EVALUATION OF THE SHEARING PROPERTIES OF WOVEN FABRICS: RATED FORCE

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Abstract This paper introduces a very simple way to evaluate low stress shearing properties of woven fabrics with the advantages of simplicity and easy accessibility. A 200-gram load is applied on small portion of the sample instead of applying the load overall width of the fabric. As a result, buckling of the fabric will happen and the loading-unloading curve will show the behavior of the fabric during the deformations. Initial slope after buckling and the gap area between loading-unloading curves above the buckling point are the elements, which could show the shearing behavior of the woven fabrics.

Key Words Low Stress, Shearing Properties, Woven Fabrics**,** Critical Point, Buckling Point, Concentrated Force

چکیده این مقاله، یک روش بسیار ساده برای ارزشیابی خواص برشی پارچه های تاری-پودی (تحت نیروی کم) با در بر داشتن امتیازات سادگی و دستیابی راحت معرفی می‌نماید. بر عکس روش های متداول که نیرو بر کل عرض نمونه وارد می‌گردد، در این روش نمونه تحت کشش حاصل از وارد نمودن دویست گرم نیرو به یک نقطه از پارچه (قسمت کوچکی از عرض نمونه) قرار می‌گیرد. در نتیجه پدیده کُپ کردن پارچه واقع می‌شود و منحنی رفت و برگشت حاصل، رفتار پارچه را در حین این تغییرات نشان می‌دهد. شیب اولیه بعد از مرحله کُپ کردن و مساحت بین دو منحنی رفت و برگشت (مرحله رفتار بیرون سطحی پارچه)، بعنوان پارامتر های سنجش رفتار برشی پارچه تاری-پودی معرفی می‌شوند.

1. INTRODUCTION

The ability of a woven fabric to accept shear deformation is a necessary condition for a conformable fitting to a general three-dimensional surface and is the bases for the success of woven textiles as clothing materials and in a large number of industrial applications involving forming or molding operations. Therefore, the knowledge of the low stress shearing deformation of the fabric is vital to clothing manufacturers. In practice, the tools, which are used to measure this property, are KES FB1 shearing tester and FAST 3 extensibility. This paper introduces a very simple way to evaluate low stress shearing properties of woven fabrics with the advantages of simplicity and easy accessibility.

2. THEORETICAL BACKGROUND

When a piece of fabric is under conditions shown in Figure 1, two distinguishable stages of deformations would happen: In-plane and out of plane deformation. The in-plane behavior is evaluated by knowing the tensile modulus, Poisson's ratio and shear Modulus.

Concerning the fact that applied load is low, the change will obey the hook's law and considering the woven fabrics are orthotropic sheets the generalized equation will be as

$$\varepsilon_1 = (1/Y_1)\sigma_1 + (-\mu_2/Y_2)\sigma_2$$
$$\varepsilon_2 = (-\mu_1/Y_1)\sigma_1 + (1/Y_2)\sigma_2$$
$$\gamma_{12} = (1/G_{12})\tau_{12}$$

Where Y_1, Y_2 are tensile rigidities in the principal direction, μ_1 and μ_2 are the corresponding Poisson ratio for extension, and G_{12} is the shear rigidity. Symmetry requires that the tensile rigidities and Poisson ratio be related by,

$$\mu_1 Y_2 = \mu_2 Y_1$$

The tensile rigidities Y_1 and Y_2 are measured in

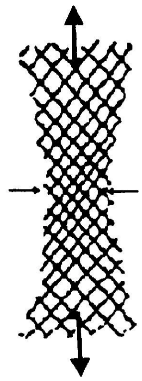


Figure 1. Testing method and behavior of the woven fabrics under concentrated force.

testing lab by tensile test. Shearing tester also measures the G.

Evaluation of the elastic constants along different directions can be obtained in terms of the properties along the axis of symmetry and the bias angles by using the following equations. (Kilby, Holloway, Hearmon and Amirbayat [1,2,3,4]).

$$1/Y_\theta = \left(\cos^2\theta/Y_1\right)+\left(\sin^2\theta/Y_2\right)+K\sin^2\theta\cos^2\theta \qquad (1)$$

$$1/G_\theta = (1/G) - 4K\sin^2\theta\cos^2\theta \qquad (2)$$

$$(\mu_\theta/Y_\theta) = (\mu/Y) + K\sin^2\theta\cos^2\theta \qquad (3)$$

Where *G* is the principal shear modulus, *Y*s are principal tensile modulus and μs refer to the Poisson's ratios μ_θ/Y_θ.

These three generalized Equations 1 through 3 are able to show in plane behavior of the fabrics along bias angles. Schematic of the variation of the Y_θ, G_θ, and μ_θ/Y_θ along bias angles (Figure 2) which agrees with the work of Alsawaf [5] was shown by Amirbayat [6].

Figure 2 shows that the values of the elastic constants are dependent upon the direction of the measurement. For example, tensile modulus varies enormously with the test angle θ. It reaches its lowest values at 45°, while the shear modulus is highest around 45°.

