

Audronė Ragaišienė,  
Jolita Rusinavičiūtė

Kaunas University of Technology,  
Department of Textile Technology  
Studentu Str. 56, LT-51424 Kaunas, Lithuania  
E-mail: audrone.ragaišiene@ktu.lt

# Comparitive Investigation of Mechanical Indices of Sheep's Wool and Dog Hair Fibre

## Abstract

The aim of this research is to analyse and compare mechanical indices – breaking force, tenacity, elongation at break, work of break, and toughness of dog's hair and sheep's wool fibre and to investigate the relationship between the geometrical and mechanical indices of these fibres. In textiles it is very important to choose the right component for the blend. Fibre length, diameter, linear density, tenacity, elongation at break and other strength properties are very important for these fibres parameters of yarn. It was estimated that sheep's and dog's fibres are visually very different and the diameter of these fibres varied in a big interval; however their length is more similar. Also it was established that geometrical indices of the fibres influence their mechanical indices of them i. e. fibres of minimal length have maximal values of these indices.

**Key words:** sheep wool fibre, dog hair fibre, tenacity, elongation at break, toughness.

rior for determining the trading price, processing performance and finally – the usage of wool [3]. It was estimated that the coefficient of variation of the fibre breaking load depends on the fibre diameter [4] and variation therein influenced the breaking of the yarn during the spinning process, as well as the yarn count and uniformity [5]. In literature there is not so much information about dog fibre and the possibilities of blending it with other fibre, i. e. wool, cotton and linen. It is known that many years ago people started to use dog fibre in Northern Countries. Textile goods with dog's hair protect from the cold and have medicinal properties [6]. There are so many kinds of dog in world and, if combed or picked out, dog hair really could be blended with other fibres and used in yarn manufacturing, which would be the application of an untapped resource.

The tensile properties of a fibre bundle are greatly influenced by the tensile properties of the constituent fibres which form the bundle [7], hence it is necessary to establish fibre strength properties because the strength is a very important requirement for yarn.

Thus fibre diameter, length and strength are the most important indices which influence yarn [8 – 10], followed by fabric properties; and it is very important to blend the right component before making the yarn.

The aim of this research was to analyse and compare mechanical indices – the breaking force, breaking tenacity, elongation at break, work of break and breaking toughness of dog's hair and sheep's wool fibre and to investigate the relationship between geometrical and mechanical indices of these fibres.

## Materials and test methods

In this research sheep's wool and dog's hair fibre were used, indicated as S1, S2, S3 and D1, D2, D3 (see **Table 1**). The dog fibres were combed from different kinds of dogs: Chow Chow (D1), Pekingese (D2) and Yorkshire terrier (D3). The type of sheep's wool was from a primitive Lithuanian breed and the S1, S2, S3 wool was from different batches.

The fibres were tested on standard test equipment using standard test methods. The strength properties of the fibres mentioned were analysed. First the linear density of every fibre was tested. Wool fibre is crimp and to determinate the linear density of this fibre is really complicated. In this investigation the linear density was determined from the fibre bundle as specified in standard [11]. A length meter - FM-04/b ('Mettler Toledo', Switzerland) was used to make this bundle. Every type of fibre bundle was pressed with the metal oppressor of the length meter with one end and a bundle was combed in that position. The bundle was combed till every hair became straight. Then the other end of the bundle was pressed and the combed bundle was cut to a length of ( $l = 5$  cm) [11]. This was repeated 20 times for every bundle. Then every example was weighed and the number of fibres calculated.

The linear density (tex) of every fibre was determined as follows:

$$T = \frac{m}{l \times n} \times 10^{-5} \quad (1)$$

where:

$m$  – mass of fibre bundle in g  
 $l$  – length of fibre in bundle in mm  
 $n$  – number of fibres in bundle.

