circularity as a measure of deviation from a perfect circle is directly related to the appearance draped sample profile. For example, very stiff fabrics that have no folds and have a slight difference between the value of the minimum and maximum amplitude will have greater value of circularity (closer to 1). Fabrics with a larger number of folds and the greater difference between the values of the minimum and maximum amplitude, will have a lower value of circularity. Figures 6-9 show the appearance of draped sample profiles.

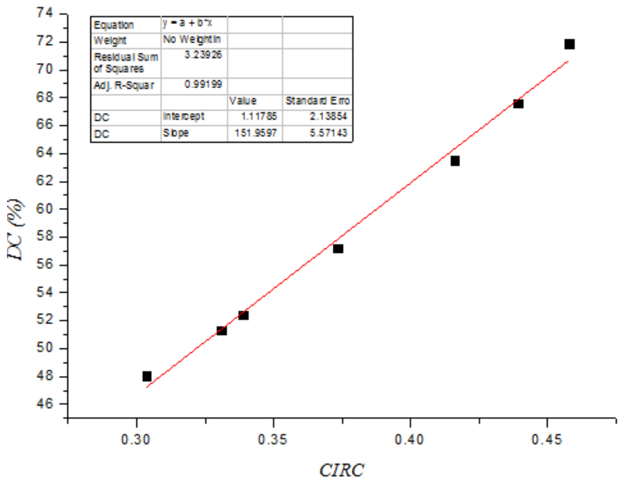

Figure 2 Relation between drape coefficient and drape profile circularity for fabrics with different weft threads density according tables 1 and 5

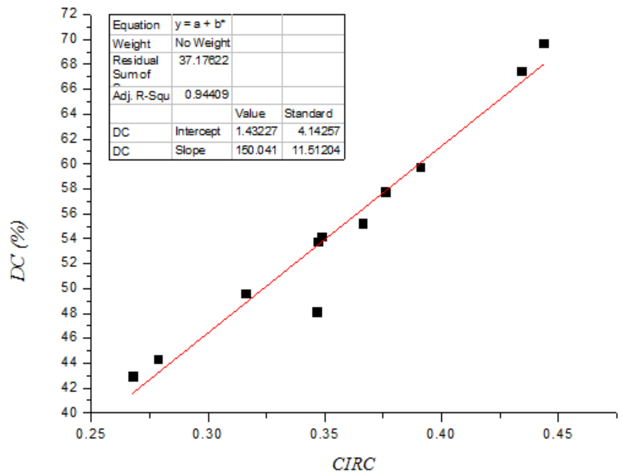

Figure 3 Relation between drape coefficient and drape profile circularity for fabrics with different weft linear density according tables 3 and 6

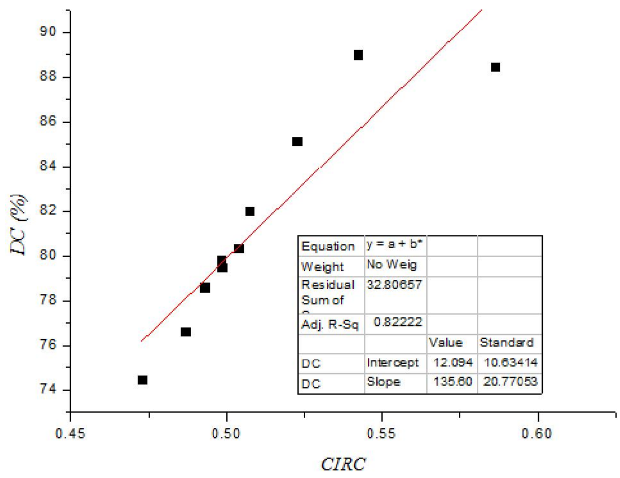

Figure 4 Relation between drape coefficient and drape profile circularity for fabrics 50/50 % Pes/Co with different weaves applied (according tables 3 and 7)

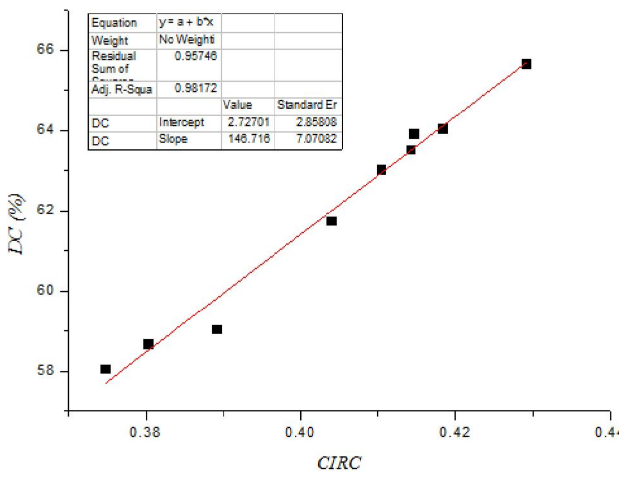

Figure 5 Relation between drape coefficient and drape profile circularity for cotton fabrics with different weaves applied (according tables 4 and 8)

