MECHANICAL WEARING COMFORT OF HEAT PROTECTION CLOTHS

P. Tamás[1], M Halász[2], O. Cherkaoui[3], N. Tatár[2], D. Benmoussa[3]

[1] Budapest University of Technology and Economics, Faculty of Mechanical Engineering, Department of Mechatronics, Optics and Mechanical Engineering Informatics,
H-1111 Budapest, Műegyetem rkp. 3., Hungary,
[2] Budapest University of Technology and Economics, Faculty of Mechanical Engineering, Department of Polymer Engineering, H-1111 Budapest, Műegyetem rkp. 3., Hungary
[3] The Advanced School of Textile and Clothing Industry of Casablanca, Research and Development Laboratory, Km 8 road of El Jadida, BP 7731, Oulfa, Casablanca, Morocco

ABSTRACT

Intelligent textile plays deep role in defence of quick temperature fluctuation. In the focus of Hungarian-Moroccan S&T program is an intelligent textile with a special technology integrated PCM micro capsules softening the influence of temperature fluctuation. Mechanical wearing comfort is primarily affected by tensile elasticity and body-fitting ability of fabric. Because the subjects of investigation is knitted fabrics for examination of body-fitting ability of fabric there is the drape test and examination of tensile elasticity there is the bursting test in a complex multi-axial way. Presentation shows results of drape tests and bursting test, as well as those of studying the influence of PCM capsule integration on the mechanical wearing comfort.

1. INTRODUCTION

One of the basic objectives of clothing is to stabilize of the body temperature and to provide the pleasurable thermal comfort. According to Fanger (1970) pleasurable thermal comfort means satisfaction and can be bounded to the energy transport of the human organism. However under changing environmental temperature providing thermal comfort is not a simple problem. PCMs (Phases Change Materials) can help that melt by heat removing from or solidify by transporting to the environment in case of the increase or decrease of the temperature, respectively. Integrating such materials into clothing can be an aid with damping the effects of the changing external temperature. In general PSMs are integrated in clothing by enclosing them in micro-capsules. According to some methods the capsules are blended in the material of the artificial fibres or the finished textiles are coated by them.

In addition to providing the pleasant thermal feeling the comfort of clothing has got other components. Besides the thermal properties such as heat retention the air-permeability, moisture take up, and the drying ability belong to the thermo-physiological comfort as well. According to Li (2002) and Byrne (1993) the body-fitting and the handle of the clothing material play important role in development of the comfort feeling.

Good body-fitting can be achieved by proper tailoring taking into account the sizes of the body. The handle of the clothing has profoundly been studied by Kawabata (1980). By his results the handle of textile materials is a complex property. It is influenced by the tensile elasticity, the resistance against shearing, flexibility, compressibility, the surface evenness, and the friction resistance of the textile fabrics that can be tested by the Kawabata measuring system (KES-FB). This system gives a complete solution to the objective examination of the handle of textiles and hereby their mechanical comfort.

The system KES-FB is used mainly for testing woven fabrics. Since in present work the mechanical comfort of weft knitted fabrics was examined more suitable methods were chosen. Studying the mechanical wearing comfort further on it can be stated that it is determined by the ability of fitting spatial form and the elasticity of the fabrics. To examine the former multiaxial methods are reasonable to be used. By Cusick (1965) the flexibility and the shearing resistance are the main determining properties in fabric draping. Hence measuring the draping caused by the fabric weight the ability of fitting spatial form can be characterized by a multiaxial and complex examination. In case of knitted fabrics the ability of fitting spatial form and the deformability including mainly the elastic deformation component can be tested in a multiaxial and complex way.

In our research we have coated different knitted fabrics by a material containing PCM capsules aiming at the development of heat protecting cloths. This coating is advantageous from the view of the equalization of temperature however it considerably can influence the mechanical comfort of the fabrics. To characterize the mechanical wearing comfort of the fabrics without and with coating draping and ball bursting tests were carried out.

The paper presents the results of the draping and ball burst tests the analysis of whether the coating containing PCM capsules influences the mechanical wearing comfort of the fabrics tested if so than to what degree relating to the fabrics without coating.

