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Studies of the Effects of Chemical Treatment on Bending and Torsional Rigidity of Bast Fibres

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In the presented work the influence of chemical treatment on bending and torsional rigidity of flax and hemp fibres was studied. The morphological properties, bending and torsional rigidity of bast fibres before and after chemical treatment were investigated. Method of double pendulum for determination of fibre bending rigidity and method of torsional pendulum for determination of fibre torsional rigidity were adapted to the investigation of bast fibre rigidities. During the investigations the mean periods of pendulum vibration in bending (T_g) and in torsion (T_t) were measured. On the basis of these periods the mean bending and torsional rigidities were calculated as well as coefficients of variation of the periods. It was shown that the adapted methods are useful for bast fibre rigidities investigations and that the applied chemical treatment lead to decreasing of bending and torsional rigidities of the studied fibres.

Keywords: flax, hemp, bast fibres, bending rigidity, torsional rigidity, double pendulum, chemical treatment.

1. INTRODUCTION

Among all natural fibres, bast fibres have such usable and esthetic properties that make them a material with a very wide range of applications. In recent years it has been proved that bast fibres are characterized by barrier properties to electromagnetic radiation [1 – 3], which makes them possible to be used for production of textiles substituting metal screens in some cases.

Before they are further processed, bast fibres are subjected to preliminary processing. That consists of mechanical and chemical cleaning and separating of fibres. In the course of the processing, both morphological and physical-mechanical properties of fibres change. Therefore it is necessary to control the most important fibre properties, such as their strength and rigidity. Lower values of bending rigidity and torsional rigidity of fibres are decisive for their susceptibility to yarn forming and are important parameters characterizing the fibres [4].

The aim of this work was to study the influence of chemical treatment on bending rigidity and torsional rigidity of bast fibres. Morphological properties of fibres are also to be controlled. A number of methods have been proposed to study bending rigidity of fibres [5 – 11]. Accuracy of some of them is out of date, not all the methods can be applied for studying individual bast fibres. Therefore in this work a method of studying bending rigidity of bast fibres was developed based on the method of the Searle's double pendulum [12], a well-known method of the torsional pendulum [4, 13] for studying the torsional rigidity of fibres was modified as well.

2. THE MATERIALS STUDIED

The studied object were raw loose bast fibres, of natural color and different content of impurities. The fibres origination were flax and hemp, grown in the region of Lublin, Poland. The cottonized flax fibre was obtained from 50 % tow and 50 % noils, while cottonized hemp fibre was obtained from 100 % hemp noils. Two types of flax fibres and two types of hemp fibres were studied, differing in the mechanical preparation and coded respectively: flax fibres – L1 and L2, and hemp fibres – K1 and K2.

Some fibre samples were tested raw (as received) while the others were subjected to the enzymatic treatment. The procedure of the treatment was selected on the basis of the published studies [14-17]. It consisted of boiling in alkaline and enzymatic environment followed by bleaching with enzymes.

3. EXPERIMENTAL METHODS

Bast fibre length studies are carried out basing on methods given in the Polish standard BN-86/7511-16. From a general sample, thoroughly mixed, single fibres are taken to compose a sample of about 10 g. From this sample three samples of about 0.75 g are further taken from various places and acclimatized according to the international standard ISO 139.

A measuring-calculating method of single fibres is used. From the fibre sample single fibres are taken out, then they are measured and arranged into the length classes. In the case of raw bast fibres the class range was 50 mm, and for fibres subjected to enzymatic treatment it was 10 mm. After measuring and arranging of all fibres they are acclimatized and groups of fibres from each class are successively weighed on a torsion balance with the accuracy of 0.01 g, writing down the mass of all the fibres included into the specified length class. Finally the percentage fibre mass content at the length classes and the mass-biased mean length of the fibre is calculated.