Equations 1 to 3 show that measuring tensile properties along 45° bias is a good tool to evaluate the principal shearing modulus. Combining Equations 1 and 3, i.e.

$$(1/Y_\theta) = (\cos^2\theta/Y_1) + (\sin^2\theta/Y_2) + K\sin^2\theta\cos^2\theta$$

$$(\mu_\theta/Y_\theta) = (\mu/Y) + K\sin^2\theta\cos^2\theta$$

$$(\mu_\theta/Y_\theta) + (1/Y_\theta) = (\mu/Y) + 2K\sin^2\theta\cos^2\theta + (\sin^2\theta/Y_2) + (\cos^2\theta/Y_1)$$

Substitution for $\theta = 45$ gives

$$(1+\mu_\theta)/Y_\theta = (\mu/Y) + (\cos^2\theta/Y_1) + (\sin^2\theta/Y_2) + (2K\sin^2\theta\cos^2\theta)$$

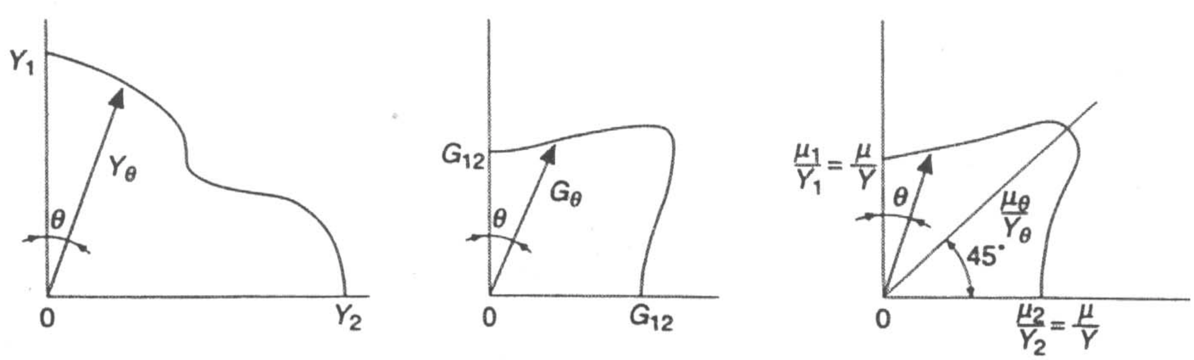
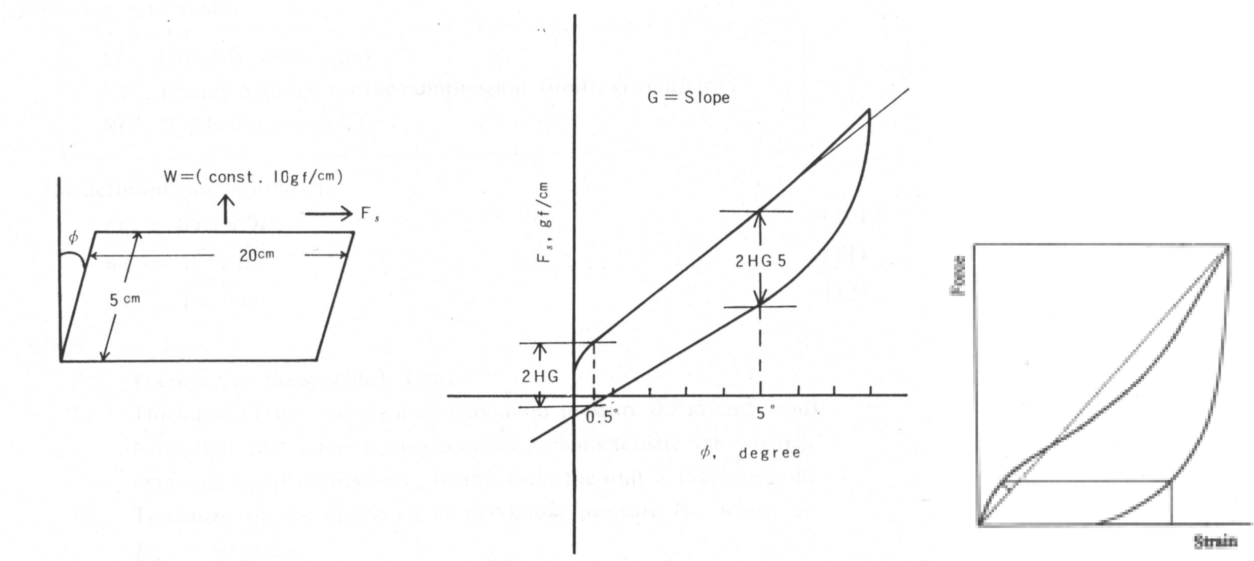


Figure 2. Fabric properties along different directions.



