TESTING POLYESTER STAPLE FIBERS FOR ESTIMATING THEIR PROCESSING BEHAVIOR IN OPEN-END SPINNING

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ABSTRACT

It is well known, that the open-end spinning of 100% polyester staple fibers is problematic in each production step compared to Cotton and blends. The biggest problems can be observed on the carding machine and the OE machine, especially the rotor box. The processing behavior of polyester fibers in interaction with the production machines has been monitored during spinning trials for manufacturing OE yarns, consisting of 100% polyester staple fibers. By using statistical methods the tested data for the polyester staple-fiber properties, sliver - and yarn properties have been analyzed regarding their influence on process behavior and yarn quality. Those properties determining the process behavior and yarn quality have been identified.

1 INTRODUCTION

Due to the increasing cotton prices on the world market, the bad economical situation within the years 2008 .. 2009 and the harder competition on the staple-fiber yarn market a lot of spinners started to produce blended staple fiber yarns (cotton blended with man made fibers) and yarns made of 100% man-made fibers. One option is to use polyester staple fibers.

During the spinning of the polyester fibers – especially in case of 100% polyester – a lot of processing problems come up within all production steps. The biggest problems have been seen while carding and especially in rotor spinning. The spinner speaks in such cases about “bad processing behavior” or “the fiber material does not run properly”. Even a change from one fiber lot to another can create a lot of problems in production.

From 2007 till 2011 in Germany a workshop has been organized in order to have a closer look at these problems. Several companies and institutes have been involved including Trützschler, Oerlikon Schlafhorst, Märkische Faser AG, Faserinstitut Bremen (Fibre), Institut für Textiltextechnik der RWTH Aachen University, Oerlikon Neumag, Schill und Seilacher, Textechno.

In the following chapters the results of the workshop will be presented in detail, especially with respect to the staple-fiber properties, which have an influence on to the processing behavior as well as to the yarn quality and how these parameters can be tested.

2 BRIEF DESCRIPTION OF THE TRIALS

For the preparation of the spinning trials the following preparations have been done:

The first step was to collect more information about processing problems in all steps of the production in polyester spinning. On base of the analysis of the interactions between the fiber material and the processing machines the possible reasons for existing problems have been discussed.

Figure 1 shows as an example the analysis of the interaction on the carding machine.

