HEMP FIBER AND SHIVE COEFFICIENT OF FRICTION

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Abstract. In recent years, there is a growing interest for the use of natural materials in composite applications, where cellulose materials are reinforced in foam gypsum matrix. As the result it is environmentally friendly low density building material, which can show high tensile and compressive strength, good heat and sound insulation properties. Hemp fibres are natural fibres and their properties vary according to the plant growing regional climatic conditions, fertilizers, plant density, harvesting time and pre-treatment technological processes. To use hemp fibre for gypsum reinforcement, it should be cut in the definite length of particles. As the result of the previous research a fibre cutting method with a rotating knife and soft material support was developed and patented. The shapes of the cutting knives and counter knives were designed. Theoretical research of the cutting process shoved that friction of the material has significant impact on the cutting energy. This paper summarizes the hemp fiber and shive coefficient of friction experiments. The coefficient of friction values were determined on four varieties of hemp fibers and shives. A significant difference between the coefficient of friction for different hemp variety fibers was not observed. The dry fiber coefficient of friction against steel was average 0.13, but for wet fibers it increased to 0.59.

Keywords: hemp fibre, foam gypsum, friction.

Introduction

Hemp fibres are used in a wide range of products, including fabrics and textiles, yarns and raw or processed spun fibres, paper, carpeting, home furnishings, construction and insulation materials, auto parts, and composites. In recent years, there is a growing interest for the use of natural materials in composite applications, where cellulose materials are reinforced in gypsum matrix. As a result it is environmentally friendly low density building material, which can show high tensile and compressive strength, good heat and sound insulation properties. Foam gypsum is produced using gyps cohesive substance, manufacturing of which is environmentally friendly and energy efficient [1]. A new energy saving composite building material – foam gypsum with fibrous hemp reinforcement is investigated at the Latvia University of Agriculture [2]. The foam gypsum was produced using the dry mineralization method mixing water, gypsum, surface active stuff (SAS), and adding hemp reinforcement. The fibre particle length used for foam gypsum reinforcement varies between 5 and 20mm. Hemp fibres are natural fibres and their properties vary according to the plant growing regional climatic conditions, fertilizers, plant density, harvesting time and pre-treatment technological processes. To use hemp fibre of foam gypsum reinforcement, it should be cut in the definite length of particles. The shapes of the cutting knives and counter knives were designed. Specific cutting energy was used as the main evaluation parameter. The experimentally obtained values for the mentioned hemp varieties of cutting properties and energy consumption using different cutting methods would be used for the fibre cutter mechanism design.

The main hypothesis for the cutter design is that the cutting method has to be used with minimum of energy consumption by reducing the frictional forces to a minimum. In the result of the research a fiber cutting method with a rotating knife and soft material support was developed and patented, Fig. 1 [3]. Fiber is compressed between the rotary knife blade and the soft material support. When the compressive stresses exceed the fiber rupture stresses, the material is being cut [4].

To determine the factors that affect the cutting energy, a theoretical model for cutting was worked out [5]. It was stated that the cutting energy depends on:

- knife-edge radius,
- blade side friction force F_{fs}.

The cutting energy strongly depends on the knife-edge radius, if the $r \to 0$, then the cutting energy $E_{cut} \to 0$. In practice, the radius of the knife blade is fixed and it will increase the blade wear down. In this case, there is increase of the friction effect and the cutting energy increases. It can be concluded that the friction coefficient has an important role in cutting energy reduction.

The friction force energy depends on the knife-edge angle and material properties. Cutting hard materials it is closely pressed against the knife blade and forms large friction force, Fig. 2a. Cutting fibrous material, it becomes convex, and the friction force does not raise, Fig. 2b.

