Application of an automatic yarn dismantler to track changes in cotton fibre properties during processing on a miniature spinning line

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Abstract

This paper reports on the application of a newly developed automatic yarn dismantler for dismantling short staple ring-spun yarns, to track changes in cotton fibre properties from lint to yarn, during processing on a miniature spinning line. The results obtained on different Upland cottons have clearly demonstrated the practical value of the yarn dismantler in enabling yarns to be automatically dismantled into their constituent fibres, which can then be tested by instrument, such as the AFIS, and the test results used to quantify changes in the various fibre properties at the different processing stages, including yarn.

Keywords: Yarn dismantler, cotton, fibre properties, AFIS test, miniature spinning

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Introduction

Cotton fibre properties, which vary widely according to genetic and environmental conditions, determine their price and textile processing performance and yarn and fabric quality. It is therefore hardly surprising that cotton fibre properties are routinely measured for trading and quality control purposes, as well as to establish the effect of different processes and processing conditions on the fibre properties. Some work has been carried out by researchers, such as Oxenham et al (1995), Ethridge and Zhu (1997), Kluka et al (1998), Zurek et al (1999), Frydrych et al (2001) and Hamilton et al (2012), using AFIS to track changes in cotton fibres properties during processing on full scale spinning machinery from lint to roving. Little, if any, research has been carried out however, to track changes in cotton fibre properties during processing, particularly miniature spinning, right up to the yarn. This is largely due to the fact that dismantling a staple fibre yarn into its constituent fibres, without damaging the fibres is a long, labour intensive and tedious manual process. Tracking changes in fibre properties, during processing, is important in order to minimise any adverse effect of processing on cotton fibre properties, notably fibre length, and to optimise cotton blends and processing conditions. With the development of a new technology and instrument, the Yarn Dismantler, which enables a short staple yarn to be dismantled into its constituent fibres without significantly changing their properties, it has become possible to accurately measure the properties of the cotton fibres at the yarn (and even fabric) stage, and to track the fibre properties during processing, right up to, and including, the yarn and fabric (Fassihi, A. and Hunter, L., 2013). The basic concept and principles of the yarn dismantler (see Figure 1), have been reported by Fassihi and Hunter (2013) and are only briefly described below.

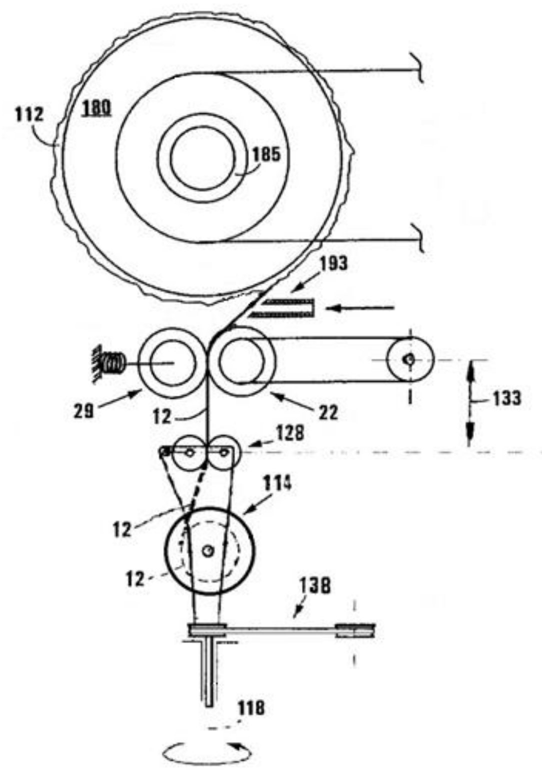

Figure 1: Schematic Diagram of the Yarn Dismantler (US Patent 6,205,758, March 2001)

