USTER® *TENSOJET 4*

Application Report

Use of USTER® *TENSOJET* in a modern Spinning Mill

Textile Technology / January 2015 / SE-…

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Contents

1 Introduction

1.1 1.1 The history of USTER® *TENSOJET 4*

Tenacity and elongation are two important characteristics of yarn quality, both of them can impact the efficiency during subsequent processing steps such as the end break in warping , or warp and weft end breaks in the weaving mill. Uster Technologies has been devoting in the yarn quality detecting field over about 60 years and innovated the first exclusively manual tensile testing devices until 1950. In the last few years, the originally-available manual tensile instruments have been replaced by modern, microprocessor-controlled automatic, conventional testing system tester USTER® *TENSORAPID 4*, the testing speed is 5 m/min and can test 500-700 samples per hour, but it cannot economically fulfilled the requirement of wide scope of yarn tensile testing by a single installation. So the unique, ultra-high speed strength testing system USTER® *TENSORAPID 4* has been created in 2001.

1.2 The unique fuction of USTER® *TENSORAPID 4*

With the maximum testing speed up to 400m/min, the USTER® *TENSORAPID 4* can completed 30'000 tests per hour. For high testing volume in a short time, the rarely occurred weak places can be obtained.

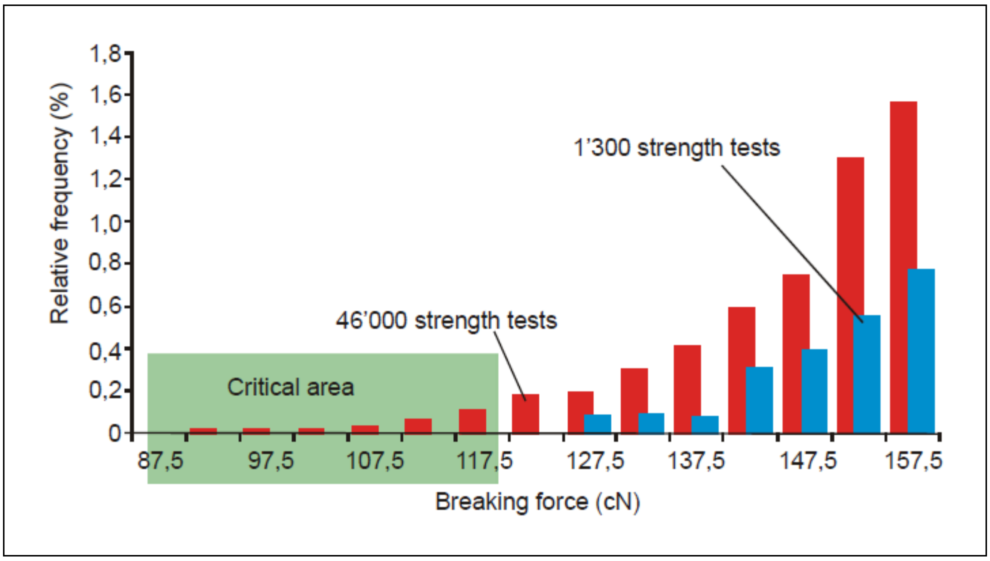

Fig. 1
Calculation of the minimum strength by increasing the number of samples

These findings (Fig. 1) clearly shows that the weak places, which are so dangerous for a weaving mill, can only be detected by taking more samples, and the high-performance tensile testing has it possible to realistically simulate the yarn stress during processing especially for warping and weft on weaving machines.

The variation value of the strength and elongation are as important as their mean value, in order to indicate the importance of the variation value, the following example is referred to:

In a spinning mill, a sample is taken from a yarn batch and the breaking force determined. When comparing this value with that of a similar batch of yarn but produced at an earlier period of time, the following result as shown schematically in Fig. 2 was obtained.

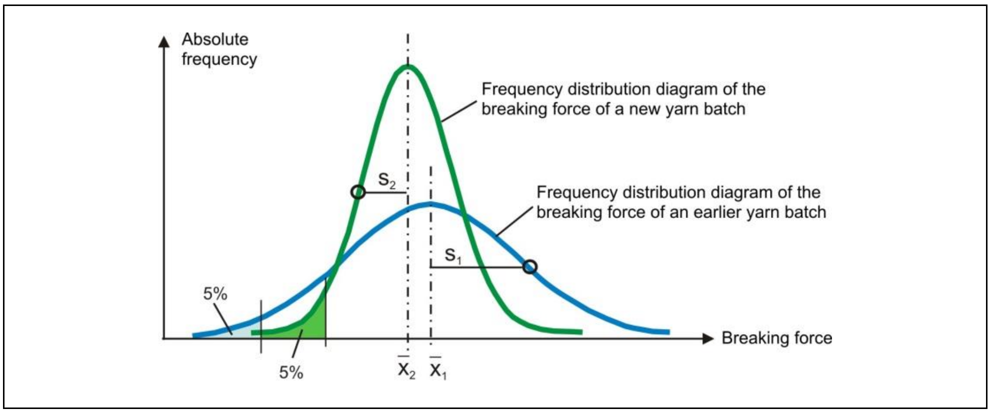

Fig. 2
The relationship between mean value and variation

Although the new batch of yarn has a low mean value of breaking force than that of the earlier produced batch of yarn, but the new batch of yarn has the lower variation. From the below figure (Fig. 3), we can see the decisive factor of weaving break is not the mean value of breaking force but the weak places, when the coefficient of variation of breaking force. As the yarn buyer is primarily interested in the weaving efficiency, the new batch of yarn is better than the earlier batch of yarn due to the lower variation value, even though the mean value is lower.

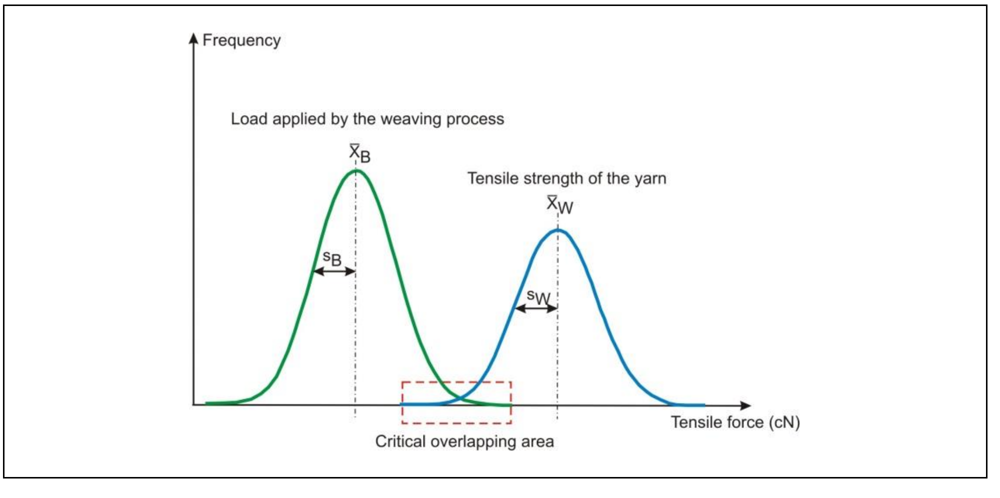

Fig. 3
Summary of the yarn strength and yarn elongation during the weaving process

This graph reflects the strength applied on yarns in the weaving process which should not overlap the yarn with the maximum tenacity in order to avoid end breaks and stops. In the worst case, there will be end breaks in the overlapping area marked as critical when the lowermost strength of the yarn is smaller than the maximum force applied on the yarn in weaving process.