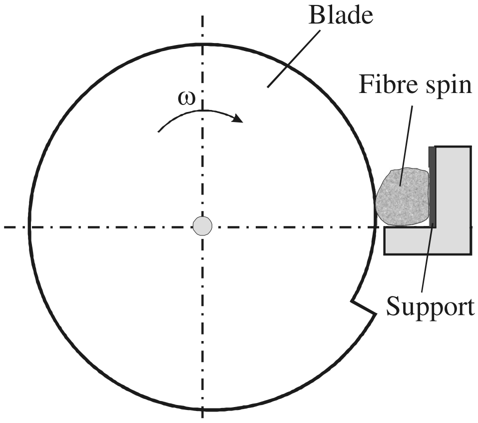

Fig. 1. **Fibre cutter with rotating knife**

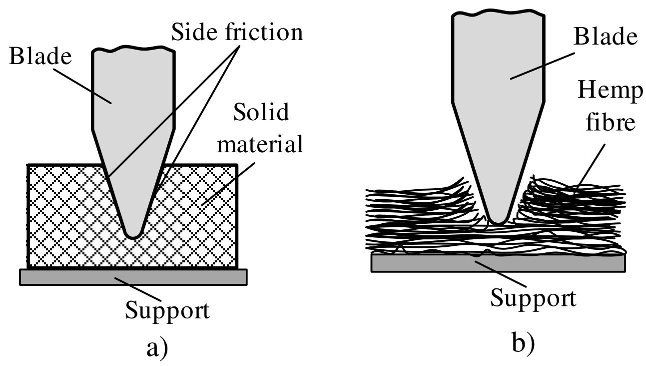

Fig. 2. **Cutting process:**
a – solid material cutting, b – fibre cutting

The blade side friction force F_{fs} can be calculated according to equation 1 [5]:

$$F_{fs} = \sigma_b \cdot \frac{h}{\cos\alpha} \cdot l \cdot f \ , \tag{1}$$

where σ_b – rupture stress of the material;
l – thickness of the material to be cut;
h – depth of the blade in the material;
α – angle of the knife-edge;
f – coefficient of the friction.

Equation 1 describes the maximum frictional force that occurs when the material during the cutting process strongly presses against the blade (Fig. 2, a). Previously performed cutting experiments showed that cutting large cross-section of hemp straw the blade lateral friction forces become very large and cause the blade jamming. This suggests that the stalks tightly press against the side of the blade and the friction stresses are approaching the fracture stress value.

Materials and methods

The study was carried out at the Institute of Mechanics, Faculty of Engineering. Four hemp varieties were tested, produced in 2011 and 2012. To obtain fibre, air dried hemp plants were manually processed using laboratory-scale equipment. Firstly, the hemp plants were passed through a breaker to crash the stems. Then fibres were separated from the cores with a scotching machine consisting of a wooden blade and board. Finally, the fibre filaments with small core particles were obtained. The fibre filaments were cut into particles approximately 40 mm length and then used as the samples for friction tests.

Friction is the resistance which one body offers to the motion of the second body when the latter slides over the former. The friction force F_b is tangent to the surfaces of contact of the two bodies and always opposes the motion (Fig. 3).

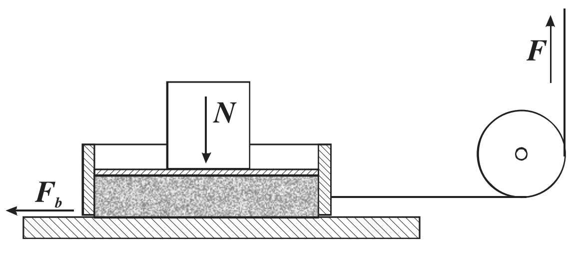

Fig. 3. **Experimental design of friction force measuring:** N – normal force, F – horizontal force equal to the friction force F_b

The friction force can be determined by measuring the pulling force. The pulling force F is equal to the force of friction F_b.

The static coefficient of friction f for any two surfaces is the ratio of the limiting friction to the corresponding normal pressure force:

$$f = \frac{F_b}{N}, \tag{2}$$

where F_b – maximum friction of impending motion;
N – normal pressure force.

When two surfaces move relative to each other, the ratio of the friction force developed to the normal pressure force is called the dynamic coefficient of friction [6].

The coefficient of friction is investigated by moving the hemp fiber or the chopped stalks against the blade material on the horizontal surface (Fig. 3). The horizontal speed was controlled up to 800 mm·min^{-1} by the Zwick testing machine (Fig. 4). The pulling force is measured using Zwick software.