The yarn 12, to be dismantled, is fed through guide rollers 128 to the driven unwinding rollers 22 and 29. The untwisting spindle (116) is driven by belt 138 in a direction which is appropriate for untwisting the yarn about an untwisting axis 118. Untwisting takes place between the guide rollers 128 and the unwinding nip rollers 22 and 29, i.e. over a very short distance, indicated by 133. The untwisted yarn is collected on the surface of a hollow rotating perforated drum 180. Suction (191) is applied through the perforated drum surface (181), thereby holding the collected fibres to the drum surface (112), also preventing them from becoming twisted again. When sufficient yarn has been dismantled, the dismantled fibres, collected on the drum, are steamed by means of nozzle 193. The reason for steaming is to remove twist liveliness (residual torque) of the collected fibres before testing. The dismantled fibre strands are carefully removed from the drum, for conditioning and testing, on an Advanced Fibre Information System (AFIS), for example. This paper reports on the fibre test results obtained at the different stages during miniature scale ring spinning process of various Upland cottons, and discusses the changes in the various fibre properties which occurred from the lint to the final yarn.

Experimental

Cotton lint samples, from each of six locally grown cotton varieties (American Upland types), were processed into carded yarn on a Platt Miniature line at the Material Science and Manufacturing Operating Unit of the Council for Scientific and Industrial Research (CSIR) Textile Division, Port Elizabeth, South Africa. The processing route layout (flow chart) is shown in Figure 2. The six cottons were selected so as to cover a fairly wide range of length (25.7 to 29.2 mm) as well as micronaire (2.8 to 4.7), on the basis of the HVI test results given in Table1.

Table 1: HVI Measured Fibre Properties

Lot / FIBRE PROPERTIES	CA180	CA209	CA522	CA527	CA178	CA208
UHML (mm)	29.2	29	27.7	26.9	29.2	29.2
Uniformity Index (%)	83	84	80	82	81	83
Strength (gf/tex)*	33.8	33.7	29.5	31.7	32.6	30.8
Elongation (%)	6.2	6.3	7.0	6.4	5.7	8.0
Micronnaire	3.6	4.7	2.8	4.0	4.0	4.5

*HVI / Pressley level

The Platt Miniature Spinning Line comprises a Shirley Analyser, card, drawframe and an eight spindle ringframe. Each card sliver (5.62 ktex) was given three draw frame passages, the draft being set at 11.7 for each drawing process, to achieve a linear density of 2.7 ktex for the final (i.e. 3rd drawing) sliver. The final draw frame slivers, so produced, were processed through a 4-roller drafting system miniature ring frame (ring diameter =51 mm), using two different drafts to produce 25/1 tex yarns (at two twist levels, 650 and other 760 tpm Z twist) and 40/1 tex yarns (also at two twist levels, 510 and other 600 tpm, Z twist), respectively. The spindle speed was set at 10000 rpm. Cotton samples were collected at each processing stage for AFIS testing.