(a) (b)

Figure 3. a) KES Shearing method and shearing parameters, b) Concentrated loading curve.

$$(1+\mu_{45})/Y_{45} = (\mu/Y) + (0.5/Y_1) + (0.5/Y_2) + K/2$$

$$(1+\mu_{45})/Y_{45} = (\mu/Y) + (0.5/Y_1) + (0.5/Y_2) + 0.5G_{12} - 0.5(((1+\mu_1)/Y_1) + (1+\mu_2)/Y_2)$$

Since $(\mu/Y) = (\mu_1/Y_1) = (\mu_2/Y_2)$ thus

$$(1+\mu_{45})/Y_{45} = 1/2G$$

This shows that knowing the tensile properties μ_{45} and Y_{45} one can calculate G, the principal shearing moduli.

Based on the above-mentioned theory and the response of the woven fabrics under tensile force applied over a small portion of the edges, this experimental work is done and found out that by this method one can evaluate the shearing properties of woven fabrics by using tensile tester.

3. EXPERIMENTAL WORK

1) Materials A total of 92 woven fabrics with the specifications shown in Appendix 1 were randomly chosen for the experimental work. Fabrics included different structures, with wide range of materials, such as cotton, wool, jute, synthetics and blend of different fibers.

2) Sample Preparation and Test Procedure After 24 hours of conditioning, a rectangular specimen 24cm long and 5cm wide was cut from every sample fabric, at angle of 45° to the warp direction, (which is the same to the weft direction) using a special template The strip is then folded in half to form a double ply of face-to-face fabrics 12-cm. long. The puncher inserts an eyelet 1-cm from the ply ends opposite to the fold and the second eyelet is inserted 10cm far from the first one after possible slack is removed. (Note that doubling the strip makes the samples free from any shear strain, which could be developed under tensile stress).

The samples were then subjected to a single loading-unloading cycle at a rate of 10 mm/min with a 200g maximum force using a simple attachment to the jaws of Testometric-micro 350 made in the Shirly developments, with 10kg load cell.

It is noticeable that the samples were tested by KES shearing tester [1] as well and the results were based as actual values for the comparison and evaluation of the new suggested method.

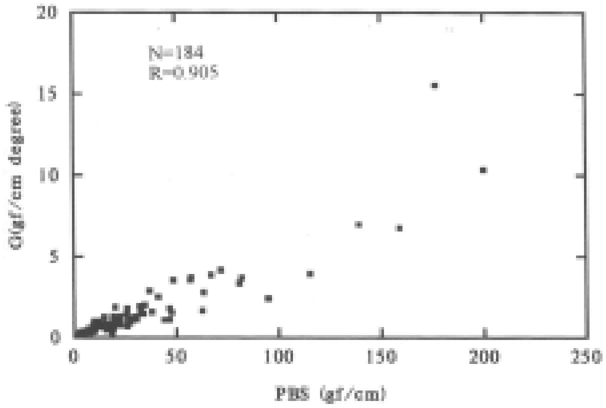


Figure 4. The plot of shearing modulus versus PBS.

3) Features of the Loading Unloading Curve

Figure 3 (a and b) shows the typical load extension curves of the KES shearing tester and the new suggested loading unloading method respectively. The incremental curve of the new method shows an initial negative curvature, which changes sign upon further extension.

Despite the fact that the loading curves of the new method are not all the same but they all have a common zone between themselves. This zone specifies the limit of in plane deformation after which a sample begins its out of plane deformation and

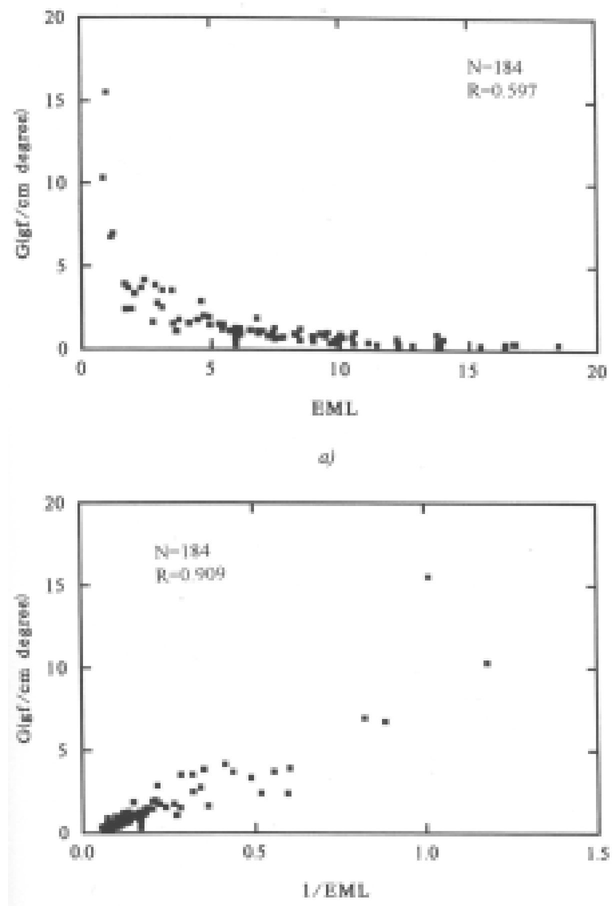


Figure 5. The plots of shearing modulus versus the EML and 1/EML.