2 Trials

2.1 Limits to show the weak places

2.1.1 Theory of how to calculate the weak places

Common limits for Elongation:

→ Loss of elongation by the process (source: Karl Mayer ex Benninger)

Loss of elongation	
Package winding	0…-0.5%
Warping	---
Sizing (cotton ring yarn)	-1…-1.5%
Sizing (cotton rotor yarn)	-1.5…2%
Sizing (viscose)	-2…-4%
Sizing (polyester)	+0.5…+1%

→ Minimum (residual) elongation for weaving (source: Karl Mayer ex Benninger)

Cotton, viscose	4…4.5%
Coarse yarns, denim	3.5…4%
Cotton/polyester	8…10%

→ Minimum elongation in the yarn when checking cones (source: Karl Curriger, Toyota)

- in general: 5 – 7%
- coarse yarns: >5%

Sources of too low elongations in the yarn:

The yarn elongation is mainly given by fiber elongation, yarn type, twist, spinning and winding condition. The sizing process causes another loss of elongation, especially with a too hot temperature and/or "over-drying" (like with a hair dryer on human hairs).

Some guidelines and additional subjects to consider:

Some guidelines
If yarn shows a good elongation but still many stops → check IPI values
what is good / bad? → use USP
Warp breaks: important to check WHERE the yarn was broken and how the breaking point looks like (frayed or stright broken)

Weaving stops calculations:

When comparing breaks or making comparisons per 10^5 picks, than it's important to define the yarn length used for this 10^5 picks.
example: 10^5 picks of the common fabric width of 1,9 m means 190’000 m yarn.

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These are good guidelines to decide if certain yarn parameter are good or bad. Often used requirements are: 50% USP, for good quality and fast running looms better use the 25% USP.

Example of how to calculate limits for weak places for yarn strength

A common Weak Spot level: Mean – 4.3x CV

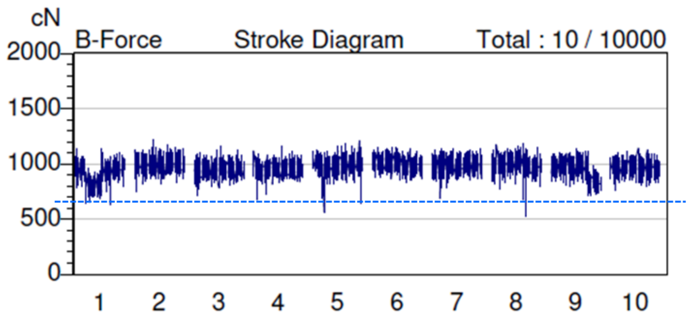
- CV = 7.3% →
- CV absolute = 7.3% of 973.4 cN = 71 cN
- Weak spot level = 973,4 – 4.3 x 71 = 668
- set Force limit to 668 cN

Total : 10 / 10000 Single test(s)

Nr	B-Force	Elong.	Tenacity	B-Work
	cN	%	cN/tex	cN.cm
Mean	973.4	15.93	19.65	4691
s	71.08	0.80	1.435	480.4
CV	7.3	5.0	7.3	10.2
Q95	1.393	0.02	0.028	9.42

How it looks when the limit is set in configuration:

→ in the Stroke Diagram



→ in the Scatter Plot

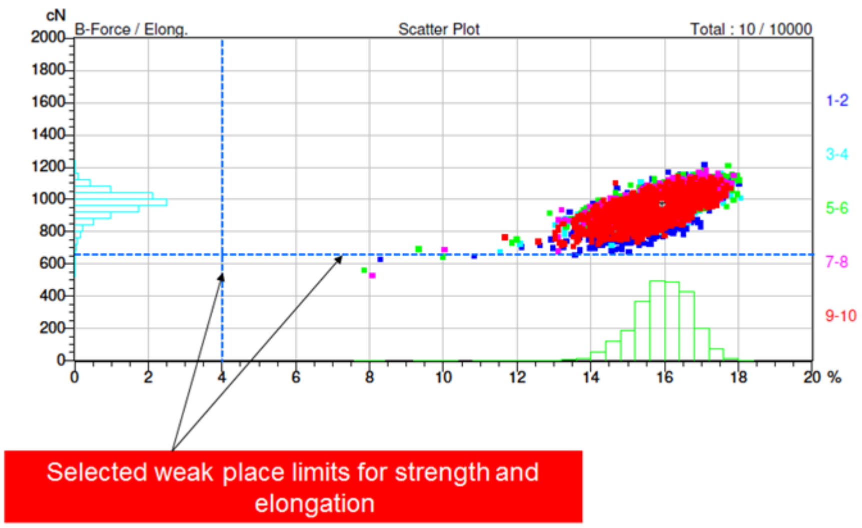


Fig. 4 Example of how to calculate limits for weak places for yarn strength

2.2 Results with relation to the content of splices

In the winding process, the splices are consisted of bobbins changes, yarn breakers and the mainly clearer cuts. The number of yarn changes and yarn breakers is objective while the number of clearer cuts is depended on the clearing limit setting sensitivity. All the cuts are replacing a disturbing defect with a less disturbing splice. But is the splice is better than the defect taken out?

To show the possible influence of different splice levels and to find out if a higher splice (cut) level by the higher number of IPI in the yarn, also cause more weak places, we did the following trials.

Trial 1: 3 levels of 0, 35 and 300 splices

Material: 100% CO, Ne 32, combed, ring, cones n = 10'000 tests each
Content of splices: 0, 35 and 300 per 100 km

0 splice = tested bobbins
35 splices = splices only by bobbin changes
300 splices = splices by bobbin and a sensitive setting

The test results (Table 1) and related figures (Fig. 5) are given below:

		B-Forxce cN	Elongation %	Tenacity cN/tex	B-Work cN.cm
Trial 1 (300 cuts)	Mean	346.3	4.72	18.76	412.2
	CV	8.41	9.11	8.41	14.2
	Min	104.5	1.93	5.66	77.96
Trial 2 (35 cuts)	Mean	360.3	4.92	19.52	446.8
	CV	8.03	8.65	8.03	13.4
	Min	187.6	2.57	10.17	126.2
Trial 3 (0 cut)	Mean	357.1	4.96	19.35	448
	CV	8.18	8.4	8.18	13.45
	Min	243.4	2.97	13.19	198.4