## Introduction

Wool is a natural fibre and has many kinds. There is sheep's wool as well as Angora goat, camel, rabbit, dog, cat hair, etc. Angora goat, rabbit and other animal fibre are popular in home textile because of their special properties. A natural hairy wool surface gives thermo-mechanical properties to textile materials [1]. This feature is very important for wool's application (usage), but it does not play the main role. Fibre diameter and length show the quality of wool [2]. The fibre diameter of wool is the primary crite-

A hundred hairs were taken from every type of fibre for length and diameter measurement. The length meter FM-04/b ('Mettler Toledo', Switzerland) was used for fibre length measurement. As specified in standard [12], the combed bundle of fibre was lain under the length meter velvet ribbon and pressed plate. Every end of hair was pinched with tweezers and pulled next to the ruler in an upward direction until the other end of the hair remains in the clamping plate. Rulers help set the hair length.

The diameter of every fibre was analyzed with an optical microscope - Biolan R1 ('OMO', Russia) with an ocular micrometer - MOB-15×Y4.2 ('Lomo', Russia), as specified in standard [13]. Magnification was 300×.

Diameter ( $\mu\text{m}$ ) of every fibre was determined as follows:

$$d = (a_2 - a_1)p \quad (2)$$

where:  $a_1$  and  $a_2$  – the ocular micrometer scale reference,  $p$  – minimal interval of ocular micrometer ( $0.46 \mu\text{m}$ ).

A hundred hairs were taken from every type of fibre and every hair was researched with a Strength Tester, BDO-

FBO.5 TH ('Zwick/Roell', Germany). The experiment was performed as specified in standard [14]. The experimental length of fibre was 20 mm, the initial stress – 0.5 cN, and clamp movement speed – 10 mm/min. All fibres were conditioned at a temperature and relative humidity of  $20 \pm 2 \text{ }^\circ\text{C}$  and  $65 \pm 2 \%$ , respectively, as specified in the standard [15].

The results of this research was the estimation of the breaking force, tenacity, elongation at break, work of break and coefficient of variation of all these indices for fibres S1, S2, S3 and D1, D2, D3. The toughness ( $J/\text{tex}$ ) of all the fibres researched was determined:

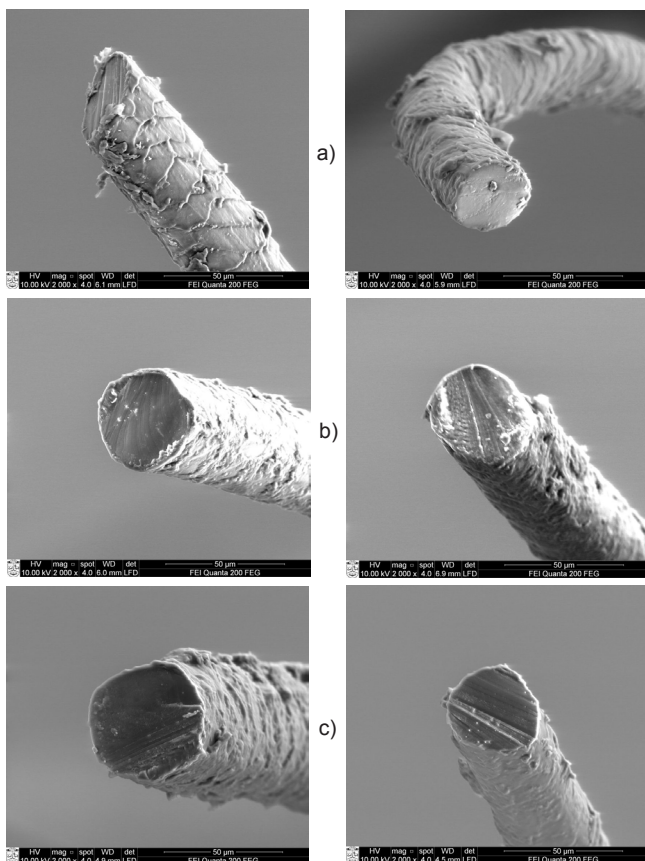
$$w = \frac{W}{T}, \quad (3)$$

where:  $W$  – work of break in J;  $T$  – linear density in tex.

