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Investigation of friction properties of yarns from natural fibres

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1. Introduction

Natural fibres and their blends with classic fibres bear valuable properties, so at present there are various products made of these fibres. It determine that absorbing and discharging moisture, nonirritating, antibacterial, anti-allergic, protection against the sun's harmful Ultra Violetic rays and other valuable properties are better, than classic yarns. They may be used for clothing, underwear, socks, higienic, textile products as well as for composites.

During the knitting process, the moving yarn is flexed, turned and pressed to mechanical machinery parts, which have various curved surfaces. A result of this process is yarn tension. When processing these yarns, it is vitally important to know the friction properties of these yarns, which are indicating the possibilities of processing and, together with knitted structure, are indicating the properties of the knitting.

The friction is directly influencing productivity and quality of textile production. Some of the characteristics of textile products, such as touch, felt and wear properties, tightness, softness depend on friction [1 - 4]. This is very important reason for the investigation of friction properties.

Many different factors influence the yarn friction. Yarn stress is the main factor, which influence all dynamic friction characteristics. The friction also depends on friction body bending angle, friction solid sleekness and temperature, on twist of the exploratory yarn, surface greasiness, moving speed, yarn roughness, downiness, electrify properties, etc. [1, 5 - 9].

The influence of sleekness, temperature and electrify properties of yarns are when moving speed is high. The yarn moving speed in knitting machines is not high. Increase of the yarn bending angle gives increase of frictional resistance. High yarn twist decrease the friction coefficient. It is possible to use yarns for knitting, if they are not too stiff (high friction ratio), if the yarn tension is not too high or friction ratio is too low. In other case it is not possible to acquire the knitting, which will have stable parameters. Objective of this work is to define the friction properties of yarns from natural fibres, depending on main knitting parameters: yarn initial stress, yarn moving speed and radius of friction body.

2. Object of investigation

The experiments were performed with flax, bamboo, flax + bamboo, soy, cotton + seaweed (Sea Cell) yarns. These are yarns dedicated for various textile products made by knitting. It shows the twist factor, which for yarns for knitting is 25 - 36 (Table 1).

Flax is one of the strongest natural fibres. It is more brittle and less flexible [1, 2, 10 - 12].

Table 1

The results of yarn tension

Yarn	Linear density, tex	Composition	Twist factor α	Breaking force *F*, cN	Elongation at break ε, %
Flax	33	100% Flax	25	623	1.67
Cotton+ Sea Cell	19	75% Cotton 25% Sea Cell	30	372	5.98
Flax+ Bamboo	24	80% Bamboo 20% Flax	36	179	10.45
Bamboo	14	100% Bamboo	27	127	11.67
Soy	14	100% Soy	34	269	15.68

Bamboo is a revolutionary new fibre that has unparalleled advantages, including strength, versatility and luxurious softness [12 - 14].

Soya-bean fibre – natural man made albuminous fibre. It has antibacterial properties. Used especially for skin-contact [13, 15].

Seaweed fibre is saturated with various minerals, microelements and vitamins. While wearing this fibre, skin feels crème-effect. Weed is protecting the skin, has antiphlogistic, antiallergic properties, is not irritative to skin [16].

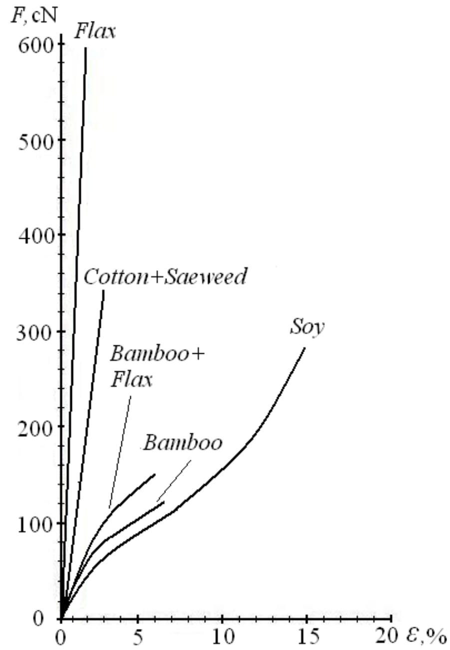

Fig. 1 Yarns stress-strain curves

Investigated yarn stress-strain curves and other characteristics are shown in Fig. 1 and in Table 1. The tensile stress-strain curves of investigated yarns were determined with a Zwick/Z 005 universal testing machine. They are demonstrating, that examined yarns have different rigidity and tensility, what is influencing their friction properties and conversion. Due to high rigidity and tensility, some yarns were impossible to use for knitting of ordinary single jersey structure.