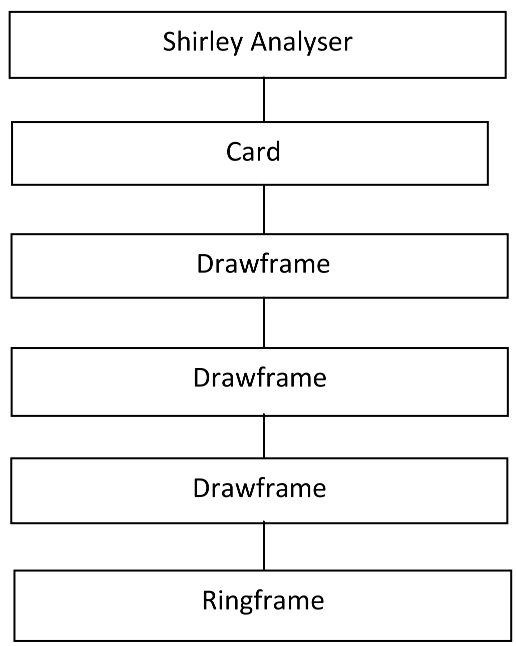

Figure 2: Processing flow chart for Platt Miniature Spinning Line

The Uster AFIS system of measuring and characterising cotton fibre characteristics, on a single fibre basis, was chosen for this research, since it is the most widely used and suitable commercial system for this purpose. The AFIS MultiData Module Version 4.22, which measures length and nep parameters as well as maturity and fineness (Uster AFIS - L & M, N module), was used to measure the properties of the fibres collected at the different stages of processing, including the fibres obtained from the dismantled yarn. It should be noted that fineness and maturity results were available for only four of the six cottons. Thirty cotton samples (+ 0.5 gram each, giving a total of at least 30 x 3000 = 90000 fibres for AFIS testing), were collected for each cotton, from the lint and every processing stage thereafter. The samples were collected as follows from the final (i.e third) drawframe passage slivers and spinning frame:

a) Third passage drawframe slivers from 6 spindles, i.e. the input to the spinning frame. Five subsamples, from each third passage drawframe sliver, were taken from different sections of the sliver, giving a total of 30 subsamples (i.e. 5 subsamples/sliver sample x 6 = 30 subsamples) per sample.
b) Six spinning tubes for each of the four yarns spun from the corresponding miniature slivers described in (a). Similarly, 30 subsamples, in total, of dismantled yarns were prepared from the corresponding six dismantled yarns (i.e. 5 dismantled subsamples/yarn tube x 6 = 30). Subsamples were prepared from different segments of the dismantled yarn from each tube.

A yarn dismantling speed of 2m/min was used for these trials (Fassihi, A. and Hunter, L., 2013). All samples were conditioned for 24 hours at 65% RH and 20˚C before testing on the AFIS was carried out.

AFIS Testing Protocol Used

A 0.5 g cotton sample was used for one test. The cotton fibre specimen was hand prepared into a roving form (30 to 35 cm long), by making sure any tangled fibre clusters were opened and straightened. The hand prepared sample was fed into the feed roller of the AFIS machine.

Statistical Analyses

Statistical analyses were carried out, where considered appropriate, to determine significant differences at the 95% confidence level (t-test) between fibre test results, the SPSS Statistics 20 software being used for this purpose.

Results and Discussion

An initial analysis indicated that the different yarn linear densities and twist levels did not significantly affect the results or trends and, therefore the test results obtained on 40 tex, 600 tpm Z twist yarns, are presented and discussed here.

Mean Fibre Length [L(w)]

From Figure 3 it can be seen that the mean fibre length (L(w)) was reduced significantly (7-9%) during the Shirley Analyser opening and cleaning process, indicating considerable fibre breakage resulting from the associated mechanical opening and cleaning actions on the cotton. Carding had a very small and inconsistent effect on the mean fibre length, while each drawframe passage caused an increase in mean fibre length, particularly the first one after carding (6%). The increase in fibre length due to drawing could be due to the straightening and parallelisation of the fibres and also to partial fibre crimp removal, as well as some short fibre loss, as was found by Oxenham et al (1995) and Suh et al (1997) on a conventional full scale processing line. The mean length of the fibre from the dismantled yarns was very similar to that in the third drawframe sliver (input to the ringframe). Statistical analysis of the results showed that the differences were statistically significant, at the 95% confidence level, between the lint results and the Shirley Analyser opening and cleaning results, and between the card and the 1st drawing passage results, for all of the samples.

Upper Quartile Length [UQL(w)]

As can be seen from Figure 4, the upper quartile length [UQL(w)] decreased as a result of the Shirley Analyser process, remained approximately the same during carding, and increased with the 1st drawing passage, after which it did not change consistently, the trends and explanations being much the same as those for L(w).