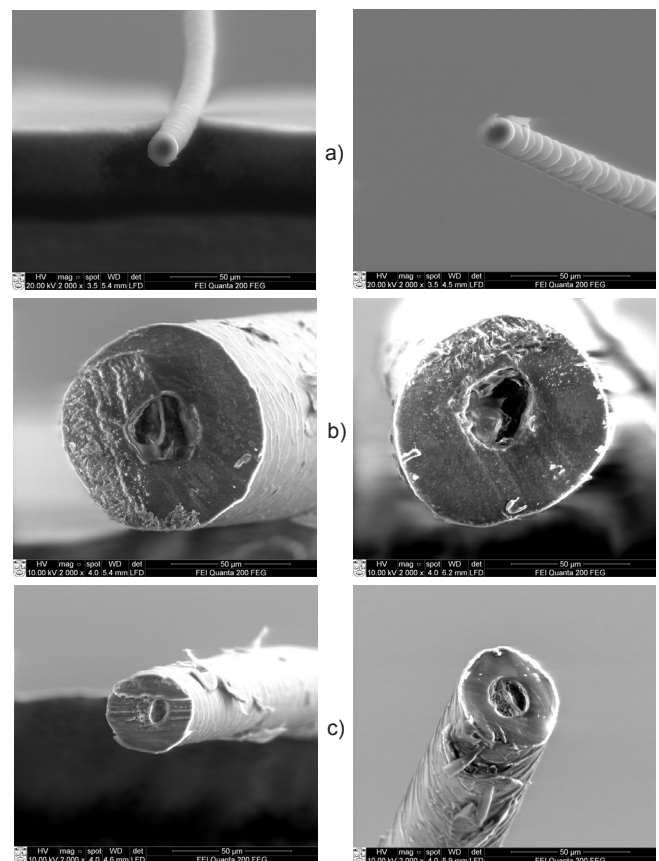
Photographs of the fibres were taken using a scanning electron microscope – (SEM) Quanta - 200 FEG (FEI), magnification – 2000×, scale –  $50 \mu\text{m}$ . 5 images with diameter and cross-section measurement were taken for every fibre.

## Results and discussions

Photographs of the sheep's wool fibre investigated are presented in **Figure 1** and of the dog's hair fibre in **Figure 2**. It can be seen from photographs that the diameter, which is the most important parameter, of fibres S1, S2 and S3 is almost similar to each other, whereas it significantly differ for dog's fibres, especially for the diameter of dog fibres D1 and D2. Dog fibres have scales on their surface, like sheep fibres, which is standard for wool fibre. But the scale shape and distribution on the dog fibre surface are different from the sheep fibre surface. The scales of dog fibres D2 and D3 are smaller, more delicate and similar to those of Alpaca wool fibre [16]. The scales of fibre D1 are more densely located and of a completely different structure than the other fibres investigated. It can be seen from **Figures 1** and **2** that the cross-section of all fibres researched is of an irregular round form; but dog and sheep fibres have another difference, i. e. all dog's hair fibres have channels inside them. Moreover channels are located in the centre of the fibres and are more or less of a round shape. It was estimated that the value of the channel diameter de-



**Figure 1.** SEM images of sheep's wool fibre: a) S1, b) S2 and c) S3.



**Figure 2.** SEM images of dog hair fibre: a) D1, b) D2 and c) D3.

pend on the value of fibre diameter, with the thicker fibre having the biggest channel. Thus the diameter of fibre D1 channels is about 8  $\mu\text{m}$ , of D2 fibre – about 30  $\mu\text{m}$  and of D3 fibre – about 15  $\mu\text{m}$ . Sheep fibres S1, S2, S3 are of a more matted colour than dog fibres and are almost the same sandy colour. Dog fibre D1 is of a white colour, D2 – a black colour and in the bundle of fibre D3 hairs of white, black and grey colour can be found.

