USTER® ZWEIGLE
FRICTION TESTER 5

APPLICATION REPORT

Friction measurement

THE YARN PROCESS CONTROL SYSTEM
1 Introduction

Friction plays a very important role in the textile industry, and we can see friction everywhere: Friction between yarn and yarn guiding elements, fiber-to-fiber friction, friction in spinning, winding, warping, weaving, and knitting [1, 2]. Yarns experience friction either between themselves or against metallic surfaces before being processed into a fabric in weaving and knitting machinery. Yarn friction is important with respect to the running behavior of a yarn in post spinning processes [1, 2]. It is a fact that yarn friction is an important quality parameter which can affect the yarn performance and especially the knittability and weaveability of a yarn [4, 5, 6].

This paper deals with the USTER® ZWEIGLE FRICTION TESTER 5, a PC-operated instrument which is for quick and reliable determination and recording of yarn coefficient of friction $\mu$. By monitoring yarn friction it is possible to optimize the waxing of yarns on winding machines along with the influences that various chemical additives can have on the running properties of single and plied yarns. The unique measurement method of the USTER® ZWEIGLE FRICTION TESTER 5, in which a constant yarn tension is established at the point of measurement guarantees reliable and highly accurate test results.

2 Importance of yarn friction

Besides the traditional yarn parameters such as evenness, imperfections, strength and elongation, the friction plays also an important role in the evaluation of a yarn. As previously mentioned, yarns are subjected to friction either between themselves or against metallic surfaces before being processed into a fabric in weaving and knitting machinery. Both yarn to yarn and yarn to metal frictions play a significant role in textile processing. High yarn to yarn and yarn to metal frictions may increase the end break rate during weaving [6].

In various studies it was found that in different knitted structures an increase in yarn friction significantly increased the number of yarn breakages during knitting. Reducing the yarn friction by waxing the yarn under low tension (generally) will reduce the number of yarn breakages, although the magnitude of this reduction varied according to the structure [7, 8].

In this paper we will mainly concentrate on yarn friction. Measurement of yarn friction can help to improve the subsequent processes:

Spinning
- Determination of optimum wax type and application
- Selection of waxes and chemical agents based on quality and price
- Reduction of claims and more sense of security
- Minimization of friction variations between cones
Knitting
- Tool to maintain or to raise production levels
- Ensures constant quality
- Reduces costs
- Reduces breaks and down time
- Assists in setting company-own internal friction level standards
- Helps to trace back claims
- Reduces fly in the mill
- Increases needle lifetime

Finishing
- Selection of right agents based on quality and price
- Reduction of claims
- Minimization of friction variations between cones

Thus, in order to avoid claims, retailers, weavers, knitters and yarn traders have implemented parameters for the definition of the friction in their yarn standards or profiles in order to source their yarn according to their requirements and the end use of the product.

3 Basics of friction

3.1 Classical friction

When two surfaces slide over another then there is a force resisting motion which is called friction (Fig. 1). The two basic laws of friction are [1, 2].

1. The frictional force $F_2$ is proportional to the normal load $F_1$ so that the coefficient of friction $\mu = \frac{F_2}{F_1}$ is a constant for given two surfaces.

2. The friction is practically independent of the geometric area of contact between the two surfaces.

When an attempt is made to slide an object on a surface, a force is required to start the movement. This force acts in the opposite direction of the objects movement. Once the object is moving, the force required to keep it moving is lower than the original starting force. The force that has to be overcome in order to keep the movement is known as sliding or dynamic friction. The force required to initiate sliding is called the static friction. The dynamic friction is higher than the force required maintaining sliding [1, 9].
The force of friction is calculated as follows:

\[ F_2 = \mu \times F_1 \]

- \( F_2 \): Force of friction (N)
- \( F_1 \): Normal force (N)
- \( \mu \): Coefficient of friction

The coefficient of friction depends on the roughness of the surfaces of A1 and A2 and on the lubricant between these two surfaces.

The coefficient of friction is a value without dimensions, lying between 0 and 1. The higher the value, the higher the friction.

During knitting one expects to retain friction (mean value and variation of friction or yarn tension) at the lowest possible level [10].