2. EXPERIMENTAL PROCEDURES

2.1 Test Materials

Heat protected fabrics of different knitted structures were prepared of PAN (polyacrylonitrile) yarn of 74.5 tex linear density (2 ply thread from PAN multifilament). At choosing the knitted structures the small difference between the strains in course and wale directions and the small twisting of the fabric were technically important. Basic data of fabrics are contained by Table 1.

Table 1: The tested materials

Fabric	Structure of weft knitted fabric	Mass per unit area [g/m^2]	Thickness [mm]	Course density [course/100mm]	Wale density [wale/100mm]	Coa-ting
1	Roma Rib	There are no measurements, because of the hard twisting of fabric.				no
1T						yes
2	Roma Rib	342	2,98	110	60	no
2T		517	2,67	80	80	yes
3	Rib	336	2,02	75	110	no
3T		492	1,98	70	120	yes
4	Missfire needle knit	There are no measurements, because of the hard twisting of fabric.				no
4T						yes
5	Milano Rib	390	2,14	80	120	no
5T		485	2,44	70	140	yes
6	Modified Milano Rib	457	2,54	80	120	no
6T		526	2,15	70	140	yes
7	Interlock	489	2,55	85	130	no
7T		535	2,33	70	160	yes

2.2 Drape test

The draping was measured with Sylvie 3D Drape Tester developed at Budapest University of Technology and Economics that includes a 3D laser scanner (Tamás at. all 2006). The equipment scans surface of the draped fabric sample and saves all the related data while the connected computer calculates the draping parameters (Kuzmina at. all 2005).

Figure 1 illustrates the Sylvie 3D Drape Tester. The 180 mm diameter, circular table of the device is sunk into the base plate. The 300 mm diameter, circular fabric sample to be examined has to be placed on the moving table. The table is raised with a motor controlled by a computer and this way it is ensured that the wrinkles of the textiles are always formed at the same speed under the same dynamical circumstances (Halász at. all 2008).

During the measurement the 4 laser line emitters project a light line onto the fabric, and it is recorded by the 4 cameras placed on the measuring frame above the line emitters. The height of the frame is moved with a step distance every time and the equipment scans the draping sample and reads its surface data. The equipment controlled by the computer is built in a black box and this way it is ensured that the measuring space is dark. The images are downloaded on the computer after each step of photography (Al-Gaadi at. all 2010).

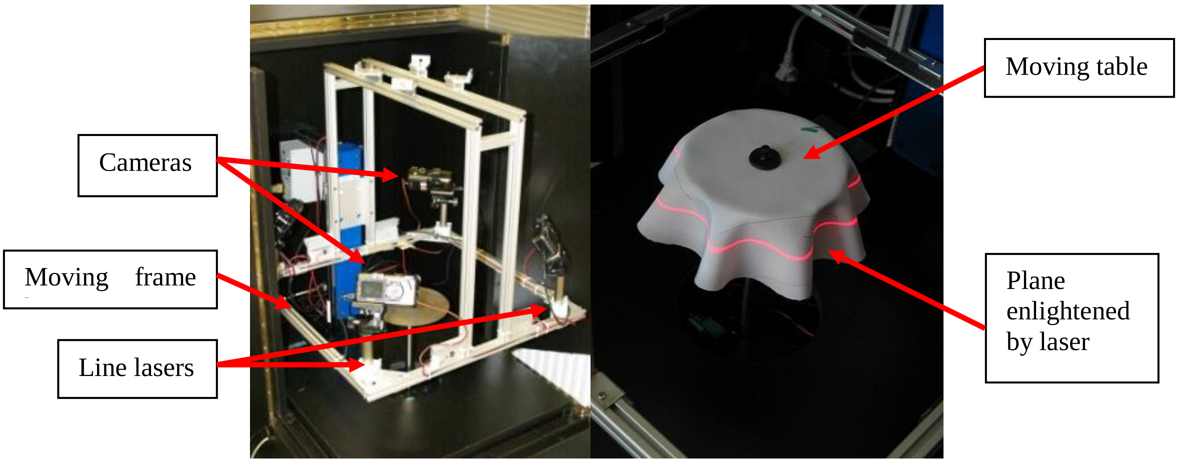


Figure 1: Sylvie 3D Drape Tester (Szabó at. all 2008)

By calibration data the point-cloud of surface points are measured and edge points are determined by picture processing methods (Figure 2.) (Geršak at. all 2013).

