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# Technical and classical yarns friction properties investigation

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## 1. Introduction

Friction is very important characteristic of textile materials. Through the friction fibres are connected into yarns and the yarns into fabric or knitting. Some of the characteristics of textile products, such as touch and felt properties, softness etc., depend on friction [1].

In technological processes of textile industry yarns or fabrics are moving not only on working surfaces, but also in respect of each other. All these facts have a big influence on weaving and especially knitting technological processes (for example, when making loops in knitting machinery etc.). Interaction between the yarns, based on friction, determines different mechanical properties of the woven and tricot fabrics, such as: traction, compression, twisting and shear characteristics [1-3]. The friction is directly influencing productivity and quality of textile production. This is very important reason for the investigation of friction properties.

In reprocessing of the yarn, it is frequently moving on metal, ceramic and other surfaces, so between the yarn and working surfaces there are friction forces. For that reason many experiments, investigating friction between a yarn and metal, ceramics or glass surfaces are performed by the method of friction cylinder. But it is necessary to remark, that a yarn can interact with parallel or perpendicular yarn. Not many experiments about the friction between the yarns are performed. The majority of experiments are performed on the friction between single fibres, sliding in respect of each other [4-7]. Friction experiments with the new types of yarns, from metaaramid and paraaramid fibres are also missing.

Many different factors influence the yarn friction. Yarn tension force 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, 4, 5, 8, 9]. The influence of all these factors was almost not investigated for the yarns, designed for technical protective textile materials. The objective of this work is to investigate and compare friction properties of technical and classical yarns, used for the protective knitting, when the yarn is moving on nonmoving cylinder, needle, rotating disc in parallel and perpendicular yarn directions.

## 2. Methods of investigation

The majority of technical and classical yarns are used for knitted protective products (protective gloves, head covers, military and police sweaters), so it is very important, if these yarns with specific properties can be processed in the knitting machinery, especially because of its friction properties. The experiments were performed with classical cotton, polyacrylnitrilic (PAN), polyamide (PA6) and technical (high strength SVM and non-flammable Fenilon and Nomex ) yarns. The results of the yarn tension are shown in Table 1.

Table 1

The results of the yarn tension

| Yarn | Linear density, tex | Breaking force, N | Elongation at break, % |
|---|---|---|---|
| SVM | 29.4 | 35.0 | 6.4 |
| Fenilon | 14.3*2 | 10.1 | 28.0 |
| Nomex | 18*2 | 8.9 | 5.4 |
| PA 6 | 6.8*2 | 6.2 | 27.2 |
| PAN | 16.5 | 2.3 | 21.8 |
| Cotton | 20*2 | 7.1 | 13.0 |

The coefficient of friction was determined analysing the friction of a yarn and cylinder, needle and disc, and using twisted yarn methods. Experiments were performed under normal conditions: air humidity 65±2 % and temperature 20±2°C. Experiments were performed with constant speed of the yarn movement (0.15 m/s), when the experimented yarn is surrounding:

1) nonmoving metal cylinder, with the diameter of 10 mm;
2) knitting needle, with the diameter of 1.5 mm;
3) pulley, rotating in the ball bearing.

In all the cases the dependence of friction coefficient on initial yarn tension force $T_1$ was investigated. In order to avoid the influence of the yarn unbandage from the bobbin, the branch was tensed with 3 weights of different mass causing the yarn tension force of 10, 20, 30 cN. The experiment was performed on a stand, which scheme is shown in Fig. 1.

Mass *M* gives the input tension force $T_1$ for yarn *S*, which is wrapped on the friction body *V*. The output

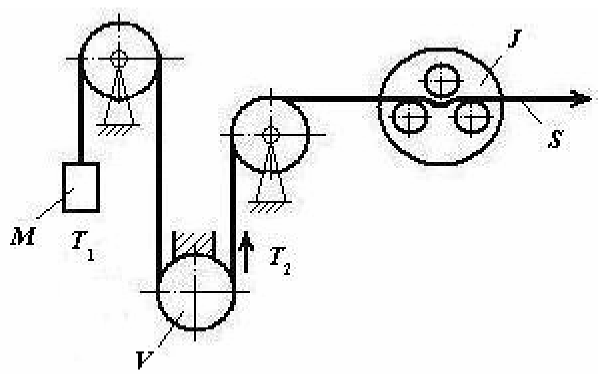



Fig. 1 Scheme of yarn friction measurement device tension $T_2$ is measured by sensor *J*.