Short Fibre Content [SFC(w) and SFC(n)]

As can be seen from Figures 5 and 6, the two measures of short fibre content, namely SFC(w) and SFC(n), showed very similar trends and will thus be discussed as one, namely short fibre content (SFC). There was a substantial increase in short fibre content as a result of the opening and cleaning by the Shirley Analyser, indicating considerable fibre breakage, as was also reflected in the L(w) and UQL results. Carding tended to decrease SFC slightly, but not consistently, whereas drawing decreased the SFC significantly, particularly the first passage, probably due to the straightening and parallelisation of the fibres, some short fibre loss and also partial removable of fibre crimp. The SFC results for the dismantled yarns were very similar to those for the 3rd drawframe sliver, indicating very little effect of the miniature ringframe drafting and twist insertion on SFC, probably due to the fact that a twistless sliver (3rd drawframe sliver), serves as the input to the ring frame, as opposed to the twisted roving input normally used for full-scale spinning. The SFC values obtained on fibres from the dismantled yarns on average were lower by at least 10%, than those obtained on fibres from the lint, indicating that short fibres are lost, together with some fibre straightening possibly, when processing the lint into yarn on the miniature system.

Fibre Nep Count

The nep levels at each of the processing stages are plotted in Figure 7. The number of neps increased during the Shirley Analyzer opening and cleaning, but decreased substantially during carding, these changes being statistically significant at the 95% confidence level. These results are in line with those of Kluka et al (1998) and Frydrych et al (2001) for processing on full scale machinery. There was a slight reduction in neps during the 1st drawing passage, which could be due to fibre straightening and disentangling of some loosely structured neps, these changes being significant at the 95% confidence level for four of the six cottons. In all six cases, four of which are statistically significant at the 95% confidence level, the number of neps in the dismantled yarn was higher than those in the 3rd drawframe slivers, which could possibly be due to the consolidation of loosely constructed fibrous clusters during twist insertion, or possibly the creation of nep like structures during the dismantling process. On average, the nep levels in dismantled yarn were about 75% lower than those in the lint, confirming the effectiveness of the miniature card, in particular, in removing neps in the lint supplied to it.

Fibre Linear Density (mtex)

As already mentioned, fineness and maturity results were only available for four of the lots. From Figure 8 it is apparent that the Shirley Analyser opening and cleaning process caused a small decrease in the fibre linear density, the decrease being statistically significant for three of the four cottons. The decrease could be due to the removal of trash particles or relatively coarse fibres. Subsequent processes, particularly the first drawframe passage, increased the average linear density, which could be as a result of the removal, or loss, of relatively fine, short and immature fibres during these processes. Most of these increases were statistically significant at the 95% confidence level. There was no significant difference between the fibre linear density of the dismantled yarn fibres and that of the 3rd drawframe fibres. The average increase in fibre linear density, from lint to dismantled yarn, was approximately 10%, this could be due to the removal of relatively short and fine fibres, but should be investigated.

Fibre Maturity Ratio

According to the results plotted in Figure 9, the maturity ratio decreased slightly (2-4%) during the opening and cleaning on the Shirley Analyser, the decrease being statistically significant at the 95% confidence level, whereas carding did not change the maturity ratio significantly. Maturity ratio increased substantially during the progressive drawing stages, being about 7% higher after the first drawing process, all the increases, but one, being statistically significant. The maturity ratio of the fibres from the dismantled yarn, also showed a slight increase compared to the 3rd drawframe fibres, which could be the result of a loss of short immature fibres during twisting. The maturity ratio at the yarn stage was, on average, some 8% higher than at the lint stage. The trends for maturity ratio are generally in line with those obtained for fibre fineness.

Immature Fibre Content (% IFC)

As can be seen from Figure 10, the Shirley Analyser increased the IFC significantly for three of the four cottons (5-10%), the results being in keeping with the observed changes in maturity ratio. Carding did not affect the IFC consistently. The IFC decreased with each process after carding, the largest decrease taking place during the 1st drawframe passage, the decrease (about 30%) being in line with the trend observed for maturity ratio. The IFC of the dismantled fibres was slightly lower than that of the fibres in the 3rd drawframe sliver, the differences, however, being statistically significant in only one case. The values for the dismantled yarn were, on average, some 26% lower than those for the lint, which reflects the substantial effect which processing, particularly the drawframe, can have on IFC levels, an aspect worth investigating further.