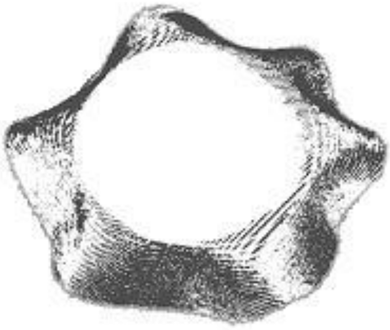


Figure 2: Point cloud and edge-points

2.3 Bursting test

Figure 3 shows the bursting equipment and the measuring process can be seen in Figure 4.

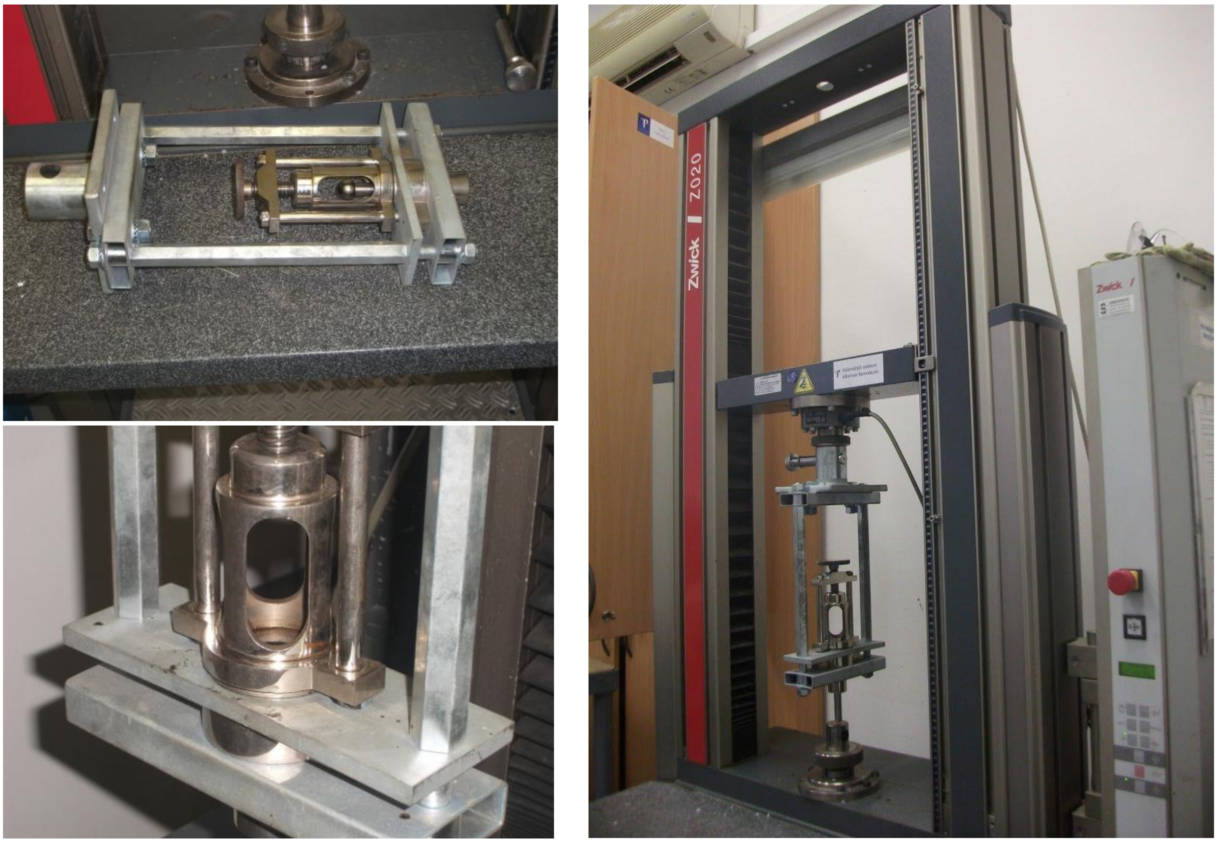


Figure 3: Bursting equipment (on the left side) and as it is installed on Zwick Z020 testing machine (on the right side)