Linear density, diameter, length and strength indices are very important in the fibre blending process. **Table 1** presents calculated values of geometrical indices (T, d, l) i.e. the average value (x), coefficient of variation (V), and absolute random error ( $\Delta$ ) of fibres S1, S2, S3, D1, D2 and D3. It is evident from **Table 1** that the linear density of dog fibre D2 is the maximum value (3.85 tex) and that of fibre D1 – the minimum value (0.13 tex) of all the fibres. It is known that wool fibre is crimp and to determinate the linear density of this fibre is really complicated. Thus in this investigation the linear density was determined from the fibre bundle. The bundle was combed till every hair became straight, as specified in standard [11]. The coefficient of variation of the linear density varies from 5.12% (D2 fibre) to 14.45% (D3 fibre).

The diameter of the sheep's wool fibres varies in the range of 44.97 - 52.71  $\mu\text{m}$  and that of dog fibres – 13.5 - 86.79  $\mu\text{m}$ . Coefficients of variation of almost all the the geometrical indices of the dog fibres are bigger than those of the sheep fibre, which can be explained by the fact that fibres D1 and D3 consist of more different single hairs than sheep's wool (see **Figure 3**). However, in general, all coefficients of variation of the geometrical indices do not exceed the value of 15%.

The average length of the sheep fibres is 62.6 - 105.9 mm and that of dog fibres – 57.4 - 103.6 mm (see **Table 1**). Thus in this research they were grouped into three categories according to this index: minimal length group 57 - 62 mm (S2 and D1 fibres), medium length group 71 - 83 mm (S1 and D3 fibres), and maximal length 103-105 mm group (S3 and D2 fibres). An interesting fact is that the fibre diameter in these groups is very different: it can be seen that fibre D1 is shorter than S2 by 9% and thinner by 70%. The opposite tendency is in the next group: S1 is shorter than D3 by 14% and thicker by 30%. Thus it can be said that

**Table 1.** Summary of geometrical indices of sheep's wool and dog's hair fibre.

Fibre symbol	Linear density			Diameter			Length		
	$\chi$ . tex	V. %	$\Delta$ . tex	$\chi$ . $\mu\text{m}$	V. %	$\Delta$ . $\mu\text{m}$	$\chi$ . mm	V. %	$\Delta$ . mm
S1	2.33	6.32	$\pm 0.04$	52.71	6.44	$\pm 0.67$	71.73	6.16	$\pm 2.55$
S2	1.74	7.72	$\pm 0.06$	44.97	9.53	$\pm 0.85$	62.60	7.43	$\pm 1.92$
S3	1.96	8.28	$\pm 0.04$	48.50	8.40	$\pm 0.81$	105.92	7.08	$\pm 2.96$
D1	0.13	12.44	$\pm 0.03$	13.50	14.59	$\pm 0.39$	57.43	11.73	$\pm 1.76$
D2	3.85	5.12	$\pm 0.06$	86.79	7.32	$\pm 1.26$	103.61	11.76	$\pm 2.78$
D3	0.90	14.45	$\pm 0.05$	36.90	13.97	$\pm 1.02$	83.18	9.45	$\pm 1.83$

**Table 2.** Comparison of the average value of fibre diameter, established by different microscopes.

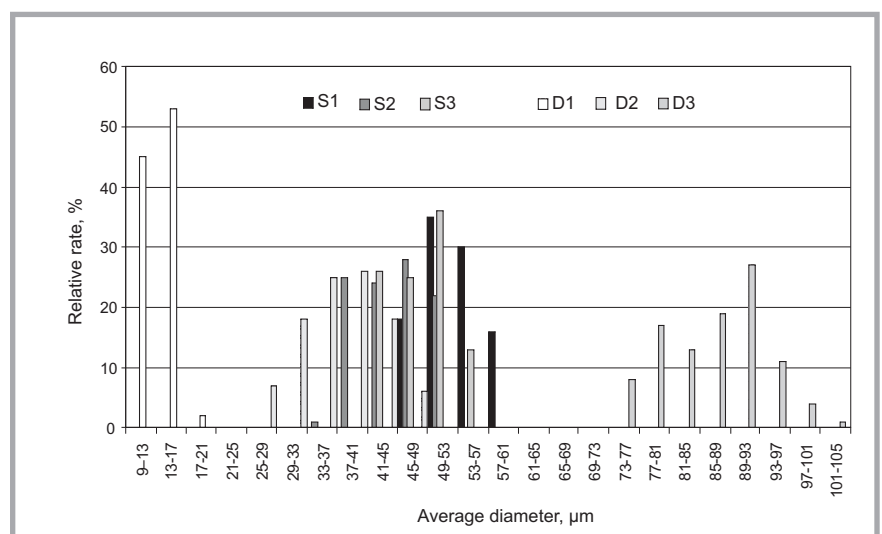
Fibre symbol	Diameter, $\mu\text{m}$		Difference, %
	Microscope Biolan R1	Microscope SEM	
S1	52.71	48.28	8.40
S2	44.97	41.15	8.49
S3	48.50	44.68	7.88
D1	13.50	13.69	1.39
D2	86.79	80.93	6.75
D3	36.90	39.46	6.49

