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Bagging of Thin Polymer Materials: Geometry, Resistance and Application

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New testing method based on bagging principle and aimed to determine mechanical properties of thin walled polymer materials (textiles, membranes, paper) is presented. The obtained data proves that bagging of a disc shaped specimen through a rounded hole is a simple and informative method for a new and more simple evaluation of such properties as smoothness, rigidity, hardness, softness, drape, i.e. those that determine performance stability of mentioned materials. Original instrumental base - KTU-Griff-Tester - is described together with the technical data of its new testing device and its application scope. Theoretical descriptions of material behaviour and optimal regimes for bagging test realisation are given. Optimal conditions for the determination of mechanical properties of a certain type of material are indicated. It is expected that this new instrumental tool can allow evaluating anisotropy level, brittleness and other properties of plain material in a more simple way.

Keywords: textiles, polymer materials, hand, bagging, performance stability.

1. INTRODUCTION

The data published till nowadays shows that one of the most perspective methods of textiles mechanical testing, suitable to evaluate not only its performance but also some specific properties is pulling (or extracting) of a disc shaped specimen through a rounded hole [1 – 5]. During the testing $H-P$ (the path – resistance) plot is registered on the basis of which textile hand and other service parameters are evaluated. At present there is the possibility to optimise testing regimes and parameters of testing equipment [6 – 8].

The aim of this research was to create the specialised device for the realisation of specimen pulling process, to optimise the testing conditions and to analyse the regularities of textile behaviour in such testing conditions.

2. METHOD

Experimental testing was performed by a special device KTU-Griff-Tester mountable on a standard tensile testing machine. The device (Fig. 1) consisting of two transparent parallel plates (the replaceable pad with the centre hole and supporting plate with the similar hole) is made of plexiglas. The distance h between the plates can be adjusted in the wide scale from 0 mm up to 15 mm with the accuracy of 0.05 mm [9, 10].

Spherical punch $\varphi = 5$ mm with the needle shaped handle pulls the textile specimen through the hole of the pad. The specimen $R = 56.5$ mm in pulling through the hole of the pad process obtains the complicated shape of waved (wrinkled) shell, the geometry of which depends upon the type of tested material and testing regimes. During testing the variations of shells shape was registered by a digital camera.

The object of the investigations were textile materials (Table 1) different in type, structure, composition, thickness and other parameters.

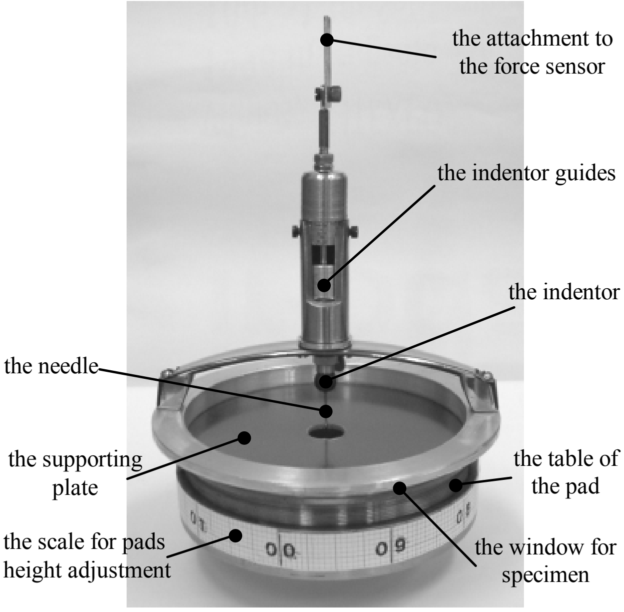

Fig. 1. Specimen clamping device

3. RESULTS

The proper selection of r parameter (radius of the pads hole) plays an important role in the determination of optimal testing conditions. The values of pulling force P and the punch height H increases, decreasing the size r of the hole (Fig. 2) or decreasing the distance h between the limiting plates (Fig. 3). The parameters of $H-P$ curve is significantly effected by the properties of the tested materials. The most important among them is the thickness δ of the specimen, which determines the values of r and h parameters. In the case when r and h values are low, the specimen jams in the hole or between the limiting plates. The optimisation of r and h parameters was performed on the basis of certain conditions concerning the ratio between specimen volume and appropriate active areas of KTU-Griff-Tester device.