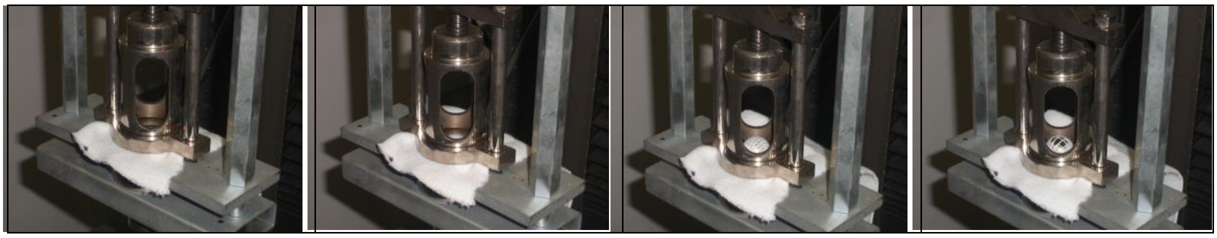


Figure 4: The process of bursting test

The process of the test (Halász at. al (2012)): after fixing the sample on the frame of the apparatus a polished ball, whose diameter is smaller than the inner diameter of the frame, moves at a constant speed and it is compressed on the sample. The vertical displacement of the sample depending on the reaction force is recorded. The Table 2 contains the parameters of the device used for the tests.

Table 2: The parameters of the bursting equipment

The diameter of the ball	19 mm
The inner diameter of the frame	25 mm
The maximum of the vertical displacement of the ball	45 mm
The moving speed of the ball	100 mm/min

3. RESULTS AND DISCUSSION

3.1 Results of draping tests

Results of draping tests are presented in Table 3. It was impossible to measure the draping of fabrics 1 and 4 because of the hard twisting of the knitted material. There are no results in case of coated fabrics since there are no measurable weight generated wrinkles because of the stiffening effect of the coating, hence the draping coefficient was considered 100 %.

Table 3: Results of draping tests

Fabric	Draping coefficients [%]	Wave number [pc]	Minimum radius [mm]	Maximum radius [mm]	Average radius [mm]	Standard deviation of radii [mm]
2	54,3	8	96,1	142,3	125,6	13,6
3	53,8	9	101,3	145,2	125,4	12,8
5	70,1	8	106,8	146,4	134,7	10,7
6	78,8	10	114,2	149,4	139,4	8,4
7	76,6	9	111,2	149,6	138,1	9,9

Figure 5 shows the pictures of fabrics taken during the scanning process and the edge curve of the 3D model produced by image processing of the scanned data. The plane projected curves obtained by the measurement and the draping coefficients calculated correspond to each other well.

3.2 Results of bursting tests

Firstly a burst test was performed to determine the bursting force and the displacement to failure. Subsequently multi-cycle loading-unloading examinations were carried out with a maximum load of the 50% of the bursting force.

Results of bursting tests are shown in Table 4. In case of bursting tests the force and the displacement values are the average of three measurements. In case of cyclic bursting tests the total deformation is based on the first cycle. The elastic, delayed elastic and remaining deformation components are defined as a percentage of the total deformation according to Figure 6 (Gyimesi, (1968)).

