USTER® *LABORATORY SYSTEMS*

Application Report

Physical properties of spun yarns

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Think quality

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Contents

1 Introduction

Uster Technologies has introduced more than 60 quality characteristics in the past 50 years. In addition, our company permanently measures fiber and yarn samples from all over the world to determine the quality characteristics for the USTER® *STATISTICS*. Therefore, a considerable amount of know-how to describe the physical properties of yarns could be collected.

Furthermore, Uster Technologies offers training courses either in Uster or in the mills of our customers. Our textile technologists are asked many questions which deal with the physical properties of yarns.

As a result, our company decided to publish a collection of various yarn properties. This booklet is used for training purposes and serves as a platform for more detailed application trainings for laboratory and on-line systems.

We take this opportunity to gratefully acknowledging the contribution of other companies to this paper. The sources of third parties are mentioned in the chapters.

2 Fiber length

2.1 Fiber length versus yarn count / ring-spun yarn / Cotton 100%

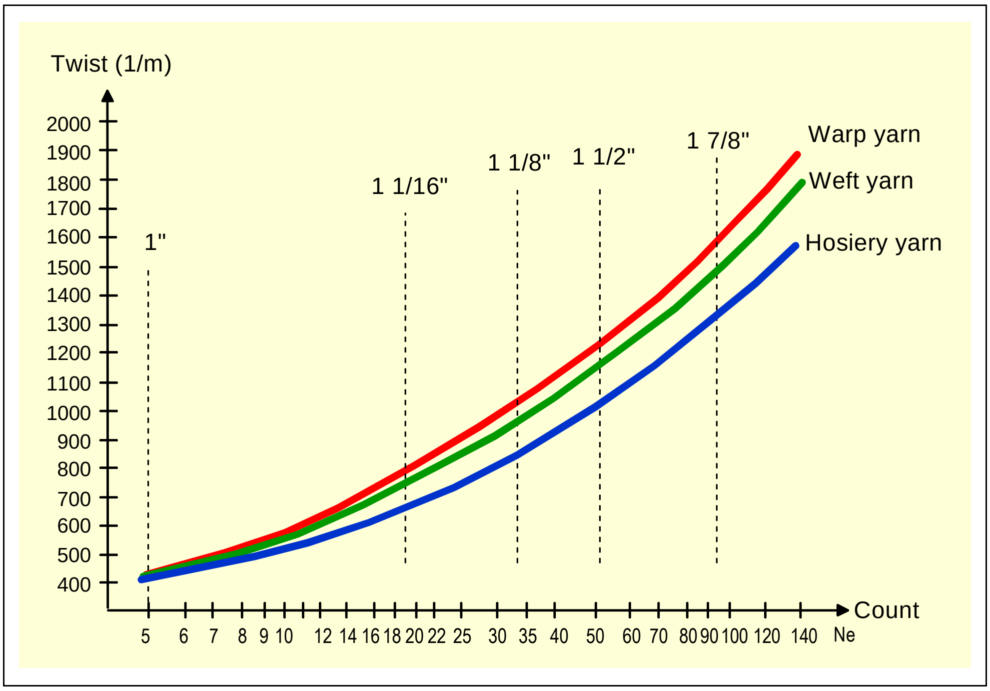

Fig. 1

Fine yarns require long staple fibers and high twist. Coarse yarns can be produced with short fibers and low twist. The relationship is shown in Fig. 1. The recommended fiber lengths with respect to yarn count is represented in Fig. 1.

The warp yarns are the yarns with the highest twist.

The twist of weft yarns is approximately 10% below the warp yarns.

The twist of hosiery yarns is approximately 20% below the warp yarns.

2.2 Fiber length versus yarn count / rotor-spun yarn / Cotton 100%

Fig. 2 shows the relationship between fiber length, count and twist. The shortest fibers are comber noil and cotton waste. These short fibers are not suitable for fine OE rotor-spun yarns.

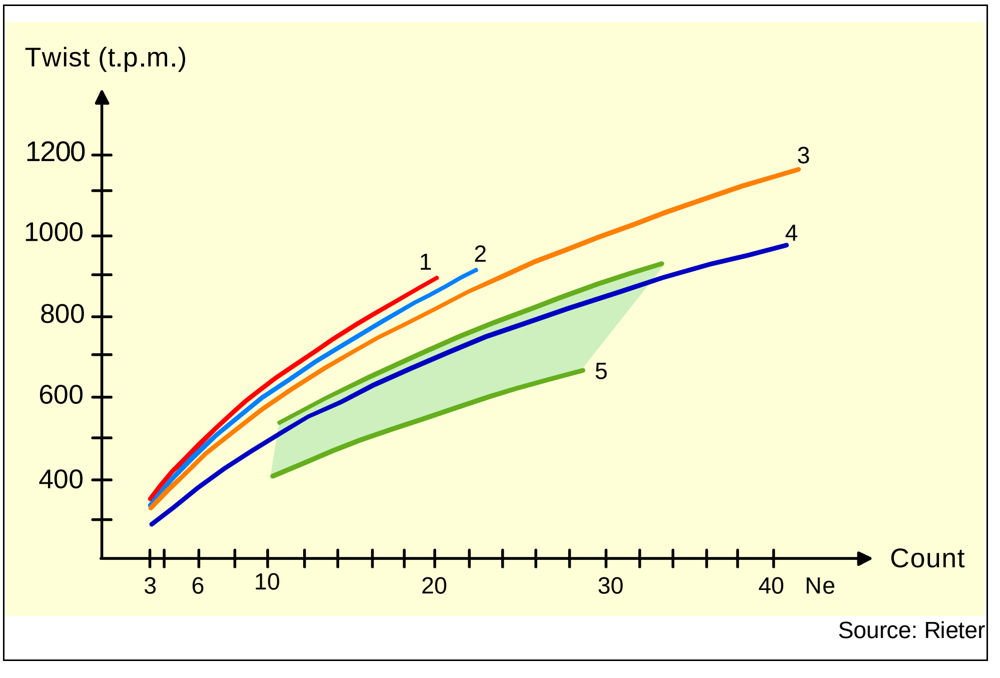

Fig. 2

Explanation of figures:

1 = Comber noil ($\alpha e = 5.1$)

2 = Cotton waste ($\alpha e = 5.0$)

3 = Cotton 1“ - 11/8“ ($\alpha e = 4.7$)

4 = Synthetic fibers 38 mm ($\alpha e = 3$)

5 = Twist for hosiery yarns, raw mat. according to 3, 4 ($\alpha e = 3.2$ to 4.1)

3 Yarn count

3.1 Between bobbin variations versus yarn count

Fig. 3

Fig. 3 shows the relationship between bobbin count variation and count. Various evaluations for the USTER® *STATISTICS* have shown that it is more challenging to produce fine yarns with small "between bobbin variations" than for coarse yarns due to the reduced fibers in the cross-section. Therefore, the red line is increasing for fine yarns.

3.2 Yarn count versus air humidity

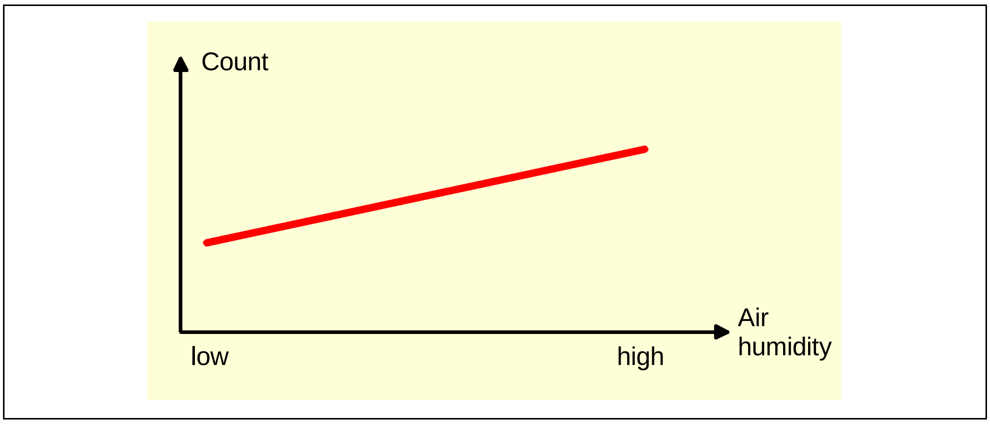

Fig. 4

When determining the yarn count it has to be taken into consideration that the count depends on the water absorption of the yarn. Therefore, the count has to be determined under constant environmental conditions of 20°/65% r.H. or 27°/65% r.H., and the bobbins have to be adapted to the climate of the test room prior to the test if the yarn has been processed in a different environment.

As a result, when count values are determined, the environmental conditions have to be determined as well and mentioned on the data sheet.

4 Yarn evenness

4.1 Yarn evenness versus fiber fineness

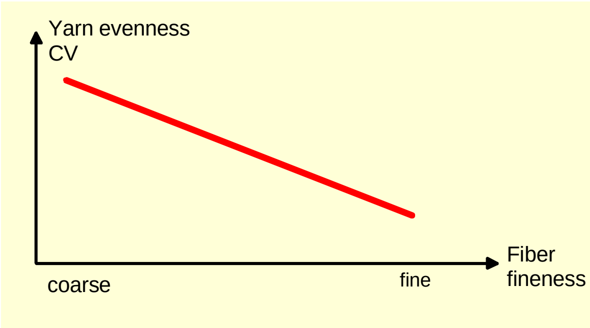

Fig. 5

For a given count the evenness depends on the fiber fineness. The evenness can be lowered by using fine fibers. The theoretical background is Martindale's formula:

$$CV_{lim} = \frac{1}{\sqrt{n}} \bullet 100\%$$

CV_{lim} = Limit irregularity
n = number of fibers in the cross-section

4.2 Yarn evenness versus number of fibers in cross-section / Measured evenness and limit irregularity

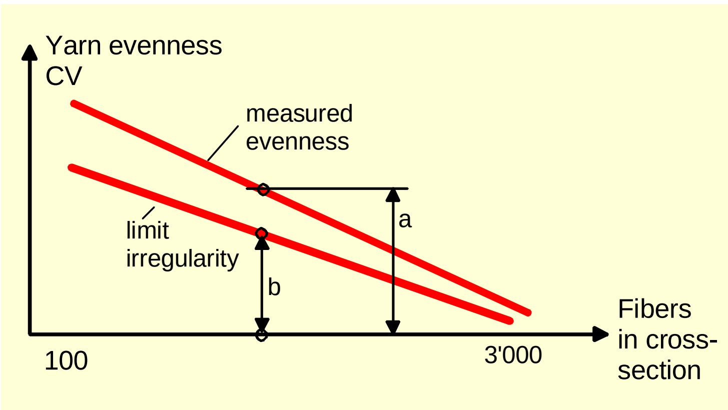

Fig. 6

The limit irregularity can be reached in case of an ideal distribution of fibers. The ratio between the evenness value obtained under practical conditions and the limit irregularity is called the "irregularity index I".

$$I = \frac{CV_m}{CV_{lim}} = \frac{a}{b}$$

CV_m = Measured evenness
CV_{lim} = Limit irregularity

Hence, if for a given yarn count the number of fibers in the cross-section is high, the evenness is low and vice versa.