4 Measuring method of the USTER® ZWEIGLE FRICTION TESTER 5

4.1 Measuring principle

The USTER® ZWEIGLE FRICTION TESTER 5 uses the classical friction measurement principle (Chapter 3.1, Fig. 1) The USTER® ZWEIGLE FRICTION TESTER 5 based on the force required to move a yarn horizontally through a disk tensioner. The yarn passes through the two plates. A constant force is applied to the upper disk which in turn produces a defined force on the yarn. The coefficient of friction can be calculated from the two forces \( F_1 \) and \( F_2 \) (Fig. 1 and Fig. 2). It is the friction between yarn and metal.
The critical feature of the USTER® ZWEBLE FRICTION TESTER 5 is the configuration of the measuring beam with the two rollers and the measuring sensor. This enables variations in tension in the yarn package to be immediately compensated. During the measurement, an area of "zero" force is developed between the two rollers. This is because the yarn first passes in one direction, and then in another direction, both at a constant speed of 200 meters per minute. Placing a load of 20 cN (20 gf) on top of the yarn tensioner (F1, Fig. 1 and Fig. 2) will exert a force to the yarn. The two rollers are very sensible and can detect every small lateral movement in both directions individually. Both rollers are connected to a sensor (Fig. 2) which then measures the variation of the force exerted on the yarn. Since the force F1 (Fig. 1 and Fig. 2) applied on the yarn is known and the force F2 is measured, the coefficient of friction can be calculated (Fig. 1 and Fig. 2).

Fig. 2 shows the measuring system with the tensioner, the load on the tensioner and the rollers.
The force of friction is calculated as follows:
\[ F_2 = \mu \times F_1 \]

- \( F_1 \): Normal force (N) applied by the load on the yarn tensioner in Fig. 1 and Fig. 2.
- \( F_2 \): Force of friction (N)
- \( \mu \): Coefficient of friction = \( F_2/F_1 \) (see Fig. 1 and Fig. 2)

- The tensioner friction principle is a simple and reliable way of determining yarn friction.
- The coefficient of friction is not depending upon the angle of contact as is in the case of the friction measurement by means of a rod.
- The principle simulates the initial stress exerted on a yarn by a disk tensioner similar to those used on knitting machines.
- The principle simulates the tensioners found on a weaving machine.
- Possible variations within a yarn package are eliminated through the configuration of the measuring beam with the two rollers.
- The system needs only one measuring head.

### 4.2 Evaluation possibilities

#### 4.2.1 Numeric results

There are three possibilities for numeric test results:

- Individual test results per test, per bobbin / cone
- Statistics for individual mean test results per bobbin / cone
- Statistics for the overall test results of all tests and bobbins / cones

Results are given for the tested yarn length of 200 m. Besides the mean various statistical values are calculated, such as standard deviation (s), coefficient of variation (CV), minimum and maximum values. The mean value per 200 m is the standard value which is recommended by Uster Technologies in order to be used for any comparisons between yarns.

<table>
<thead>
<tr>
<th>Article</th>
<th>27820</th>
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<td>Speed</td>
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<tr>
<td>Length</td>
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<tr>
<td>Test time</td>
<td>60 s</td>
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<td>Friction material</td>
<td>Steel</td>
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</table>

**INFO 1:** Trial no. 3658  
Mean [\( \mu \)] = 0.28  
CV[\%] = 4.77  
Max [\( \mu \)] = 0.34  
Min [\( \mu \)] = 0.22

**INFO 2:** Testex round trial 2005/2  
Material: Ring-spun yarn, combed, bobbins  
Count: I. Mächler

**INFO 3:** USTER® PRODUCTS 9 (20)
4.2.2 Diagram

The friction diagram shows the continuous results of the friction measurement (Fig. 5).

There are various possibilities for diagrams.

- Diagram with a friction range 0 to 1.
- Diagram with absolute or relative values.
- Parallel or serial diagram.

The respective diagram of a test series is produced in addition to the statistical analysis in serial form (Fig. 6). This figure shows a test series of 6 bobbins. The diagram shows the variation of the friction from bobbin to bobbin.
The respective diagram of a test series is produced in addition to the statistical analysis in parallel form (Fig. 7).

### 4.3 Test recommendations

Uster Technologies recommends the following test set-up:

- Test speed: 200m/min (fixed in the instrument)
- Test duration: 1 minute
- Test length: 200 m/min per bobbin / per cone
- Temperature: 20 degrees C, 65% r.H. (ISO 139)

### 5 Influence on yarn friction

In this section, we will concentrate on various factors and their effect on the yarn friction.