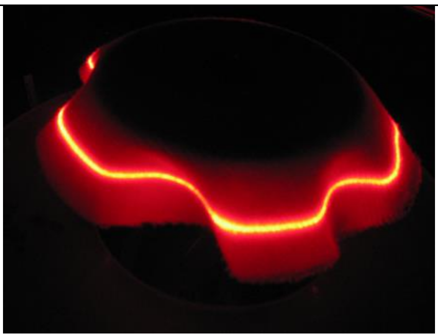
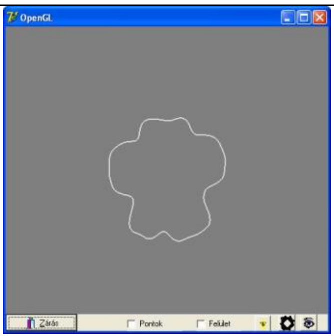
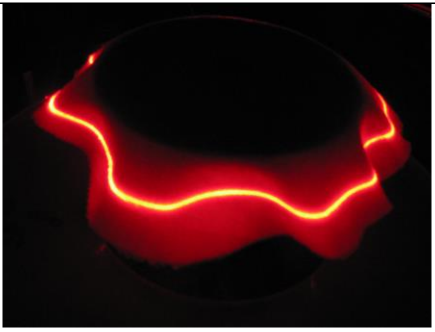
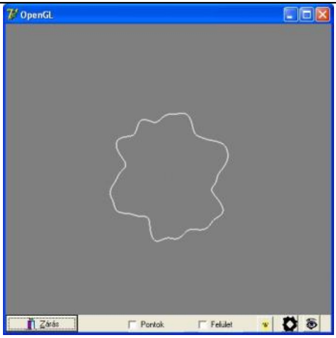
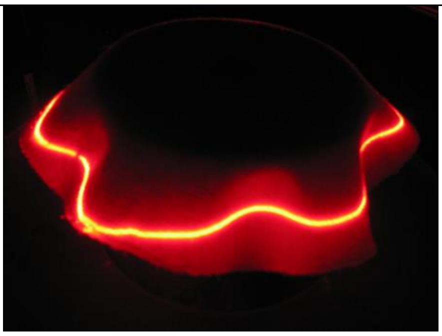
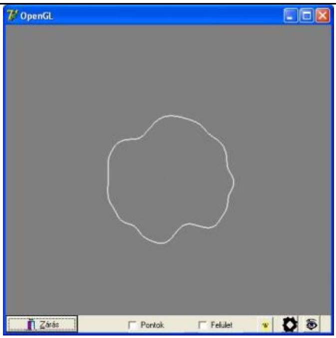
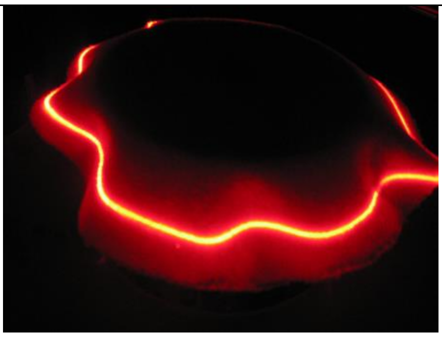
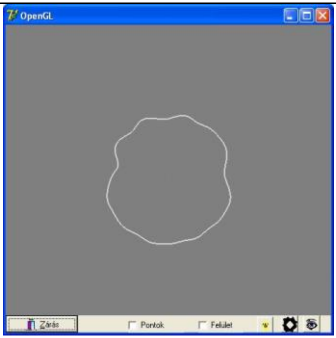
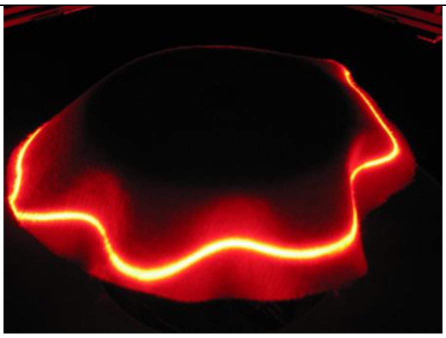
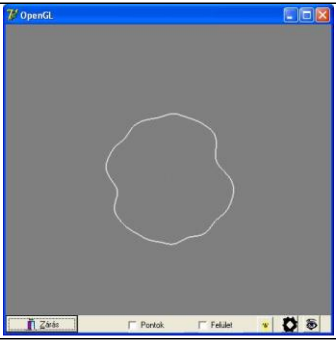
Fabric	The scanned draping fabric	The edge curve of the computer model projected on the basis plan
2		
3		
5		
6		
7		