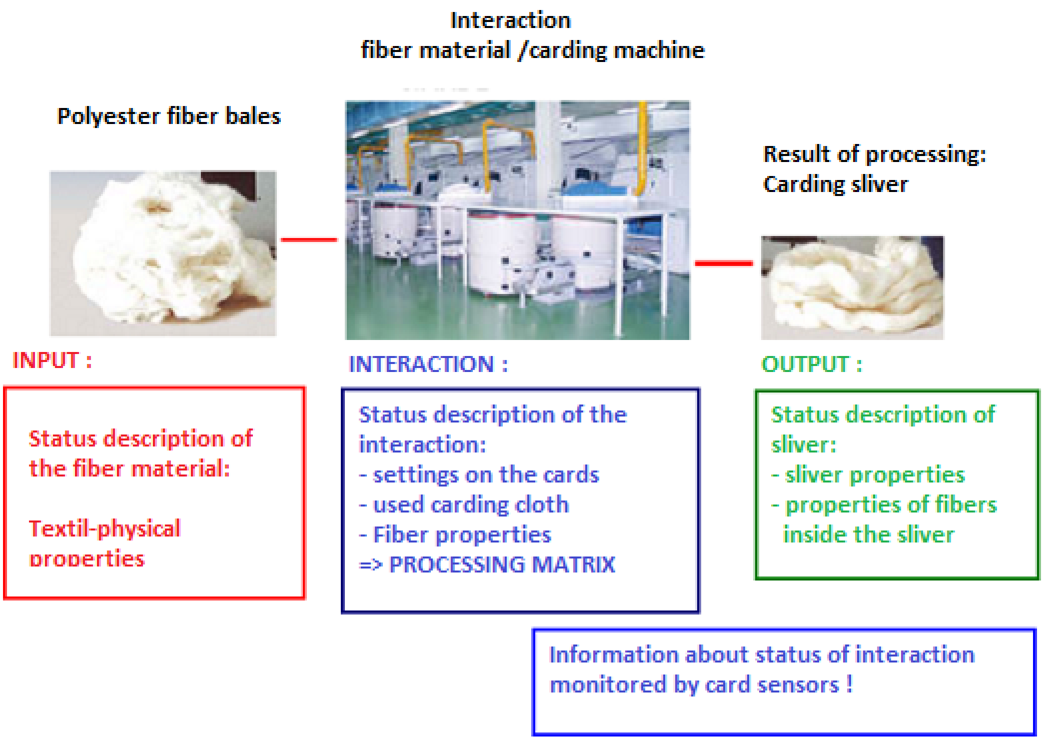

Fig. 1: Interaction fiber material / carding machine

Based on the analysis of the interaction of every production step the fiber properties (INPUT), the machine parameters (INTERACTION) and the sliver / fiber properties (OUTPUT = INPUT for the following production step) have been defined. Finally the spinning trials for producing 100% polyester OE yarns have been planned and then realized.

The result of the trials was a very big amount of testing data for

- 4 different Cotton-type Polyester fiber materials (A, B, C, D),
- 3 Carding machine settings (production 60 kg/h, 80 kg/h, 100 kg/h)
- 2 Rotor-speeds (90.000 rpm, 100.000 rpm)
- 5 Processing steps have been analyzed (bales, opened fibers before carding, carding sliver, 2. draw frame sliver, yarn)
- 50 different parameters have been tested on all these samples

This big data amount allows analyzing the data by means of statistical methods. By using the F-T-Test it was possible to find out those parameters, which have a significant statistical influence on to the yarn quality and the processing behavior. All other data have been sorted out in order to reduce the data amount.

With a multiple correlation analysis of the remaining data the percentage of the influence of these effecting parameters has been calculated. Finally multiple-linear-regression formulas for the description of interaction of the fiber material with machines, i.e. the processing behavior, have been found.

3 PROPERTIES DETERMINING THE PROCESSING BEHAVIOR

During the spinning trials 24 different OE yarn versions have been manufactured and tested. Significant statistical differences have only been found for the following parameters:

- CVm%: Mass variation
- Fmax: Breaking force
- Emax: Elongation at Fmax
- Thin places - 40%
- Thick places +35%
- Neps + 140%

Thus a correlation analysis has been performed on these parameters. For the parameters CVm% and Emax, the results will be shown as examples.

3.1 1. EXAMPLE : RESULTS FOR CVm% VALUES

The table 1 shows the results of the correlation analysis for the CVm% values. The 2nd column shows the machine parameters (MP), single fiber parameters (SFP) and sliver parameters (SP) with a significant effect on the CVm% values of the yarns. The last column shows the influence (in %) of these parameters on the CVm% values.

CV%mass variation Yarn:		Correlation %
1	MP: Production speed carding (RSC)	0,90%
2	MP: Rotor speed (RSP)	15,25%
3	SFP: Crimp bow length (CBL)	0,35%
4	SP: Cohesion length / cN/tex (HL)	5,77%
5	SP: Cohesion elongation % (HD)	7,62%
6	SFP: Remaining crimp (RKR)	7,05%
7	SFP: Spin Finish Content % (SFC):	4,53%
8	SFP: Young-Modulus (AMO)	2,01%
	TOTAL INFLUENCE %	43,48%

Tab. 1: Results of the multiple correlation analysis for CVm%

After the correlation analysis a multiple regression has been calculated. The formula (1) shows the calculated regression function CVm% = f (MP, SFP, SP):

CV = a1*RSP + a2*HL + a3*RKR + a4*AMO + a5*RSP*RSP + a6*HL*HL + a7*HD*HD + a8*RKR*RKR + a9*AMO*AMO + a10*RSP*RKR (1)

The correlation coefficient for the formula (1) is R = 91,49 %.