The number of fibers in the cross-section of coarse yarns is high. As a result, the yarn evenness of coarse yarns is low (Martindale's formula). A few missing fibers, therefore, can hardly affect the evenness in coarse yarns, whereas a few missing fibers in fine yarns can be substantial.

4.3 Yarn evenness versus short fiber content

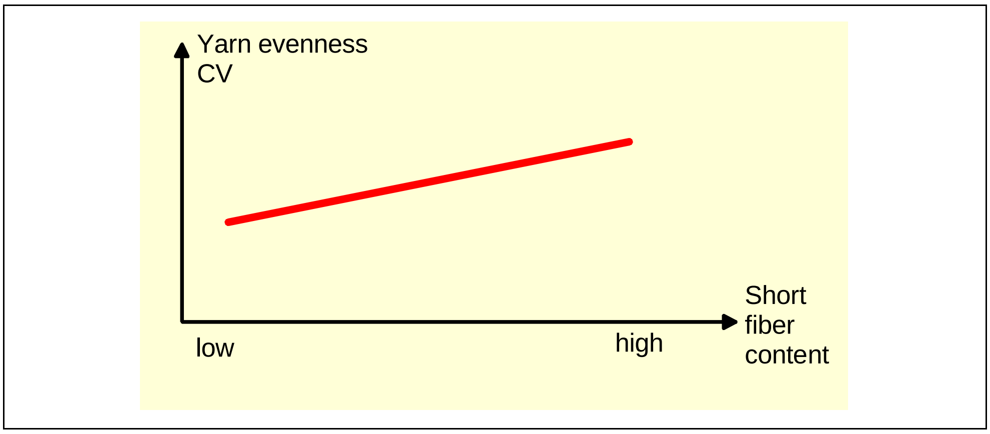

Fig. 7

High short fiber content increases the yarn unevenness of ring-spun yarns because the short fibers cannot be controlled in the draw box. Therefore, it is required to reduce the amount of short fibers for fine yarns.

4.4 Yarn evenness versus thick and thin places

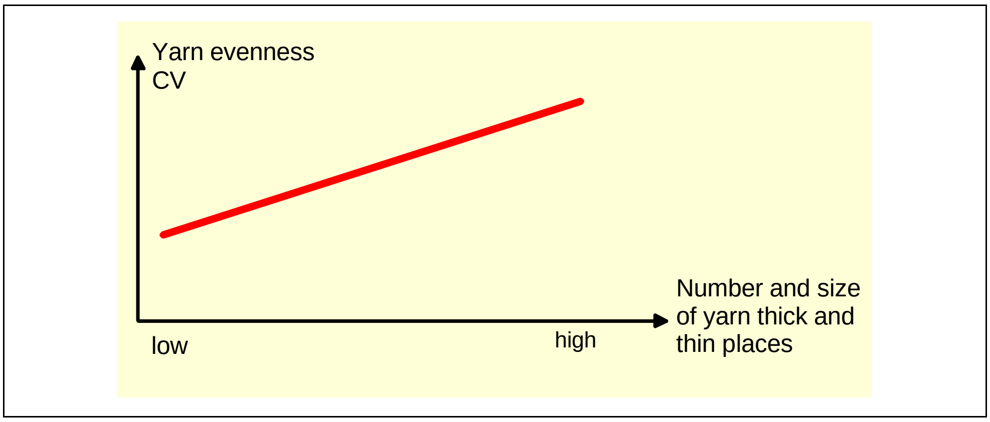

Fig. 8

There is a relationship between yarn thick and thin places and yarn evenness. As thin and thick places are a considerable part of the entire evenness of a yarn it has to be expected that the evenness for a given yarn count will increase with the number and size of thick and thin places or vice versa.

4.5 Yarn evenness versus neps

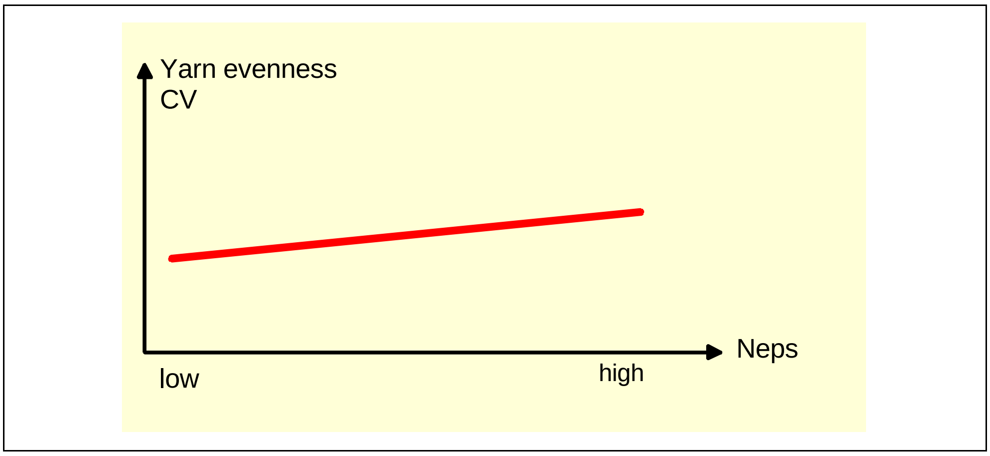

Fig. 9

Neps are thick places of very short length. Therefore, the number of neps can only slightly influence the yarn evenness.

4.6 Yarn evenness versus yarn count / Comparison of various spinning systems

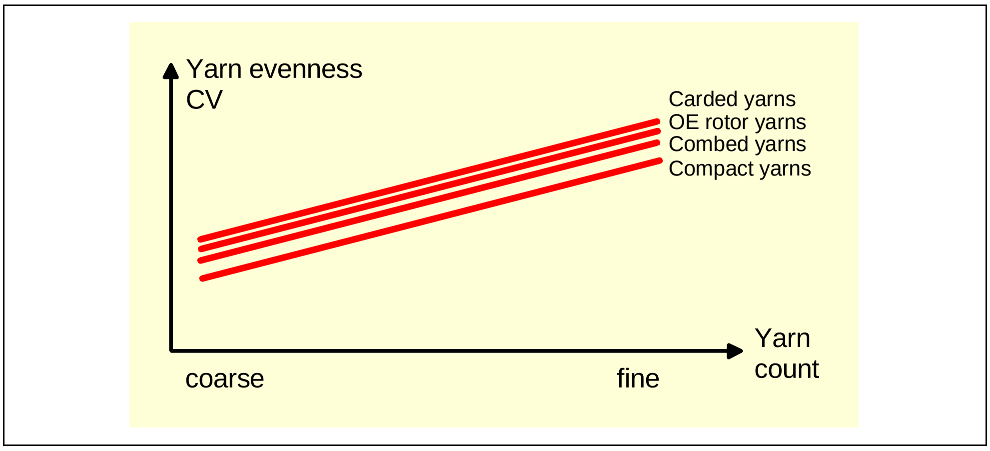

Fig. 10

The yarn evenness depends on the number of fibers in the cross-section as mentioned under 4.1. The theoretical background is again Martindale's formula. Fine yarns with a low number of fibers in the cross-section have a higher unevenness than coarse yarns.

In addition, the yarn evenness also depends on the spinning technology. Compact yarns have the lowermost evenness. Carded ring-spun yarns have the highest evenness.

4.7 Yarn evenness versus yarn twist

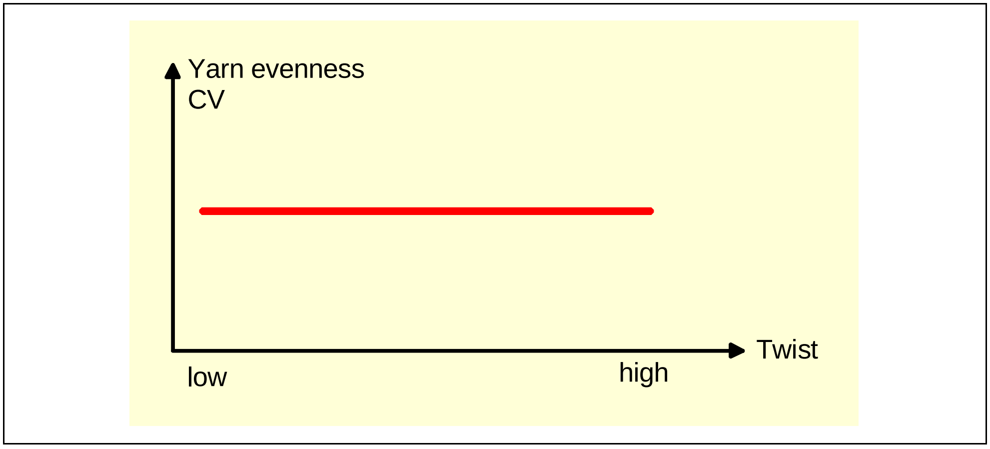

Fig. 11

The twist has no influence on the yarn evenness. Mass variations in yarns have its origin in drawing process.

4.8 Yarn evenness versus cut length

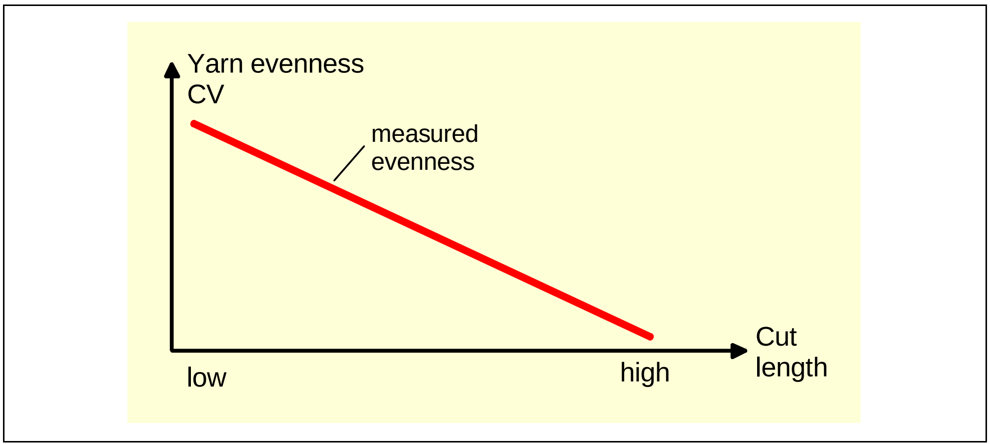

Fig. 12

The “normal” yarn evenness measured with an electronic instrument is a comparison of mass variations of yarn pieces of 1 cm length. If yarns are cut into prices of 0.1 m, 1 m, 10 m, etc., the variation between the yarn pieces decreases. The longer the yarn pieces, the lower the yarn evenness.