When the yarn is moving on a metal cylinder, knitting needle or the disc, rotating in a ball bearing or when the yarns slide in respect of each other, tension force $T_2$ in the running-off part of yarn was measured with electronic tensiometer sensor ELTENS FY-23. It was rejected to measure tension force of the running-on part of the yarn, because constant weight was connected to this part of yarn, so there was no tension force oscillations, caused by the balloon, bobbin conicality, fibres adhesion. The friction force was measured in 3 ways.

2.1. Friction measurement, when the yarn is wrapped on non moving cylinder

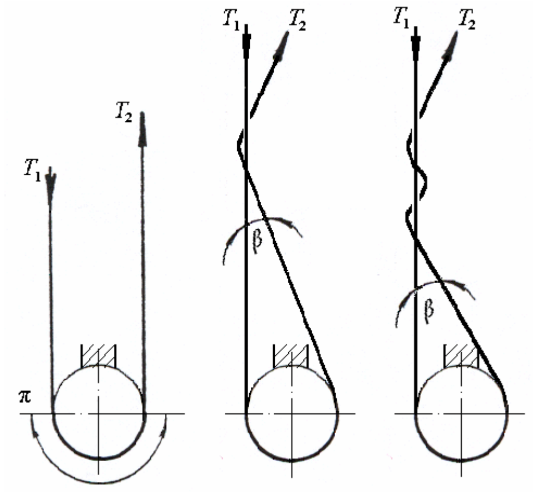
When the yarn parts are parallel (Fig. 2, a), the coefficient of friction is calculated using Oiler formula

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

$$\mu = ln(T_2 / T)_1 / \pi \quad (2)$$

where $\mu$ is coefficient of friction; $T_2$ is yarn tension force us the running-off part; $T_1$ is yarn tension force us the running-on part.

It was performed for 3 cases (Fig. 2).



a b c

Fig. 2 Friction measurement, when the yarn is sliding on a nonmoving cylinder: a - yarn branches are parallel, friction angle $\pi$; b - running-off part of yarn is wrapped one time around the running-on part of part of yarn; c - running-off part of yarn is wrappe two times around the running-on part of yarn

When the yarn branches are twisted in respect of each other (Fig. 2, a, c), the coefficient of friction is recommended to calculate by J. Lindberg and N. Gralen formula [1, 4]

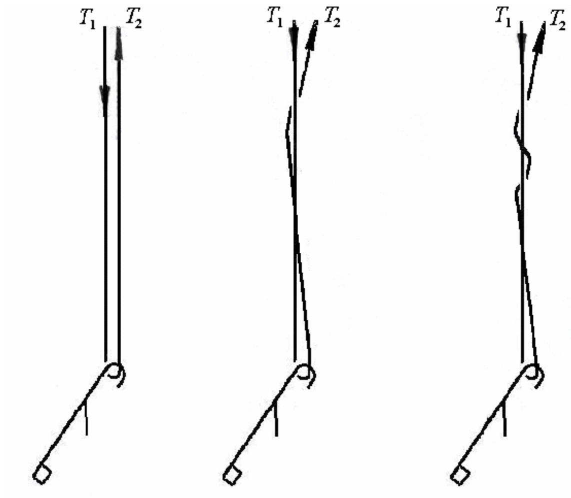
$$\mu = ln(T_2 / T_1)/(\pi n\beta) \quad (3)$$

where $\beta$ is the angle between twisted yarn branches; $n$ is the number of twists in two twisted yarn branches.

It is difficult to evaluate the term $\pi \cdot n \cdot \beta$ precisely, because in the experiment this angle varies, if the yarn friction and rigidity are different. In the experiments where yarn strands are bonded only friction resistance (left product in formula (4) was determined

$$\mu(\pi n\beta) = ln(T_2 / T_1) \quad (4)$$

2.2. Coefficient of friction measurement, when the yarn is sliding on knitting needle

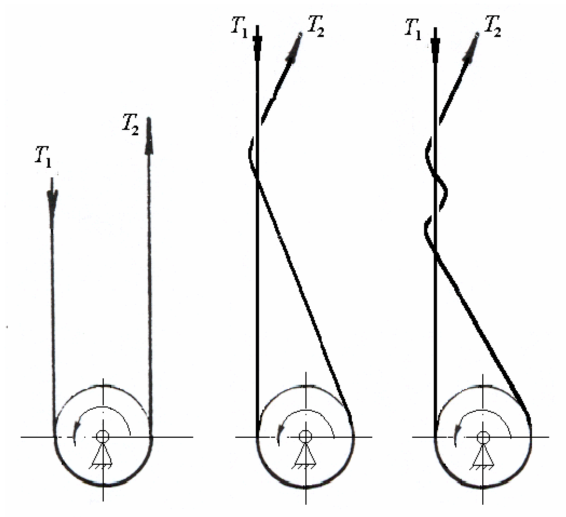


a b c

Fig. 3 Yarn position during friction experiments in knitting needle, when the yarn is wrapping the needle by angle $\pi$ and when using twisted yarn method