SUMMARY AND CONCLUSIONS

The recently developed automatic yarn dismantler has been used to investigate the changes in cotton fibre properties during processing into yarn on a Platt miniature spinning line, with the yarn dismantler proving its value in enabling fibres in the ringspun yarns to be extracted and measured for their properties on an AFIS. It was found that a slight decrease in fibre length occurred during the Shirley Analyser opening and cleaning process, indicating fibre damage and breakage resulting from the associated mechanical actions, this being confirmed by associated increases in short fibre content (SFC). Miniature carding surprisingly improved the mean fibre length slightly. The first minature drawing process, after miniature carding, had a significant effect on most of the fibre length parameters, increasing mean fibre length and decreasing SFC. It was found that the mean length of the fibres from the dismantled yarn was slightly higher, and the SFC lower than that of 3rd drawframe sliver input to the ringframe, suggesting that, during spinning, short fibres were lost as fly and possibly also that some fibre straightening may have occurred.

It was found that the Shirley Analser opening and cleaning process increased the number of fibrous neps, while carding decreased the nep levels, as would be expected. The drawframe and ringframe drafting processes resulted in a slight reduction in neps, possibly due to some disentangling of neps and fibre straightening. The results obtained on fibres from the dismantled yarns indicated that the spinning process may have caused some nep formation, possibly by consolidating or tightening some pre-nep structures.

Fibre linear density and maturity ratio tended to show similar trends during miniature processing, changing little during the Shirley Analyser opening and cleaning process, but then increasing consistently in the subsequent processes, this being attributed to the removal of short, relatively fine and immature fibres during carding and the loss of such fibres during the drawing and spinning processes, the maturity ratio of the fibres in the yarn being some 7% higher than that in the lint. As could be expected, the immature fibre content (IFC) generally showed the opposite trends to the maturity ratio, the IFC in the dismantled yarn being about 15% lower than that in the lint.