#### 5.1 Waxing of the staple fiber yarns

It is a common practice to wax staple-spun yarns for knitting applications in order to improve and maintain their performance on the knitting machine. For optimal running of yarns during knitting, there needs to be a uniform wax distribution along the entire length of the yarn and a minimum of wax rub-off [3]. While producing the cross-wound cone on a winder, paraffin wax is applied in dry state to the yarn surface.
Under ideal conditions, the paraffin must lie between the protruding fibers and should not penetrate into the core of the yarn, thus maintaining the yarn’s elasticity. Paraffin functions like a lubricant when yarn comes into contact with any surface and, consequently, it reduces the coefficient of friction.

A number of paraffin waxes are offered on the market; they differ in their texture, firmness and melting points with regard to temperature [10].

The amount of paraffin deposited on the yarn has a marked influence on the dynamic characteristics of the yarn [3]. The application of paraffin can reduce the value of $\mu$ by about 50%. However if too much paraffin is applied, an undesirable film is formed and leads to an increase in friction value ($\mu$). Fig. 8 shows the qualitative relationship between paraffin content and the coefficient of friction [10]. According to the Fig. 8, at a given running speed, the yarn coefficient of friction decreases to a minimum with increasing wax deposited and then increases with further yarn waxing.

Of the three zones indicated, zone B is clearly the preferred range of deposition, usually 0.5 to 1.0 g paraffin per kg of yarn [3].

\[ \mu = \text{coefficient of friction} \]
\[ P = \text{paraffin content on yarn} \]
\[ A = \mu \text{ strongly reduced (around 50%) } \]
\[ B = \text{practically constant } \mu \text{ value} \]
\[ C = \text{distinctly increasing } \mu \text{ value} \]

The preference with commonly used paraffin wax rings is for a coarse microcrystalline structure, which allows small wax particles to be removed and held onto the yarn surface as shown in Fig. 9 as this should enable a uniform distribution of deposition [3].

Steaming or high-humidity conditioning of wax yarns can result in an increased friction coefficient. Steaming will melt the wax particles and also causes a partial penetration of wax into the yarn. If the yarn has to be treated in this way, the deposition of wax should be regulated to offset the effect by selecting the correct wax [3].
Paraffin wax types vary according to melting point, oil content, microstructure and hardness. There are only a few publications available of selecting a wax type for optimal running performance.

However, in the literature it is mentioned that the selection depends on many factors such as:

- fiber type
- yarn structure
- count and moisture content
- room temperature and humidity in the winding area and during storage and shipment.

By comparing different types of waxing rings (Fig. 10), on the waxing device it is possible to quickly ascertain the wax that produces the lowest coefficient of friction. This type of wax is then the one to use on the production machine. With the help of the USTER® ZWEIGLE FRICTION TESTER 5, the right wax type and settings on the winder can be determined quickly (Fig. 9).

There are a number of commercial producers\(^1\) of waxing rings. A company offers a wide range of different types and is taken as an example\(^2\) (Fig. 10, Table 1). More information about other manufacturers can be found on their respective websites.

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\(^1\) Reseda Binder, Albstadt-Ebingen Germany, [12]
Gibson Parafin, Istanbul, Turkey [13]
Pellizzari s.r.l., Valdagno, Italy, [14]

\(^2\) Reseda Binder, Albstadt-Ebingen Germany, [12]
The yarn process control system

**Fig. 10**
Various commercial waxing rings (Reseda Binder) [12]

<table>
<thead>
<tr>
<th>Type</th>
<th>Application of wax (RESEDA BINDER) [12]</th>
</tr>
</thead>
<tbody>
<tr>
<td>NATURAFIN Yellow</td>
<td>Largely universal, suitable for cotton, wool, synthetics and their blends</td>
</tr>
<tr>
<td>NATURAFIN Green</td>
<td>Wool, cotton, cotton blends. Recommended for larger applications of wax, such as wool yarns and bleached yarns.</td>
</tr>
<tr>
<td>NATURAFIN Red</td>
<td>For yarns which are bleached or dyed after waxing</td>
</tr>
<tr>
<td>NATURAFIN Blue</td>
<td>For yarns spun with soft twist or at low yarn tension. Bleached yarns.</td>
</tr>
</tbody>
</table>