Figure 5: The pictures of the draping test and the plane projected edge curves

Table 4: Results of bursting tests

	Bursting tests		Cyclic bursting tests				
Fabric	Bursting force [N]	Displacement to failure [mm]	Maximum force [N]	Displacement of the ball at the maximum force			
				Total K_T [mm]	Elastic K_E [%]	Delayed elastic K_{DE} [%]	Remaining K_R [%]
1	616	20,2	314	15,5	4,2	37,5	58,3
1T	682	14,0	344	7,7	10,6	40,9	48,5
2	340	25,0	173	18,8	3,2	34,4	62,4
2T	387	17,5	195	11,2	6,8	38,6	54,5
3	441	17,9	224	14,2	5,1	36,8	58,1
3T	514	15,8	259	10,8	5,4	50,0	44,6
5	631	18,6	321	15,5	3,3	37,5	59,2
5T	800	18,7	406	13,0	5,9	31,7	62,4
6	787	21,4	400	16,8	4,8	35,5	59,7
6T	558	15,5	283	12,0	5,7	34,5	59,8
7	794	22,9	402	18,0	3,9	34,1	62,0
7T	767	19,6	385	13,2	5,1	35,7	59,2

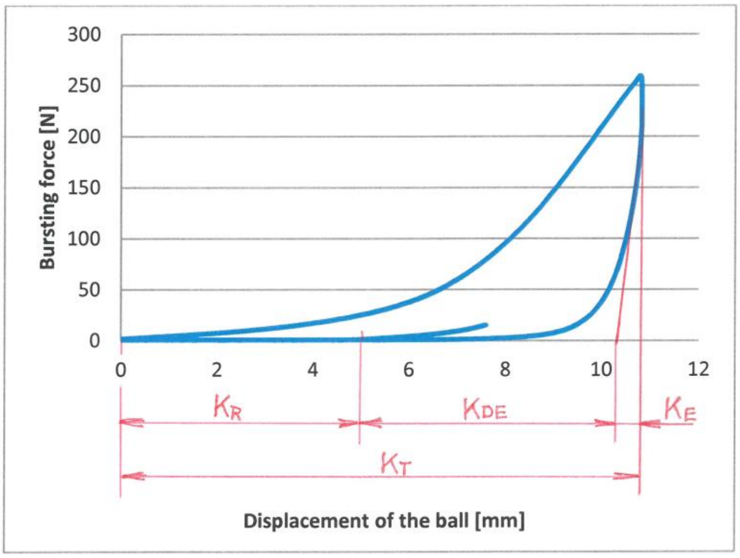


Figure 6: Constructing method of the deformation components

As an example Figure 7 presents bursting and cyclic bursting test diagrams of fabrics 3 and 3T.