Linear density of bast fibres is measured on the basis of methods given in the Polish standard BN-86/7511-16. From the fibres of each length class, segments of 10 mm length are cut out with a special knife of two edges. After mixing of these segments 10 samples of 100 fibres each

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are formed. All single fibres or fibres split less than to the half of their length are considered to be one fibre. Each splitting longer than 5 mm is treated as two fibres. Further the samples are weighed on a torsion balance with accuracy of 1 % of the weighed mass and then linear density of the fibre is calculated as a ratio of summary fibre mass to summary fibre length.

The method of Searle's double pendulum [12] was taken as a basis for measurements of the bending rigidity of bast fibres. Figure 1 presents a diagram of the measuring instrument used for the fibres of linear densities 1 – 6 den [12].

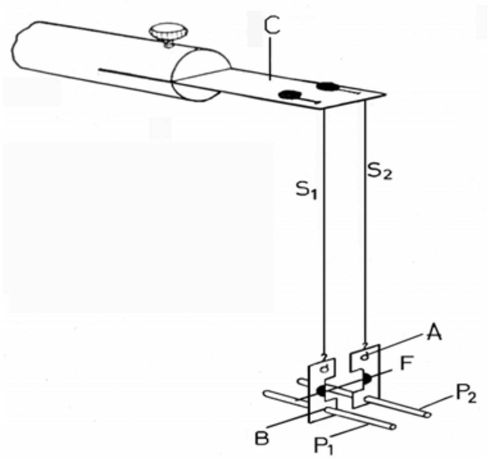

Fig. 1. Scheme of the instrument for measuring bending rigidity of fibres (drawing from [12])

The scheme shows a pair of pendulums P_1 and P_2. Each pendulum is a metal rod of diameter 0.70 mm and length 14 mm. The rod in a hole B is attached to a metal plate of special shape and thickness 0.005 or 0.010 inch [12]. The shape of the plates is chosen in such a way that the top hole in the plate that the pendulum is attached to, the bottom hole that the rod goes through, the inner edge of the plate and the centre of gravity of the plates are all on the vertical axis.

In the instrument described in [12] the pendulums used were made of an alloy of phosphorus and bronze, of mass about 0.065 g and moment of inertia 7.75 10^{-10} kg×m^2. Identical moments of inertia of both pendulums ensure that the measuring error does not exceed 5 % of the measured value. The pendulums are hung on the block plate C by the filaments S_1 and S_2 of 20 cm length. At the bottom ends the filaments have little hooks by which the pendulums are hung in holes A. In plate C the filaments are drawn through small holes 5 mm apart and the ends are fixed with wax to the surface of the plate. The fibre specimen (F) of 5 mm length is glued to the surface of the plates as shown in Fig. 1, so the spacing of the filaments S_1 and S_2 along the whole length is the same (5 mm).

The essence of the measurement is in activating the transverse vibration of the fibre-pendulum system. The registered period of vibration depends on fibre bending rigidity (C_g), which is calculated by the following formula [12]:

$$C_g = \frac{2\pi^2 J_p L}{T_g^2}, \qquad (1)$$

where J_p is a moment of inertia of one pendulum, kg×m^2; L is the length of fibre specimen, m, T_g is the mean period of vibration of the fibre-pendulum system, s.

Bast fibres due to their natural structure are characterized by much higher rigidity than the filaments formerly studied [12] by means of the instrument described above. Therefore, adapting the instrument for studies of bast fibres, we introduced the following changes into the parameters of the pendulums and of the whole vibrating system:

- the length of filaments S_1 and S_2 was increased to 60 cm;
- the aluminum pendulums were used of mass 0.114 g, having the moment of inertia $8.55 \cdot 10^{-9}$ kg×m^2;
- the spacing of filaments was increased from 5 mm to 30 mm;
- the length of the fibre specimen was also increased from 5 mm to 30 mm in accordance with the distance between the pendulums.

A special template consisting of a brass block with two holes and two pins for a pair of pendulums was designed. Using this template it is much easier to mount the fibre specimen on the pendulum plates and to transfer the pendulums with the fibre attached to them from the template to the hooks. A special grip was also made in which the ends of pendulums are fastened and transferred to the hooks. The fibre is fastened on the pendulum plates by means of glue based on poly(vinyl alcohol), soluble in water. Glue drops should be small, not to have any influence on the measurement results.