TABLE 1. Features Extracted from the Curves. (Appendix 2)

Sym.	Parameters	Units
AAC	Area under the loading curve, above the critical point	gf.
ABC	Area under the loading curve, below the critical point	gf.
AGA	Gap area between two curves, above the critical point	gf.
ATH	Area under the loading curve, for 200-gram load (AAC+ABC)	gf.
ECP	Strain at critical point	%
EML	Strain at 200-gram load	%
ES	Ending slope	gf.
IS	Initial slope (first 10-gram loading)	gf.
MG	Maximum distance (strain) between loading-unloading curves	%
PBS	Post buckling slope (20-gram load after buckling point)	gf.
SCP	Load at critical point	gf.
SUC	Slope up to critical point	gf.

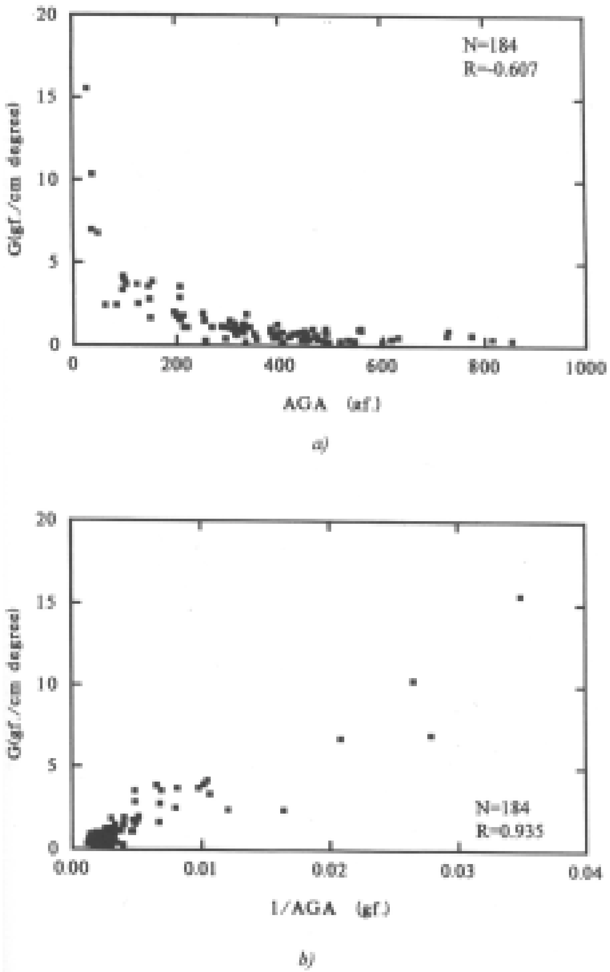


Figure 6. The plots of shearing modulus versus AGA and 1/AGA.

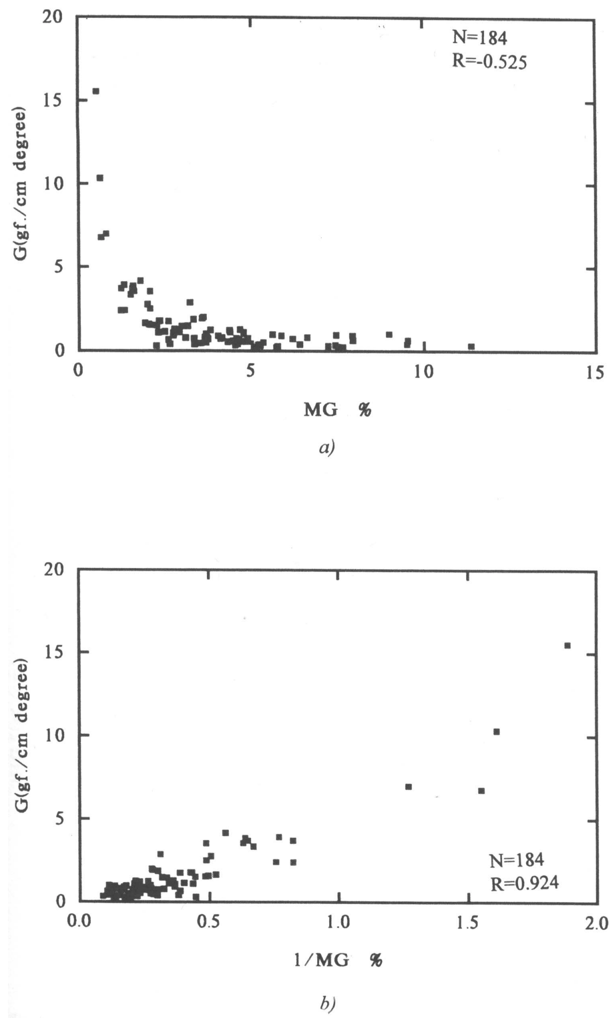


Figure 7. The plots of the shearing modulus versus MG and 1/MG.

it is called buckling zone [7-10]. On the unloading curves of the new method, there is also a zone, which sample leaves the buckling status and return back to its plane form. This zone is called unbuckling zone [11,12]. The zones could make the curves to two parts. Parameters extracted from the curves in respect to the buckling zones are shown in Table 1. Figure 9 shows the above-mentioned features extracted from the loading-unloading curve.