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Table 1. The characteristics of the investigated materials

Material type	Material code	Composition	Weave (knit) type	Thickness, mm	Specimen weight, g	Anisotropy level
Knitted fabrics	G-1	100% cotton	plain	0.59	1.54	1.93
	G-2	50% cotton + 50% PA	warp-knit tricot	0.46	0.97	0.65
	M	100% cotton	weft-knit 1×1 rib	0.82	1.76	7.60
	V	100% cotton	weft-knit 2×2 rib	0.79	1.43	12.50
	R	100% cotton	interlock 1×1 rib	0.87	2.14	6.50
	T1	100% acetate	combined	2.20	3.10	.....
	T2	50% cotton + 50% viscose	weft-knit 1×1 rib	1.00	2.60	3.10
	T3	100% cotton	plain	0.60	2.35	.....
	T0	100% cotton	interlock 1×1 rib	0.89	2.47	7.30
Woven fabrics	A	50% wool + 50% PE	hopsack	0.63	2.52	2.70
	A3	50% PE + 50% viscose	hopsack	0.39	1.24	0.20

If both parameters r and h or one of them is too low the pulling curve $H-P$ looses its typical shape because the deformation mode changes essentially, i.e. instead of specimen sliding it is pulled with all possible residual deformations.

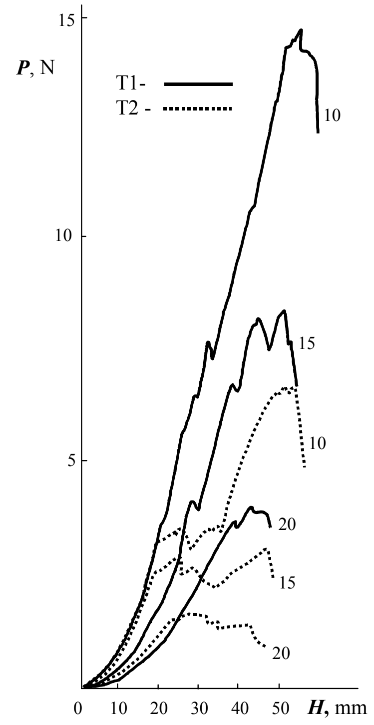
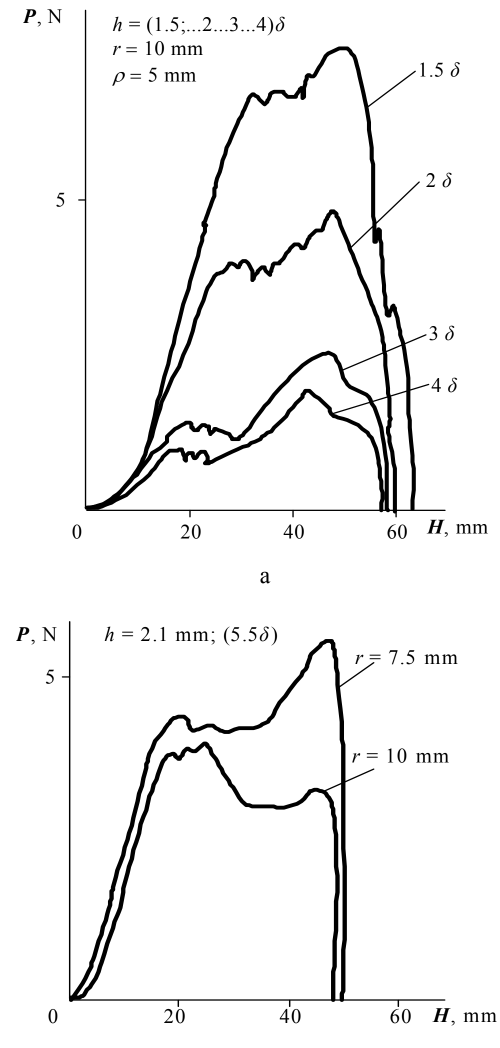


Fig. 2. The curves of specimens T1 and T2 pulling through a rounded hole at $h = 5$ mm and $r = 10$; 15 and 20 mm

The chamfer angle of the stands hole edges ρ has a significant effect upon the parameters of $H-P$ curve (Fig. 4). In the case of sharp edge ($\rho = 0$). The curve obtains the stepped shape. With the increase of chamfer angle ρ values of the parameters H and P decreases and the curve becomes smoother.