Table 9 The values of the coefficients *a* and *b* of the regression equation $DC = a + b \cdot CIRC$

$DC = a + b \cdot CIRC$	**a**	**b**	r^2
Fabrics with different weft thread densities (Figure 2)	1.11785	151.959	0.9919
Fabrics with different weft linear densities (Figure 3)	1.143227	150.041	0.944
Fabrics 50/50% Pes/Co with different weaves (Figure 4)	12.0948	135.606	0.8222
Cotton fabrics with different weaves (Figure 5)	2.72701	146.7162	0.9817

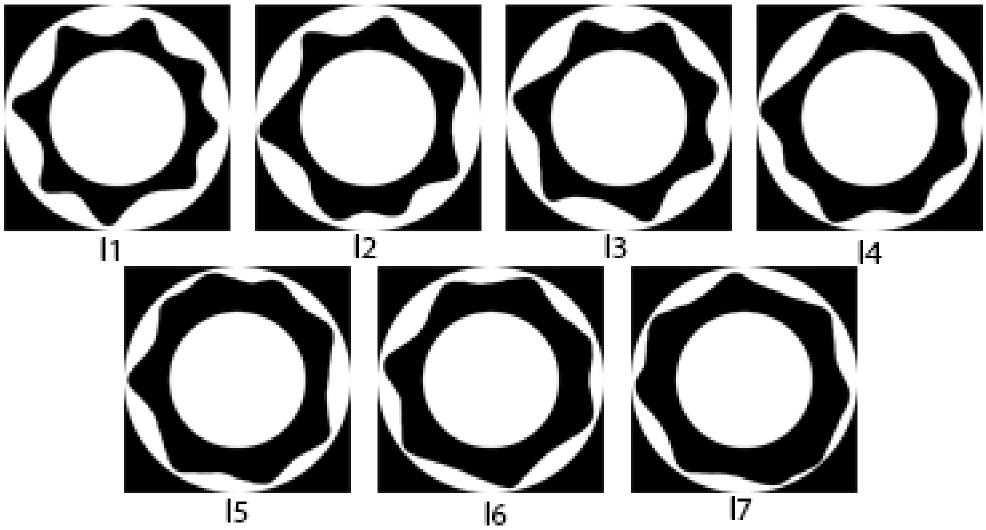

Figure 6 Profile appearance of draped cotton fabric samples from Table 1

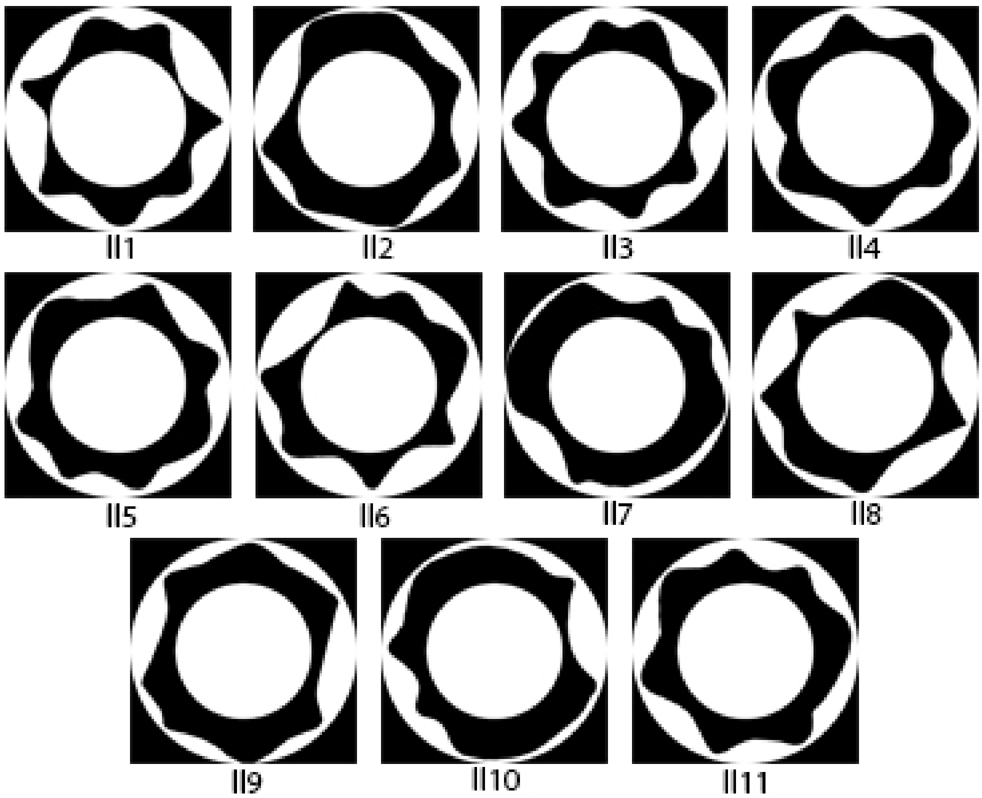

Figure 7 Profile appearance of draped cotton type fabric samples from Table 2

Figure 6 shows profiles of samples of raw cotton fabrics in plain weave with different weft thread density. Based on the results in Table 5 and Figure 6, it can be concluded that with the increase in density of the weft threads, also increase values of drape coefficients (the difference between black and white in the ring), but also increases the value of the circularity. With the higher values of drape coefficient, the differences between values of the minimum and maximum amplitudes are smaller and drape profile tends to perfect circle.

For fabric samples with different linear densities (Figure 7, Table 6), it can be carried out the same conclusion, although from the figure can be seen that these two groups of samples have different appearance of drape profile.