3. Methods of investigation

The coefficient of friction was determined analysing the friction of yarns to 3 different diameters of the friction body: 10 mm diameter cylinder, 6 mm diameter cylinder and 2 mm diameter needle, at different speeds (0.05, 0.10, 0.15 m/s). The 6 mm and 10 mm diameter cylinders were made from steel wire, which is used in the textile machines without any extra processing. It is known, that very big friction body cleanness increases the friction coefficient.

In all the cases the dependence of friction coefficient on initial yarn stress T_1 was investigated. In order to avoid the influence of yarn unbandage from the bobbin, the branch was tensed with 4 weights of mass (2, 6, 10, 15 cN). The experiments were performed under normal conditions: air humidity 65±2 % and temperature 20±2° C.

The coefficient of friction is calculated using Euiler formula:

$$T_2 = T_1 e^{\mu\varphi} \quad (1)$$

$$\mu = \ln(T_2 / T_1) / \varphi \quad (2)$$

where μ is coefficient of friction, T_2 is running-off part of yarn stress, T_1 is running-on part of yarn stress, φ is yarn bending angle.

The experiment was performed on a equipment, which scheme is shown in Fig. 2. The bending angle is 180° (during moment of loop forming process).

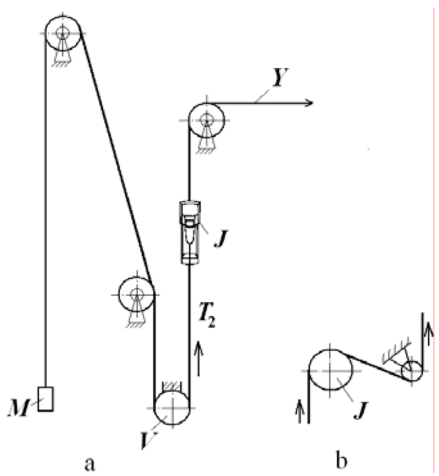

Fig. 2 Scheme of yarn friction measurement device: a - yarn movement in measurement device; b - yarn movement in sensor J

Mass M gives the input tension T_1 for yarn Y, which is wrapped on the friction body V. The output tension T_2 is measured by sensor (J). This is MEMMINGER – IRO firm the new generation electronic device MLT WESCO, which measures yarn stress straight with the sensor J. Movement schemes of the yarn is presented in Fig. 2.

4. Investigation results

The scatter of results was checked for all yarns and the scatter of measurement results does not exceed 10% and it is possible to assume, that the experiments were performed with adequate precision.

Results of the friction investigation are shown in Tables 2 and 3.

Table 2

The dependence of friction ratio on yarn speed, when initial stress is changing and the friction body is needle

Fibre	Yarn speed, m/s	T_1, cN			
		2	6	10	15
Flax	0.05	0.23	0.28	0.30	0.30
	0.10	0.24	0.29	0.31	0.31
	0.15	0.25	0.32	0.34	0.33
Bamboo	0.05	0.14	0.20	0.22	0.18
	0.10	0.15	0.20	0.23	0.19
	0.15	0.17	0.21	0.23	0.21
Flax+Bamboo	0.05	0.21	0.22	0.23	0.20
	0.10	0.21	0.23	0.23	0.21
	0.15	0.22	0.24	0.25	0.23
Cotton+Sea Cell	0.05	0.15	0.19	0.21	0.17
	0.10	0.17	0.20	0.23	0.18
	0.15	0.19	0.21	0.23	0.20
Soy	0.05	0.13	0.17	0.19	0.17
	0.10	0.13	0.18	0.20	0.18
	0.15	0.15	0.19	0.22	0.19

Table 3

The dependence of friction ratio on radius of the friction body, when initial stress is changing and speed is 0.15 m/s

Fibre	Diameter of friction body, m	T_1, cN			
		2	6	10	15
Flax	0.002	0.25	0.32	0.34	0.33
	0.006	0.26	0.27	0.29	0.29
	0.010	0.31	0.32	0.34	0.29
Bamboo	0.002	0.17	0.21	0.23	0.21
	0.006	0.16	0.25	0.35	0.24
	0.010	0.19	0.21	0.22	0.20
Flax+Bamboo	0.002	0.22	0.24	0.25	0.23
	0.006	0.20	0.24	0.25	0.24
	0.010	0.19	0.24	0.26	0.21
Cotton+Sea Cell	0.002	0.19	0.21	0.23	0.20
	0.006	0.15	0.18	0.20	0.22
	0.010	0.17	0.21	0.23	0.18
Soy	0.002	0.15	0.19	0.22	0.19
	0.006	0.15	0.20	0.21	0.20
	0.010	0.15	0.21	0.22	0.20

The results of the influence on yarn friction ratio, when the initial yarn stress is changing, are presented in Table 2 and Figs. 3 and 4.