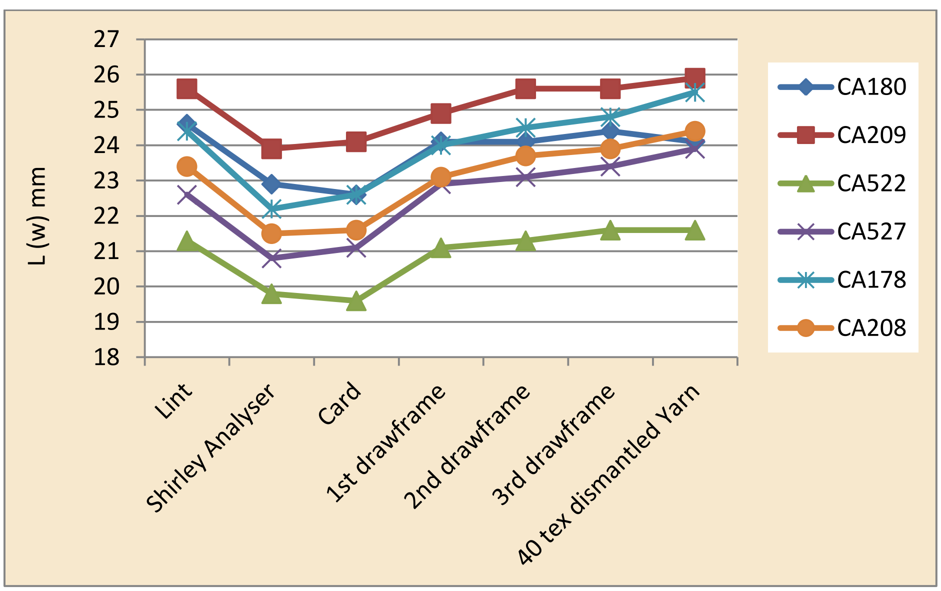

Figure 3: Mean Fibre Length [L(w)] at the different Processing Stages

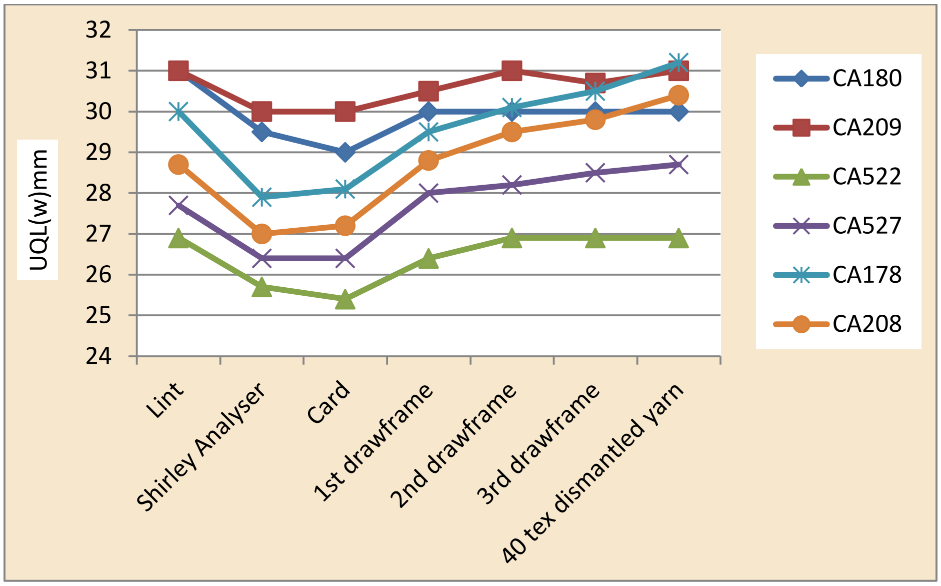

Figure 4: Upper Quartile Length [UQL(w)] at the different Processing Stages

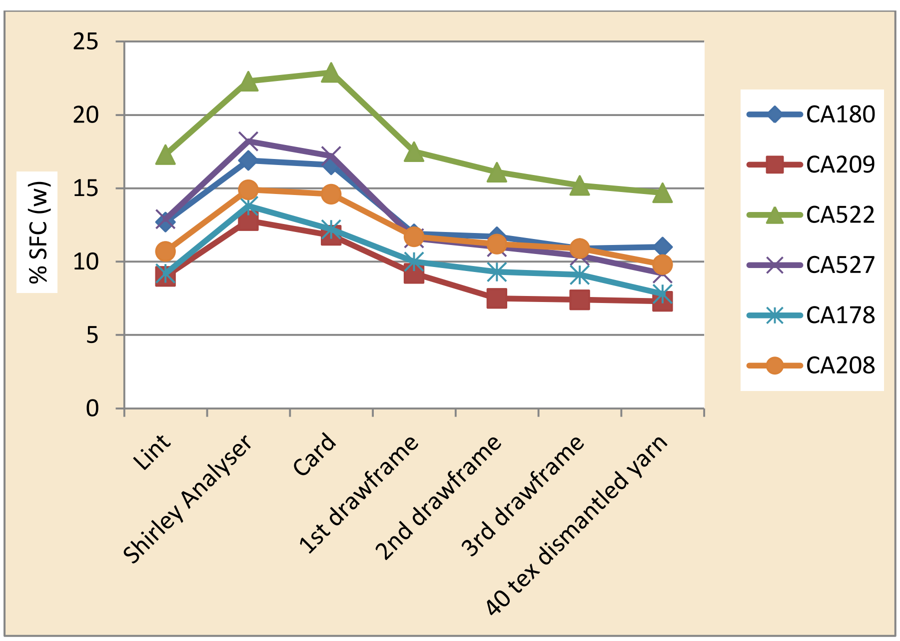

Figure 5 : Short Fibre Content [SFC(w)] at the different Processing Stages