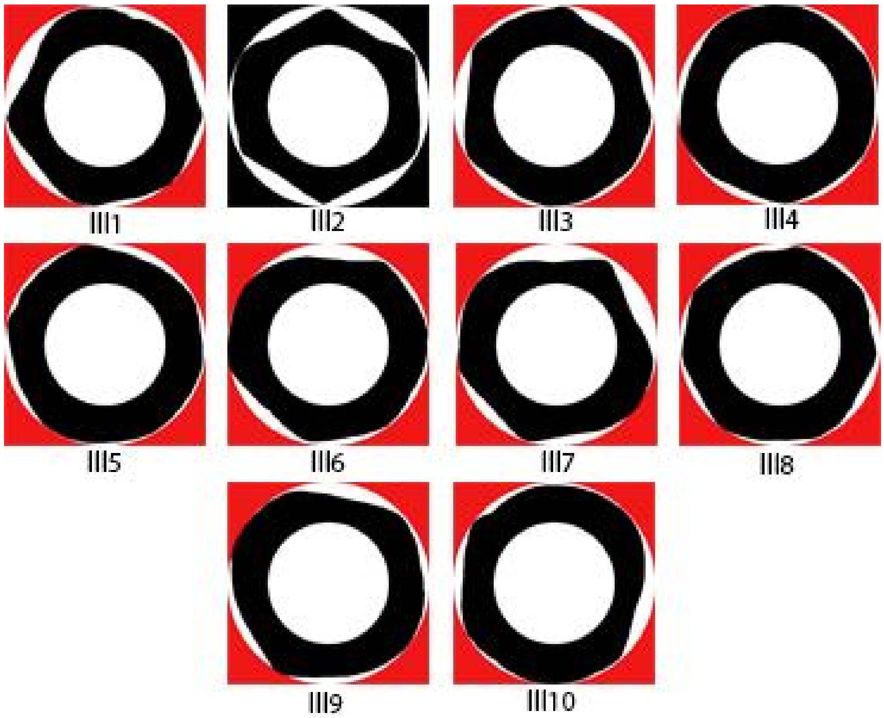

Figure 8 Profile appearance of draped fabric samples 50/50 Pes/Co from Table 3

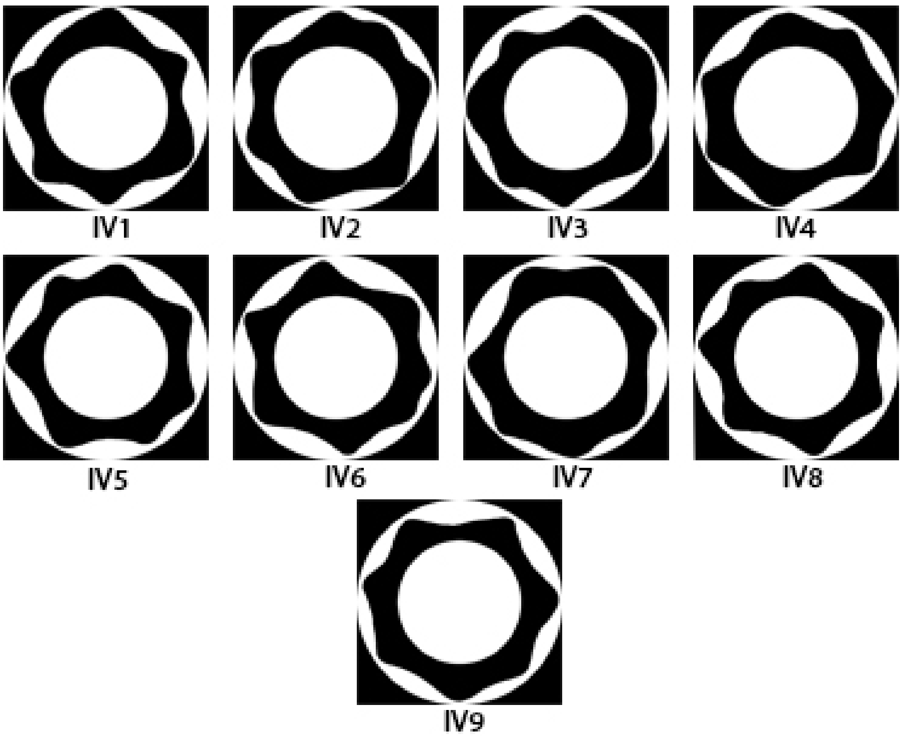

Figure 9 Profile appearance of draped cotton fabric samples from Table 4

On Figures 8 and 9 are shown draped profiles fabric samples in which the changed weave. The samples of fabric from a blend of fibers (50 Pes/50 Co) have significantly higher drape coefficients (Table 7) than samples of cotton fabrics (Table 8), considering that these are a very stiff fabric structures. From Figure 8 and the value of circularity of the drape profile in Table 7, can be seen that samples have a smaller number of folds or no folds and a small difference in values between the minimum and maximum amplitude. While, on the contrary, with fabric samples in Table 8, drape coefficients have lower values and greater difference between values of the minimum and maximum amplitude, and thus the lower the value of circularity of a drape profile.

4 CONCLUSION

The studies on the draping of textile materials showed that the drape coefficient parameter gives insight into the percentage of the projected part of fabric that folds under the influence of its own weight. However, it is known that the draping of fabric depends on the structural and mechanical properties of the fabric and that these factors affect the configuration of drape profile. Also, two fabrics can have the same values of drape coefficients and completely different configuration drape profiles, which can be interpreted and evaluated as bad or good draping.

For this reason it is necessary to examine other drape parameters that provide detailed insight into the configuration of drape profile depending on the characteristics of the fabric. One such parameter is the drape profile circularity. Therefore, this study examined the connection between the circularity of a drape profile and the drape in different configuration of drape profiles depending on the structural characteristics of the fabric. The results show that the value of drape profile circularity correlated with the values of the drape coefficient, so that using the circularity adds more detailed description of the profile draping of fabric.