Table 1 The result with relation to the splice level

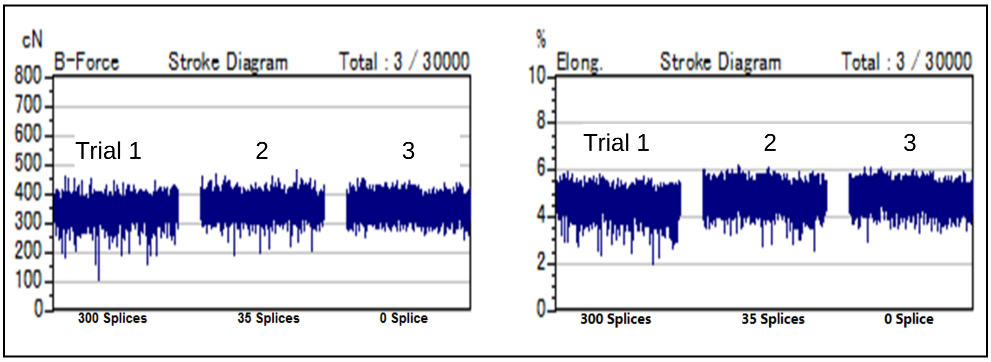


Fig. 5 The stroke diagram of splice levels

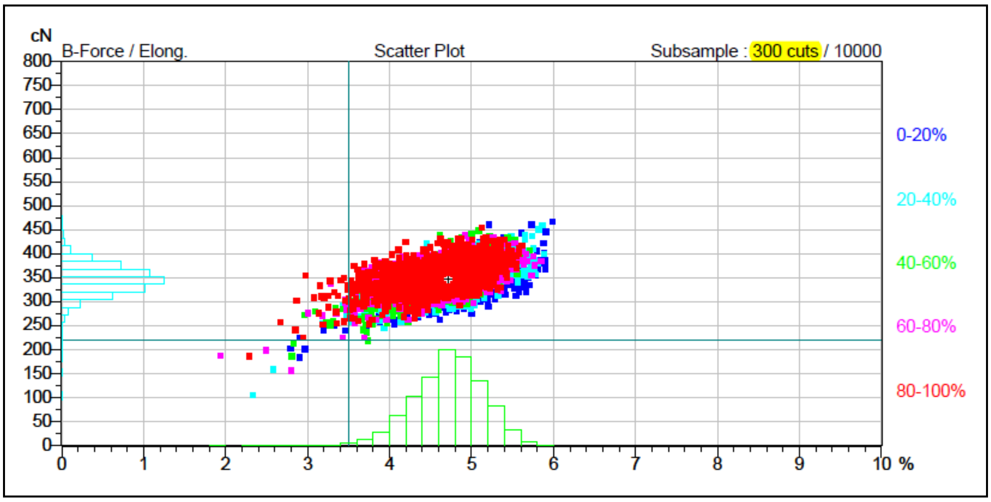


Fig. 6
The scatter plot of trial 1 with 300 splices

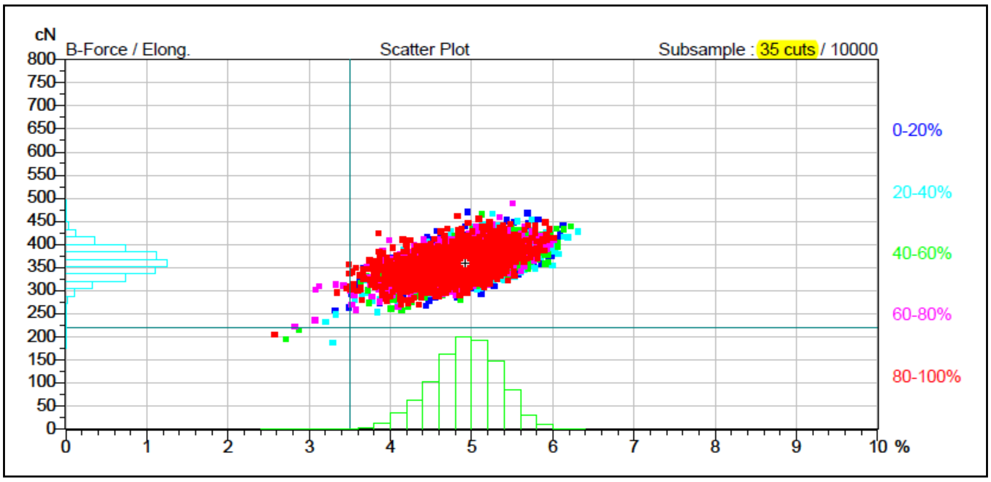


Fig. 7
The scatter plot of trial 2 with 35 splices

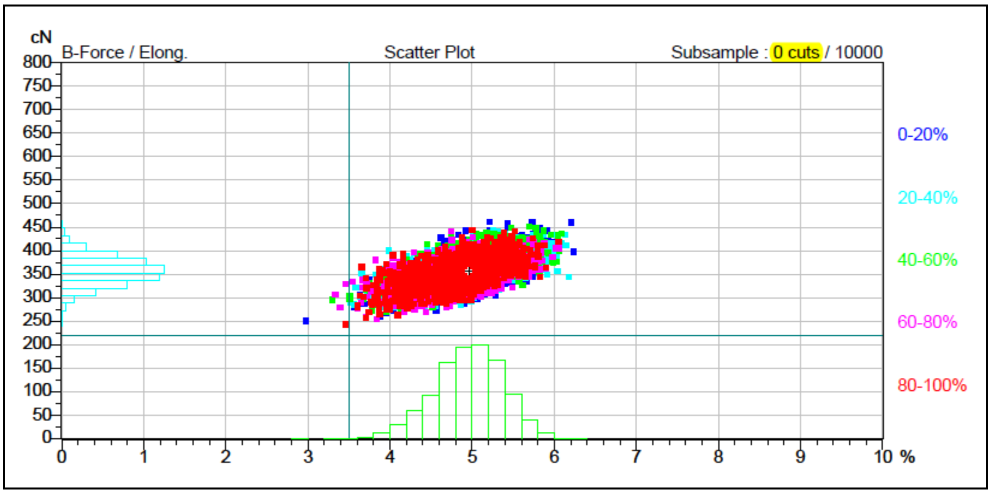


Fig. 8
The scatter plot of trial 3 with 0 splices

Conclusion

The analysis of the test results shows that the splice level impact the yarn property a lot especially the weak place. The more splices, the more weak places. In Table 1, there is no obvious different (the mean value and the CV) in the summary data except the minimum value which is the hint foreshadowing. In the stroke diagrams (Fig. 5), we can get the visible difference, the 300 splices has a big fluctuate both in strength and elongation strokes, the 35 splices has the a litter smooth stroke diagram and the stroke diagram of 0 splice is gradual. With the help of weak place setting at 220 cN of strength and 3.5 % of elongation (Fig. 6 – Fig. 8), we can easy find the significant different. The 0 splice have only a few weak places, 35 splices has a litter more weak places and the 300 splices has the most weak places due to the too low strength and elongation.