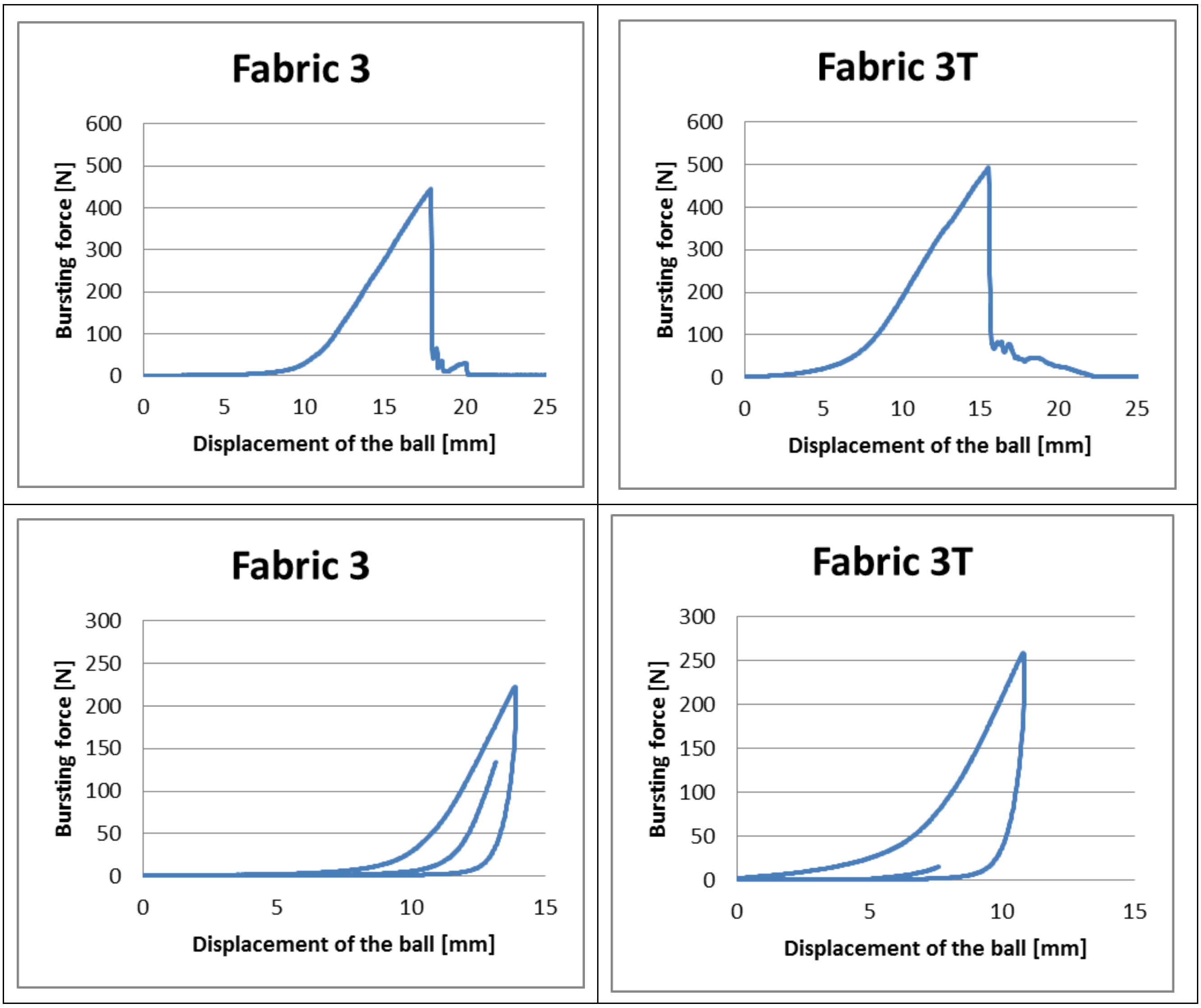


Figure 7: Bursting and cyclic bursting test diagrams of fabric 3 and 3T

Figure 8 shows the samples of fabrics 3 és 3T after testing

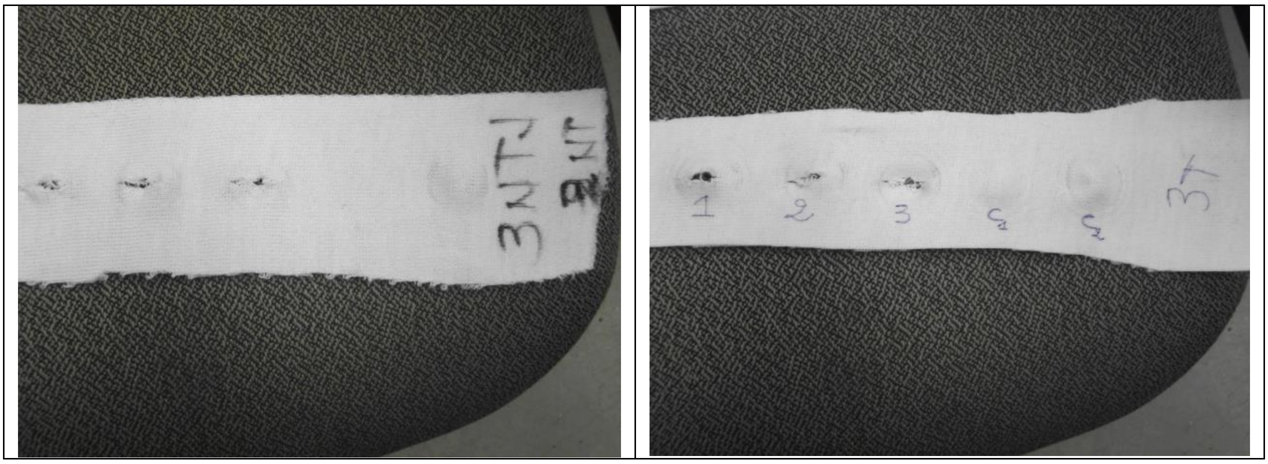


Figure 8: Samples of fabric 3 and 3T after test

3.3 Evaluation of results

On the basis of the drape tests it can be established that the fabrics without coating behave like normal clothing materials. The higher draping coefficient of fabrics 5, 6 and 7 can be attributed to the denser structure and the related higher area density and thickness. Coating strongly affects the draping ability to such degree that in the case of coated fabrics there was not any measurable effect.