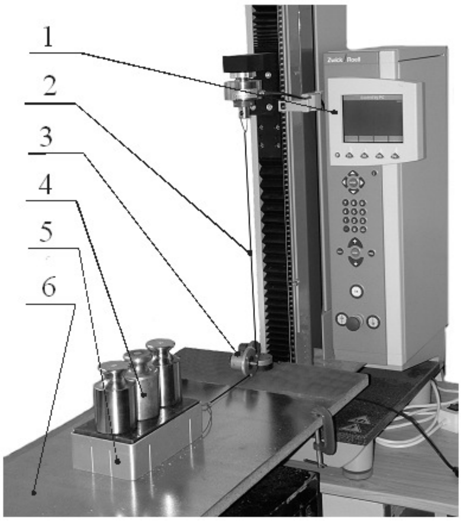

Fig. 4. **Experimental setup:** 1 – Zwick testing machine; 2 – cable; 3 – spool; 4 – weights; 5 – box; 6 – surface plate

The box filled with biomass is moved with several speeds: 1 mm·min^{-1} to obtain the static coefficient of friction and 800 mm·min^{-1} to obtain the dynamic coefficient of friction. As a result of the experiment friction curves for different hemp varieties were obtained. The friction force curves for dry hemp fiber to the knife steel are shown in Figure 2, but for moist fiber and wet steel surface in Figure 6.

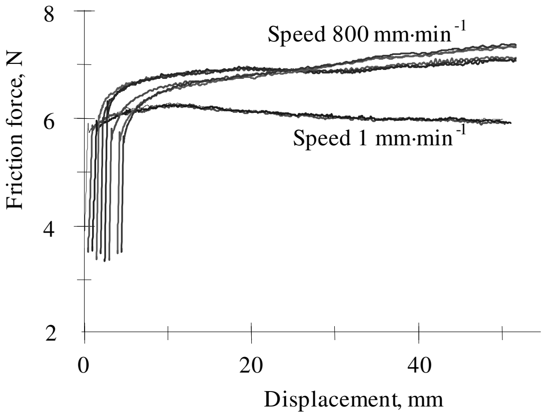

Fig. 5. **Frictional force for dry fibers (Futura) on dry surface**

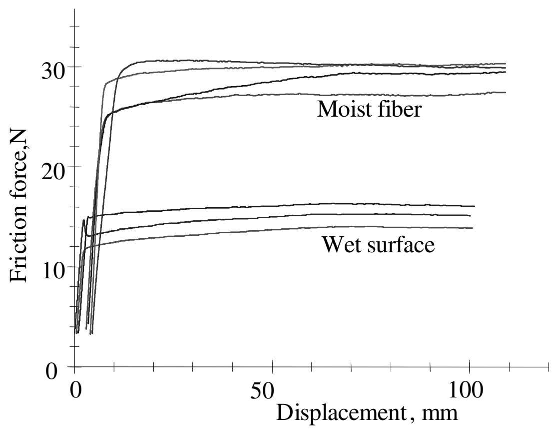

Fig. 6. **Frictional force for moist fibers on dry surface and dry fibers on wet surface**

In order to ensure sufficient accuracy, with every variety of hemp 10 repetitions were made. Considering that the predicted frictional force is less than 30 N, the Zwick testing machine was equipped with a load cell with measuring range 50 N.

Results and discussion

The experiments were performed with two-year hemp yields. Figure 7 shows the static friction coefficient variation for two cannabis varieties, depending on the vintage year. The variety Futura friction coefficient variation between the years is 8 %, but for the variety Tygra 4 %.