The resistance properties of tested materials in pulling process through the rounded hole were evaluated on the basis of the values at the extreme points of $H-P$ curve, i.e. on the basis of slope angle $tg\alpha$ of the curves initial part. The investigations of textile behaviour in pulling through a hole process have shown that the roughness of a specimen surface significantly depends upon the thickness δ and the anisotropy level of tested materials (Fig. 6).



a

b

Fig. 3. Typical pulling curves *H-P*: a – when the distance between the limiting plates varies in the range from 1.5 δ up to 4 δ (fabric R); b – for different radiuses r of the hole (fabric G-2)

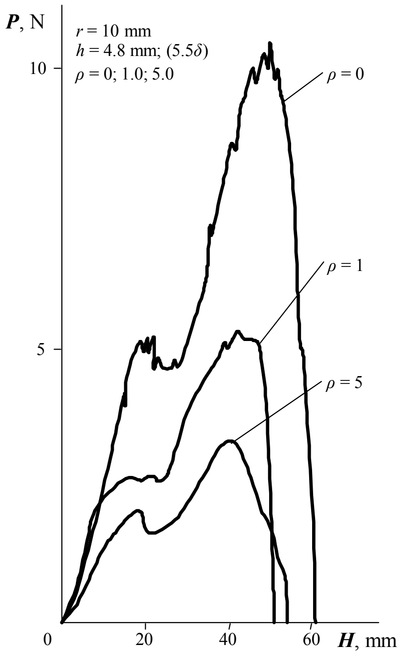


Fig. 4. The dependence of pulling curves shape upon the chamfer angle ρ of holes edges for fabric R

Evidently the parameters of $H-P$ curves strongly depend upon the type of tested material (Fig. 5). The shape of $H-P$ curves of woven fabrics A and A3 greatly differs from that of knitted material T0.

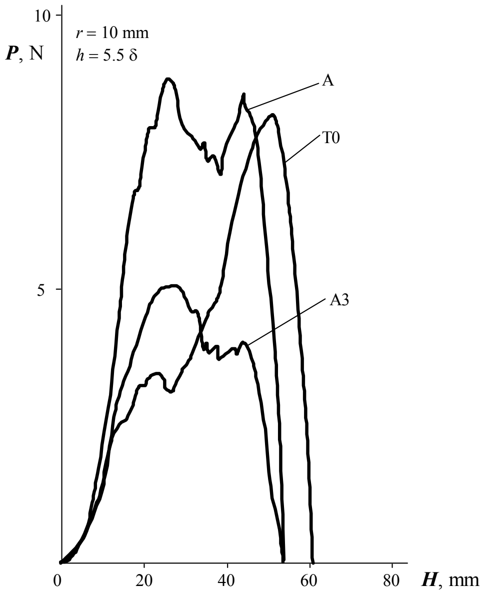
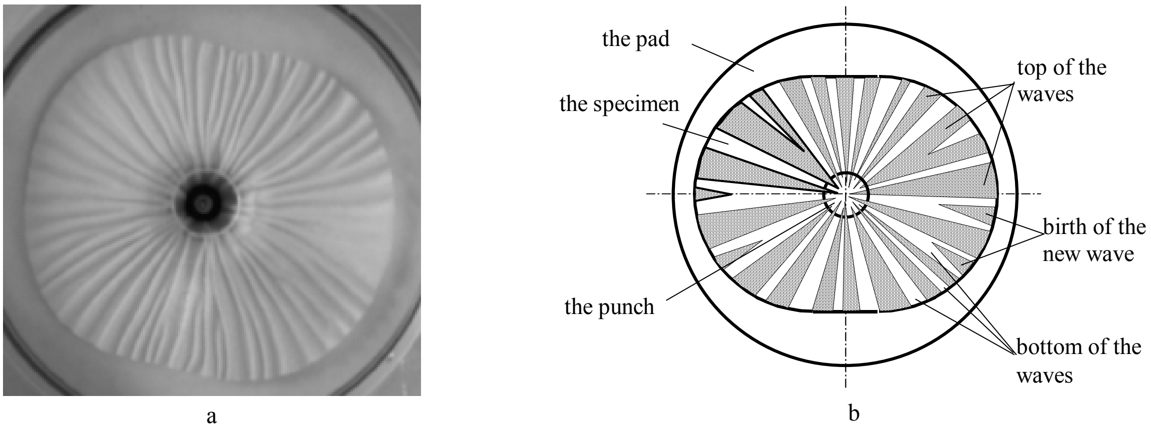


Fig. 5. Pulling curves of woven fabrics A and A3 and knitted fabric T0 in the case when $r = 10$ mm and $h = 5.5\ \delta$

If the distance h between the limiting pales remains constant, more waves are found on the surface of thick material than on the thin one, while the anisotropy level determines the whole wrinkling process. The projection of such specimen during testing deviates from the shape of a circle, i.e. from its initial shape. (Fig. 7).