The results show, that when yarn movement speed is increasing, the friction ratio increase and have the maximum in Fig. 3 and 4. That shows about the nonlinear reliance on T_2 from T_1. It may be related with area of friction contact, which is increasing till the yarn is straighten (10 cN) and after increasing not su much as T_1 is increasing.

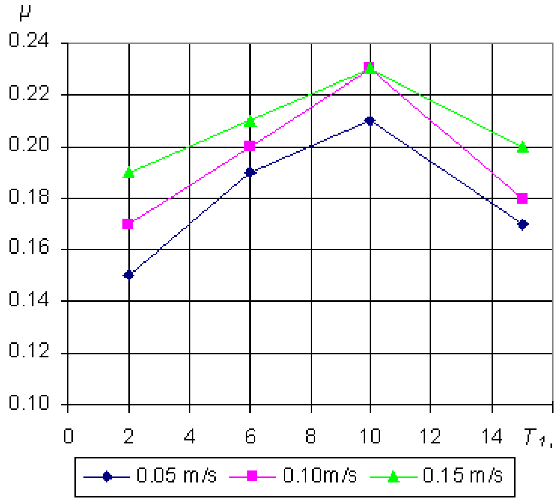

Fig. 3 Friction ratio dependence of cotton + seaweed yarn on the yarn initial stress and movement speed

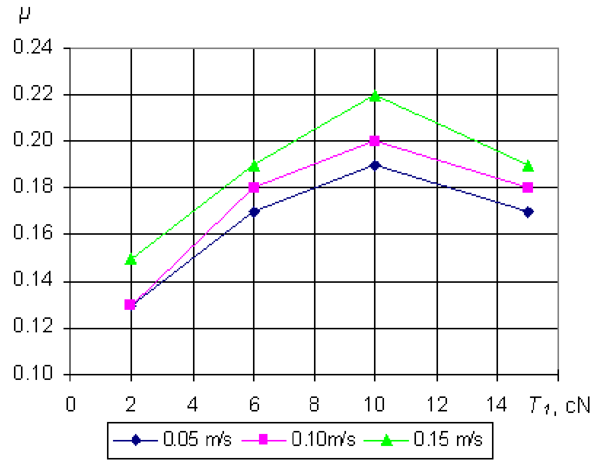

Fig. 4 Friction ratio dependence of soy yarn on the yarn initial stress and movement speed

The results of the influence on yarn friction ratio, when the diameter of friction body is changing, are presented in Table 3 and Figs. 5 and 6.

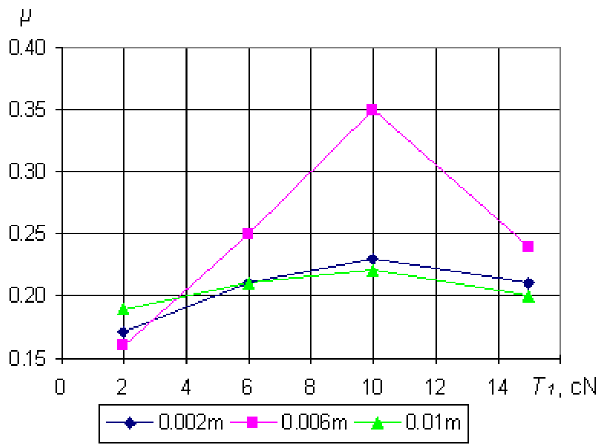

Fig. 5 Friction ratio dependence of bamboo yarn on the initial stress and radius of the friction body

The influence of initial yarn stress is the same as in Figs. 3 and 4.The results indicate, that when the radius of the friction body is increasing, the friction ratio can increase as well as decrease.