in this investigation there is no rule for the different kinds of sheep's wool and dog's hair fibres, nor can it be said that longer fibre is always thinner too. The last group only confirmed that the length in this group is almost uniform (difference 2%); however, the diameter of fibre D2 is thinner than that of S3 by 46%. The same tendencies are estimated by evaluating the linear density of fibres. For example, fibres S1 and D3 are in the same length group, but the linear density of fibre S1 exceeds that of fibre D3 by 61%. Moreover the value of the linear density of fibre S2 is approximately 10 times bigger than that of fibre D1, when these fibres are in the minimal length group.

The average diameter values experimentally obtained (with optical microscope

Biolan R1 and scanning electron microscope SEM) were compared with each other (see **Table 2**). It can be seen from **Table 2** that the difference between the average values of the diameter of fibre obtained with the different microscopes is 1 - 8%, which may be influenced by the different number of measurements in these experiments. The comparative investigation of the estimation of the fibre diameter shows that measurement with the microscope Biolan R1 is right.

It is known that there is the possibility of calculating a theoretical value of the fibre linear density [16, 17]. In this investigation the values of linear density obtained were compared with that determined by formula [16]:



**Figure 3.** Histogram of fibre diameter distribution investigated.



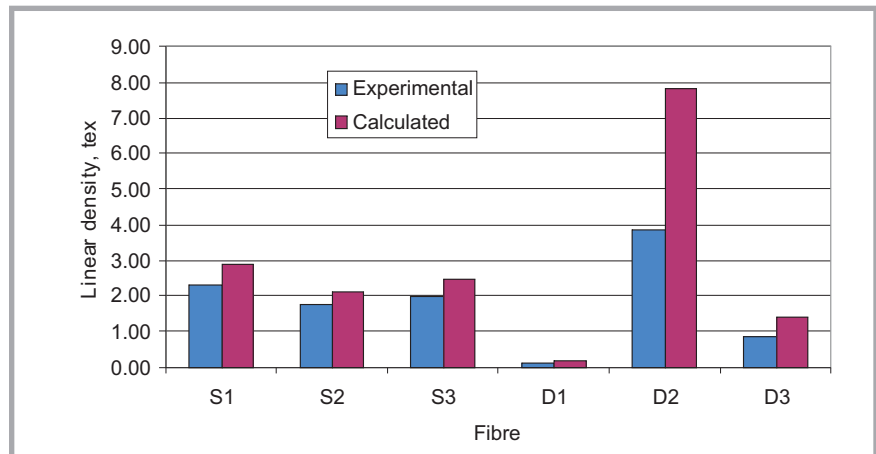
$$T = \frac{\pi}{4} \times d^2 \times \rho \times 10^{-3} \quad (4)$$

where:  $d$  – fibre diameter in  $\mu\text{m}$ ;  $\rho$  – fibre density (1.32  $\text{g}/\text{cm}^2$ ).

Comparison of the average value of the linear density of sheep's wool and dog's hair fibre, established by the different ways is presented in **Figure 4**. It can be seen from **Figure 4** that the difference between the experimental and calculated value of the linear density of sheep's wool is 17 - 19% and that of dog's hair – 31 - 50%. Average values of the dog hair linear density calculated are approximately two times higher than the experimental values. Formula (4) highlights the fact that the real diameter of all the fibres is not a correct round figure. It can be seen from **Figure 1** that the fibres researched are of an irregular round form. Also in formula (4) are unconsidered channels and air gaps [17], which were found in every dog hair cross-section. It should also be emphasised that the fibre linear density was established using the fibre bundle, not fibre alone. Thus there are some reasons for these differences in the experimental and calculated value of linear density.