Since the distance between the pendulums is larger, that is caused by high bending rigidity of the fibres, only fibres longer than 30 mm were studied.

To determine torsional rigidity of the fibres a method of torsional pendulum is applied, adapted for the purposes of this work. A torsional pendulum consists of a weight at the end of a flexible pull rod. which can be substituted by the fibre specimen. One of the axes of the weight overlapped the longitudinal axis of the pull rod. With twisting of the weight by a small angle and then immediate removal of the torsional action, torsional vibrations appear in the system. The registered period of torsional vibration T_t depends on the moment of inertia J of the weight and on the torsional rigidity C_t of the pull rod that the weight is hung on. Substituting the pull rod with the fibre specimen the torsional rigidity of the fibre can be obtained using the formula [4]:

$$C_t = \frac{4\pi^2 J}{T_t^2}. \qquad (2)$$

Determination of the period of vibration in this method is the point where difficulties appear. In order to make the testing easier and to increase the accuracy of measurement, certain changes were introduced to the traditional method. The way of activating torsional vibrations of the system was modified. A table was built into the measuring instrument, which can be lifted to a necessary height at twisting the fibre-weight system. After twisting of the fibre with the weight by 360° angle of torsion, the table quickly goes down and at the same moment the measurement begins. On the surface of the table and of the weight there are parting lines that should overlap before the measurement is started.

Fibre specimens were placed in the instrument by means of paper frames in which the fibres were fastened with glue. Such specimens were placed in the instrument, loaded with a weight in the bottom part and only in the final stage the paper frames were cut out. Measurement of the period of vibration by chronographs was also eliminated. The whole test was recorded by a video camera, which made it possible to read off and determine periods of vibration of pendulum T_t in the off-line mode.

Bast fibres before the chemical treatment had a big content of very short fibers, so only the fibres longer than 50 mm were selected for the measurements of torsional rigidity.

4. RESULTS AND DISCUSSION

The results of studies concerning morphological, mechanical and physical features of bast fibres before and after chemical treatment are presented below both in numerical form (Table 1) and graphically (Fig. 2 and Fig. 3). Results concerning fibres before treatment are marked with letter N and after treatment – with letter O.

Table 1. The measured quantities for the flax and hemp fibres before and after chemical treatment

Fibre		Parameters				Coefficients of variation, %		
		L, mm	Tt, dtex	T_g, s	T_t, s	for Tt	for T_g	for T_t
L1	N	107.8	41.0	5.19	6.74	39	31	61
	O	63.7	30.0	6.99	9.34	61	31	40
L2	N	38.3	36.5	6.25	7.54	15	26	59
	O	32.0	31.2	7.48	7.64	30	35	39
K1	N	57.0	60.0	3.73	7.28	16	26	45
	O	73.0	41.4	5.40	7.67	31	28	59
K2	N	37.8	41.0	5.55	5.85	27	32	49
	O	55.7	34.2	8.83	7.66	27	36	59

The results presented in Table 1 indicate that bast fibres both before and after chemical treatment are characterized by diversified length. Before treatment the fibres L1 are the longest, and the fibres K2 are the shortest. After the chemical treatment length of the fibres changed considerably. The flax fibres subjected to enzymatic treatment are shorter than before the treatment. The effect is concerned with the fact that before chemical treatment flax fibres had proportional distribution of fibres in the first two length classes (0 – 50) mm and (50 – 100) mm. Due to chemical treatment some fibres from higher length classes shortened and so became found in a lower classes now. Therefore, the mass-biased mean length of flax fibres decreased after treatment. In the case of hemp fibres the effect of chemical treatment was opposite – the fibres are longer than before the treatment. Since the source material of hemp fibres were 100 % noils, the fibres before chemical treatment had over 50 % of them in the shortest length class (0 – 50) mm. Due to chemical treatment all fibres shortened. The shortest fibres were destroyed and as the result the mass-biased mean length of hemp fibres increased after the treatment. The change in the fibre lengths is directly concerned with the shortening effect that chemical treatment has on fibres and also with the form of the source material used for production of cottonized bast fibres.