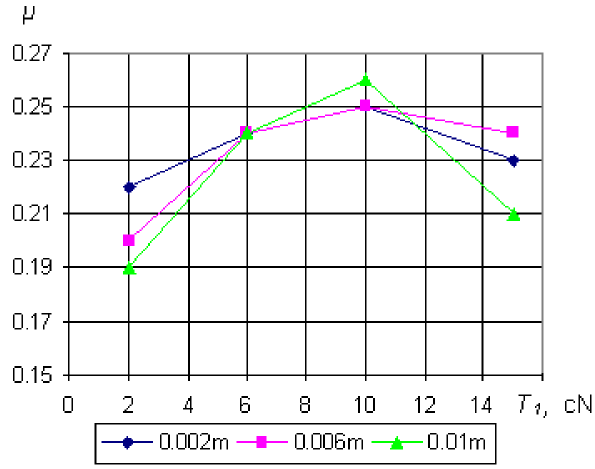

Fig. 6 Friction ratio dependence of bamboo + flax yarn on the initial stress and radius of the friction body

It also depends on resistance of yarns to bending.

Bending rigidity of the textile yarns is not high, but in sewing, knitting machinery yarn is in contact with the needles, sinkers, thread guiders dimensions of which are small, but curvature in the segment at certain moments (e.g. bending yarn into a loop) is high. There are some expressions to calculate the T_2 [9, 17], where the yarn is elastic and results gives T_2 decrease, when T_1 increases. According [17] T_2 may be calculated in such way

$$T_2 = T_1 e^{\mu\varphi} - \frac{H}{2(R+r)^2}(e^{\mu\varphi} - 1) \qquad (3)$$

where R is friction body radius, r is yarn radius, H is bending rigidity.

This expression is valid for elastic yarns and show decreasing of T_2, when R is increasing. Experimental results show that T_2 may decrease and increase.

In reality, the yarn behavior is viscoelastic (yarn has small area of loop of hysteresis). When yarn is moving through big curvature surface for bending rigidity the unbandaged yarn tension force will be equal to [17]

$$T_2 = T_1 e^{\mu\varphi} + \frac{M_T}{2(R+r)}(1 - \alpha e^{\mu\varphi}) \qquad (4)$$

where M_T is limit bending moment of the yarn, from which there is no resistance of bending because the structure of yarn is changed

$$M_T = \frac{H}{\rho_T} \qquad (5)$$

$$\alpha = (R+r)/\rho_T \qquad (6)$$

where ρ_T is limit radius of friction body and yarn

Coefficient α shows the part of elastic deformation and is fluctuating from 0 to 1.

Tension of the yarn, when it is moving on the body with high surface curvature, depends on yarn and body surface friction ratio μ and irreversible deformation of the yarn, which is characterized by the area of the hysteresis curve. It means, that friction ratio, while increasing yarn load, is reaching its maximum, after which it starts to decrease. There are two mechanisms of friction, which depends on friction body and elastic properties of the investigated material. These properties determine the decrease or increase of friction ratio, depending on the radius of the body. The same is presented in the works of the other authors as well [17 – 19]. In the work [17] there is shown experimental and calculated results of friction resistance of cotton yarn on friction body with different radius. There was determined that with decreasing of radius of friction body, friction resistance was decreasing from 7.5 mm till 1.5 mm radius and after was increasing till 0.125 mm.

The results of the yarns initial stress influence on the friction ratio are presented in Fig. 7.

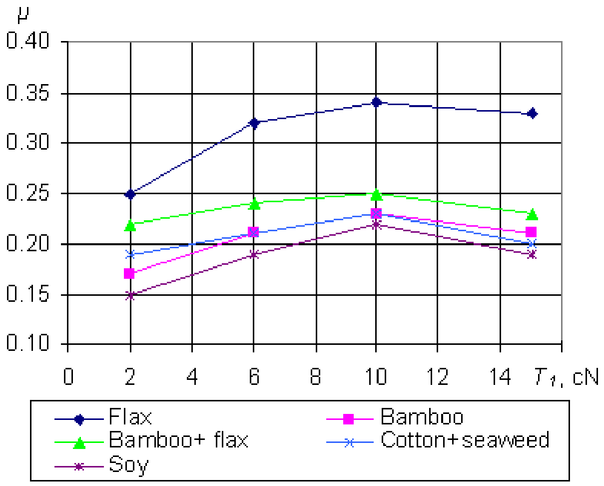

Fig. 7 All experimented yarns friction ratio dependence on the yarn initial stress, when the friction body V is needle

The results are demonstrate, that when the initial stress of the yarn increases up to 10 cN, the friction ratio is increasing, but with further increasing of the initial yarn stress, the friction ratio remains the same or is decreasing. The highest values were obtained on flax, lowest – soy.