a

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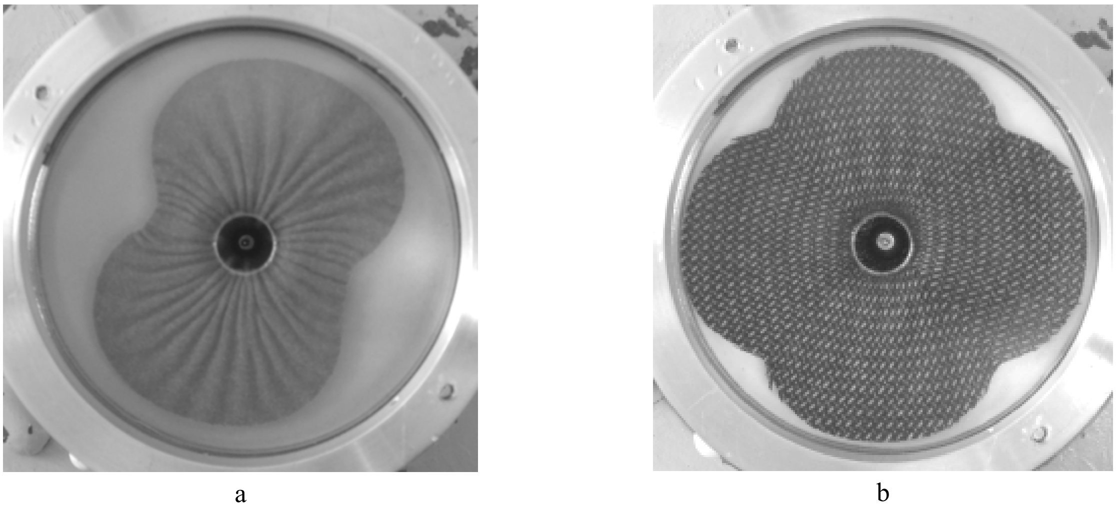
Fig. 6. Wave distributions and their shapes on the surface of the specimen: a – captured image; b – schematic view



a

b

Fig. 7. Spatial shapes: a – of knitted material T0 at $H = 40$ mm; b – of woven fabric A at $H = 20$ mm

Table 2. The dependence of wave number *N* upon the distance between the limiting plates *h*

Material code	*h*, mm						
	6	5	4	3	2	1.5	1
G-1	8	11	15	26	39	40	
G-2	9	12	15	21	30	34	49
M	9	10	17	19	24	28	
V	7	10	12	21	26	30	
R	7	12	15	21	29	33	
T1	9	12	17	23			
T2	8	13	15	21	28	34	
T3	8	12	16	20	31	36	
T0	10	10	13	21	30	36	
The average value	8.3	11.3	15	21	29.6	33.9	49
Calculated N when $R_z = 0.95\,R$	8	10	13	17	25	34	51

In the case of knitted material the specimen obtains the shape of Kasini oval, while in the case of woven fabric – the shape of epicicloid. When the specimen is pulled through the hole, the first waves appear in stiffer direction of the specimen, i.e. for knitted materials – in wale direction. In perpendicular direction usually no waves are observed or only few wide waves appear, which later, with the increase of deformation, splits into smaller ones. Usually the beginning of wave splitting is recorded observing the behaviour of specimen in the process of pulling. The wide wave in its middle part rebounds from the limiting plate (the supporting plate or the pad) and starts to bend in opposite direction. This process starts at the outer contour of the specimen and spreads in the form of taper wedge towards the hole of the pad.

The total number of the waves in the zone of specimen's stiffer direction is always higher than that in perpendicular softer direction. Table 2 presents the number of measured and calculated waves *N* for 9 different materials

The obtained results have shown that independently of the type of the material at small values of displacements R_z of the specimen, i.e. at the beginning of specimen sliding, experimentally determined number of waves *N* and those calculated according to the equation

$$N = \frac{2\sqrt{2}}{C}\sqrt{3\left(2R^2 - RR_z\right) - \left(4R - R_z\right)\sqrt{2R^2 - RR_z}}$$

agree with acceptably high accuracy. It proves that surface roughness prediction model based on the approximate calculations of sine curve length is reliable.

4. CONCLUSIONS

1. Technical parameters of a new testing device KTU-Griff-Tester are presented together with the possibilities of its application for textile hand determination.

2. The relationship between the parameters of pulling curve *H* - *P* and testing conditions (the radius *r* of the pads hole, the distance *h* between the limiting plates and the chamfer angle ρ of pads hole edges) are investigated.

3. Typical cases of surface roughness variations of woven and knitted specimens are illustrated.

4. The dependence between the roughness (number of the waves *N*) of the specimen surface and the distance *h* between the limiting plates is defined. The equation to predict the value of *N* parameter is presented.

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