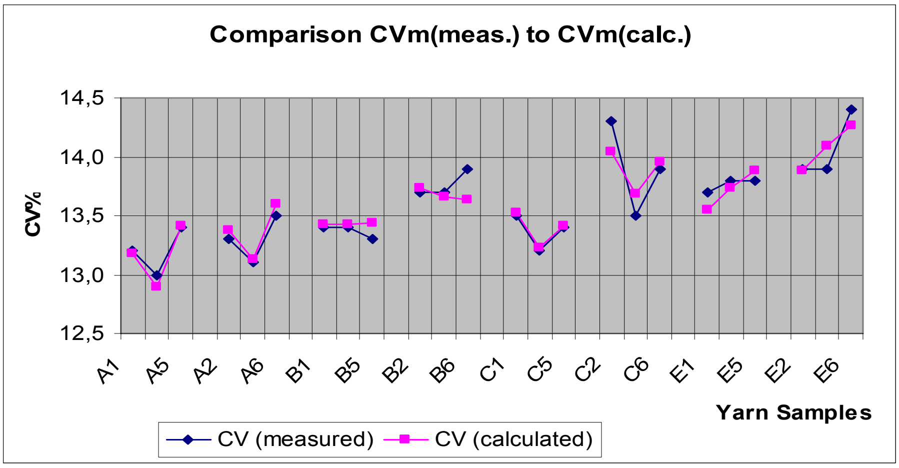

Fig. 2: Comparison CVm% (measured) to CVm% (calculated acc.to (1))

3.2 2. EXAMPLE : RESULTS FOR Emax% VALUES

The table 2 shows for the Emax% values the correlative influence in %. The 2. column shows the machine parameters (MP), single fiber parameters (SFP) and sliver parameters (SP) with a significant effect on to the Emax% values of the yarns.

Emax % of the yarn:		Correlation %
1	MP: Production speed carding (PSC)	0,00 %
2	MP: Rotor speed (RSP)	15,99 %
3	SFP: Remaining crimp (RKR)	8,01 %
4	SP: Cohesion length cN/tex (HL)	34,05 %
5	SP: Cohesion elongation % (HD)	0,92 %
6	SFP: Fiber hooks % (FHO)	0,00 %
7	SFP: Spin Finish Content % (SFC)	5,41 %
8	SFP: Young-Modulus : (AMO)	10,52 %
	TOTAL INFLUENCE %	74,90 %

Tab. 2: Results of the multiple correlation analysis for Emax

The formula (2) shows the calculated regression function CVm% = f (MP, SFP, SP):

Emax = a1 + a2*RSP + a3*HL + a4*RKR + a5*AMO (2)

Coefficient of correlation: R = 90,58 %

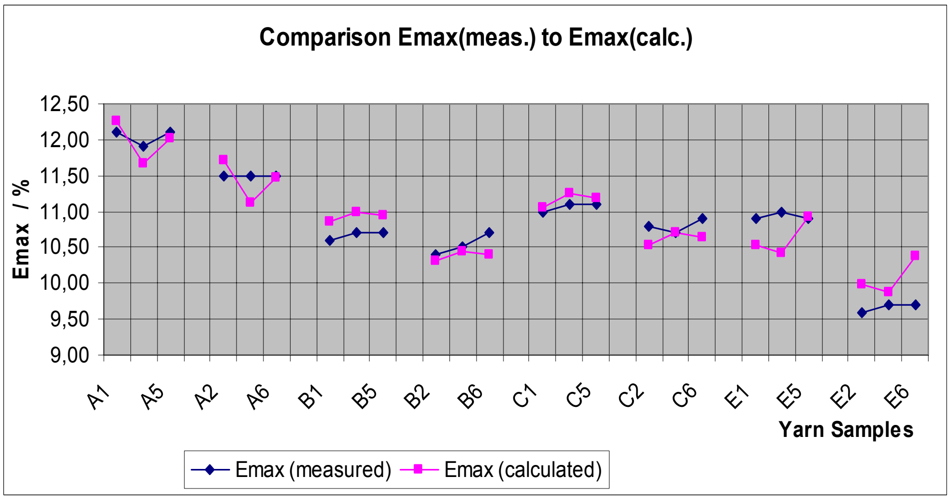

Fig. 3: Comparison Emax (measured) to Emax (calculated acc.to (2))

3.3 CONCLUSION FOR THE EFFECTING PARAMETERS

Considering the results of the correlation analysis for all significant different yarn parameters, the following parameters determining the processing behavior and the yarn quality in case of polyester fiber spinning (OE spinning):