5. Conclusions

The results of the investigation show, that for all the investigated yarns, when the movement speed of the yarn is increasing, the friction ratio is increasing as well. The highest values of friction coefficient were obtained when investigating flax, lowest – soy yarn.

When the radius of the friction body, at certain initial yarn stress, is increasing, the friction ratio can increase as well as decrease.

When changing the initial stress of the yarn up to 10 cN, the friction ratio is increasing, but with further increasing of the initial yarn stress, the friction ratio remains the same (for flax) or is decreasing.

After analysis of the friction results is possible to state, that flax yarn can be characterized as having the highest friction properties and are the most rigid of all the investigated yarns. The lowest friction values were obtained when examining soy yarn, which were least rigid of all the investigated yarns.

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V. Svetnickienė, R. Čiukas

SIŪLŲ IŠ NATŪRALIŲ PLUOŠTŲ TRINTIES SAVYBIŲ TYRIMAS

R e z i u m ė

Straipsnyje pateikti natūralių pluoštų ir jų mišinių su klasikiniais pluoštais siūlų trinties savybių tyrimo rezultatai. Perdirbant įvairius siūlus, būtina žinoti jų trinties savybes bei trinties koeficientą nuo kurių priklauso jų perdirbamumas, o kartu su mezginio struktūra ir mezginio savybės. Tyrimai buvo atlikti su lininiais, bambuko ir lino, medvilnės ir dumblių, bambuko, taip pat sojos siūlais. Eksperimentais nustatyta siūlo greičio, ašinio įtempio, trinties kūno kreivumo įtaka trinties koeficientui. Nustatyta, kad didelis kreivumas bei didesnė ašinė jėga mažina trinties koeficientą. Esant mažoms ašinėms jėgoms trinties koeficientas didėja. Siūlo greitis turi nedaug įtakos, todėl visi tirti siūlai gali būti lengvai perdirbami mezgant, išskyrus linus, kurių trinties koeficientas ir standumas yra didžiausi. Rekomenduojama linus naudoti mišriems verpalams.

Nustatyta, kad tirtų siūlų trinties koeficientas maksimalus esant 10 cN ašinei siūlo įražai.

V. Svetnickienė, R. Čiukas

INVESTIGATION OF FRICTION PROPERTIES OF YARNS FROM NATURAL FIBRES

S u m m a r y

Investigation results of friction properties of natural fibres ant their blends with classic fibres yarns are presented in the article. When processing various yarns, it is vitally important to know the friction properties and friction ratio of these yarns, which indicate the possibilities of processing and, together with knitted structure, indicate the properties of the knitting. The experiments were performed with flax, bamboo, bamboo + flax, soy, cotton + sea cell yarns. Yarn speed, axial tension, friction body curvature dependence on friction ratio were determinated by these experiments. The experiments show, that big curvature and big axial force make friction ration to decrease. The friction ration is increasing, when axial force is small. Yarn speed has a small influence, that's why all the investigated yarns can be easily processed in knitting, except flax, which has the highest friction properties and is the most rigid. We recommend to use flax just in mixed yarns.

It is determined, that for investigated yarns there is maximum of friction ratio then axial stress of yarn is 10 cN.

В. Светницкене, Р.Чюкас

ИССЛЕДОВАНИЕ ФРИКЦИОННЫХ СВОЙСТВ НИТЕЙ ИЗ НАТУРАЛЬНЫХ ВОЛОКОН

Р е з ю м е

В статье представлены результаты исследования свойств трения нитей и смешанной пряжи из натуральных волокон. При переработке разных нитей необходимо знать их фрикционные свойства и коэффициент трения которые определяют возможности их переработки и совместно со структурой связанного изделия определяют её свойства. Исследования проводились с льняной, бамбук + лён, хлопок + водоросли, бамбуковой, соевой пряжей. Экспериментами определено влияние скорости, осевой силы в нити и кривизна поверхности трения на коэффициент трения. Установлено что большая кривизна и осевая сила уменьшают коэффициент трения. При малой осевой силе коэффициент трения увеличивается. Скорость нити имеет незначительное влияние, поэтому все исследуемые нити могут быть легко переработаны на вязальных машинах, кроме льняных, у которых коэффициент трения и жесткость наибольшая. Целесообразно лён применять в смешанной пряже.

Установлено, что для исследуемых нитей имеется максимум коэффициента трения при осевой силе натяжения нити 10 сН.

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