The cases a, b, c (Fig. 3) are the same, as mentioned before, but instead of nonmoving cylinder the yarn is moving on nonmoving needle.

2.3. Friction measurement, when the moving yarn is turning freely rotating disc



a b c

Fig. 4 Yarn position, when the yarn is moving on the surface of rotating in the ball bearings pulley and the yarn is wrapping it by angle $\pi$ (a) and by twisted yarn method (b and c)

The method of J. Lindberg and N. Gralen is dedicated to measure friction between yarns. The basis of this method is the difference of tension forces between two twisted yarns, one of which is tensed. The friction is investigated using this method, when running-off part of the yarn is wrapping running-on part of the yarn one or two times. Both yarns are sliding in respect of each other.

The principle of this method: when the tensioned yarn is moving with certain speed, it is surrounding the pulley, rotating in the ball bearing (Fig. 4, a). The running-off part of the yarn is wrapping the running-on part of the yarn one (Fig. 4, b) and two times (Fig. 4, c). Tension forces of the running-off part of yarn $T_2$ are measured, the friction resistance, using J.Linberg and N.Gralen formula (4) is calculated.

The variant a did not give any result, because the friction force was insignificant in all cases.

### 3. Investigation results

In knitting process the yarn tension force varies until 10 cN, though in different points of loop formation it supposedly can change no more than three times, therefore friction experiments were performed when the tension force of the running-on part of yarn was 10, 20, 30 cN.

The scatter of results was checked for technical yarns.

Table 2

Variation coefficients of the experiments

| $T_1$, cN | v, % | | |
|---|---|---|---|
| | SVM | Fenilon | Nomex |
| 10 | 5.4 | 4.8 | 8.3 |
| 20 | 4.1 | 9.4 | 4.9 |
| 30 | 6.6 | 6.2 | 5.3 |

The Table 2 shows, that the scatter of measurement results does not exceed 10 % and it is possible to assume, that the experiments were performed with adequate precision.

For all yarns, when they were parallel and were sliding on nonmoving metal cylinder and nonmoving needle, the coefficient of friction was calculated and shown in Table 3.

Results of friction coefficient analysis show that by increasing the tension force of the yarn the coefficient

Table 3

Coefficient of friction when yarn branches are paralleled and they are sliding on nonmoving cylinder (Fig. 2, a) and on knitting needle (Fig. 3, a)

| Yarn | Cylinder | | | Needle | | |
|---|---|---|---|---|---|---|
| | $T_1$, cN | | | $T_1$, cN | | |
| | 10 | 20 | 30 | 10 | 20 | 30 |
| SVM | 0.42 | 0.32 | 0.32 | 0.33 | 0.22 | 0.15 |
| Fenilon | 0.36 | 0.28 | 0.25 | 0.31 | 0.23 | 0.19 |
| Nomex | 0.35 | 0.24 | 0.23 | 0.15 | 0.11 | 0.10 |
| PA 6 | 0.41 | 0.35 | 0.34 | 0.34 | 0.28 | 0.22 |
| PAN | 0.37 | 0.30 | 0.27 | 0.24 | 0.18 | 0.11 |
| Cotton | 0.36 | 0.33 | 0.30 | 0.17 | 0.15 | 0.14 |

of friction decreases for all yarns, though its values are lower for technical SVM, Fenilon and Nomex yarns. The decrease of coefficient of friction is higher for technical yarn.

The decrease of friction coefficient can be explained as the investigated yarns have the rigidity, which is not evaluated in the Eq. (1).

The decrease of friction force when threads are sliding on knitting needle may be explained according the Eq. (5), which shows [6], that tension force $T_2$ will be lower when radius $R$ is declined

$$T_2 = T_1 e^{\mu \frac{R}{R+r} \cdot \alpha} \tag{5}$$

where $R$ is radius of friction body; $r$ is radius of the yarn.

