New methods to determine periodic strength and elongation variations
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1 Introduction

Periodic mass variations in yarns lead to disturbing faults which might become visible as patterns in woven or knitted fabrics. Further, the strength and elongation of yarns is also reduced. As such faults do not arise from the raw material but occur during the manufacturing process such as from a defective roller of the drawbox, they have to be determined and removed at an early stage. The spectrogram is used to determine periodic faults. The mass spectrogram has been known for evenness testing on the USTER® TESTER for a long time and is well established in the market. The spectrogram for strength and elongation is available with the introduction of the fourth generation of tensile strength testing systems.

2 Pre-conditions

For the spectrogram calculation of the USTER® TESTER, a periodic fault has to occur at least twenty times with the same frequency in order to be determined as a period fault and then to be shown in the spectrogram. During an evenness test, the whole yarn length is tested millimetre by millimetre. During a tensile test, the specimen length is 50 cm to which another 30 cm have to be added which are needed for the clamping process of the yarn on the system. This means that the yarn length per test is 80 cm. It can, therefore, be deduced from this length that short, periodic faults less than 80 cm are not detected. Periodic faults occurring during the strength tests are determined for lengths of more than three metres which is in contrast with the evenness tests. Therefore, the spectrograms during tensile strength tests look different to the ones of the evenness tests. In order to obtain a reliable statement, a minimum number of tests has to be made.

Minimum number of tests with the USTER® TENSORAPID 4: 205. It is advisable, however, to carry out a considerably higher number of tests to get statistically significant results.

3 Definition of the spectrogram

The spectrogram is a representation of the maximum tensile strength and the elongation at maximum strength in the frequency domain. If a periodic fault with a frequency of f₁ occurs in the yarn, such a fault is shown as a peak in the spectrogram in position f₁. As the frequency spectrum for textile tests is not very practical, the representation based on wave lengths is given preference. The wave length directly shows the distance at which the periodic fault repeats itself.
Fig. 1 shows a spectrogram of the evenness test with a periodic fault at a wavelength of $\lambda_1$.

4 Practical tests

The following examples were first tested with the evenness tester USTER® TESTER 4 and then with the strength tester USTER® TENSORAPID 4.

4.1 Filament yarn, polyester FDY, dtex 150f80

The mass diagram of a polyester yarn is shown in Fig. 2. A nearly periodic fault can be clearly seen in the diagram. This fault appears in the spectrogram (Fig. 3) during a yarn length of about 15 – 50 meters. Faults which are red during several channels are considered as drafting faults. This fault can be traced back to the quench air duct. Such drawing faults are mostly caused by vibrations of the individual filaments in quench air duct as a result of the cooling air.
The filament yarn was then tested with the USTER® TENSORAPID 4. As is shown in Fig. 4, the fault reappears in the spectrogram of the strength. The fault length is identical with the one of the USTER® TESTER 4-CX, i.e. these nearly-periodic mass variations also result in strength variations.

4.2 Filament yarn, polyester POY, dtex 89f80

A second test was made with a partially-drawn filament yarn (POY) which was made of 100% PES with a fineness dtex 89f80. Two periodic faults can be seen in the diagram of the mass. The variation of the diagram is caused by a period fault with a wavelength of 1.4 m. A second mass variation can be recognized with a wavelength of 15 to 70 m.

Faults can be shown and detected noticeably better in the diagram because it is possible to zoom diagrams after an evenness test.
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The fault at 1.4 m is caused by the reversal mechanism at the winding machine and is equivalent to a complete movement from right to left and back.

The fault with a wavelength range of 15 to 70 m can again be traced back to the quench air duct. The cooling process in the filament production is a very delicate process.

The tensile strength test is shown as stroke diagram in Fig. 7. As described above, the fault of 1.4 m cannot be depicted in the stroke diagram of the USTER® TENSORAPID 4 because the fault length is too short.

The periodic fault with a wavelength of 2.7 m can be detected in the spectrogram of strength. It has to be noted that the diagram and spectrogram for the elongation are identical to the diagram and spectrogram for strength. The fault of 2.7 m wavelength can only be seen vaguely in the mass spectrogram whereas it is clearly recognisable in spectrograms of strength and elongation (Fig. 8).
This example shows that periodic mass variations do not automatically affect the spectrograms of tensile strength and elongation and vice versa. There are faults which only occur in evenness tests and faults which can only be detected in tensile strength tests.

The scatter plot, Fig. 9 is another type of graphs which can be printed out with tensile strength testing systems. The maximum tensile strength along with the pertaining elongation at maximum force of one single test is shown as a single dot. If 500 tests are made, 500 points are visible in the scatter plot. The distribution of tensile strength and elongation can be clearly seen in the scatter plot. If the points are very close together over a wide area, the material is highly homogenous. If the points are scattered in the diagram, the material is inhomogeneous and indicate spinning faults.

Several outliers are visible in this scatter plot with polyester filament yarn which are visible in strength and elongation. It can be assumed that this filament yarn will lead to problems in the subsequent processing steps.

The red lines serve to show the weak places in the yarn separately. Measuring dots which are on the left of the elongation limit and below the strength limit are shown separately in the print-out.
5 Summary

With this novel feature to analyze of the tensile strength and elongation with spectrograms with the USTER® TENSORAPID 4, it is possible to detect periodic faults quickly for the first time. This allows a quick conclusion about a defective machine part and enables the spinning specialist to swiftly intervene in the spinning process in order to improve the yarn quality. Further, it is crucial for the subsequent processing steps to detect periodic faults and depending on the type of faults, such faults can lead to disturbing patterns in the woven or knitted product.

These examples have shown that a periodic fault does not necessarily have an effect on the strength and on the elongation at the same time. There are some cases where only the strength or the elongation are affected, and some faults only appear either in tensile tests or in evenness tests.

The spectrograms for the strength tester USTER® TENSORAPID 4 are an additional interesting feature of the USTER® TESTER 4 because it is now possible to perform more extensive tests on the yarn and to eliminate any possible fault sources much sooner.