5 REFERENCES

1. Lojen D.Ž., Jevšnik S.: Some Aspects of Fabric Drape, Fibres & Textiles in Eastern Europe 15(4), 2007, pp. 39-45
2. Cusick G.E.: A study of Fabric Drape, Faculty of Technology, University of Manchester, 1962
3. Kenkare N., May-Plumlee T.: Evaluation of drape characteristics in fabrics, International Journal of Clothing Science and Technology 17(2), 2005, pp. 109-123
4. HU J.: Structure and mechanics of woven fabrics, Woodhead Publishing Limited in association with The Textile Institute, North America, 2004
5. Kenkare N., May-Plumlee T.: Fabric Drape Measurement: A Modified Method Using Digital Image Processing, Journal of Textile and Apparel, Technology and Management 4(3), 2005, pp. 1-8
6. Robson D., Long C.C.: Drape Analysis using Imaging Techniques, Clothing and Textiles Research Journal 18(1), 2000, pp. 1-8
7. Stylios G.K., Powell N.J., Cheng L.: An investigation into the engineering of the drapability of fabric, Transactions of the Institute of Measurement and Control 24(1), 2002, pp. 33-50
8. Lo W.M., Hu J.L., Li L.K.: Modeling a Fabric Drape Profil, Textile Research Journal 72(5), 2002, pp. 454-463
9. Özdil N., Özgüney A.T., Mengüç G., Sertsöz S.: Influence of yarn and fabric construction parameters on drape and bending behaviour of cotton woven fabrics, Tekstil ve Konfeksiyon 24(2), 2014, pp. 169-179
10. Šarac T., Stepanović J., Demboski G., Petrović V.: Cotton type fabric drape prediction, Industria textila 68(1), 2017, pp. 3-8
11. Šarac T., Stepanović J., Demboski G., Petrović V.: Fabric draping and cotton fabric structure relation analysis, Advanced Technologies 4(1), 2015, pp. 84-88
12. Nofitoska M., Demboski G., Carvalho M.A.F.: Effect of fabric structure variation on garment aesthetic properties, Tekstil ve Konfeksiyon 22(2), 2012, pp. 132-136
13. Saville B.P.: Physical testing of textiles, Woodhead Publishing Limited in association with The Textile Institute, Abington Hall, Abington, 2000
14. Sanad R., Cassidy T., Cheung V., Evans E.: Fabric and Garment Drape Measurement - Part 2, Journal of Fiber Bioengineering and Informatics 6(1), 2013., pp. 1-22
15. Kenkare N.S.: Three dimensional modeling of fabric drape, North Carolina State University, 2005