For other variants of experiments only friction resistance (the product of coefficient of friction and angle) is shown, because the angle of strands crossing was inconstant in different experiments and for different yarns. Results are shown in Tables 4-6.

Table 4

Results of friction experiments, when the yarn was moving on a cylinder

| Yarn | 1a | | | 1b | | | 1c | | |
|---|---|---|---|---|---|---|---|---|---|
| | $T_1$, cN | | | $T_1$, cN | | | $T_1$, cN | | |
| | 10 | 20 | 30 | 10 | 20 | 30 | 10 | 20 | 30 |
| SVM | 1.31 | 1.01 | 0.92 | 1.36 | 1.13 | 0.97 | 1.46 | 1.25 | 0.99 |
| Fenilon | 1.13 | 0.88 | 0.79 | 1.34 | 1.03 | 1.04 | 1.53 | 1.41 | 1.32 |
| Nomex | 1.10 | 0.74 | 0.72 | 1.25 | 0.88 | 0.76 | 1.46 | 1.05 | 0.87 |
| PA 6 | 1.28 | 1.11 | 1.07 | 1.39 | 1.27 | 1.17 | 1.61 | 1.48 | 1.29 |
| PAN | 1.16 | 0.93 | 0.85 | 1.34 | 1.10 | 0.94 | 1.46 | 1.19 | 0.97 |
| Cotton | 1.12 | 1.05 | 0.93 | 1.41 | 1.22 | 0.99 | 1.63 | 1.37 | 1.19 |

Table 5

Results of friction experiments, when the yarn was moving on a needle

| Yarn | 2a | | | 2b | | | 2c | | |
|---|---|---|---|---|---|---|---|---|---|
| | $T_1$, cN | | | $T_1$, cN | | | $T_1$, cN | | |
| | 10 | 20 | 30 | 10 | 20 | 30 | 10 | 20 | 30 |
| SVM | 1.03 | 0.68 | 0.47 | 1.16 | 0.77 | 0.61 | 1.25 | 0.92 | 0.80 |
| Fenilon | 0.99 | 0.72 | 0.59 | 1.19 | 0.92 | 0.63 | 1.36 | 1.03 | 0.72 |
| Nomex | 0.47 | 0.34 | 0.31 | 0.74 | 0.53 | 0.47 | 0.88 | 0.72 | 0.68 |
| PA 6 | 1.07 | 0.88 | 0.69 | 1.19 | 1.01 | 0.80 | 1.39 | 1.15 | 0.92 |
| PAN | 0.76 | 0.56 | 0.36 | 0.89 | 0.76 | 0.54 | 0.99 | 0.90 | 0.79 |
| Cotton | 0.53 | 0.48 | 0.43 | 0.69 | 0.62 | 0.53 | 1.07 | 0.83 | 0.61 |

Table 6

Results of friction experiments, when the yarn was moving on rotating pulley

| Yarn | 3b | | | 3c | | |
|---|---|---|---|---|---|---|
| | $T_1$, cN | | | $T_1$, cN | | |
| | 10 | 20 | 30 | 10 | 20 | 30 |
| SVM | 0.69 | 0.30 | 0.21 | 0.83 | 0.50 | 0.42 |
| Fenilon | 0.69 | 0.37 | 0.28 | 1.03 | 0.53 | 0.42 |
| Nomex | 0.59 | 0.30 | 0.18 | 0.88 | 0.50 | 0.36 |
| PA 6 | 0.74 | 0.44 | 0.38 | 0.99 | 0.74 | 0.45 |
| PAN | 0.59 | 0.30 | 0.26 | 0.92 | 0.50 | 0.36 |
| Cotton | 0.74 | 0.47 | 0.29 | 1.16 | 0.77 | 0.43 |

## 4. Conclusions

The received results for all yarns by all methods show that the increase of yarns tension force decreases friction force. When the yarn is moving through the needle, the friction resistance is lower, than when the yarn is sliding on a cylinder.

Friction resistance of twisted yarns is increasing when revolution frequency increases. Friction resistance of the yarn is the highest while they are sliding on a nonmoving cylinder, lower – while moving through the needle. Friction resistance of the yarns, twisted into one strand and moving on rotating disc is two times lower than if they were sliding on a cylinder surface.