As it is seen, before the treatment the hemp fibres are much coarser than flax fibres, the coarsest are fibres K1, while the finest are fibres L2. After the treatment all the fibres became finer, nevertheless, the fibres K1 remained the coarsest, and the fibres L1 – the finest. Mostly the linear density decreased for fibre K1, i.e. by 31 %. Linear density of fibres L2 decreased least, i.e. by 14.5 %.

Concerning the bast fibre rigidities the mean periods of pendulums vibration in bending (T_g) and in torsion (T_t) on whose basis the mean bending and torsional rigidities were calculated as well as coefficients of variation of the periods are shown in Table 1. In the investigations of fibre rigidities in each case 30 singular periods were measured. Mean bending rigidities of the fibres are shown in Fig. 2, and mean torsional rigidities in Fig. 3.

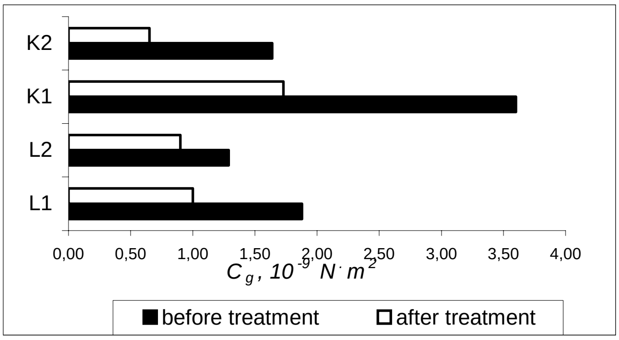

Fig. 2. Bending rigidity of bast fibres before and after chemical treatment

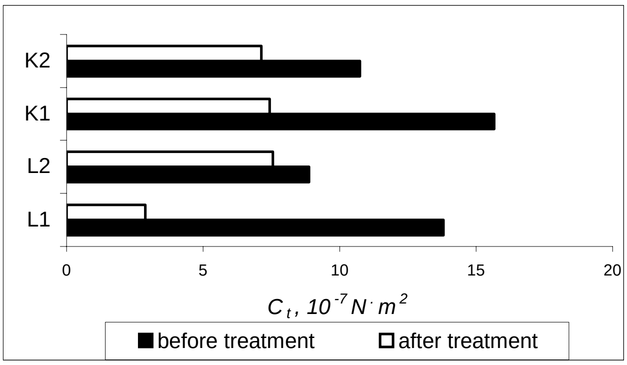

Fig. 3. Torsional rigidity of bast fibres before and after chemical treatment

In values of torsional rigidities the length of investigated samples is taken into account.

From the data in Table 1, in Fig. 2 and Fig. 3 it is evidently seen that the coarsest fibres are also the most rigid. Before chemical treatment the flax fibre L2 had the lowest bending rigidity, whereas the hemp fibre K1 the highest. After chemical treatment the bending rigidity of fibres decreased even more than twice with the only exception for fibre L2, bending rigidity of which decreased approximately by 30 %. The remark should be made that in result of chemical treatment the finer hemp fibre K2 became even less rigid than flax fibres. Quite similar situation is seen for the results of the influence of chemical treatment on bast fibre torsional rigidity. The smallest decrease of torsional rigidity occurred for L2 fibres. After chemical treatment the hemp fibres became almost so low rigid in torsion as the flax fibre L2.

5. CONCLUSIONS

Method of double pendulum for determination of fibre bending rigidity and method of torsional pendulum for determination of fibre torsional rigidity are adapted to the investigation of bast fibre rigidity. The studies of bending and torsional rigidities of flax and hemp fibres before and after chemical treatment are performed. Bast fibres, due to their specific structure, are characterized by high values of bending and torsional rigidity. The purpose of their chemical treatment is to decrease markedly the fibre rigidity to improve the processability of bast fibres. The obtained results indicate that chemical treatment considerably decreases bending and torsional rigidity of flax and hemp fibres.

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