TABLE 2. The Correlation Values between Measured Shearing Parameters and Features Extracted from the Curves of the New Method (184 Cases of Woven Fabrics).

KES	**Features extracted from the curve of the new method**										
sh. Par.	**AAC**	**ABC**	**AGA**	**ATH**	**ECP**	**EML**	**MG**	**PBS**	**SCP**	**SI**	**SUC**
G	-0.642	0.305	-0.607	-0.638	0.111	-0.597	-0.525	0.905	0.643	0.748	0.771
2HG.5	-0.524	0.443	-0.505	-0.512	0.242	-0.528	-0.375	0.836	0.729	0.677	0.784
2HG5	*-0.665*	0.382	-0.625	-0.658	0.184	-0.645	-0.509	0.911	0.709	0.762	0.799

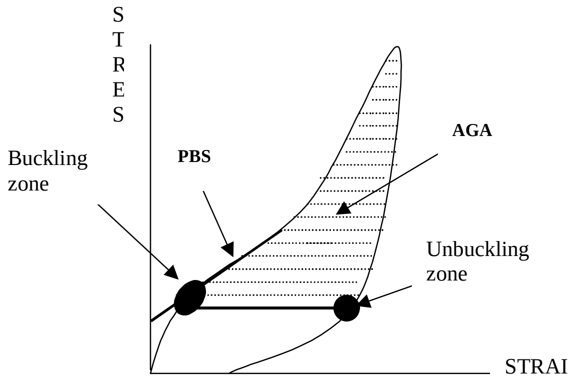


Figure 8. Showing features (PBS and AGA) related to the shearing properties.

4. RESULTS AND DISCUSSIONS

Table 2 shows the correlation coefficient between shearing rigidity (G), shearing hysteresis at 0.5° (2HG.5°) and the shearing hysteresis at 5° (2HG5°) and the features extracted from the curves of the proposed method.

If we divide the loading curve to 3 portions, initial (from zero up to the critical point), buckling, and the top zones, the highest correlation coefficient with regard to the shearing parameters belongs to the post-buckling slope (PBS). This portion of the curve indicates the situation during the initial out of plane movement of the fabric, where sample has its maximum tolerance of compressibility.

As Table 2 shows, some of the features like EML and AAC are negatively correlated to the shearing parameters indicating the fact that as the shearing modulus raises the extracted features are decreased. This means that the inverse value of the extracted feature could have a positive correlation with the shearing modulus. Therefore, reciprocal transformation is applied for some of the variables (those that are negatively correlated) and the correlation coefficient results are shown in Table 3.

Among the parameters shown in Table 3, the inverse values of AGA gave the highest value of correlation. This gap area denotes the out of plane response of the fabric during loading and unloading. The relationship with inverse value is positive informing that when shearing modulus is increased the inverse value also will increase or the actual area will be decreased. This is concluded that stiffer fabric (high shear modulus) would have lower extension due to the prefixed loading. Figures 4, 5, 6 and 7 show the plots of shear modulus versus PBS, 1/EML, 1/AGA and 1/MG.

In addition, the pre-buckling zone shows the behavior of the fabric during the compression as a