Results of bursting tests proved that the coating had got a large influence on the fabric properties. As a general trend it can be stated that coating increases the bursting force and decreases the deformation. The cyclic tests show that the elastic deformation component increases and the remaining component decreases as a result of coating.

4. CONCLUSIONS

Knitted fabrics produced in the frame of Hungarian-Moroccan S & T program was coated with a special technology integrated PCM micro capsules softening the influence of temperature fluctuation and tested as well compared with fabrics without coating. Mechanical wearing comfort is primarily affected by tensile elasticity and body-fitting ability of fabric. These properties were examined by draping and ball bursting tests. The measurements showed that coating is disadvantageous concerning the mechanical wearing comfort hence the method of integrating the capsules containing PCM could need further refining.

5. REFERENCES

Fanger, P. O., “Thermal Comfort: analysis and applications in environmental engineering”, McGraw-Hill Book Company, New York, 1970.

Li, Y., “The Science of Clothing Comfort”, Textile Progress, 31, 122, 2002.

Byrne M.S., Garden A.P.W., Fritz A.M., “Fiber Types and End-uses: A Perceptual Study”, Journal of the Textile Institute, 84, 275-288, 1993.

Kawabata, S., “The standardization and analysis of hand evaluation”, Textile Machinery Society of Japan, Osaka, 1980.

Cusick, G. E., “The dependence of fabric drape on bending and shear stiffness”, Journal of the Textile Institute, 56, 596-606, 1965.

Tamás, P., Geršak, J., Halász, M., “Sylvie 3D Drape Tester – New System for Measuring Fabric Drape”, TEKSTIL, Zagreb, 2006/10, P 497-502, 2006

Kuzmina, J., Tamás, P., Halász, M., Gróf, Gy., “Image-based Cloth Capture and Cloth Simulation Used for Estimation Cloth Draping Parameters”, AUTEX 2005, 5th World Textile Conference, Portorož, Slovenia, 27-29 June 2005, 2005

Halász, M., Tamás, P., Gräff, J., Szabó, L., “Computer Aided Measuring of Textile-mechanical Parameters”, Materials Science Forum Vol. 589 (2008) pp 311-316, 2008

Szabó, L., Halász, M., “Examination of Dependence of Drape Coefficient on the Samples Size”, TEKSTIL, Zagreb, 2008/9, P 439-447, 2008

Al-Gaadi, B., Halász, M., Tamás, P., “Textiles dynamically influenced drapability”, Materials Science Forum, 659, 361-366, 2010.

Halász, M., Décsei-Paróczi, A., Tamás, P., Vas, L. M., “Modeling high flexible underclothes based on bursting test results”, 3rd International Joint Conference on Environmental and Light Industry Technologies, 21 – 22 November 2012, Budapest, Hungary, Óbuda University, CD of Proceedings, paper ISITD 8, p 10, 2012

Gyimesi, J., “Textilanyagok fizikai vizsgálata”, (Physical examination of textile materials), Műszaki Könyvkiadó, Budapest, 1968

Geršak, J., Halász, M., Tamás, P., Kokas-Palicska, L., “Complex fabric deformation and clothing modeling in 3D”, LAMBERT Academic Publishing, 2013.

ACKNOWLEDGEMENTS

This work was supported by the Hungarian National Research, Development and Innovation Office, the Hungarian Science and Technology Foundation (TÉT 12 DE-1-2013-0006, TÉT_12_MA-1-2013-0008) and by the Hungarian Research Fund (OTKA K100949) and by the New Széchenyi Plan (Project ID: TÁMOP-4.2.1/B-09/KMR-2010-0002). This project was connected to the scientific program of the “Development of quality-oriented and harmonized R+D+I strategy and functional model at BME” project.