Determination of the strength and elongation of splices
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1 Introduction

A splice, also called yarn joint, has the purpose to join together two ends of a yarn as a result of yarn fault removal on OE rotor and winding machines and bobbin changes during the winding process. This means when a detected fault is cut from a yarn, the resulting yarn ends are pieced together, either by knotting or splicing them by using an automatic splicing piecing device [1]. In the past, it was common practice to knot yarns together, but the knots were a source of weakness and were defects in their own right. Nowadays, yarns are spliced together using mechanical splicers, air-jet splicers, water-jet splicers and thermo-splicers, etc. which produce a joint that is usually at least 70% of the strength, and generally less than 130% of the thickness of the parent yarn. The splice efficiency is used as a measure of the spliced part of the yarn, expressed as a percentage of that reference yarn. The adoption of splicing has greatly reduced problems in weaving, knitting, and dyeing [2].

A yarn must have a certain minimum tensile strength and a minimum elongation in order to stand up to the processes subsequent to spinning. This is also and especially valid for splices that join together two ends of a yarn. Since an average ring-spun yarn (Ne 30) can have more than 100 splices over a length of 100 km, it is important to monitor the parameters of the splices carefully.

Besides the quality aspect that needs to be fulfilled by the yarn, its processing quality depends to a certain extent also on the quality of the splices. Today, approximately one splice per kilometer has to be expected in a cone. Considering the costs for a yarn break in knitting, warping, sizing or weaving, the splices play an important role in this respect as well. The number of splices must be kept at a low level, but the potential weak places (splice) must have the highest strength possible. This is only possible by checking the strength of the splices regularly by means of an instrument.

The USTER® ZWEIGLE SPLICE TESTER has been especially developed to measure splices in an easy and practical way. The instrument can be taken to the winding or spinning machine, in order to carry out the tests directly at the machine.

2 Explanation of splices

A splice, also called yarn joint, has the purpose to join together two ends of a yarn as a result of yarn fault removal on OE rotor and winding machines and bobbin changes during the winding process. This means that the yarn clearer often eliminates a disturbing defect and replaces it with a less disturbing splice. This procedure is done according to the following principle:
1. During the winding process from bobbin to cone, the yarn is completely monitored for yarn faults with an electronic device, the yarn clearer.

2. As soon as the yarn clearer detects a yarn fault, the yarn will be separated by the cutter. The winding process is interrupted.

3. The yarn fault will be removed by the suction of the winding machine.

4. Both ends, the upper yarn from the cone as well as the lower yarn from the bobbin, are going to be combined again. The yarn joint is done by splicing with a splicing device or knotting with a knotting device. The latter is only used very rarely for special yarns. A good splice should not be realized by the human eye. Present yarn clearers also monitor the quality of the yarn joint.

5. The winding process continues up to the next fault or until there is no yarn on the bobbin any-more.

As we can see from the principle of yarn clearing, the yarn clearer often eliminates a disturbing defect and replaces it with a less disturbing splice.

Splice joints are almost invisible in contrast to knots which used to be yarn joints in the past. Various researchers mentioned that the strength of the splices is critical and to obtain a suitable splice in terms of size, a compromise may need to be reached between splice strength and appearance. A well spliced joint has a diameter 20 to 30 % greater than the yarn over a length of approximately 15 to 20 mm, and an average strength of around 80% of the yarn strength with a low CV% of strength [1]. Fig. 2 1 shows the picture of several splices.
2.1 Basic principles of splicing

For a satisfactory splice, the two yarn ends have first to be prepared to make them properly tapered. Also, the fibers must be adequately separated and paralleled so that they are capable of intermingling when the splice is made. Fig. 3 illustrates the basic principle of the splicing process [1 and 2]:

[1] Positioning of the yarns and cutting the unwanted yarn ends: The winding process was stopped in order to cut out the fault. The ends of the yarn are now parallel and face opposite directions. The scissors are ready to cut the unwanted yarn ends after the two yarns have been laid in place.