2.3 Results with relation to the contamination content (FD from UQ3)

The content of contamination in the yarn is important to the strength and elongation and therefore the yarn breaking in weaving process, for the reason that the foreign material and vegetable fiber have the different strength and elongation to yarn fiber. For finding out the influence of contamination levels to weak places in the yarn and simulate the yarn breaks in weaving process, we did the following trial. The FD/Veg scatter plots are from the UQ3 (**Fehler! Verweisquelle konnte nicht gefunden werden.** and Fig. 10). The F/E results (Table 2) and related figures (Fig. 11 and Fig. 12) are given below:

Material: 100%CO, Ne 30, combed, ring yarn, cones, n=30’000 tests each

FD and Veg level scatter plot from UQ3

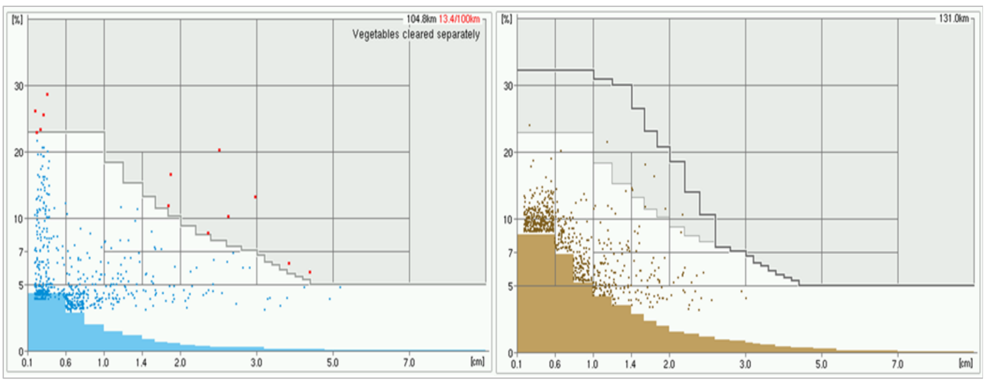


Fig. 9
Low High FD and Veg level

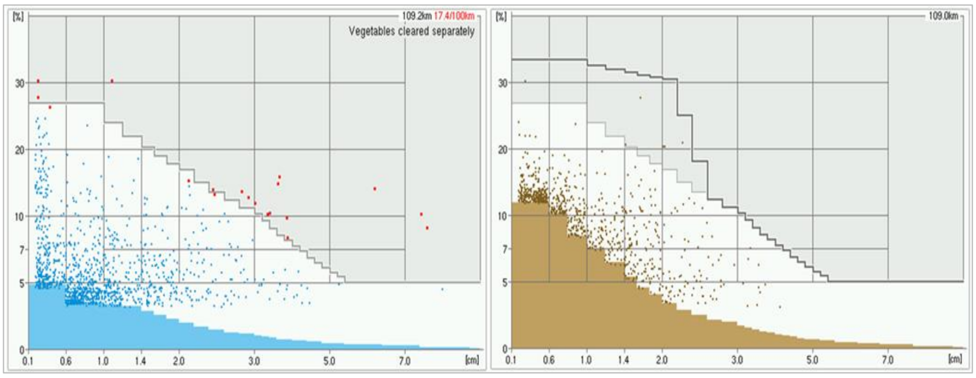


Fig. 10
High FD and Veg level

			B-Force cN	Elongation %	Tenacity cN/tex
FD and Veg level	Low	Mean	388.7	4.7	19.75
		CV	7.63	8.62	7.63
		USP07	39	86	38
		P0.01	278.9	3.24	14.17
	High	Mean	361.2	5.11	18.35
		CV	10.03	9.95	10.03
		USP07	56	64	58
		P0.01	212	2.88	10.77

Table 2
The result with relation to the splice level

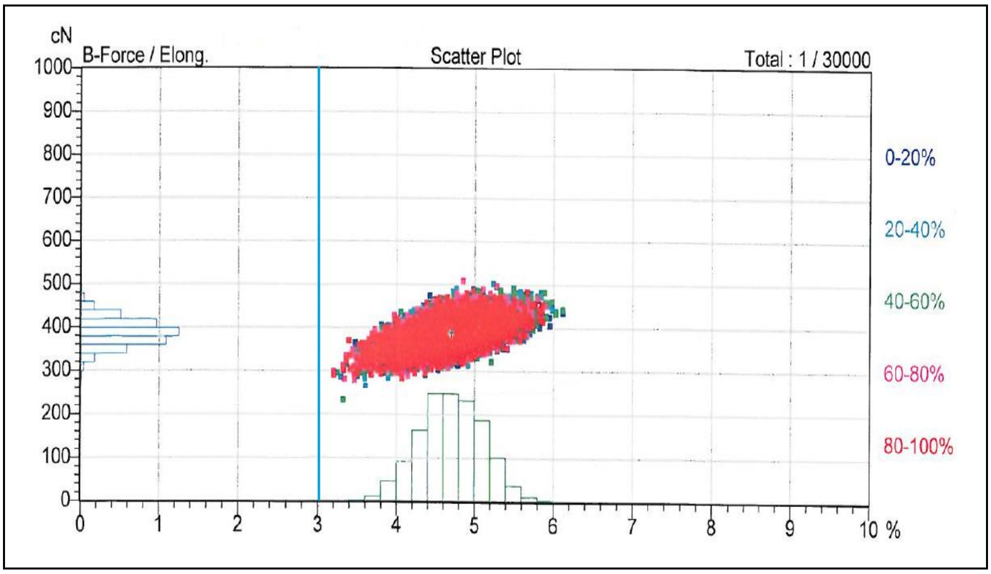


Fig. 11
The scatter plot of ***low*** *FD/Veg level*

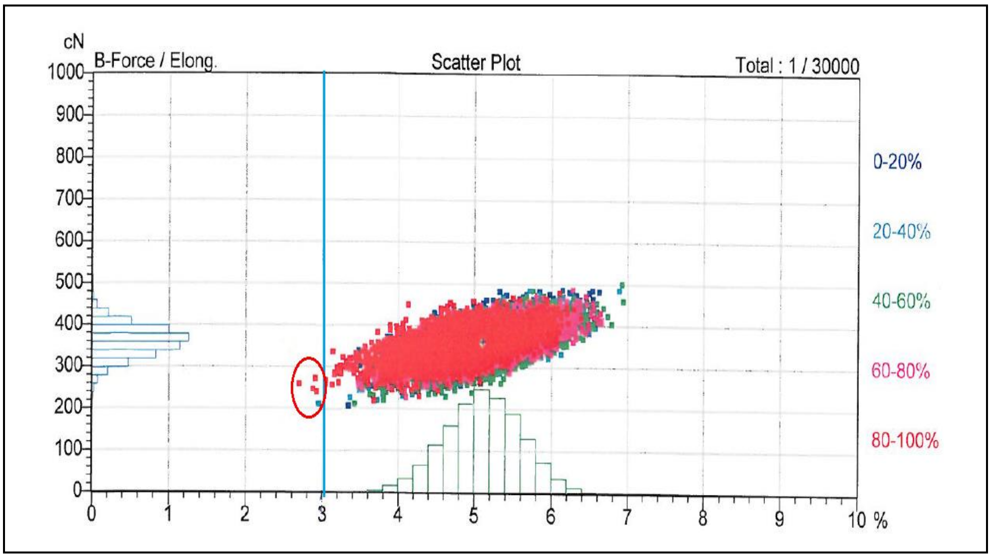


Fig. 12
*The scatter plot of **high** FD/Veg level*

Conclusion

The analysis of the test result shows that (Table 2): For the low FD/Veg level, the breaking force is 388.7 cN with the CV is 7.63% and the USP is 39, simultaneously, for the high FD/Veg level, the breaking force is 361.2 cN with the CV is 10.03% and the USP is 56. The strength of low FD/Veg level has a much better result than the high FE/Veg level. The low FD/Veg level also shows the better result of elongation than that of high FD/Veg level with CV of elongation is 8.62 and the P0.01(3) is 3.24, at the mean-time the high FD/Veg level has a variation of elongation is 9.95 and the P0.01 is 2.88.