4.9 Yarn evenness and imperfections versus air humidity

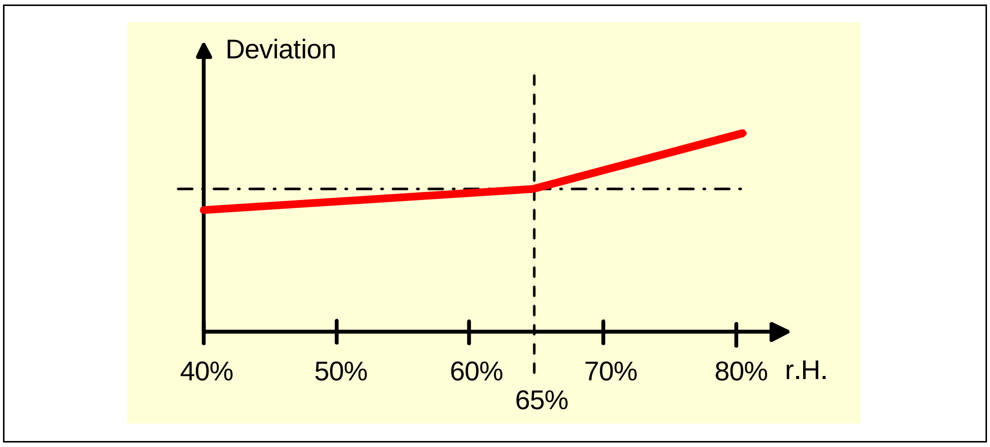

Fig. 13

Most of the quality characteristics of yarns are affected by the environmental condition in the test room and the moisture content of the yarn. The standard tests conditions are 20°/65% r.H. or 27°/65% in tropical countries. As Fig. 13 shows, the evenness and the imperfections increase when the humidity increases and vice versa.

5 Yarn imperfections

5.1 Yarn thick and thin places versus short fiber content

Fig. 14

The number of thin and thick places increases with the amount of short fibers. Since the short fibers can hardly be controlled in the drawboxes, it leads to the formation of thick and thin places.

5.2 Yarn neps versus yarn count

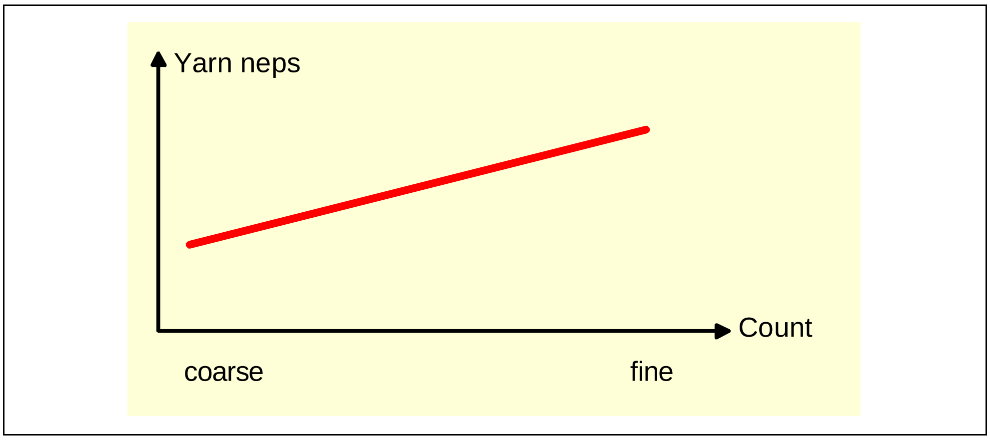

Fig. 15

If fibers of a given number of neps are processed into coarse and fine yarns, the evenness tester will count less neps in the coarse yarn and more neps in fine yarns. Since all deviations are referred to the mean value of the yarn, neps of a given size are less significant in coarse yarns.

5.3 Yarn thick and thin places versus yarn count

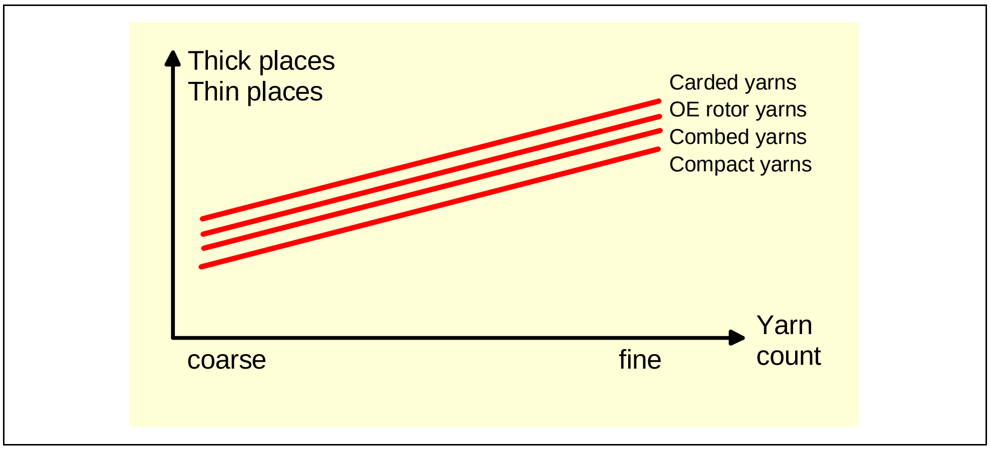

Fig. 16

The number of thick and thin places increases with a decreasing number of fibers in the cross-section.

5.4 Neps in yarns versus neps in raw material

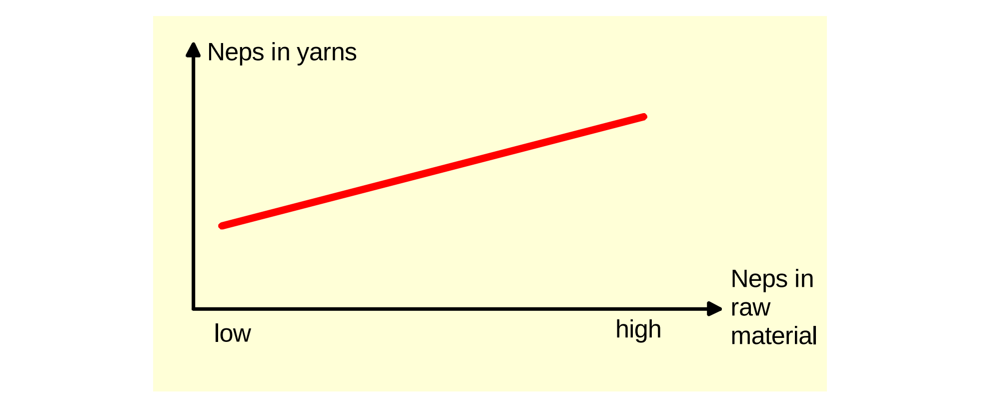

Fig. 17

There is strong relationship between neps in yarns and neps in raw material. More neps in the raw material result in more neps in yarns under the same process conditions.

6 Yarn strength and elongation

6.1 Yarn strength versus yarn twist / Cotton

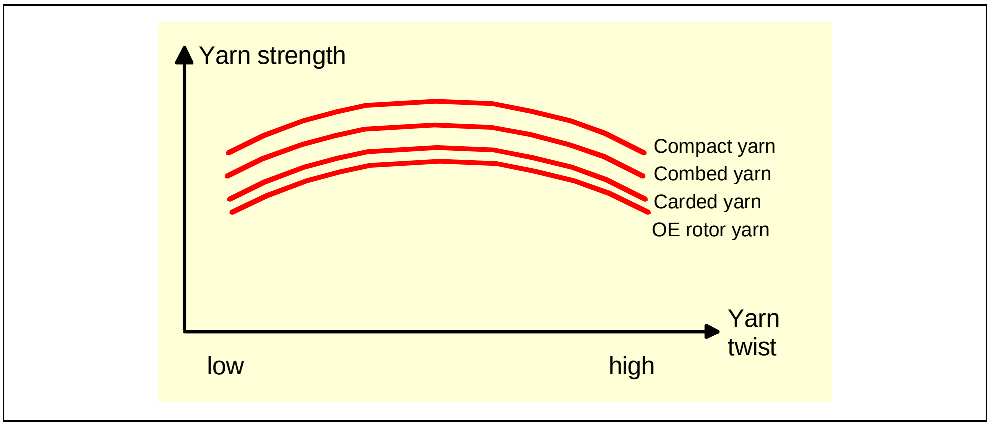

Fig. 18

If the yarn twist increases, the yarn strength increases as well. A yarn of medium count of Nec 30 reaches the peak value at about 1000 turns per meter. At higher twist the yarn strength is decreasing again.

Most of the fibers in the cross-section of compact yarns contribute to the yarn strength.

The protruding fibers of combed yarns do not contribute to the yarn strength.

The short fibers of carded yarns cause a reduction of the yarn strength.

The wrapped fibers of OE rotor yarns do not contribute to the yarn strength.

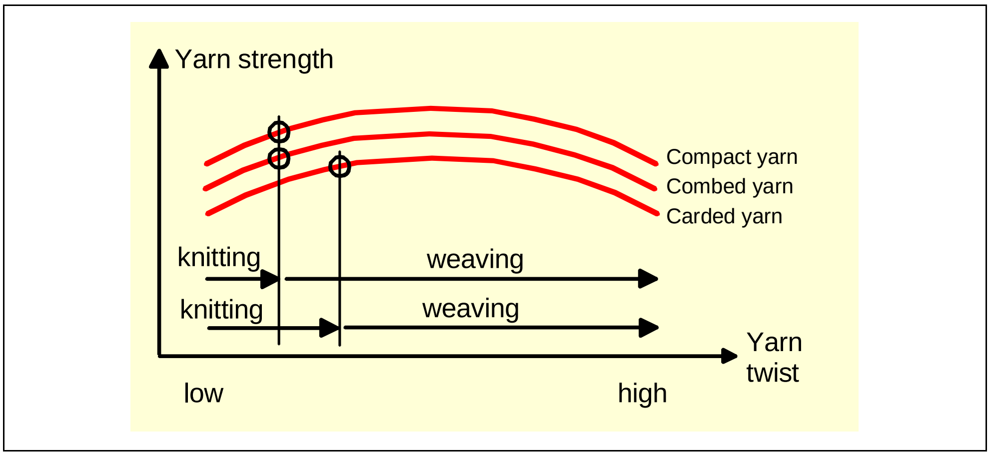

Fig. 19

The twist multiplyer αe for combed yarns for knitted fabrics should not exceed 3.7, whereas in case of carded yarns a twist multiplyer up to 3.9 is tolerated for yarns for knitted fabrics.