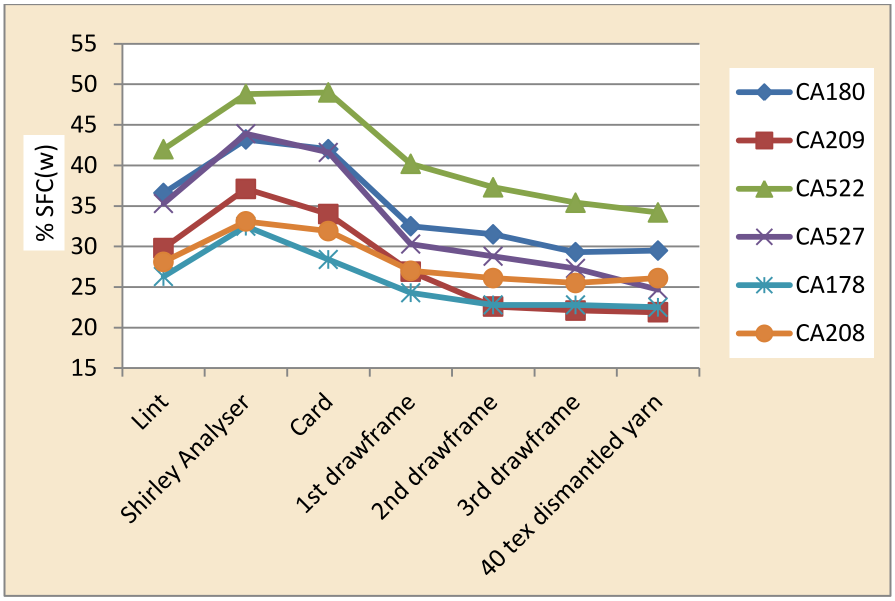

Figure: 6: Short Fibre Content [SFC(n) in %] at the different Processing Stages

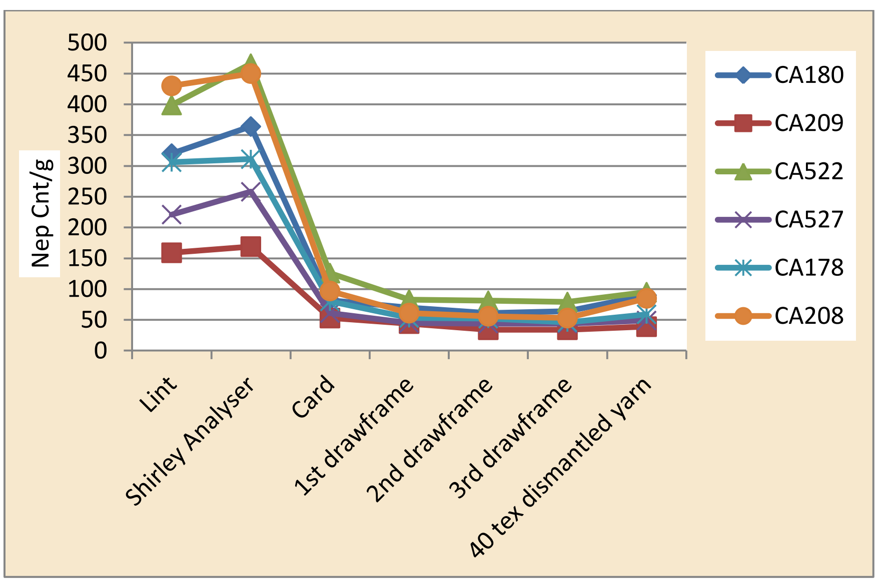

Figure 7 : Nep (count/g) at the different Processing Stages

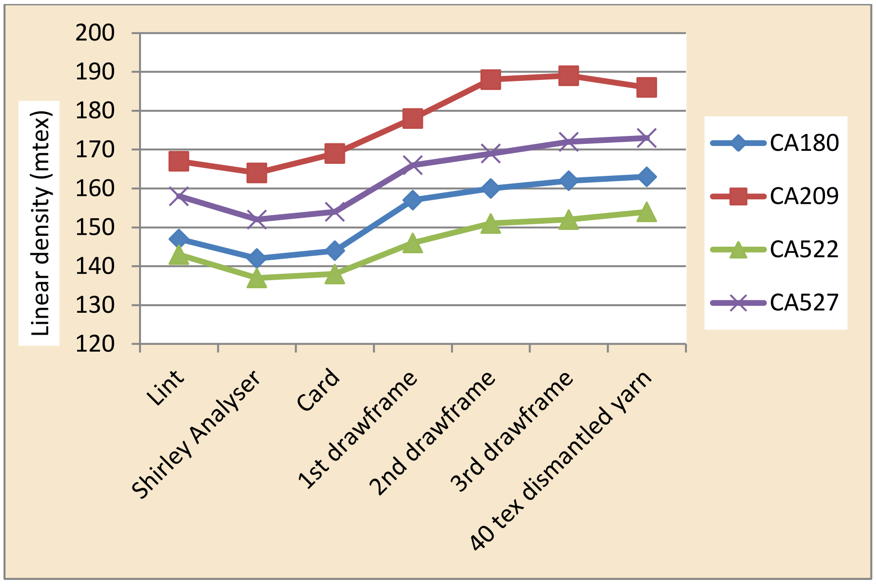