PARAMETERS with significant infuence:			Correlation results:
1	Production speed carding (PSC)	MP	(5 of 6 times included)
2	Rotor speed (RSP)	MP	(6 of 6 times included)
3	Remaining crimp (RKR)	SFP	(3 of 6 times included)
4	Cohesion length cN/tex (HL)	SP	(5 of 6 times included)
5	Cohesion elongation % (HD)	SP	(5 of 6 times included)
6	Spin Finish Content % (SFC)	SFP	(6 of 6 times included)
7	Young-Modulus : (AMO)	SFP	(6 of 6 times included)

Tab. 3: Properties determining the process behavior / yarn quality

This result is surprising and shows, that for the polyester staple fiber spinning the situation is completely different to the cotton spinning process:

- The processing behavior and the yarn quality are strongly effected by the properties of the individual fibers and their interaction within the fiber composite "sliver". Not the 'standard' properties single-fiber strength, elongation, and crimp are important, but such properties as the elastic behavior of the fibers (Young-Modulus) and remaining crimp (the amount of crimp remaining in the fiber after a high load). The spin finish content and their distribution on the fibers, which influence the metal/fiber-friction on the carding machine and inside the rotor, as well as the fiber-to-fiber-friction within the sliver, play an important role.

- Also the machine settings, especially the processing speed on the carding machine as well as the rotor speed effect the processing behavior and yarn quality, but this is not a surprise.

- Finally the interaction of the fibers within the sliver during the drafting process has a big influence, which is described by the properties cohesion length and cohesion elongation.

4 HOW TO TEST THESE PROPERTIES

4.1 TESTING SINGLE FIBER PROPERTIES

The single fiber properties of the polyester staple fibers have been tested by the TEXTECHNO FAVIMAT+, which is able to test the following properties on single fibers in one run:

* single-fiber strength/elongation properties, including modulus values (Young's etc);
* mechanical crimp properties like crimp force, crimp extension, crimp stability & remaining crimp;
* geometrical crimp properties like number of crimps per cm, crimp amplitude, and crimp length,
* linear density of the fiber (vibroscopic method),
* Fiber-to-metal friction properties.

For a statistically assured result a quite high quantity of single fibers has to be tested. Therefore an automatic testing is recommended, using the FAVIMAT+ with the automatic fiber feeding devices AIROBOT 2 or AUTOFEED. Fig. 4 shows the FAVIMAT+ AUTOFEED system. The fiber samples are fed to the AUTOFEED as an opened flock.

Fig. 4: FAVIMAT+ AUTOFEED (without TESTCONTROL computer system)

4.1.1 YOUNG'S MODULUS

Young's modulus – also called E-modulus or elastic modulus – is well known: it describes the behavior of the fiber in the elastic (Hook) range. It is calculated from the force-elongation diagram according to the definition given in figure 5. For the tests on the polyester staple-fibers within the spinning trial, the elongation related Young's modulus has been measured. Therefore it was important, to define the lower elongation E(1) on that way, that E(1) is surely above the end of the crimp range of the fibers.