Yarns with low twist are used for knitted fabrics, yarns with high twist are used for crepe yarns. Yarns with average twist are used for regular woven fabrics.

6.2 Yarn strength versus yarn evenness

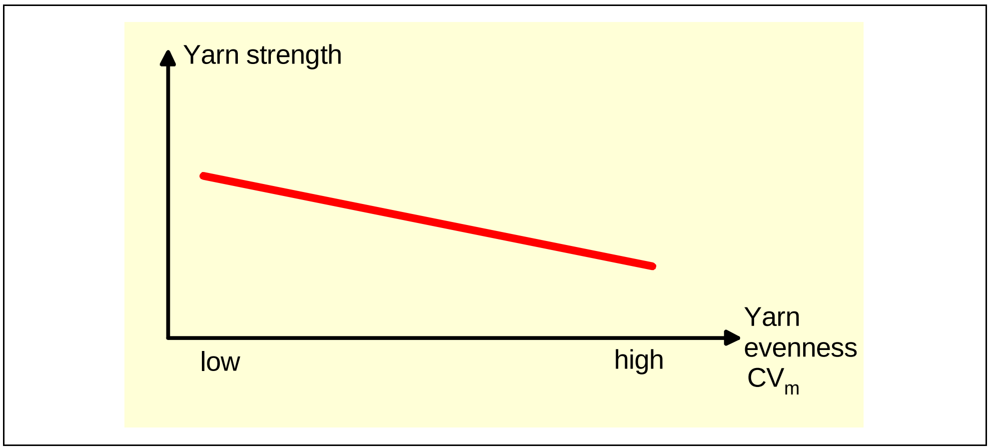

Fig. 20

For a given count the yarn strength is high if the evenness is low because the number of weak places is low as well.

6.3 Yarn strength versus fiber strength

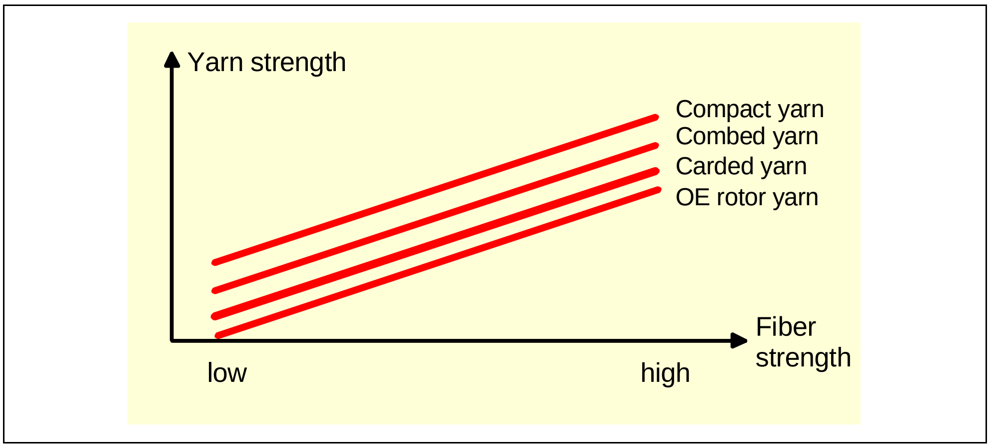

Fig. 21

There is a strong correlation between yarn strength and fiber strength for a given twist.

6.4 Yarn strength versus test specimen length

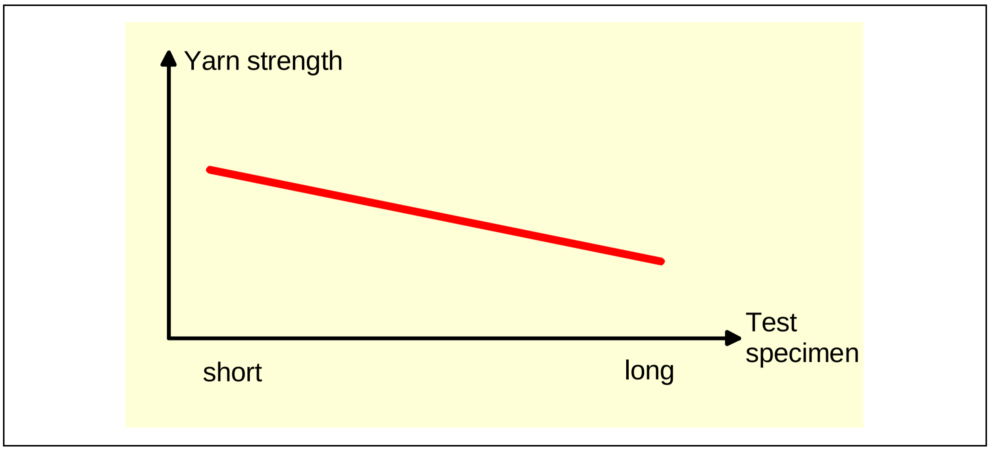

Fig. 22

It has to be taken into consideration that the specimen length plays a considerable role when carrying out strength tests, because the probability of weak places is higher when the test specimen between the 2 clamps of the testing system is long.

Therefore, for correct test results the specimen length must be specified on the data sheet.

6.5 Yarn strength versus test speed

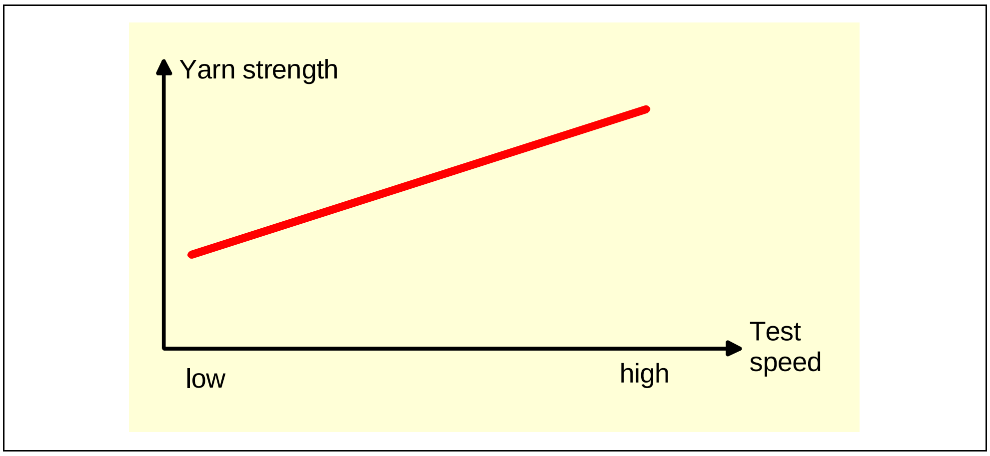

Fig. 23

The yarn strength depends on the test speed. The higher the test speed, the higher the strength. Therefore, the test speed must be printed out on the data sheet. The force applied on yarns on modern weaving and knitting machines is a fast process. Therefore, it is recommended to also carry out the strength tests at high speed.

6.6 Yarn tenacity versus yarn count

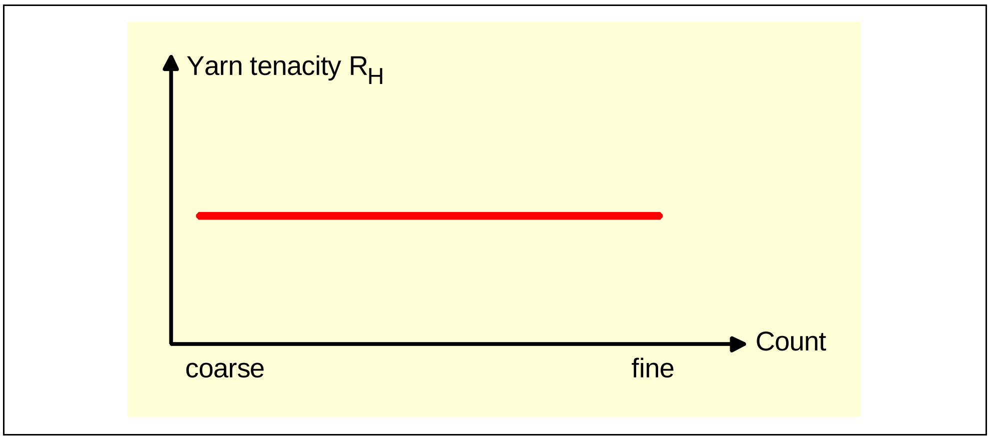

Fig. 24

The tenacity (in cN/tex or gf/tex) is constant for coarse and fine yarns for a given raw material. Statistical evaluations have shown that the count has hardly any influence on the tenacity of yarns.

6.7 Yarn strength versus air humidity

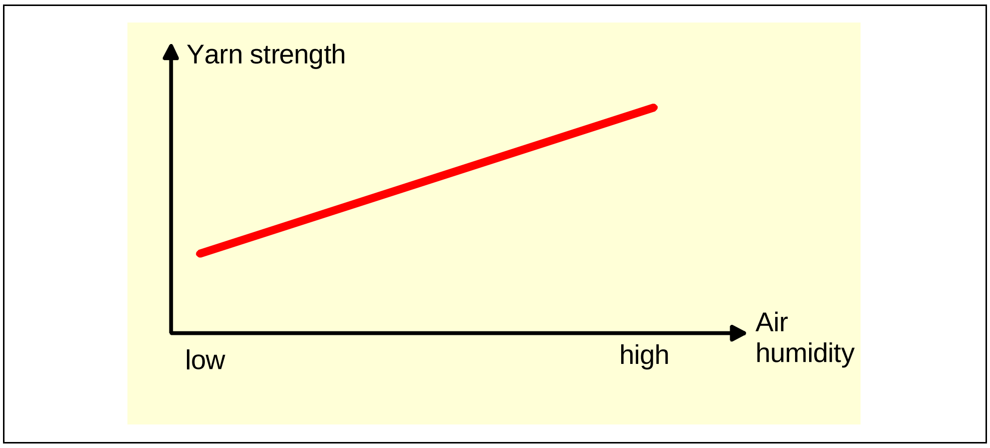

Fig. 25

The yarn strength of all natural fibers increases if the air humidity increases. A higher moisture content of the yarn the fiber-to-fiber friction changes due to the swelling of the fibers.

6.8 Yarn tenacity variation versus yarn count

Fig. 26

The tenacity variation is higher for fine yarns because the probability of weak places in fine yarns is higher.