The minimal (min) and maximal (max) breaking force, breaking tenacity, elongation at break, work of break and breaking toughness values, the average values, coefficient of variation and standard deviation (S) of every fibre are presented in **Table 3**.

It can be seen from **Table 3** that among all the dog's fibres, D1 has the maximal tenacity value and minimal value of diameter and length. The same results were estimated with fibre S2 for the sheep fibres. Hence it was established that the breaking tenacity of almost all fibres investigated directly relates to the length of the fibre: D1 and S2 belong to the same length group, have a minimal length (57 - 62 mm) and have the maximal breaking tenacity (30 - 160  $\text{cN}/\text{tex}$ ); the other fibres D2, S3, S1 and D3 have midi and mini values of the geometrical indices investigated, and the breaking tenacity of these fibres has midi and mini values too. The same tendencies were obtained in the investigation of the breaking toughness and elongation at break. This index is the maximum value of the shortest fibre of sheep's wool S2. The exception is the shortest fibre of dog's hair - D1, belonging to the minimal length



**Figure 4.** Comparison of experimental and calculated average values of the linear density of fibres investigated.

group, with their elongation at break also being minimal. The reason for this may lie in the really small diameter of this fibre (13.5  $\mu\text{m}$ ). Similar values of the diameter, length, linear density and elongation at break of Alpaca wool fibre were established in literature [16].

**Figures 5** and **6** present average values of the breaking tenacity and elongation at break and absolute random error of fibres S1, S2, S3, D1, D2 and D3.

It was estimated that fibre D1 has the biggest tenacity (160.85  $\text{cN}/\text{tex}$ ) among the dog fibres and S2 (30.10  $\text{cN}/\text{tex}$ ) among the sheep fibres. Also D2 has the

lowest tenacity among the dog fibres (20.12  $\text{cN}/\text{tex}$ ) and S1 – among the sheep fibres (11.52  $\text{cN}/\text{tex}$ ). **Figure 6** show that fibre D1 has the minimal value of elongation at break (35.32%) among all the fibres. This fibre is also the shortest of all the fibres. This index is the maximum value of sheep's wool fibre S2 (60.04%).

After all tests it was observed that dog's hair has good geometrical and strength properties. These fibres are flexible, robust and strong. Channels were found in the dog's hair cross-section. A similar structure is mostly responsible for the high thermal quality of alpaca wool [16]. Thus dog fibres are very warm too.

**Table 3.** Mechanical indices of sheep's wool and dog's hair investigated.

Fibre symbol	S1	S2	S3	D1	D2	D3	
Breaking force, cN	Min and max value, cN	16.48 - 36.84	29.39 - 67.27	22.09 - 39.95	13.01 - 29.59	50.72 - 102.80	12.65 - 26.75
	$\bar{x}$ , cN	26.84	52.38	30.12	20.91	77.45	19.19
	V, %	21.53	18.01	14.27	19.82	16.69	18.45
	S, cN	5.78	9.43	4.29	4.14	12.93	3.54
Breaking tenacity, cN/tex	Min and max value, cN/tex	7.07 - 15.81	16.89 - 38.66	11.27 - 20.38	100.08 - 227.62	13.17 - 26.70	14.06 - 29.72
	$\bar{x}$ , cN/tex	11.52	30.10	15.37	160.85	20.12	21.32
	V, %	21.53	18.01	14.27	19.83	16.69	18.45
	S, cN/tex	2.48	5.42	2.19	31.85	3.36	3.93
Elongation at break, %	Min and max value, %	19.74 - 55.21	41.05 - 89.05	25.01 - 60.00	15.49 - 58.10	40.28 - 69.86	30.50 - 52.11
	$\bar{x}$ , %	38.66	60.04	42.52	35.32	50.81	40.92
	V, %	19.65	16.88	17.03	27.93	12.68	10.05
	S, %	7.60	10.13	7.24	9.86	6.44	4.11
Work of breaking, kJ	Min and max value, kJ	0.51 - 2.99	2.21 - 6.66	0.12 - 3.25	0.31 - 2.04	3.21 - 7.76	0.49 - 2.10
	$\bar{x}$ , kJ	1.47	4.16	1.77	0.97	5.32	1.02
	V, %	32.71	25.09	22.47	35.01	21.78	25.30
	S, kJ	0.48	1.04	0.40	0.34	1.16	0.26
Breaking toughness, kJ/tex	Min and max value, kJ/tex	0.22 - 1.28	1.27 - 3.83	0.06 - 1.66	2.38 - 15.69	0.83 - 2.02	0.54 - 2.33
	$\bar{x}$ , kJ/tex	0.63	2.39	0.90	7.46	1.38	1.13
	V, %	32.71	25.09	22.47	35.01	21.78	25.30
	S, kJ/tex	0.21	0.60	0.20	2.62	0.30	0.29