With another type of representation of the same results, the scatter plot (Fig. 11) the low FD/Veg level has the nice cloud while the high Fe/Veg level has a much wider cloud caused by the higher variation of strength and elongation.

The high FD/Veg level yarn has 5 breaks below the weak place limit for elongation (3% of the elongation). For the weaving stops calculation, it will result in about 40 … 10^5 picks of the common fabric width of 1,9 m (Considering only the weft yarn as a possible source of faults).

2.4 The importance of yarn conditionings

From the practical experience of weaving, we know that the weaving breaks caused by conditioned yarns are smaller than that of non-conditioned yarns. With the moisture, the fiber swelling increased, the fiber strength increased and the friction between fibers also become higher. In order to show the importance of conditioning and compare unconditioned with conditioned yarns of various conditioning conditions, we did the following trials.

Material: 100%CO, Ne 30, carded, ring yarn, cones, n=10'000 tests each

Conditioning process:

Trial 2.4.1 Unconditioned
Direct from production

Trial 2.4.2 Conditioned in a XORELLA type with minimum cycle
Pro 1: 1st cycle: 5 minutes at 54°C
2nd cycle: 20 minutes at 56°C

Trial 2.4.3 Conditioned with XORELLA type with normal cycle
Pro 5: 1st cycle: 5 minutes at 86°C
2nd cycle: 10 minutes at 90°C

Trial 2.4.4 Conditioned with XORELLA type with double cycle
2x Pro 1: 1st cycle: 5 minutes at 54°C
2nd cycle: 20 minutes at 56°C

Trial 2.4.5 Conditioned with standard Lab climate
48 hours at 20°C and 65% RH

The test results (Table 3) and related figures (Fig. 13 to Fig. 19) are given below.

Trial	Type of conditioning	Strength (cN)	Tenacity (cN/tex)	Elongation (%)
2.4.1	Unconditioned: direct from production	359.1	18.24	5.25
2.4.2	Conditioned in a XORELLA type with minimum cycle	363.7	18.47	5.65
2.4.3	Conditioned with XORELLA type with normal cycle	371.4	18.87	6.33
2.4.4	Conditioned with XORELLA type with double cycle	375.3	19.07	6.36
2.4.5	Conditioning with standard Lab climate at 20C and 65% RH	376	19.1	5.99

Table 3
The result with relation to the different conditioning process

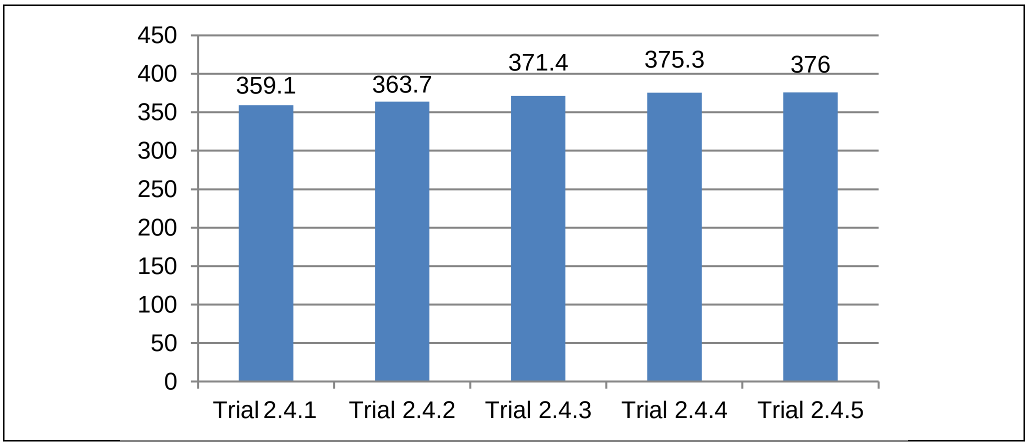


Fig. 13
***Strength** difference between unconditioned yarn and conditioned yarns*

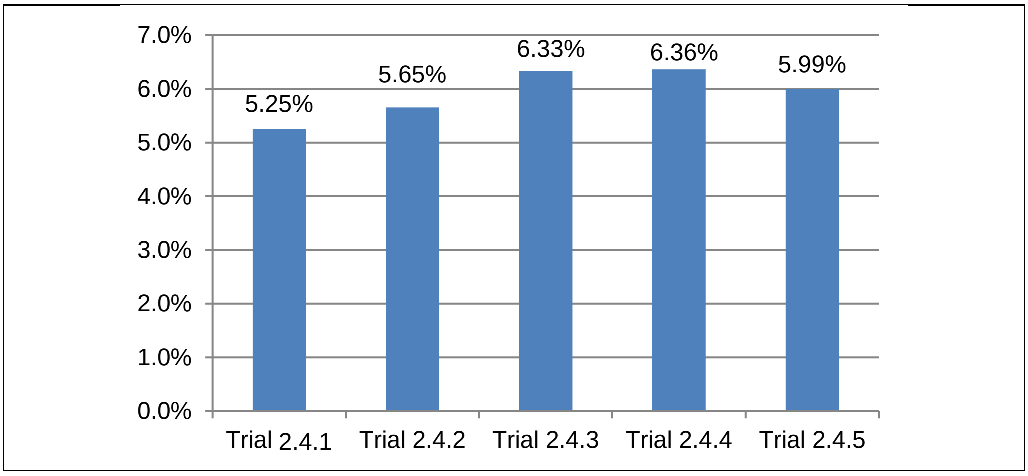


Fig. 14
***Elongation** difference between unconditioned yarn and conditioned yarns*