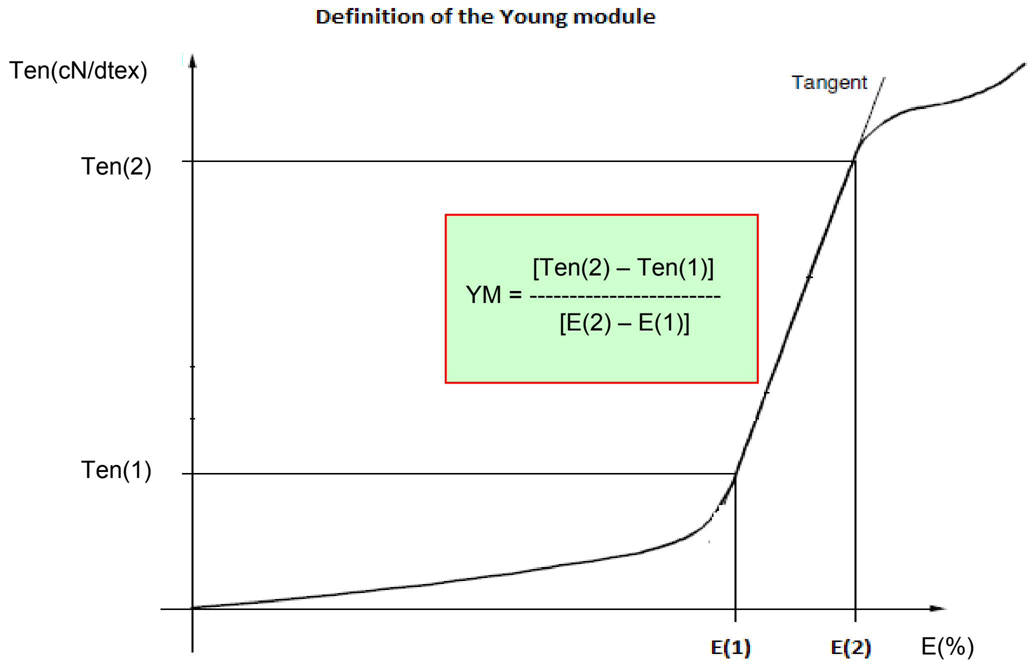

Fig. 5: Definition of the Young's modulus

4.1.2 REMAINING CRIMP

The remaining crimp value belongs to the mechanical crimp properties of man-made fibers. For testing the mechanical crimp properties no international standard is available. From the literature several test methods are known, like HOECHST method, PUCHEGGER method etc. The FAVIMAT+ software allows the operator to select his preferred method. During the spinning trials the HOECHST method was used in order to assess the mechanical crimp behavior of the polyester staple fibers. The definition of the remaining crimp for the HOECHST method is shown below.

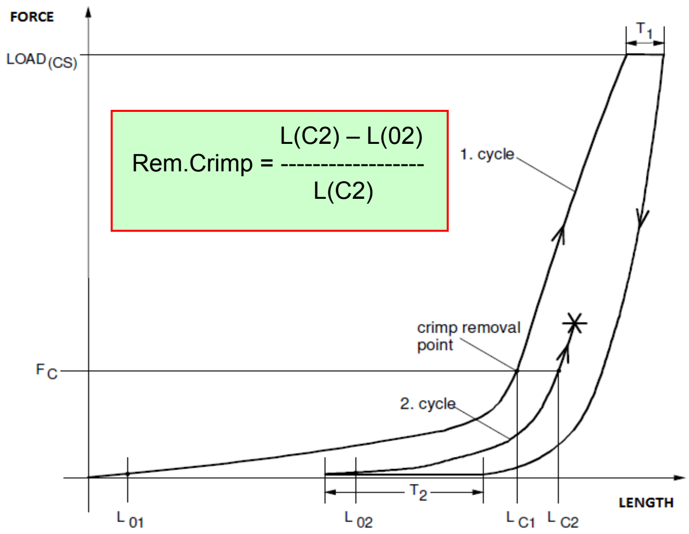

Fig. 6: Definition of Remaining crimp value

4.1.3 SPIN-FINISH CONTENT / FIBER-TO-METAL FRICTION

The spin-finish content SFC can be measured by using the ALFA 300 of our subsidiary LENZING INSTRUMENTS (refer figure 7).

Fig. 7: Automatic spin-finish analyzer ALFA 300

The ALFA 300 gives the average value of the spin-finish content of the whole tested sample. There is no possibility to get information about the distribution of the spin-finish oil within the sample/along the fibers, which is essential for the fiber-to-metal friction behavior.

Therefore TEXTECHNO developed a new clamp, what allows to test the fiber-to-metal friction on FAVIMAT+. The new appliance allows testing the friction automatically, i.e. by using the fiber feeding systems ROBOT 2

Figure 8 shows the new clamp for testing the fiber-to-metal friction.

The friction clamp is attached to the draw-off mechanism. During the insertion of the fiber, the part (1) is open. Then the clamp is closed and the fiber (3) is guided through the friction pins (2). The gauge length is 10mm. Then the drawing clamps moves with a defined speed downwards for a length of 20 mm. During the movement the force variation is measured and displayed in a graph. At the end of the test the friction coefficient is calculated.