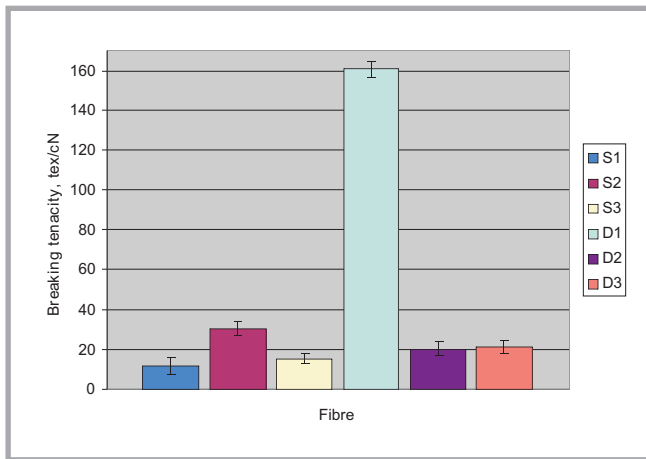


Figure 5. Statistical indicators of breaking tenacity of fibres investigated.

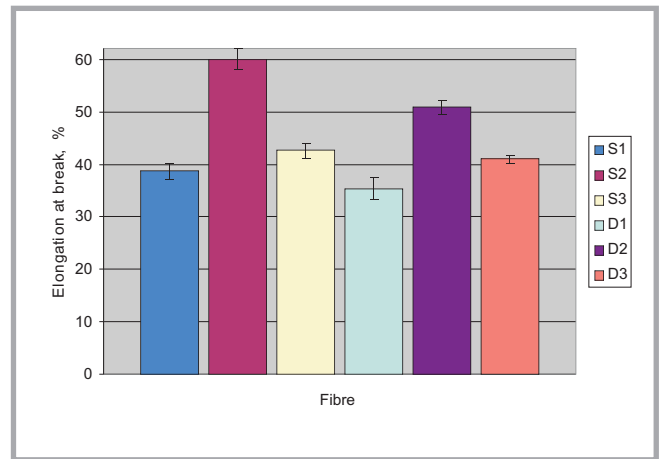


Figure 6. Statistical indicators of elongation at break of fibres investigated.

Because of this unique feature, not only woolen yarn from sheep's wool but also dog's hair can be used, even with a better effect, in special clothing articles. For example, in socks for people with poor blood circulation, in the inserts of maid's slippers and shoes, in caps, scarves, sleeves and coats, as a result of which these goods would not freeze even in the coldest winter. Also they can be used in household products and accessories (mini mats for a child's room, inserts for children's wheelchairs, heat-trapping containers, baby carriers for winter walks) and in natural medicine (knee pads, wrist and elbow bands for people suffering from rheumatic diseases, warm running back belts and corsets, collars for neck pain and incessant angina). In the next step of this research it is planned to investigate the thermal resistance of knitted fabrics made from the woolen yarns researched herein.