6.9 Yarn strength versus yarn elongation

Cotton

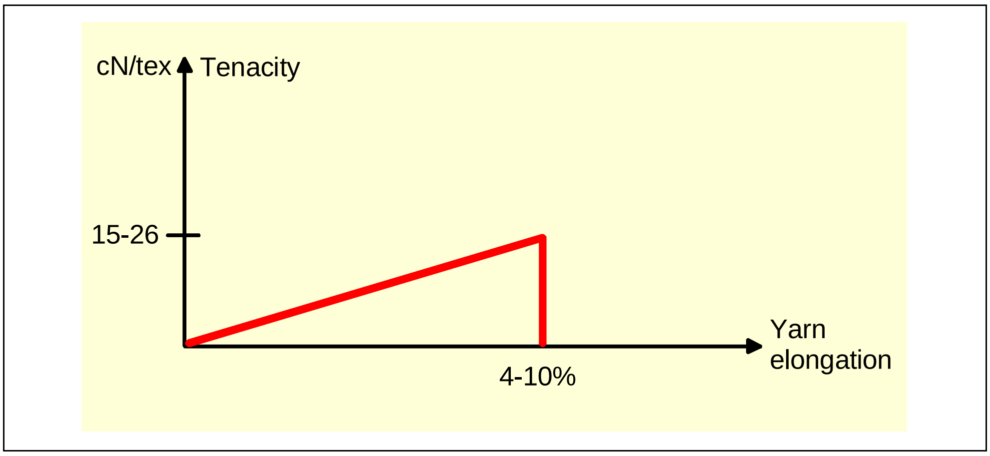

Fig. 27

There is a linear relationship between yarn strength and yarn elongation. The tenacity depends on the twist and the fiber strength. The tenacity varies between 15 and 26 cN/tex, the elongation between 4 and 10%, depending on the fiber strength, the yarn count and twist.

6.10 Yarn strength versus yarn elongation

Synthetic spun yarn/Polyester

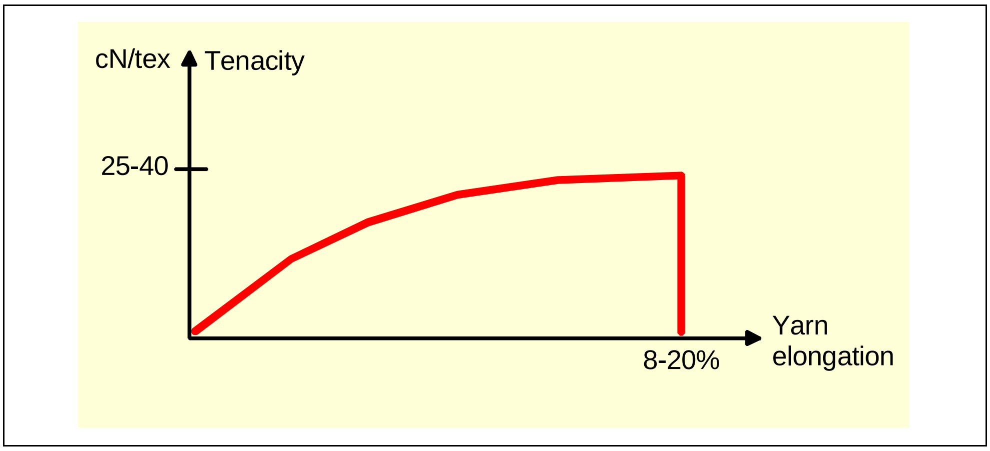

Fig. 28

There is a non-linear relationship between the yarn strength and elongation for spun yarns of polyester fibers. The tenacity reaches values between 25 and 40 cN/tex, depending on the fiber and the twist. The elongation varies between 8 and 20%.

6.11 Yarn strength versus yarn elongation

Blended yarn, cotton/synthetics

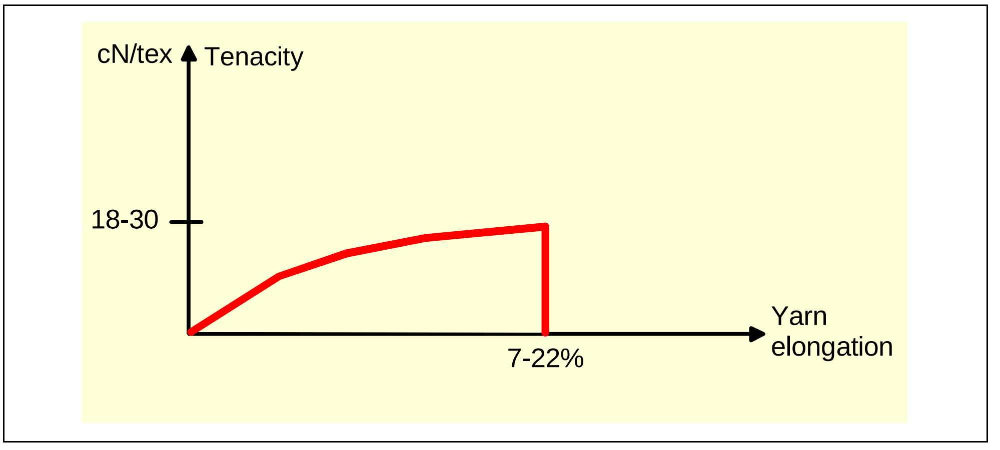

Fig. 29

Most of the blended yarns consist of cotton and polyester and have a blend ratio PES/CO 50/50% or 67/33%. The relationship between tenacity and elongation is non-linear because of the influence of synthetic fibers. The tenacity varies between 18 and 30 cN/tex, the elongation between 7 and 22%.

6.12 Yarn strength versus yarn elongation

Worsted yarn

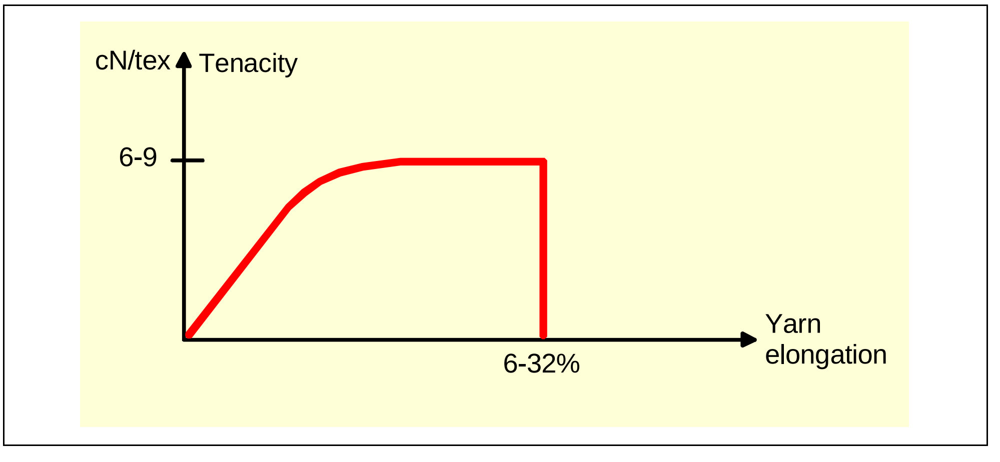

Fig. 30

The relationship between tenacity and elongation of worsted yarn is non-linear. The tenacity is low and varies between 6 and 9 cN/tex, the elongation between 6 and 32%.

6.13 Yarn elongation versus test speed

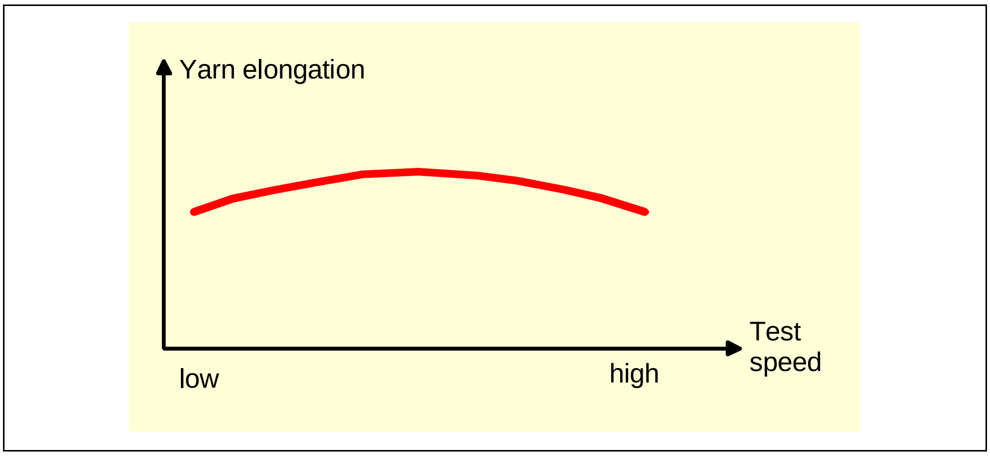

Fig. 31

The yarn elongation of spun yarn increases slightly with increasing test speed, but decreases again at high speed.

6.14 Yarn elongation versus yarn count

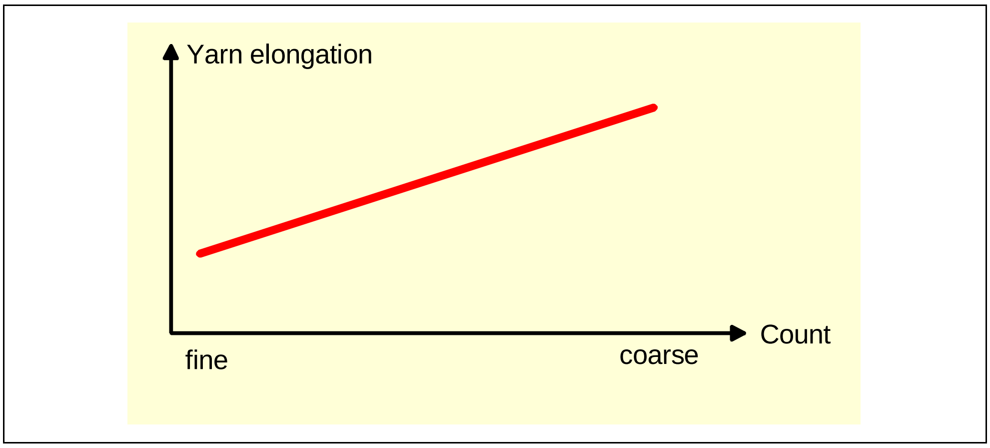

Fig. 32

The yarn elongation increases with increasing yarn count. It must be considered, however, that the twist increases with finer count as well. Higher twist also increases the elongation.