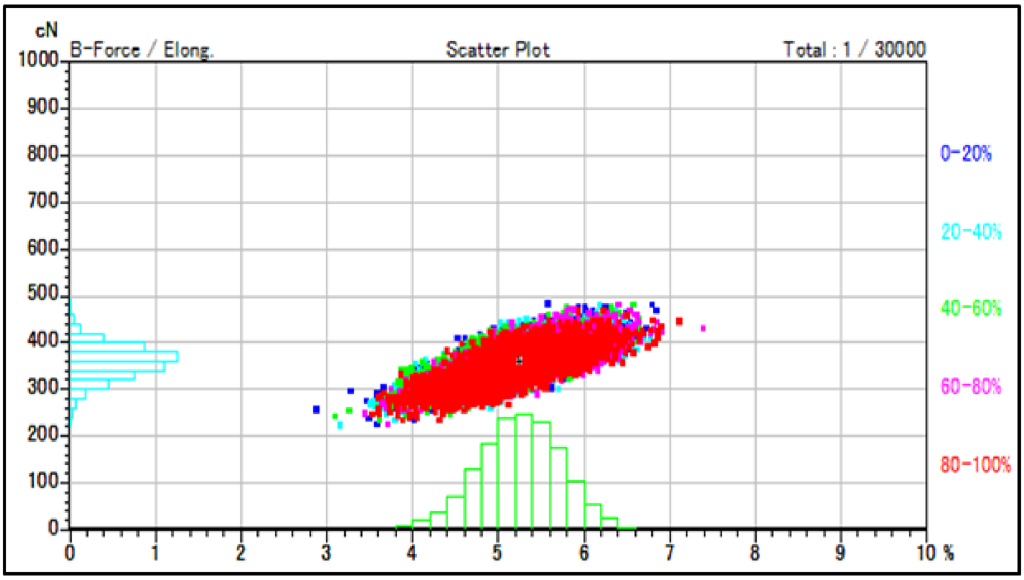


Fig. 15
Scatter plot of trial 2.4.1

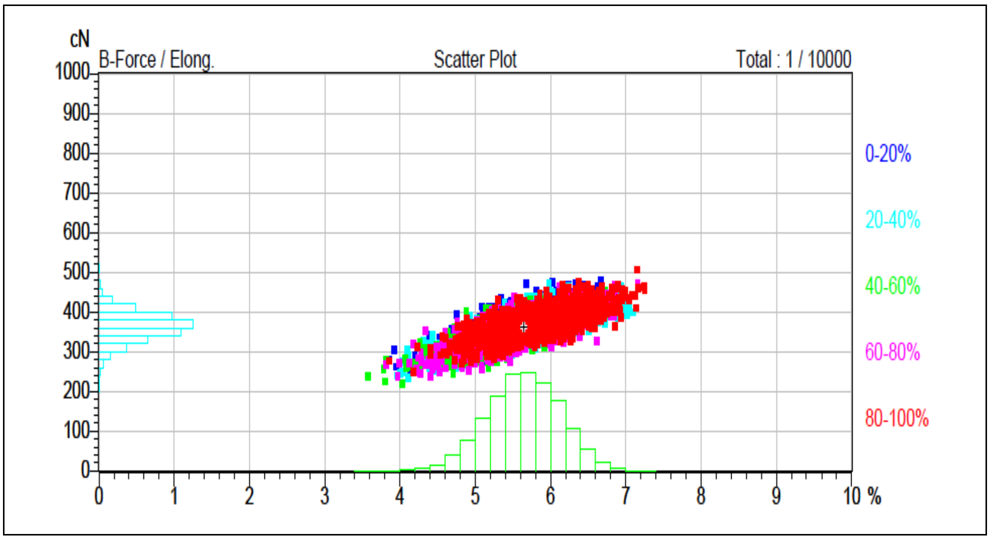


Fig. 16
Scatter plot of trial 2.4.2

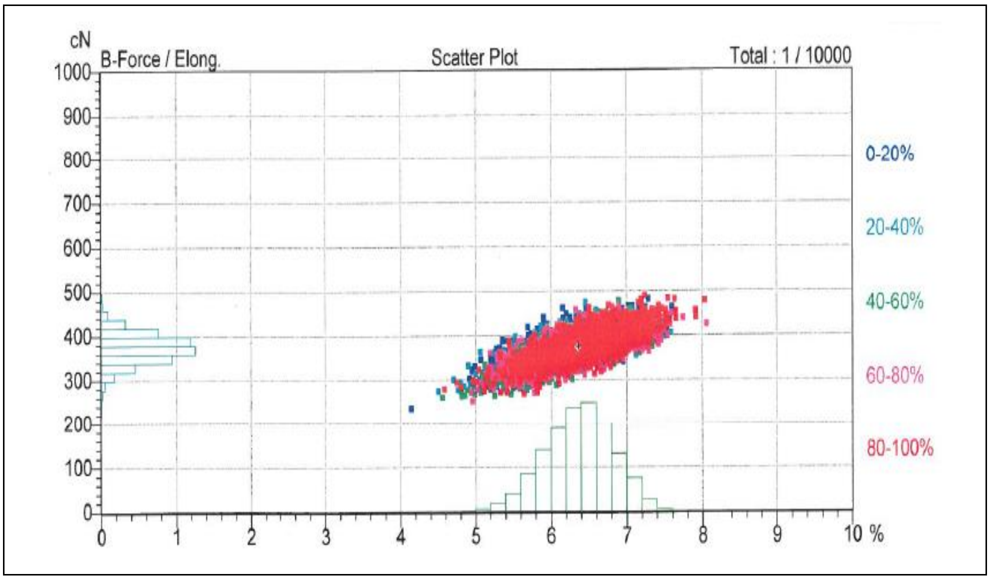


Fig. 17
Scatter plot of trial 2.4.3

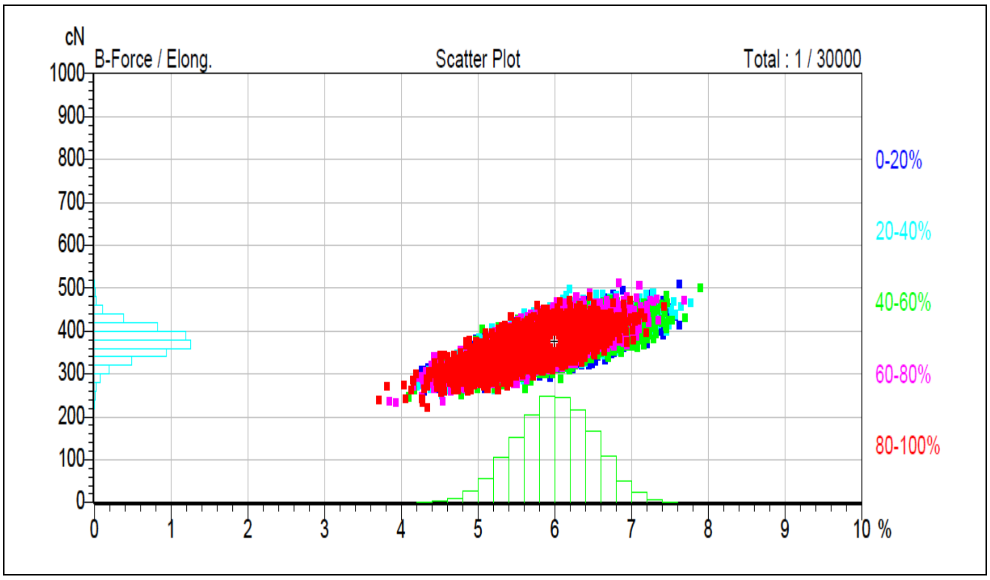


Fig. 18
Scatter plot of trial 2.4.4

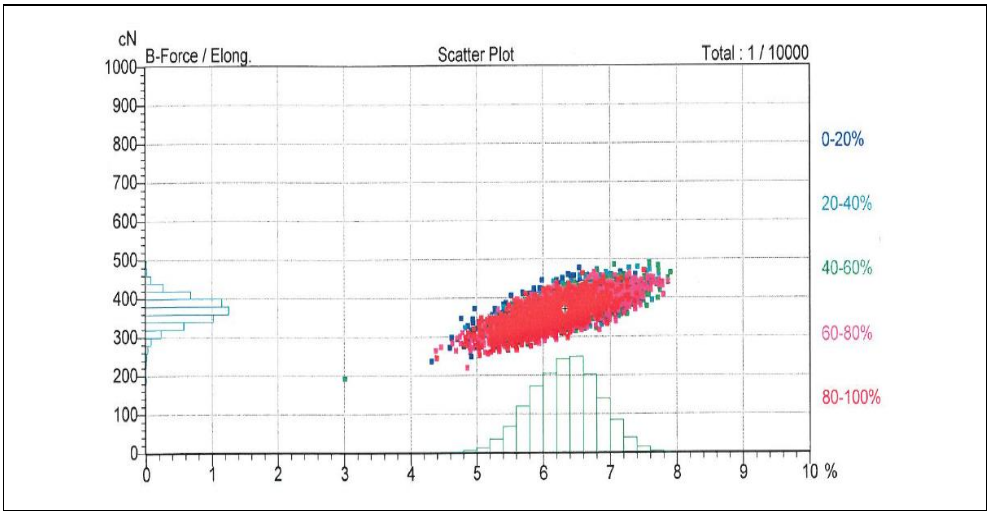


Fig. 19
Scatter plot of trial 2.4.5

Conclusion

The numerical result (Table 3) shows that the different conditioning process has strong effect on the yarn elongation, from the lowest elongation value 5.25% of yarn unconditioned, to the highest value 6.36% of the yarn under condition with XORELLA type with double cycle, the elongation value increases 21.1% in relative. But it impacts the yarn strength slightly. The relative scatter plots (Fig. 15 to Fig. 19) also clearly show the same conclusion.