[2] Conditioning the yarn ends: The clamps grasp the yarn at the appropriate places before the main splicing procedure begins. The free ends of the two yarns are sucked into end-conditioning nozzles and air blasts are provided to condition them before joining.

[3] Forming loops to retract the yarn ends: Splicing is carried out after the two conditioned yarn ends are laid inside the splicing chamber so they are parallel, facing opposite directions and appropriately spaced without the tips of the conditioned ends protruding. The both lengths are drawn back until there is a certain length of overlap of the untwisted ends within the splicing chamber.

[4] Splicing ends: A pulse of compressed air is injected through the nozzles into the chamber; the air blast intermingles the fibers and then causes the newly made joint to rotate to produce false twist.

[5] Removing spliced yarn. The yarn is then removed from the splicer and the winding process continues.
Fig. 4 shows the twist directions and twist distribution during the splicing operation. The splicing chamber in Fig. 4 (a) designed for use Z-twist yarns. The twist in the splice gives the joint a similar appearance to that of the parent yarn and also strengthens the joint.

When the splice occurs, the ends have to be in the proper relative positions. In order to avoid a thick splice, it is necessary to taper then ends to be spliced so that the joint is not obvious. In Fig. 4 (b), the tapered ends are misplaced to give a thin spot. This is an undesirable weak spot. When the yarns overlapped two much, there would be a thick spot and two undesirable splice-tails (Fig. 4 (c)). These tails are mostly the subject of customer complaints during the knitting and weaving process. The splicer should be set to avoid these tails, sometimes at the expense of a slight loss in splice strength [2].
Fig. 5 shows two bad examples. The top splice has a wrapper on the right-hand side and the bottom splice has an undesirable tail on the left-hand side.
3 Test parameters

For all above mentioned reasons and to uphold the quality standards, it is very important to maintain the correct timings, settings and tensions during the splicing process. In order to measure the quality level of the splice, the splice efficiencies (splice strengths) should be tested \([1, 2]\). The USTER® ZWEIGLE SPLICE TESTER has been especially developed to measure the strength and the elongations of both the parent yarn on either side of the splice and the splices in an easy and practical way.

3.1 Breaking force

The strength of a yarn is the resistance to deformation caused by application of a force. The unit for the breaking force of the yarn in case of the USTER® ZWEIGLE SPLICE TESTER is cN (centi Newton).

3.2 Breaking elongation

The breaking elongation of a yarn is the difference between the length of a stretched yarn and its initial length, expressed as a percentage of the initial length. In case of tensile testers it is usually measured until the maximum force is reached. The figures for the breaking elongation of the yarn in case of the USTER® ZWEIGLE SPLICE TESTER are calculated in percent of nominal specimen length.
4 Interpretation of test reports

The test report of the USTER® ZWEIGLE SPLICE TESTER contains the single values for the breaking force [cN] and breaking elongation [%], as well as various statistical values calculated out of these values.

These are:
- Mean value
- Maximum value
- Minimum value
- Coefficient of variation CV[%]

Fig. 6
Relationship between yarn twist and yarn count for ring-spun yarn

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<table>
<thead>
<tr>
<th>NR</th>
<th>STRENGTH</th>
<th>ELONGATION</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>cN</td>
<td>%</td>
</tr>
<tr>
<td>1</td>
<td>243</td>
<td>4.00</td>
</tr>
<tr>
<td>2</td>
<td>252</td>
<td>4.91</td>
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<tr>
<td>3</td>
<td>222</td>
<td>3.95</td>
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<tr>
<td>4</td>
<td>277</td>
<td>4.69</td>
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<tr>
<td>5</td>
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<td>6</td>
<td>259</td>
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<td>7</td>
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<td>8</td>
<td>239</td>
<td>4.32</td>
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<tr>
<td>9</td>
<td>302</td>
<td>5.23</td>
</tr>
<tr>
<td>10</td>
<td>291</td>
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</tbody>
</table>

**STRENGTH:**
- \( \text{\textbar} \text{\textbar} \) 261.00 cN
- \( \text{max} \) 302.00 cN
- \( \text{min} \) 222.00 cN
- \( \text{CV} \) 9.91

**ELONGATION:**
- \( \text{\textbar} \text{\textbar} \) 4.66 %
- \( \text{max} \) 5.06 %
- \( \text{min} \) 3.95 %
- \( \text{CV} \) 10.16

Fig. 5 1 shows an example of a test report. Ten splices of a yarn were tested. The average strength was 261 cN, and the average elongation was 4.66%.