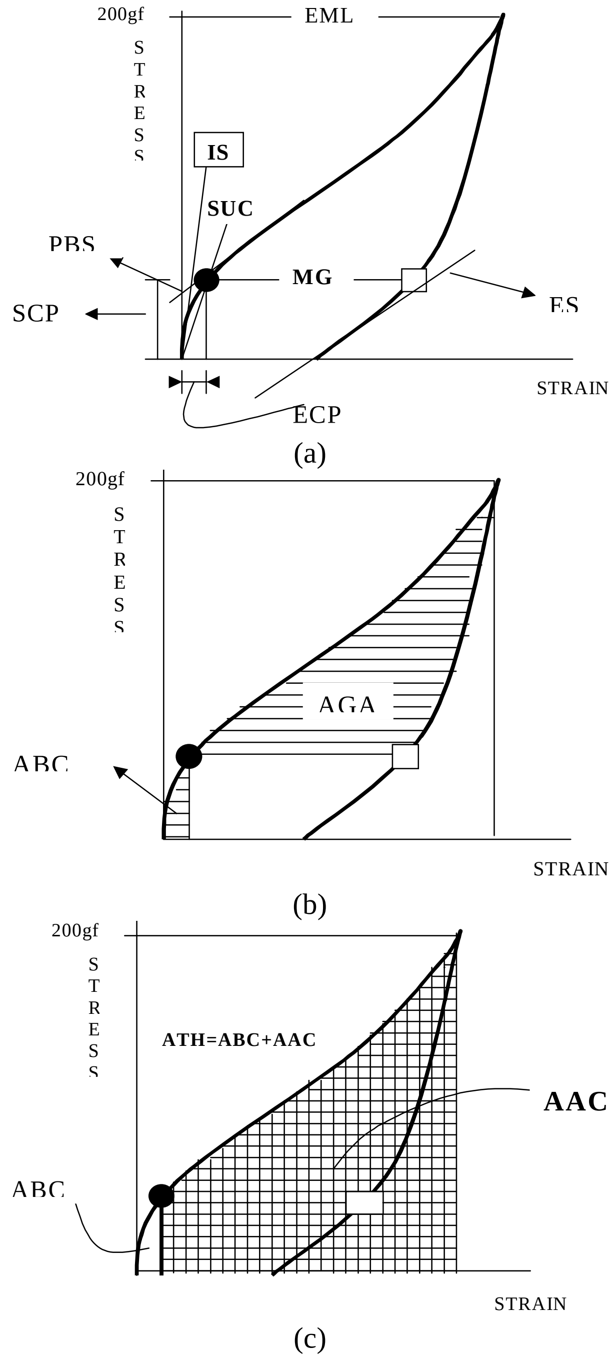


Figure 9. The features extracted from the loading-unloading curve of the method (related to Table 1).

TABLE 3. The Correlation between the Shearing Parameters and Some of the Extracted Features of the New Method.

KES Sh.. Par.	Features extracted from the curves of the new method									
	EML	1/ EML	AAC	1/AAC	AGA	**1/AGA**	ATH	1/ATH	MG	1/MG
G	-0.597	+0.909	-0.642	+0.907	-0.607	**+0.935**	-0.638	+0.891	-0.525	+0.924
2HG.5	-0.528	+0.839	-0.524	+0.839	-0.505	**+0.851**	-0.512	+0.781	-0.375	+0.782
2HG5	-0.645	+0.923	-0.665	+0.923	-0.625	**+0.903**	-0.658	+0.907	-0.509	+0.896

result features extracted from this portion of the curve are able to give enough information about the “relative formability” introduce by Lindberg [13] without needing two different testers.

5. CONCLUSIONS

This study indicates that shearing properties of the woven fabrics could be estimated from tensile properties along 45° bias samples. The two parameters, post-buckling slope (PBS) and gap area above the critical point (AGA), extracted from the loading-unloading curve when 200 gram force is applied, are able to show the shearing properties of all kinds of woven fabrics. Figure 8 would show the two introduced shearing elements.

APPENDIX 1. The Specification of the Fabrics Used in the Experiment.

F. No	Ends/ cm.	Warp Count Nm	Warp Cri. %	Picks/ cm.	Weft Co. Nm	Weft cri. %	Fab. str.	Fib. Con.	Fab. Th. Mm	Fab. Wei. g/m^2
1	040.0	180.0	03.6	28.0	095.0	04	Plain	N	0.110	**054**
2	040.0	160.0	04.0	32.0	110.0	06	Plain	P	0.100	**057**
3	040.0	165.0	04.0	30.0	100.0	05	Plain	P	0.100	**057**
4	046.0	130.0	10.0	25.0	100.0	10	Plain	P	0.140	**067**
5	011.5	033.0	08.0	11.0	033.0	12	Plain	C	0.380	**075**
6	098.0	200.0	04.0	38.0	120.0	07	Satin	P	0.165	**085**
7	018.0	034.0	06.0	10.0	034.0	10	Plain	C	0.410	**089**
8	090.0	180.0	08.0	42.0	120.0	08	Satin	P	0.190	**092**
9	018.0	034.0	06.0	12.0	034.0	10	Plain	C	0.420	**095**
10	100.0	180.0	06.0	42.0	110.0	02	Satin	P	0.199	**098**
11	098.0	180.0	05.0	40.0	100.0	08	Satin	P	0.190	**100**
12	100.0	190.0	05.0	42.0	102.0	08	Satin	P	0.195	**100**
13	018.0	034.0	06.0	14.0	034.0	11	Plain	C	0.440	**102**
14	042.0	070.0	06.0	28.0	078.0	08	Plain	V	0.198	**103**
15	037.0	068.0	05.0	28.0	064.0	08	Plain	P	0.211	**105**
16	100.0	165.0	05.0	40.0	100.0	08	Satin	P	0.200	**106**
17	058.9	095.0	11.0	32.7	088.0	06	Plain	V	0.200	**108**
18	018.0	034.0	06.0	16.0	034.0	12	Plain	C	0.450	**108**
19	050.0	090.0	04.0	36.0	068.0	06	Fancy	P	0.192	**114**
20	060.0	086.0	08.0	30.0	086.0	10	Plain	P	0.200	**114**

APPENDIX 1. Continued.