The steaming program has a strong effect to the yarn in elongation for the weaving-preparation.

2.5 Relation of yarn elongations to different winding speeds

The winding speed plays a very important role in the winding stage. The higher winding speed signifies the higher production efficiency, but at the same time brings the quality degradation. It seems to be difficult to obtain a balance between the winding speed and quality. In order to show the relationship between remaining yarn properties, such as strength, elongation (by USTER® *TESOJET 4*) and hairiness and IPI (by USTER® *TESTER 5-S800*) to different Winding speeds, we did the following trial, material: 100% CO and 50/50% CO/PES. The test result and related figure are given below.

2.5.1 With 100% CO and winding speed of 1’000 / 1’300 / 1’600 m/min

Material: 100%CO, Ne 30, carded, ring yarn, cones n = 10’000 tests each
Winding speed: 1’000 m/min, 1’300 m/min, 1’600 m/min

Nr	Winding speed m/min	CVm %	Neps +140%	Neps +200%	H	B-Force cN	Elongation %
1	1’000	10.91	114	13	6.19	349.3	4.85
2	1’300	11.02	135	12	6.41	354.6	4.93
3	1’600	11.18	170	22	7.04	349.5	4.96

Table 4
Relation of yarn properties to different winding speeds with 100%

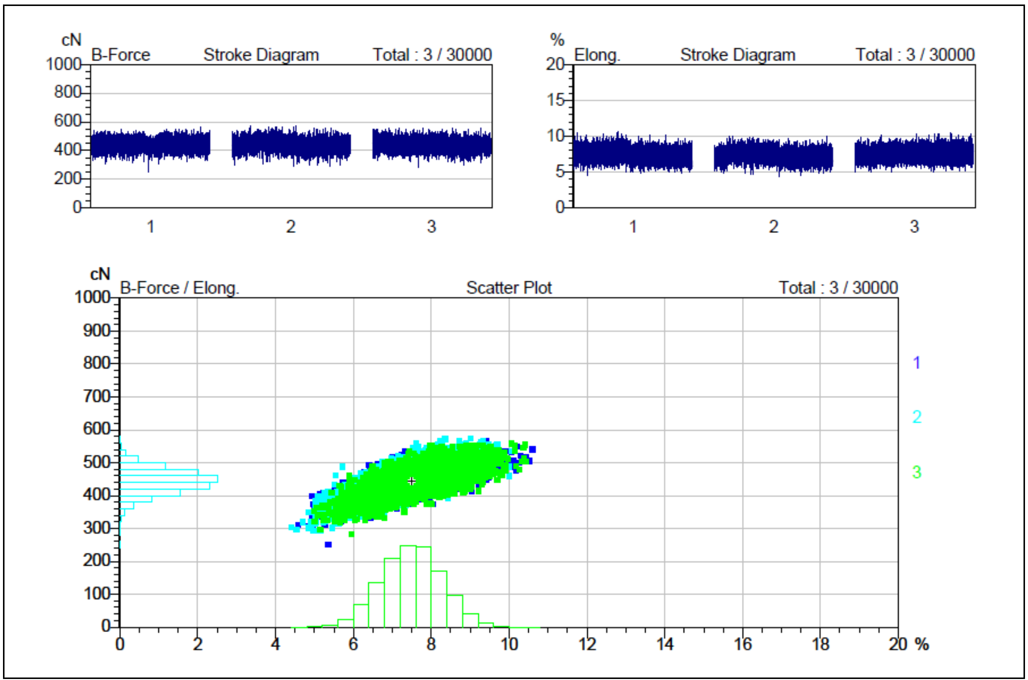


Fig. 20
Relation of yarn strength and elongation to different winding speeds with 100% CO

Conclusion

The analysis of the test result shows that there is no big difference in CVm, strength and elongation (Table 4), corresponding with the stroke diagram and the scatter plot (Fig. 20) with the winding speeds changing. But , the increase of IPI and hairiness is distinct, for example, the +140% neps increase of 20% and 50% and Hairiness increase of 5% and 10% for the winding speed increased from 1’000 to 1’300 and 1600 m/min with yarn tension kept constant.

2.5.2 With CO/PES and and winding speed 1’000 / 1’300 / 1’600 m/min

Material: 50/50% CO/PES, Ne 30, carded, ring yarn, cones n=10’000 tests each
Winding speeds: 1’000 m/min, 1’300 m/min, 1’600 m/min

Nr	Winding speed m/min	CVm %	Neps +140%	Neps +200%	H	B-Force cN	Elongation %
1	1’000	11.75	192	53.5	5.18	442.9	7.47
2	1’300	11.64	191	53.5	5.27	444	7.35
3	1’600	11.75	181.5	47.5	5.45	445.1	7.64

Table 5
Relation of yarn properties to different winding speeds with 100%

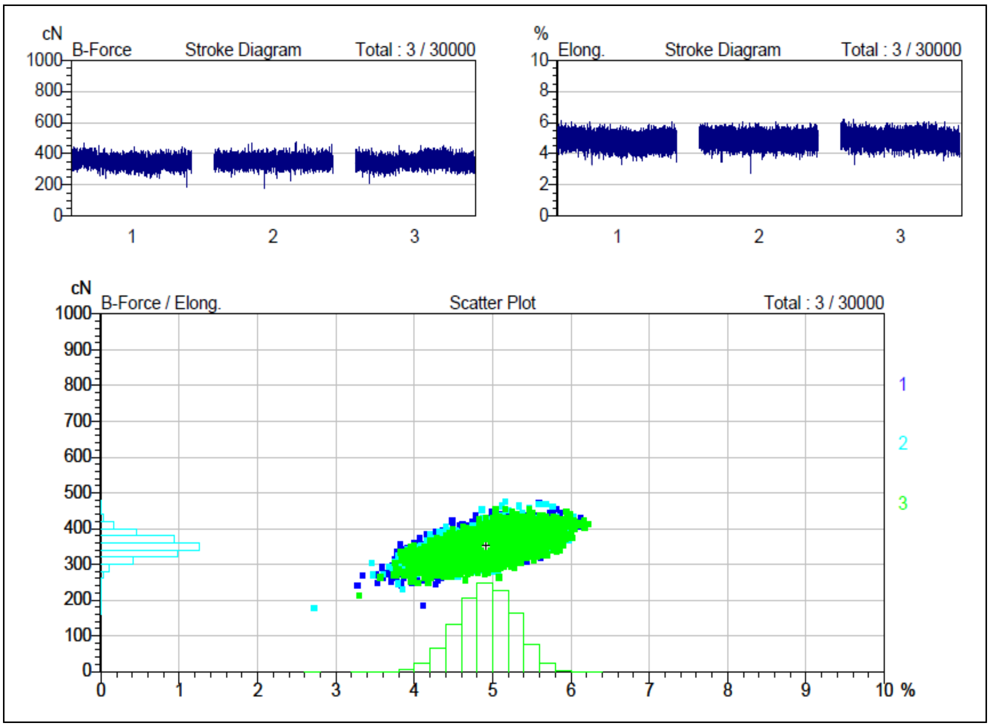


Fig. 21
Relation of yarn strength and elongation to different winding speeds with 50/50% CO/PES