## Conclusions

- It was estimated that sheep and dog fibres are visually very different and the diameter of these fibres vary from 13.5  $\mu\text{m}$  to 86.7  $\mu\text{m}$ , the length 57.4 - 105.9 mm and the linear density - 0.13 - 3.85 tex.
- All fibres investigated have scales on their surface, but the scale shape and distribution on the dog fibre surface are different from those the sheep fibre surface. The cross-section of all fibres researched is round, but all dog's hair fibres have channels inside them. It was estimated that the value of the channel diameter depend on the value of the fibre diameter, with thicker fibre having the biggest channel.

- It was established that the geometrical indices of the fibres influence their mechanical indices. The tenacity, elongation at break and toughness of the fibre depend on the length thereof, with minimal length fibres having maximal values of these indices, except the elongation at break of dog fibre D1.
- It was estimated that the tenacity of sheep and dog fibres vary from 11.52 cN/tex to 160.85 cN/tex, their elongation at break - 35.32 - 60.04%, and the toughness - 0.63 - 7.46 kJ/tex.
- Woolen yarns from sheep and dog fibre are very warm and can be used in special clothing articles, household products and in natural medicine.

## References

1. Shakyawar DB, Patni PC, Gupta NP. Studies of animal fibre blended hand-made felts: Part II - Frictional, compressional and thermal properties. *Indian Journal of Fibre & Textile Research* 2007; 15, 1(32): 301-305.
2. Reis PJ, Sahlh T. The nutritional control of the growth and properties of mohair and wool fibers: a comparative review. *Journal of Animal Science* 1994; 72: 1899-1907.
3. Oi K, Lupton CJ, Pfeiffer FA, Minikhiem DL. Evaluation of the optical fibre diameter analyser (OFDA) for measuring fiber diameter parameters of sheep and goats. *Journal of Animal Science* 1994; 72: 1675-1679.
4. Wang X. Predicting the Strength Variation of Wool from Diameter Variation. *Textile Research Journal* 2000; 70; 3: 191-194.
5. Stobart RH, Russell WC, Larsen SA, Johnson CL, Kinnison JL. Sources of variation in wool fiber diameter. *Journal of Animal Science* 1986; 62: 1181-1186.
6. Čepaitienė A. *Ethnology of Lithuania* (in Lithuanian). Vilnius: Publishing Diemedis, 2001.
7. Bohuslav N, Dipayan D. Mechanics of Parallel Fibre Bundles. *Fibres & Textile in Eastern Europe* 2006; 14, 3(57): 23-28.
8. Primacenko BM, Privalov SF, Agamov FC. Analysis of technical purpose wool blend composition for condenser spinning (in Russian). *Tekstilnaja promyshlennostj* 2002; 12: 34-36.
9. Ning P, Tao H, Ylping Q. Relation Between Fiber and Yarn Strength. *Textile Research Journal* 2001; 71; 11: 960-964.
10. Kukcinavičiūtė J, Jonaitienė V, Abromavičius R. Influence of Roving on Semi-wool and Wool Yarn Quality. In: *Magic World of Textile Conference, 2007*, pp. 35-38.
11. ASTM Designation: D 1294-95a. Standard Test Method for Tensile Strength and Breaking Tenacity of Wool Fiber Bundles 1-in. (25.4-mm) Gage Length.
12. International standard ISO 920:1976. Wool - Determination of fibre length (barbe and hauteur) using a comb sviter.
13. International standard ISO 137:1975. Wool - Determination of fibre diameter - Projection microscope method.
14. International standard ISO 5079:1995. Textiles-Fibres-Determination of breaking force and elongation at break of individual fibres.
15. International standard ISO 139:2005. Textiles-Standard atmospheres for conditioning and testing.
16. Czaplicki Z. Properties and Structure of Polish Alpaca Wool. *Fibres & Textile in Eastern Europe* 2012; 20; 1(90): 8-12.
17. Matukonis A, Palaima J, Vitkauskas A. *Material Science* (in Lithuanian). Vilnius: Mokslas, 1989.

Received 02.11.2011 Reviewed 04.04.2012