21	037.0	060.0	06.0	30.0	068.0	12	Plain	C.P	0.235	**115**
22	055.0	080.0	08.0	30.0	080.0	07	Plain	V.P	0.200	**115**
23	046.0	066.0	04.0	28.0	070.0	06	Twill	C.P	0.285	**115**
24	044.0	068.0	07.0	28.5	068.0	08	Plain	C.P	0.220	**116**
25	100.0	150.0	05.0	44.0	100.0	08	Satin	P	0.230	**118**
26	065.0	100.0	06.0	44.0	100.0	10	Twill	P	0.195	**118**
27	033.2	050.0	04.0	23.0	050.0	05	Plain	C.P	0.290	**120**
28	040.0	065.0	04.0	28.0	056.0	10	Plain	P	0.222	**120**
29	043.2	066.0	07.0	28.5	060.0	10	Plain	P	0.202	**122**
30	055.0	074.0	09.0	30.0	084.0	14	Plain	P	0.200	**123**
31	056.6	081.6	11.0	30.6	082.0	10	Plain	V	0.199	**125**
32	041.2	056.0	08.0	24.0	056.0	10	Plain	C.P	0.260	**127**
33	032.0	050.0	06.0	26.0	048.0	10	Plain	C.P	0.240	**128**
34	053.5	068.0	09.0	27.5	068.0	10	Plain	C.P	0.240	**130**
35	031.0	042.0	08.0	24.0	042.0	08	Plain	C.P	0.250	**143**
36	050.0	055.0	10.0	27.5	050.0	09	Twill	C.P	0.295	**160**
37	078.0	088.0	12.0	44.0	077.0	20	Fancy	P	0.380	**167**
38	023.0	028.0	12.0	18.0	028.0	15	Fancy	C.P	0.335	**167**
39	031.0	045.0	08.0	26.0	026.0	08	Plain.	C.P	0.330	**175**
40	020.0	44/2	20.0	22.0	52/2	08	Fancy	P&V	0.300	**201**
41	023.0	20.0	03.0	16.5	20.0	06	Plain	P	0.340	**207**
42	028.0	50/2	04.0	21.0	50/2	06	Twill	P&C	0.435	**208**
43	028.0	48/2	08.0	18.0	48/2	10	Plain	P&W	0.460	**209**
44	025.0	24.0	10.0	22.3	24.0	08	Twill	P&W	0.535	**215**
45	034.0	60/2	05.0	28.0	30.0	08	Twill	P&W	0.425	**222**
46	033.8	38.0	09.0	22.0	17.0	10	Twill	C	0.440	**226**
47	028.0	48/2	08.0	20.0	46/2	10	Twill	P&W	0.440	**228**
48	028.0	48/2	08.0	22.0	48/2	08	Twill	P&W	0.480	**228**
49	028.0	48/2	07.0	22.0	46/2	08	Twill	P&W	0.460	**229**
50	022.0	19.0	04.0	19.5	19.0	07	Plain	C&P	0.420	**230**
51	030.0	48/2	04.0	22.0	48/2	08	Twill	P&W	0.460	**231**
52	040.5	64/2	06.0	28.3	30.0	08	Twill	P&W	0.545	**235**
53	028.0	46/2	05.0	22.0	44/2	07	Twill	P&W	0.510	**235**
54	031.0	48/2	05.0	23.0	48/2	07	Twill	P&W	0.410	**239**
55	015.0	24/2	08.0	12.0	24/2	09	Plain	P&W	0.500	**244**

APPENDIX 1. Continued.

56	030.0	48/2	06.0	24.0	46/2	08	Twill	P&W	0.510	**245**
57	039.0	34.0	03.0	24.0	20.0	05	Twill	C	0.580	**246**
58	056.0	50.0	07.0	19.3	17.0	10	Plain	C	0.560	**250**
59	026.0	46/2	10.0	26.0	23.2	12	Twill	P&W	0.800	**250**
60	028.0	22.0	06.0	21.0	20.0	10	Twill	P&W	0.464	**251**
61	031.0	48/2	04.0	26.0	48/2	08	Twill	P&W	0.450	**251**
62	028.0	44/2	06.0	21.0	20.0	09	Twill	P&W	0.466	**252**
63	003.3	02.7	0.5	3.7	02.7	01	Plain	JUTE	1.300	**258**
64	028.0	44/2	07.0	25.0	44/2	08	Twill	P&W	0.460	**259**
65	027.5	17.0	03.0	23.0	26.0	11	Twill	P&W	0.580	**262**
66	033.4	22.0	13.0	21.2	24.0	11	Twill	P&C	0.460	**270**
67	037.4	034	02.0	16.5	10.5	03	Plain	AC	0.620	**270**
68	028.0	20/2	08.0	23.0	24.0	12	Fancy	P&W	0.470	**272**
69	033.0	22.0	10.0	22.0	22.0	09	Twill	P&C	0.470	**274**
70	032.0	23.5	08.0	28.0	23.5	08	Twill	P&W	0.430	**275**
71	033.5	22.0	14.0	20.5	22.0	09	Twill	P&C	0.470	**275**
72	035.2	25.0	06.0	15.0	12.0	03	Fancy	AC	0.645	**278**
73	046.0	33.0	07.5	24.0	19.5	06	Twill	C	0.460	**280**
74	012.5	14.0	20.0	10.5	06.0	12	Plain 1/1	C&AC	0.960	**294**
75	012.5	14.0	15.0	10.5	06.0	10	Bask 2/2	C&AC	1.050	**295**
76	012.5	14.0	15.0	10.5	06.0	10	Twill 2/2	C&AC	1.070	**295**
77	045.0	26.8	10.0	16.0	12.3	05	Twill	C&P	0.630	**298**
78	019.6	12.0	06.0	14.0	11.0	06	Fancy	AC	0.950	**300**
79	014.0	11.0	04.0	13.0	8.25	06	Fancy	AC	0.930	**300**
80	01.25	14.0	20.0	10.5	06.0	10	Twill 3/1	C&AC	1.100	**300**
81	012.5	14.0	20.0	10.5	06.0	10	Twill 1/3	C&AC	1.100	**300**
82	014.0	09.5	05.0	14.0	09.5	07	Plain	ACET	0.560	**310**
83	018.0	11.2	04.0	16.0	11.2	06	Fancy	AC	0.670	**320**
84	030.3	32.0	11.0	14.2	18.0	14	Velvet	V&C	0.745	**330**
85	018.0	10.0	06.0	14.0	10.0	04	Fancy	AC	0.740	**338**
86	028.7	25.5	12.0	21.6	17.0	11	Velvet	V&C	0.750	**340**
87	033.5	40/2	10.0	32.0	40/2	12	Twill	P&W	0.750	**365**
88	044.0	40/2	07.0	30.0	20.0	09	Twill	P&W	1.150	**400**
89	020.0	07/2	06.0	10.0	09/2	11	Plain	C	0.950	**406**
90	007.5	03.5	08.0	07.0	3.25	10	Twill	P&W	1.500	**440**
91	020.0	07.9	05.0	25.0	15.2	10	Plain	C	1.070	**450**
92	029.0	09.5	11.0	18.0	09.0	08	Twill	C	0.930	**500**