Conclusion

The analysis of the test result shows that there is no difference in CVm, strength elongation and even IPI for 50/50% CO/PES (Table 5), corresponding with the stroke diagram and the scatter plot (Fig. 21) with the winding speeds changing. Only the slight increase in Hairiness of 5% from 1’000 to 1’600 m/min of winding speed with yarn tension kept constant.

The two trails show that the increase of winding speed in this trial has almost no influence to the strength, elongation and yarn evenness CVm. But it will impact the IPI value and hairiness more or less depends on the different yarn materials.

2.6 Relation of ring spindle speed and yarn elongation

2.6.1 Loss of elongation with increased spindle speeds

For quite some time, it has been obvious that the increase in spindle speed at the ring spinning machine leads to a reduction in the yarn manufacturing costs, but the higher spindle speed causes the higher spinning tension, and the yarn elongation is in inverse proportion to the spinning tension. In order to show the relationship of ring spindle speed and yarn elongation, we did the following trial.

Material: 100%CO, Ne 26, combed, ring yarn, bobbins   Twist = 1'050 T/m
n=2'000 tests each
(To avoid snarls for a better testing: the samples (bobbins) were conditioned 3 days at 90% RH, then 2 days at the regular 20℃ and 65% RH)

Spindle speeds: 15'000rpm, 17'000rpm, 19'000rpm, the startup rpm =90%
(rpm=revolutions per minute)

Spindle speed rpm	B-Force cN	Tenacity cN/tex	Elongation %	Loss of Elongation %
15'000	536.3	23.61	8.21	/
17'000	546.5	24.06	8.02	-2.50%
19'000	551.1	24.26	7.38	-10.10%

Table 6
The result with relation to the spindle speeds

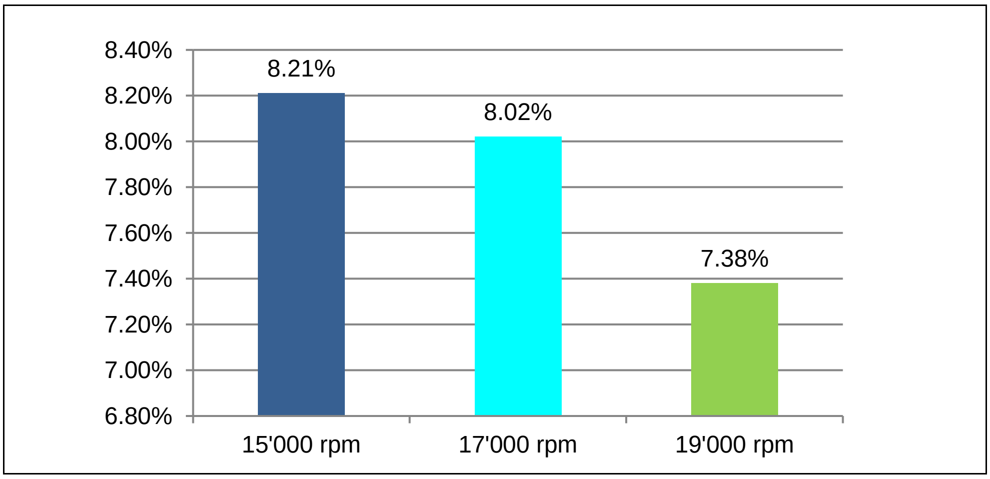


Fig. 22
The comparison of elongation related to spindle speeds

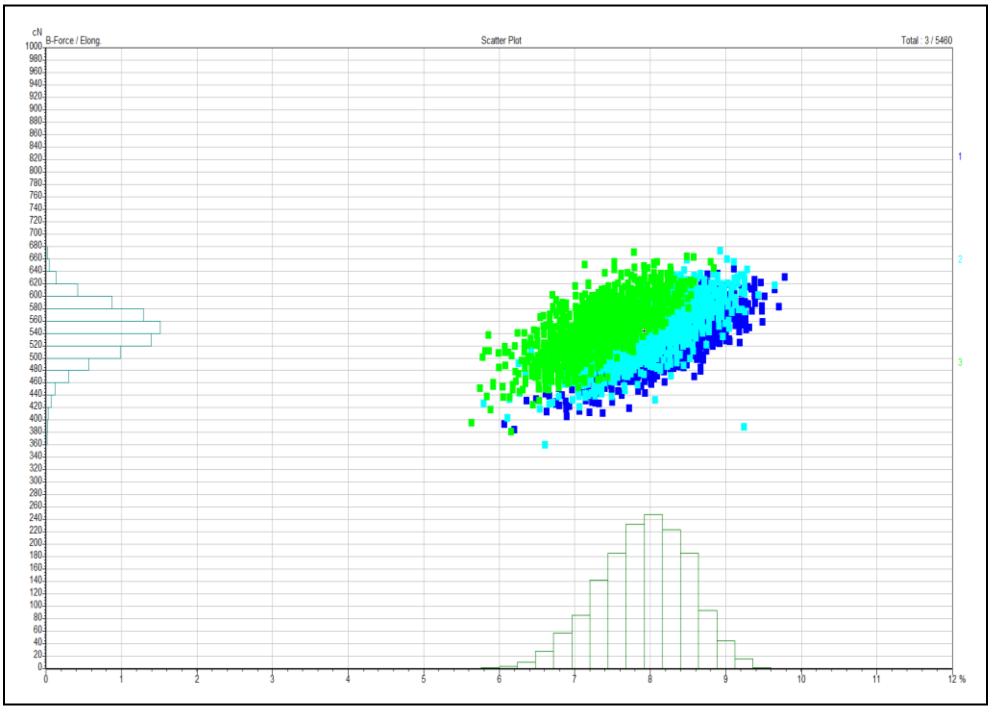


Fig. 23
The scatter plot of different spindle speeds

Explanation

Green = yarn spindle speed 19’000 rpm
Turquoise = yarn spindle speed 17’000 rpm
Dark blue = yarn spindle speed 15’000 rpm

Conclusion

The analysis of the test result shows that: with the increasing of spindle speed from 15’000 rpm to 17’000 rpm and 19’000 rpm, the yarn elongation reduces from 8.21% to 8.02% and 7.38%. The spindle speed added to 19’000 rpm from 15’000 rpm, the elongation loss 10.1% in relative.

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