5 Practical example

In a spinning mill, the splices of 20 positions of a winding machine were tested. On each position, five splices were tested. The yarn type was Ne 30, carded, 100% cotton. Fig. 7 1 and Fig. 7 2 shows the results of this trial.
The blue dots indicate the test results of the splices, whereas the colored lines show the test results (minimum, maximum and average values) of the same yarn without a splice measured also on the USTER® ZWEIGLE SPLICE TESTER as the reference (ten measurements of the reference yarn). The minimum breaking force of the reference yarn was 222 cN, the average breaking force was 261 cN and the maximum breaking force was 302 cN. In regard of the elongation, the reference yarn had a minimum breaking elongation of 3.95%, an average breaking elongation of 4.66% and a maximum breaking elongation of 5.28%.
<table>
<thead>
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<th>Reference yarn</th>
<th>Splice</th>
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<tbody>
<tr>
<td>Yarn type</td>
<td>Ne 30, 100% CO, carded</td>
<td>Ne 30, 100% CO, carded</td>
</tr>
<tr>
<td>Strength [cN]</td>
<td>261</td>
<td>200</td>
</tr>
<tr>
<td>Variation of the strength [%]</td>
<td>9.91</td>
<td>23.0</td>
</tr>
<tr>
<td>Elongation [%]</td>
<td>4.66</td>
<td>4.87</td>
</tr>
<tr>
<td>Variation of the elongation [%]</td>
<td>10.16</td>
<td>16.88</td>
</tr>
</tbody>
</table>

Table 1  Twist for various subsequent process

Out of this data, the following conclusions can be drawn. The splices only reach an average breaking force of 76% compared to the regular (reference) yarn. As a rule of thumb, the strength of a splice should reach at least 80% of the strength compared to the regular yarn. The breaking elongation on the other hand, even improved slightly, but is on the same level as the reference yarn. Regarding the variation of the strength and the variation of the elongation it can be observed that it is much higher compared to the reference yarn. This is an important quality parameter, as the high variation of the breaking force will lead to problems later on in subsequent processing. The lowest breaking force of a splice was measured at 83 cN, and the strongest splice was measured with 295 cN. This is a huge difference that must be put under control.

Therefore, it is recommended to check the splice mechanism of this winding machine and to modify the settings in order to reach higher strength values and lower variations from winding position to winding position.
6 Correlation to the splice classification of the USTER® QUANTUM

The USTER® QUANTUM offers a unique feature, which is the splice classification. Each splice is measured, classified, and marked with a green or red square in the scatter plot depending on the splice settings. Thus, it is possible to check every winding position of a winding machine in order to see if the splices fulfill the requirements with regard to the appearance.

Together with the USTER® ZWEIGLE SPLICE TESTER it is now also possible to evaluate the breaking force and the breaking elongation of the splice at the winding machine. The green rectangles in Fig. 8 between 2 and 8 cm represent correct splices. Besides the regular checks of the splices, an operator can check the splices of a specific winding position that often shows outliers classified as red rectangles in the scatter plot.

![Fig. 9 Recommendation for yarn twist limits, combed yarns](image)

Meaning of the red rectangles: The size of the splice or mass increase has exceeded the set limits.

7 Conclusion

The USTER® ZWEIGLE SPLICE TESTER is an instrument that helps spinning mills to control their splices easily, directly at the spinning or winding machine. It helps to adjust the settings of the splicers in order to guarantee optimal yarn joints. By measuring the breaking force and elongation of splices regularly, the quality of the yarn packages can be assured comprehensively.
8 Literature