6.15 Yarn elongation versus yarn twist

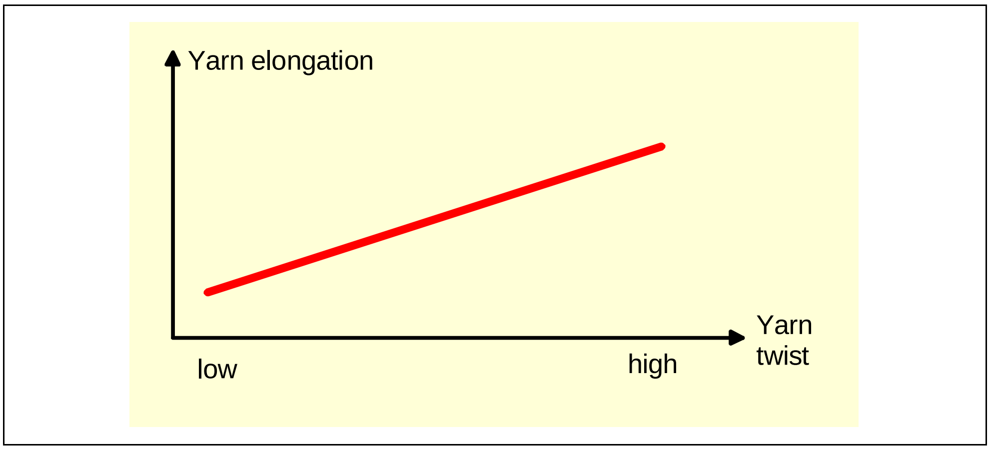

Fig. 33

The yarn elongation is low at low twist and high at high twist.

6.16 Yarn elongation versus fiber elongation

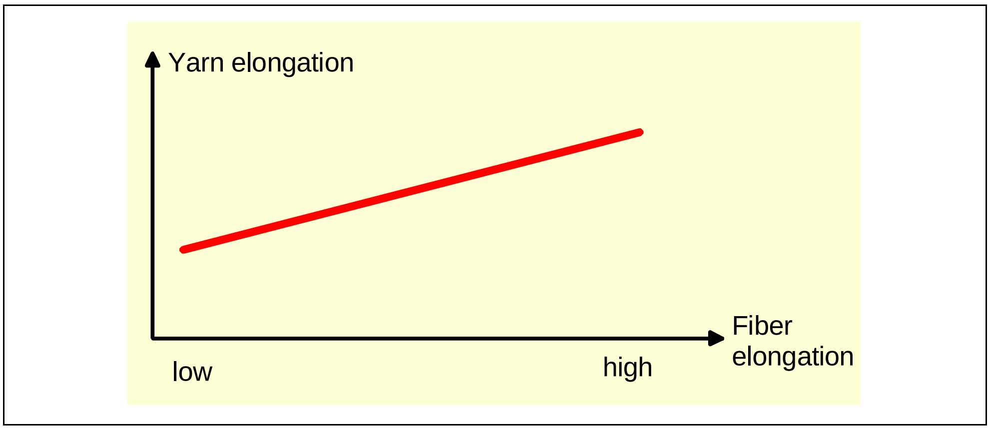

Fig. 34

There is also a high correlation between fiber elongation and yarn elongation. If the fiber elongation is low the yarn elongation is low as well and vice versa.

6.17 Variation of yarn elongation versus yarn count

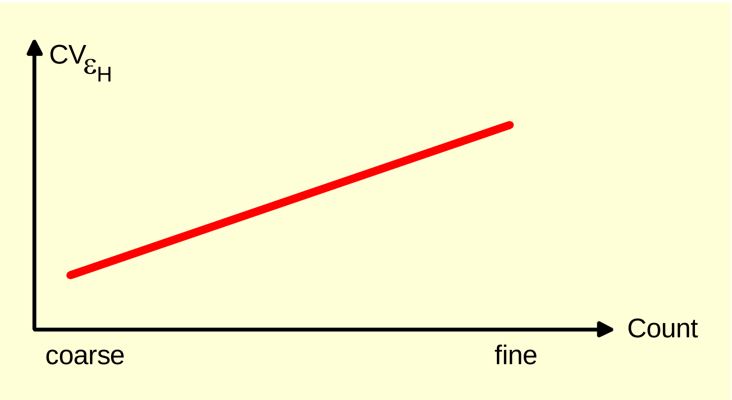

Fig. 35

The variation of yarn elongation increases with finer yarns because the probability of weak places with low elongation increases as well.

6.18 Yarn elongation versus yarn count

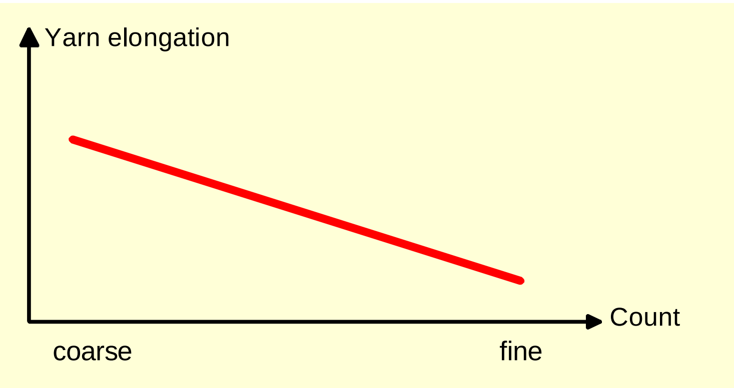

Fig. 36

The yarn elongation of coarse yarns is higher than the yarn elongation of fine yarns.

6.19 Yarn elongation versus air humidity

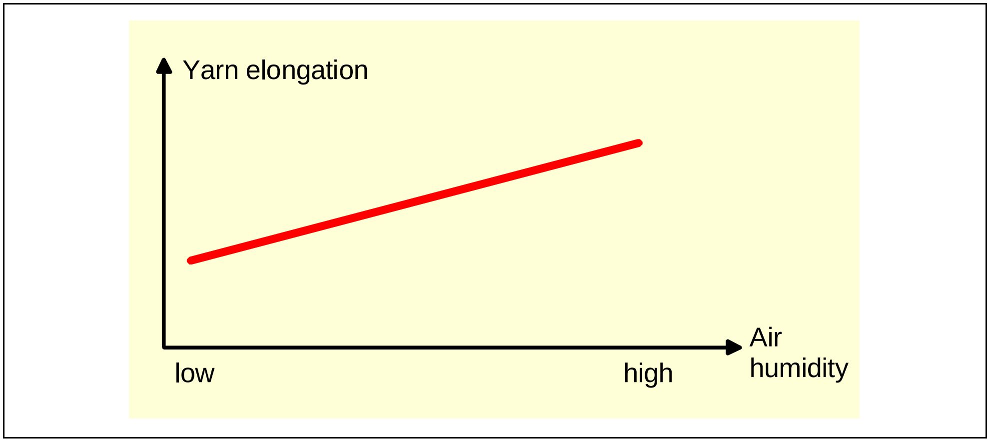

Fig. 37

The yarn elongation increases with higher air humidity, i.e. with higher moisture content of the yarn. This is caused by a different fiber-to-fiber friction when the fibers absorb more moisture.

7 Yarn dust, trash, density, roundness

7.1 Yarn dust versus yarn count / cotton

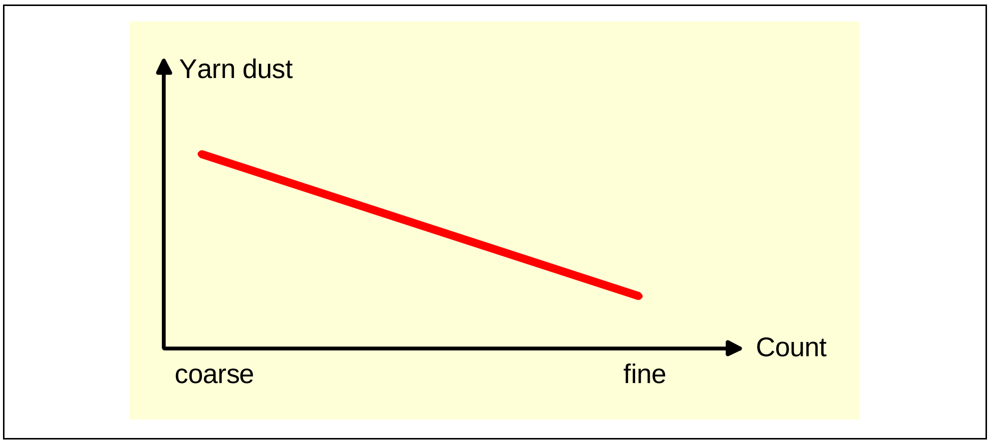

Fig. 38

The amount of dust is higher in coarse yarns than in fine yarns because of the higher number of fibers in the cross-section. The yarn dust is measured with the Sensor OI of the USTER® *TESTER 4*.

7.2 Yarn trash versus yarn count

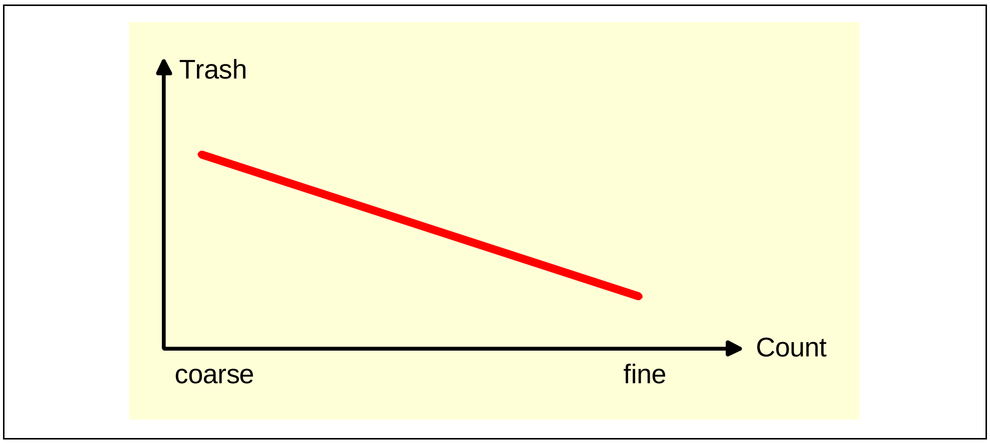

Fig. 39

The amount of trash is higher in coarse yarns compared to fine yarns because of the high number of fibers in the cross-section.