Figure 8 : Fibre Linear Density (mtex) at the different Processing Stages

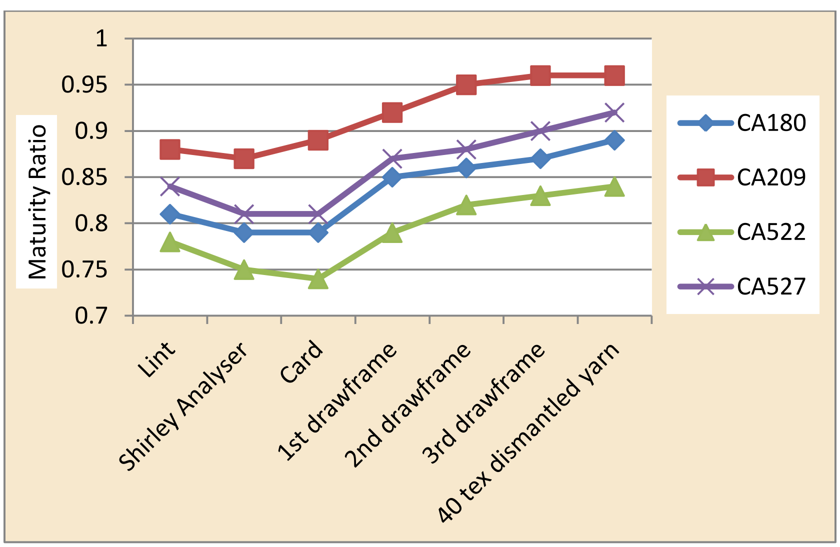

Figure 9: Maturity Ratio at the different Processing Stages

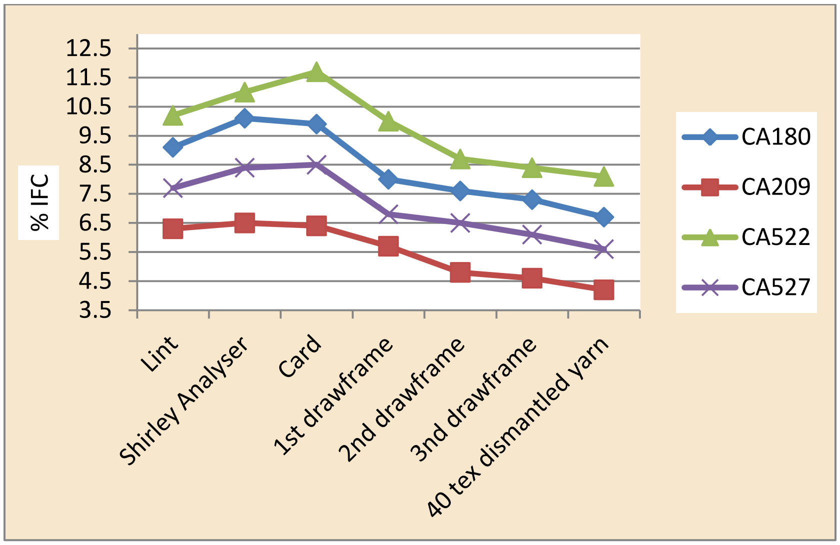

Figure 10 : IFC levels at the different Processing Stages

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