Note: AC = Acrylic, ACET = Acetate, C = Cotton, J = Jute, P = Polyester, W = Wool, V = viscose, N = Nylon.

APPENDIX 2. Features Extracted from the Curves.

Sym.	Parameters	Units
AAC	Work done when out of plane deformation forms	gf.
ABC	Work done during the in-plain movement.	gf.
AGA	Work done during the loading-unloading deformation.	gf.
ATH	Work done during the loading.	gf.
ECP	Strain at point, which out of plain deformation starts.	%
EML	Strain at point, which 200-gram force is applied.	%
ES	The return in-plain movement of the fabric when load is released.	gf.
IS	The slope of the movement in relation to 10-gram force is applied.	gf.
MG	Maximum deformation at the points which two phenomena happen.	%
PBS	Initial slope when out of plain deformation will happen.	gf.
SCP	The force applied up to the point, which out of plain deformation starts.	gf.
SUC	The slope of the line between buckling point and start point.	gf.

6. REFERENCES

1. Kilby, W. F., "Planner Stress-Strain Relationship in Woven Fabrics", Textile Institute, (1963), 54, 9.
2. Hollaway, L., In, "Design with Advanced Composite Materials", Phillips, L. N. (Editor), Springer Verlag, (1989).
3. Hearmon, R. F. S., "An Introduction to Applied Anisotropic Elasticity", Oxford University Press, (1961).
4. Amirbayat, J., "A Simple Approach to the Generalizes Properties of Orthotropic Sheets", ***International Journal of Mathematical Engineering Education***, 22, No. 4, 295.
5. Alsawaf, F. B., "Area Change as a Measure of Fabric Performance", Doctorate Thesis, University of Manchester, (1985).
6. Amirbayat, J. and Alagha, M. J., "A New Approach to Fabric Assessment", ***International Journal of Clothing Science and Technology***, 7, No. 1, (1995), 46.
7. Amirbayat, J., "The Buckling of Flexible Sheet Under Tension" ***Part I: Journal of Textile Institute***, 82, No. 1, (1991), 61.
8. Amirbayat, J. and Bowman, S., "The Buckling of Flexible Sheet under Tension" ***Part I: Experimental Studies, Journal of Textile Institute***, 1991, 82, No. 1, 71.
9. Ly, N. G., "A Model for Fabric Buckling in Shear", ***Textile Research Journal***, 55, No. 12, (1985), 744.
10. Ly, N. G., "The Buckling of Fabric Under Combined Shear and Tensile Loads", ***International Wool Textile Research Conference Proceedings***, (1985), 3, 118.
11. Alamdar Yazdi, A., "A New Method of Evaluation of the Low Stress Mechanical Properties of Woven Fabrics ", ***Doctorate Thesis***, University of Manchester, (1998).
12. Alamdar Yazdi, A. and Amirbayat, J., "Evaluation of the Basic Low Stress Mechanical Properties (Bending, Shearing and Tensile)", ***International Journal of Clothing Science and Technology***, Vol. 12, No. 5, (2000), 311.
13. Lindberg, J., Waesterberg, L. and Svenson, R., "Wool Fabrics as Garment Constractio Materials", ***Journal of Textile Institute***, 51, (1960), T1475.