7.3 Yarn density versus yarn count

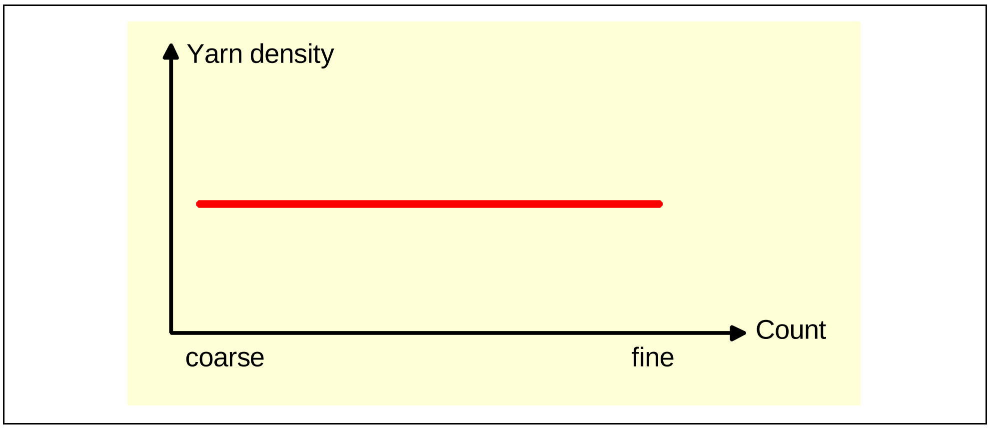

Fig. 40

The yarn density remains constant for coarse and fine yarns. This result is based on evaluations for the USTER® *STATISTICS*. It must be taken into consideration, however, that the twist for fine yarns is considerably higher than for coarse yarns. The density is measured with the Sensor OM of the USTER® *TESTER 4.*

7.4 Roundness of yarn cross-section versus yarn count

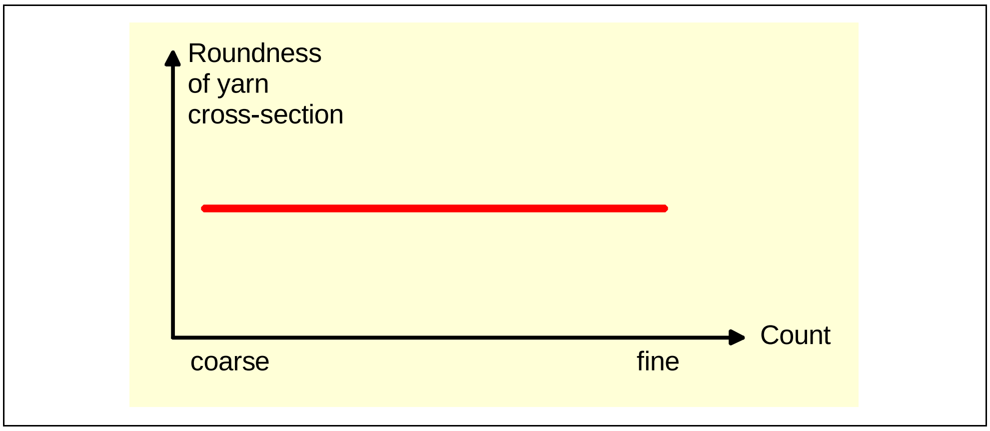

Fig. 41

The roundness of yarns can be measured with the Sensor OM of the USTER® *TESTER 4*. The roundness can affect the appearance of fabrics considerably.

The roundness remains constant for all kinds of yarn counts.

8 Work done

8.1 Definition of work done

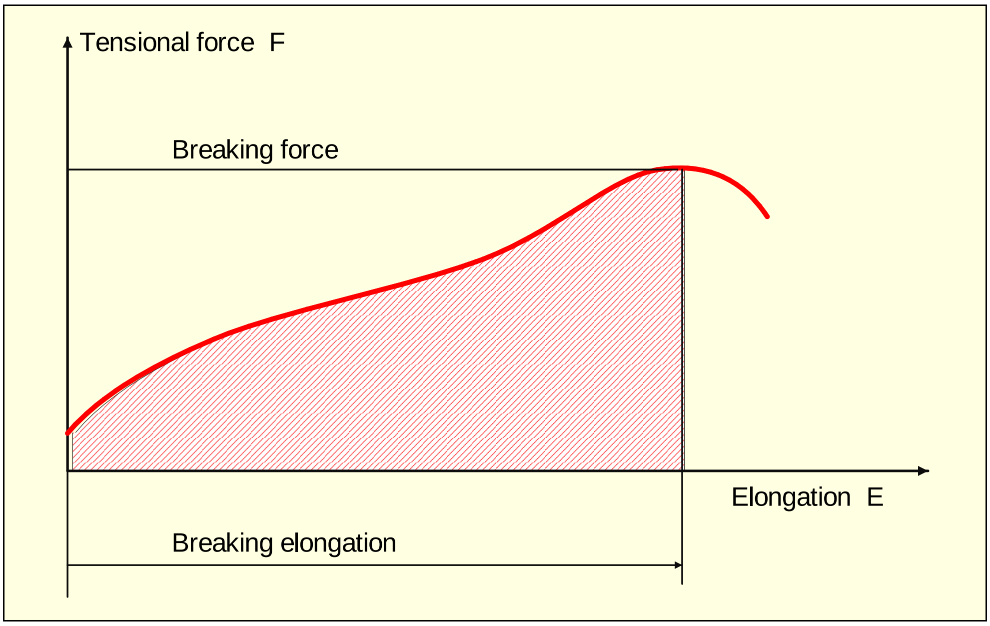

Fig. 42

The work done can be represented as the area below the force-extension diagram from zero to breaking elongation.

Missing yarn strength in weaving can be compensated to a certain extent with a better elongation. The work done takes into consideration the strength and the elongation and is, therefore, an important quality parameter to characterize yarns.

8.2 Work done versus yarn count

Fig. 43

The work done is high for coarse yarns and low for fine yarns.

8.3 Work done versus strength and elongation

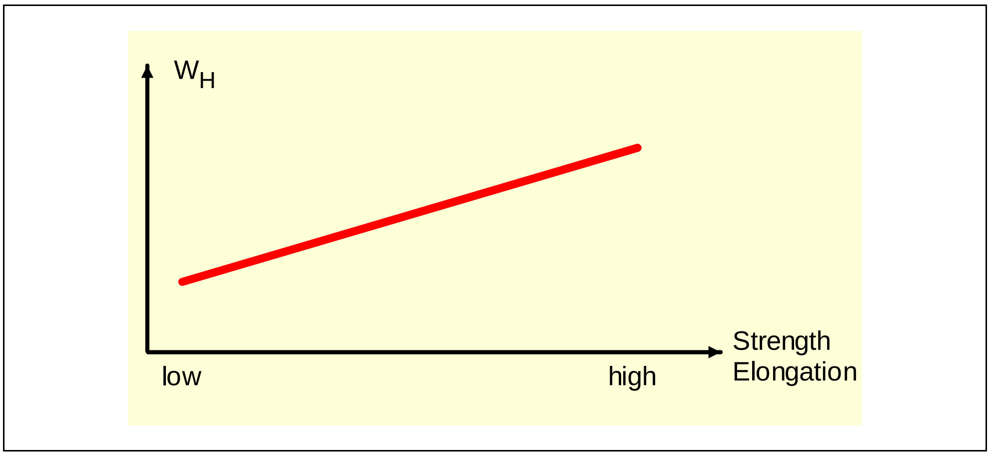

Fig. 44

The work done increases with the strength and/or elongation of yarns.

8.4 Variation of work done versus yarn count

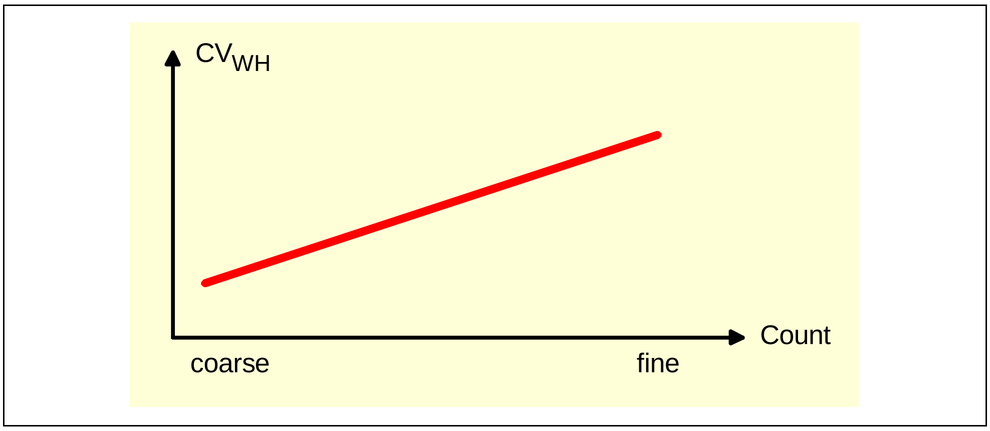

Fig. 45

As the probability for weak places is higher for fine yarns the variation of work done is also higher for fine yarns.

8.5 Work done versus air humidity

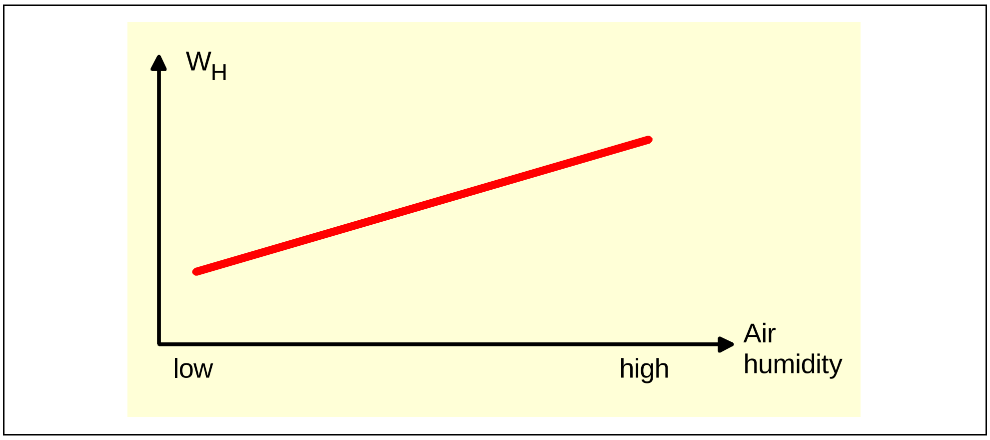

Fig. 46

Since the force and elongation with the higher absorption of moisture in yarns increases, the work done also increases.

9 Yarn hairiness

9.1 Yarn hairiness versus yarn count

Fig. 47

The hairiness of coarse yarns is higher than the hairiness of fine yarns, because the probability of protruding fibers is higher with more fibers in the cross-section.