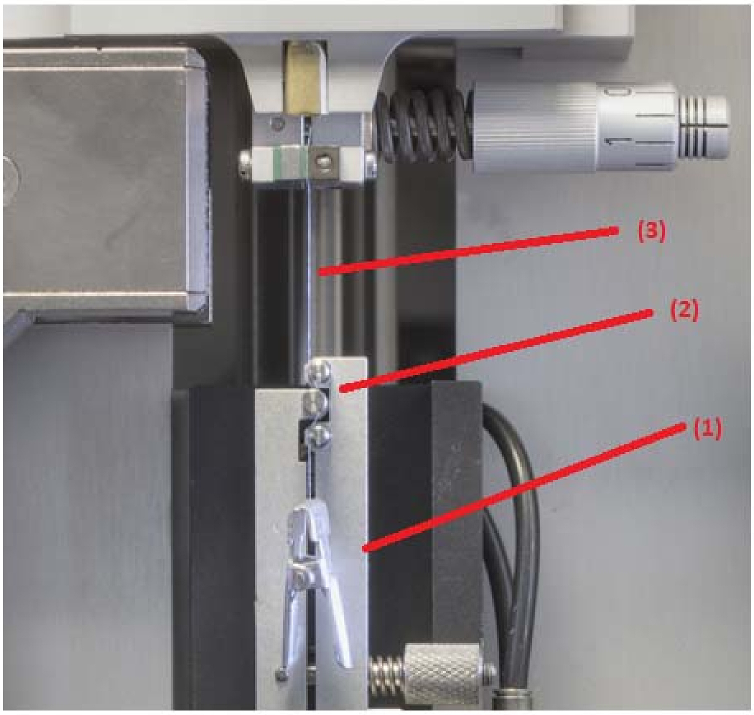

Fig. 8: Friction clamp for FAVIMAT +

4.2 TESTING SLIVER PROPERTIES

For testing the cohesion length and -elongation of slivers the cohesion-force test is used. The test has been performed on the automatic single-yarn tensile tester TEXTECHNO STATIMAT ME+, by using special sliver clamps (refer figure 9). For measuring the cohesion force a load cell of 1 N or 10 N (depending on carding or draw frame sliver) is recommended. The testing speed is 20 mm/min and the gauge length is 3 times the staple length (UHML) of the fibers, i.e. in case of polyester staple fibers 3 times the cutting length.

The cohesion force test is performed on sliver samples with a length of 1 m. The sample is inserted in the upper sliver clamp (refer figure 9) that the sample end is located 1 cm above the upper edge of the jaws. The sample should hang freely, so that the weight of the sliver itself serves as the pretension weight. Then the lower clamp is closed and the test is started. In general 10 sliver samples should be tested for getting the statistics for the cohesion-force test parameters breaking force and –elongation. After the test, the sliver sample is cut out of the clamps by means of a razor blade and the mass of the sample between the clamps is measured by using a balance.

Fig. 9: Sliver clamps

The mass of the sample, the gauge length and the measured cohesion (breaking) force are used to calculate the parameter "cohesion length". The cohesion length of the sliver is comparable to the parameter RKM on yarns: It gives the length of the sliver at which the sliver would break under its own weight.

Both parameters, i.e. cohesion length and cohesion elongation, describe the interaction of the fibers within the sliver. This interaction is controlled by fiber properties mentioned before.

5 CONCLUSION

Spinning trials have shown, that the processing behavior of polyester fibers for OE spinning is quite different from the behavior of cotton fibers. On every step of the production problems may exist and even a changing of the polyester fiber lot or bale can create new, unexpected processing problems. In comprehensive spinning trials all production steps have been analyzed regarding the interaction between the fiber material and the machines. In all production steps the textile physical properties of the fibers, slivers and the yarns have been tested. Totally 50 parameters have been tested. By using statistical methods, those properties not influencing processing behavior or yarn quality, could be identified and sorted out in order to reduce the data amount. For the remaining sliver properties, fiber properties as well as machine settings a correlation analysis has been performed. Finally it has been shown, that for the OE spinning process of 100 % polyester staple fibers the carding speed, the rotor speed, the cohesion length and cohesion elongation of the slivers as well as the remaining crimp, the Young's modulus and the spin-finish content of the individual fibers are determining the process behavior and the yarn quality.

6 ACKNOWLEDGEMENTS

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