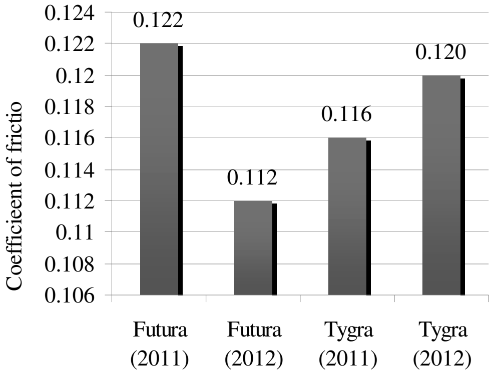

Fig. 7. **Coefficient of friction for dry fibers, speed 1 mm·min^{-1}**

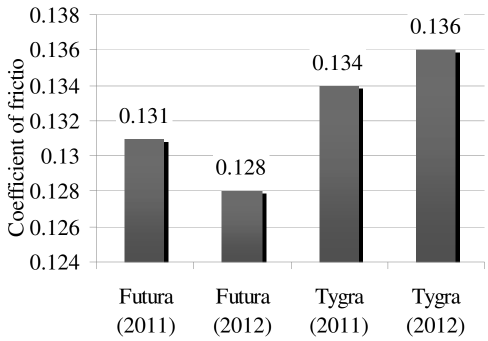

Fig. 8. **Coefficient of friction for dry fibers, speed 800 mm·min^{-1}**

A similar situation was observed in the dynamic friction coefficient variation between the harvesting years, Fig 8. Analysis of the experimental results showed that the friction coefficient variation in different harvest years did not exceed 10 %.

The average static and dynamic coefficients of the friction values were calculated for each hemp variety (Fig. 9).

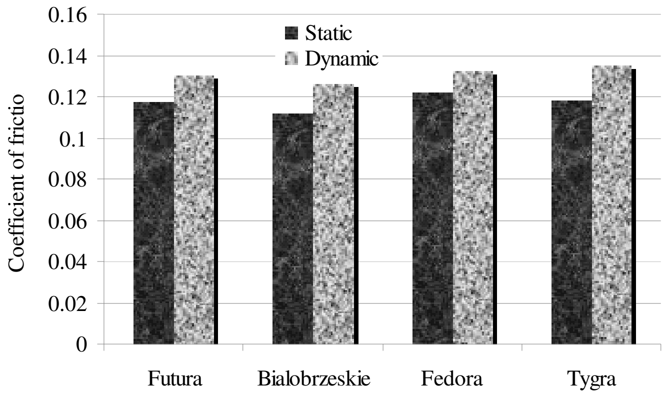

Fig. 9. **Average coefficient of friction for dry fibers, speed 800 mm·min^{-1}**

It was stated that the friction coefficient variation between different varieties of hemp is less than 8.2 % (static) and 6.7 % (dynamic). Average dynamic coefficient of friction for all hemp varieties lies between 0.126 and 0.135. It means that for practical calculations average coefficient of friction can be used. Average dynamic coefficient of friction for dry hemp fiber is 0.131 ± 0.004 (Fig. 10).

To determine the influence of humidity on the fiber coefficient of friction experiments were made to wet the steel surface and dry fiber. The result was a significant increase in the coefficient of friction, it reached an average of 0.236 ± 0.005 (Fig. 10).

Series of experiments were carried out with wet hemp fibers. The samples were impregnated by soaking for 5 seconds in cold water. The samples were removed from the water and the coefficient of friction measured against the dry steel surface. A significant increase in the coefficient of friction was stated. Average dynamic coefficient of friction for wet hemp fiber reaches 0.590 ± 0.005.

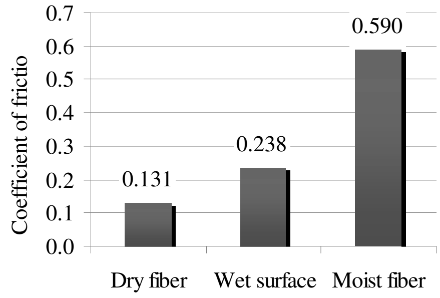

Fig. 10. **Average coefficient of friction for fibers, speed 800 mm·min^{-1}**

Dry hemp shives were used for determination of the coefficient of friction against the steel surface. Similar to the hemp fiber experiments, a significant difference was not observed between the hemp varieties. Average coefficient of friction for dry hemp shives is 0.125 ± 0.005.

Conclusions

1. The friction coefficient is essential for cutting energy reduction of hemp fiber and shive shredders.
2. The hemp fiber coefficient of friction against steel is not significantly dependent on the variety of hemp fiber and for dry fiber it is on average 0.131 ± 0.004.
3. Wet steel surface increases the friction coefficient of about 2-fold and it reaches average value of 0.236 ± 0.005.
4. The wet hemp fiber coefficient of friction against steel increased to 0.590 ± 0.005. In order to minimize the cutting energy, it is recommended to cut dry hemp fiber.

Acknowledgments

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