9.2 Yarn hairiness versus spindle speed

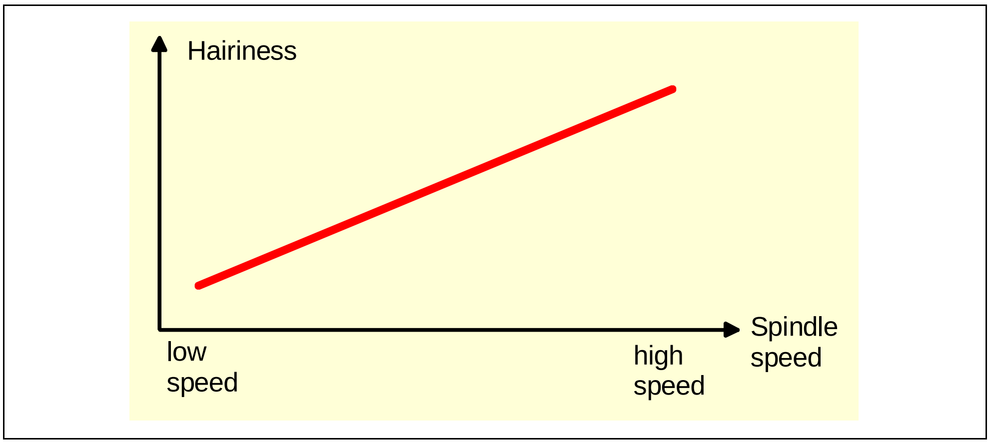

Fig. 48

For a given type of ring traveler the hairiness increases if the spindle speed increases.

9.3 Yarn hairiness versus yarn twist

Fig. 49

The reduction of twist increases the hairiness because the number of protruding fibers increases. However, there are some limitations concerning the twist multiplyer. This value should not exceed 3,7 for combed yarns.

9.4 Yarn hairiness versus life cycle of ring traveller

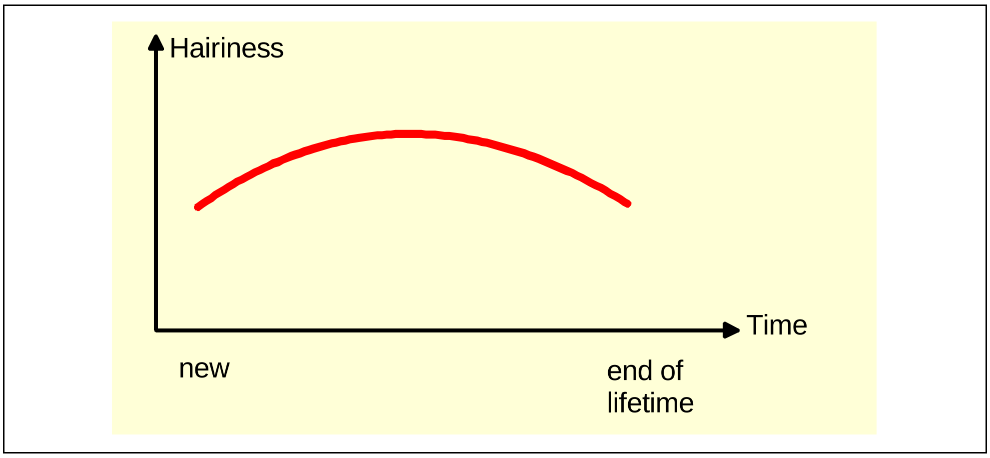

Fig. 50

The hairiness of yarns with new ring travelers is low because the rough surface of the ring traveler eliminates some of the protruding fibers. After an operating time of a few days the surface of the ring traveler is smooth and does hardly eliminate protruding fibers. At the end of the life cycle the ring traveler has sharp edges and cuts of a considerable amount of protruding fibers. Therefore, the hairiness decreases again.

9.5 Yarn hairiness increase on winding machines versus yarn type

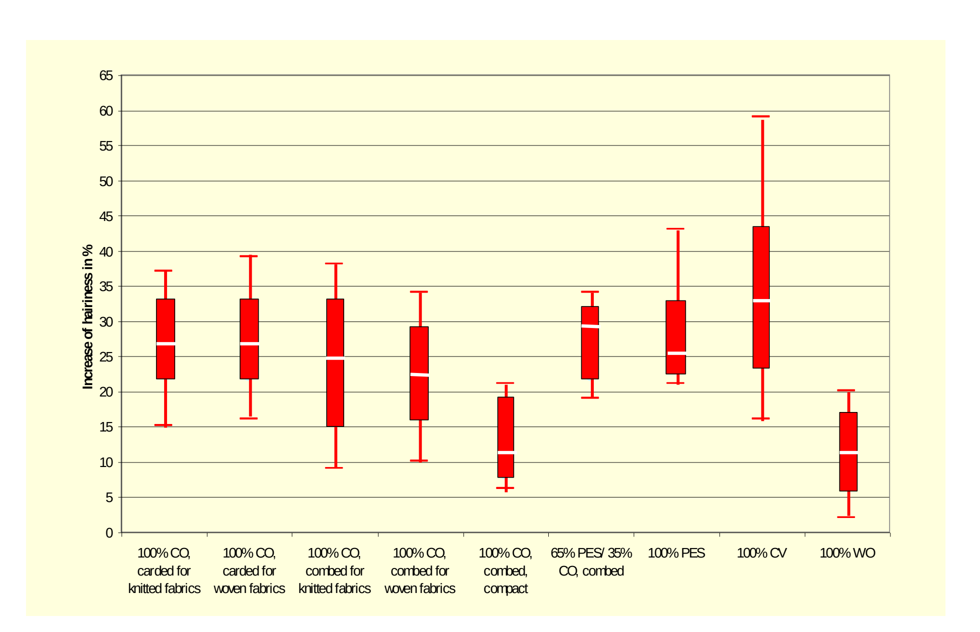

Fig. 51

Due to the friction of the yarn at the yarn guiding elements the hairiness of the yarn increases as a result of the winding process. Fig. 51 shows how much the hairiness increases for the most important yarn types. This data was collected when the samples for the USTER® *STATISTICS* were evaluated.

9.6 Yarn hairiness of conventional ring-spun yarn versus yarn hairiness of compact yarn

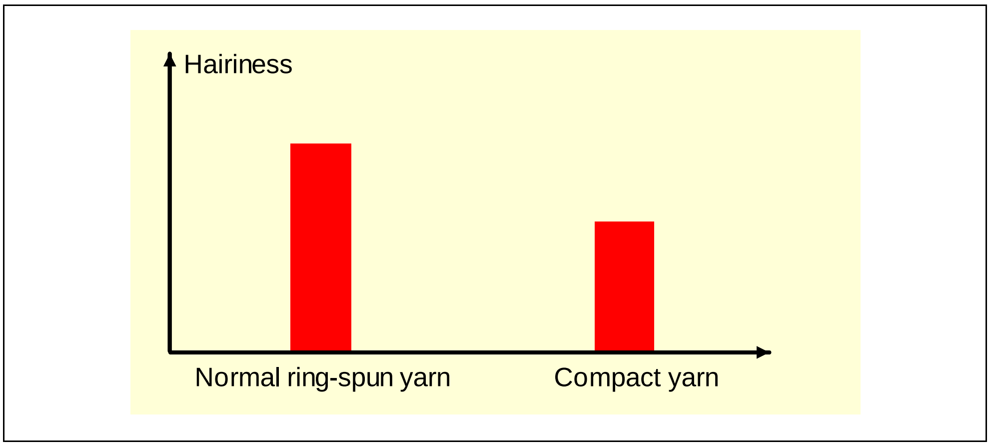

Fig. 52

The hairiness of compact spun yarn can be reduced considerably compared with conventional ring-spun yarns.

9.7 Yarn hairiness increase versus winding speed

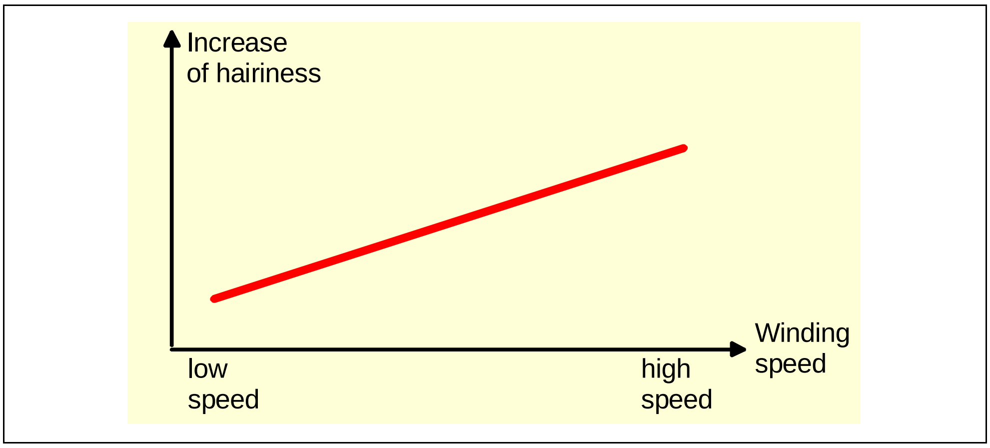

Fig. 53

On the winding machine the hairiness of yarns increases with higher winding speeds.

9.8 Yarn hairiness on bobbins versus yarn position on bobbins

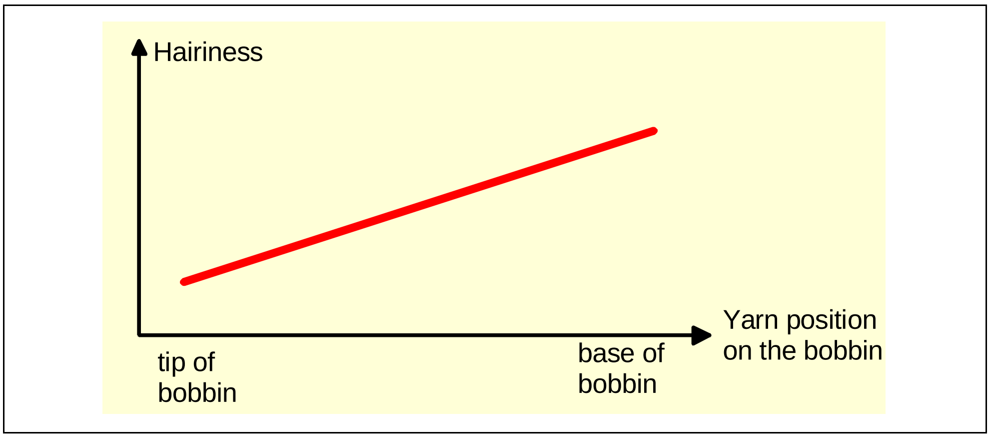

Fig. 54

The hairiness of yarns increases from the tip to the base of the bobbin due to the different yarn tension and angle of the yarn at the ring traveler. The different tension and angle at the ring traveler is caused by the vertical movement of the ring rail.

9.9 Yarn hairiness versus short fiber content

Fig. 55

If the short fiber content in the yarn increases, the number of protruding fibers increases and, therefore, the hairiness increases as well.

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