*Table 1  Recommendations of a wax manufacturer*

In a trial, various paraffin types are tested with the same 100% cotton, Ne 20 yarn. As we can see in Fig. 11, the untreated yarn displayed as a black friction diagram has the highest coefficient of friction value ($\mu = 0.28$). By using different paraffins, the coefficient of friction value can be reduced by half.
Explanations:

Untreated yarn (black diagram) $\mu = 0.28$
Yellow wax (dark blue diagram) $\mu = 0.15$
Blue wax (green diagram) $\mu = 0.15$
Orange wax (light blue diagram) $\mu = 0.14$

In the following trial (Fig. 12), a yarn (Ne 30, 100% cotton, ring-spun,) was waxed with three different wax types by Reseda Binder [12]. Technical properties of these waxes are given in Table 2.
As we can see in Fig. 12, again the untreated yarn has the highest coefficient of friction value ($\mu = 0.25$). By using different paraffins, the coefficient of friction value can be reduced by half. In this case, we could not see a significant difference between the different wax types.

5.1.1 Influence of age of wax

Fig. 13 below shows a test with 8 cones wound with old paraffin blocks. It is obvious that the age of the paraffin has a considerable influence on the friction level and the evenness of the application.

5.1.2 Influence of conditioning of the wax

In this trial, a yarn waxed with new paraffin blocks as well as with paraffin blocks which were conditioned for 72 hours. There is no significant difference can be seen in the values or in the friction diagram.
5.1.3 Missing wax

Trials have shown that when the wax is missing suddenly, then the diagram looks like in Fig. 14. As paraffin still sticks to the guiding elements of the winding machine there is not a sudden jump, but rather a slowly increasing friction value.

5.2 Jump out of tensioner

Trials have shown that the setting of the tensioner does not influence the test results in a significant way. However, it is important to set the tensioner in a way which gives a good guidance to a yarn. If the tensioner is set too tight, the yarn can jump out of the tensioner (Fig. 15). Depending on the yarn count, the tensioner must be loosened in order to avoid the yarn to break during the measurement.
6 Experience values

Experience values were developed in the textile industry for the friction coefficient of various yarn types. The values in Table 3 represent values of waxed yarns.

<table>
<thead>
<tr>
<th>Yarn type</th>
<th>Very good</th>
<th>Good</th>
<th>Beyond limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton 100%, untreated</td>
<td>0.13 – 0.15</td>
<td>0.16 – 0.17</td>
<td>0.18 – 0.25</td>
</tr>
<tr>
<td>Cotton 100%, dyed</td>
<td>0.14 – 0.16</td>
<td>0.17 – 0.18</td>
<td>0.19 – 0.25</td>
</tr>
<tr>
<td>Worsted 100%, untreated</td>
<td>0.15 – 0.16</td>
<td>0.17 – 0.18</td>
<td>0.19 – 0.25</td>
</tr>
<tr>
<td>Worsted 100%, dyed</td>
<td>0.16 – 0.17</td>
<td>0.18 – 0.19</td>
<td>0.20 – 0.25</td>
</tr>
<tr>
<td>Cotton/Polyester blend, untreated</td>
<td>0.16 – 0.17</td>
<td>0.18 – 0.19</td>
<td>0.21 – 0.25</td>
</tr>
<tr>
<td>Polyacrylic 100%</td>
<td>0.17 – 0.19</td>
<td>0.20 – 0.22</td>
<td>0.23 – 0.26</td>
</tr>
<tr>
<td>Spun silk 100%</td>
<td>0.20 – 0.22</td>
<td>0.23 – 0.24</td>
<td>0.25 – 0.28</td>
</tr>
</tbody>
</table>

Table 3 Experience values of friction coefficients (Source: Rieter)

7 Standards

There is currently no national or international standard which applies to the friction coefficient measurement of the USTER® ZWEIGLE FRICTION TESTER 5.

8 Conclusion

Friction plays a very important role in the textile industry especially with respect to the running behavior of a yarn in post spinning processes. The USTER® ZWEIGLE FRICTION TESTER 5 helps the customer for a quick and reliable way to determine and record the yarn coefficient of friction $\mu$.

The monitoring of yarn friction allows the optimum waxing of yarns on winding machines. It also allows the measurement of influences of chemical additives on running properties of single and plied grey and dyed yarns. Constant yarn tension and high accuracy guarantee reliable test results.

The instrument is designed not only for 100% cotton staple yarns, but also for blended staple yarns independent of its yarn count and color.
9 Literature