SVM and Fenilon yarns are characterized with higher friction, Nomex – with lower friction. While investigating twisted yarns there was noticed, that the running on yarn branch with tension force $T_1$ is straight. Friction resistance of the polyamide, polyacrylnitrilic and cotton yarns is changing much less. Friction resistance of the last mentioned is higher in all cases. After comparison of the determined coefficients of friction it is possible to state, that all of the investigated yarns can be processed in knitting machinery; because the coefficients of friction of technical and classical yarns, determined by needle and cylinder methods, are from the same ranking, but technical yarns have slightly lower friction. In knitting process it would be possible to keep the same SVM tension force as polyamide PA, Fenilon as PAN and SVM as cotton yarns.

Some problems may be with SVM threads, because they are very stiff and do not fit for knits, because friction is the reason of tension rising during knitting.

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TECHNINIŲ IR KLASIKINIŲ SIŪLŲ TRINTIES SAVYBIŲ TYRIMAS

R e z i u m ė

Straipsnyje pateikiami techninių ir klasikinių siūlų, naudojamų techninei apsauginei tekstilei, trinties tyrimo rezultatai. Kadangi tirti siūlai gali būti naudojami megztoms pirštinėms, kaukėms, kad neapdegtų kūnas, tai labai svarbu žinoti, ar šie siūlai, pasižymintys specifinėmis savybėmis, gali būti perdirbami mezgimo mašinomis, ypač dėl savo trinties savybių.

Tyrimui buvo naudojami techniniai (SVM, Fenilon, Nomex) ir klasikiniai (medvilniniai, PA6, PAN) siūlai. Trinties koeficientas buvo nustatomas trinties velenėlio ir susuktų siūlų metodais. Bandymai buvo atliekami esant pastoviam siūlo judėjimo greičiui, kai bandomasis siūlas juda nejudamu velenėliu, mezgimo adata, besisukančiu diskeliu lygiagrečiomis bei sukryžiuotomis siūlų vijomis, keičiant siūlo įtempį.

Tyrimai parodė, kad visi tirti siūlai gali būti perdirbami mezgimo mašinomis, nes tiek techninių, tiek klasikinių siūlų trinties koeficientai, nustatyti velenėlio ir adatos metodais, yra tos pačios eilės, tačiau perdirbant SVM siūlus, kurie yra labai standūs, įtempį reikia sumažinti.

V. Svetnickienė, R. Čiukas

TECHNICAL AND CLASSICAL YARNS FRICTION PROPERTIES INVESTIGATION

S u m m a r y

Investigation results of the technical and classical yarns, which are used for technical protective textiles are

presented in the article. Since the investigated yarns can be used in production of knitted gloves, masks for the body protection from fire, it is very important, if these yarns, having specific characteristics, can be processed in production with knitting machinery, especially due to their friction properties.

For the investigation technical – SVM, Fenilon, Nomex and classsical – Cotton, PA6, PAN yarns were used. The coefficient of friction was determined by using a friction cylinder and twisted yarn methods. The experiments were performed with the constant moving speed of a yarn, when examined yarn is moving on a non-moving cylinder, needle, rotating disc in parallel and crossing yarn strands, changing tension of the yarns.

Experiments showed, that all the investigated yarns can be processed in knitting machinery, because the coefficients of friction of technical yarns, as well as the classical yarns, determined by cylinder and needle methods, are in the same range, but for the SVM yarns the tension must be lower,because they are very stiff.

В. Светницкиене, Р. Чюкас

## ИССЛЕДОВАНИЕ СВОЙСТВ ТРЕНИЯ ТЕХНИЧЕСКИХ И КЛАССИЧЕСКИХ НИТЕЙ

Р е з ю м е

В статье представлены результаты исследования коэффициента трения технических и классических нитей, используемых для производства технического текстиля. Поскольку исследуемые нити могут быть использованы для производства огнезащитных перчаток и масок, необходимо знать, что данная пряжа, отличающаяся специфическими свойствами, может быть переработана на вязальных машинах, особенно из-за своих свойств трения.

В исследовании была использована техническая (SVM, Fenilon, Nomex) и классическая (хлопковая, PA6, PAN) пряжа. Коэффициент трения был определен по методу валика трения и методу скрученной пряжи. Изследовалась зависимость трения от начального натяжения пряжи при постоянной скорости движения пряжи, когда пряжа движится по неподвижному валику, игле, вращающемуся диску, с параллельной и перекрестной намоткой пряжи.

Исследования показали, что вся исследованная пряжа может перерабатыватся на вязальных машинах, поскольку коэффициенты трения и технической, и классической пряжи, установленные методами валика и иглы, являются того же ряда, но для нитей SVM необходимо уменшить натяжение нити при переработке, так как они очень жесткие.

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