Predicting compact yarn’s IPI faults by using HVI fiber properties

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Abstract. Compact yarns have great value for producers and its importance grow day by day. Its higher tenacity, lower unevenness and lower hairiness –if required- are some of the reasons this yarn type gains importance. Estimation using previous data has a great value in engineering. It helps to understand the product before producing it. This study deals with the effects of HVI fiber properties on compact-spun yarns’ IPI fault results.

1. Introduction
Compact yarns have great value for producers and its importance grow day by day. Its higher tenacity, lower unevenness and lower hairiness –if required- are some of the reasons this yarn type gains importance.

Yarn production of compact spinning systems basically similar to the conventional ring spinning system. In fact, it was derived from the conventional ring spinning system. Drafting zone of ring spinning system was slightly altered and compact spinning system has come into use. The main difference between the conventional and compact spinning drafting zones is compacting elements in the exit part. There are different compacting elements built by different machine manufacturers and most of them use air guided compacting system. But why do we need to use compacting during drafting? What does it change in yarn? We need it because of fiber path change during drafting. Fiber bundle need to follow a theoretical line which is guided by roving guide but during drafting process fibers tend to leave this path and move to the outer sides of apron and the cots and constitute spinning triangle. This means, we may not embed all of the fibers into yarn body and cause fiber fly and/or embed them into yarn body from one end and cause hairiness. Compacting elements of compact spinning systems are designed to minimize spinning triangle.

Estimation using previous data has a great value in engineering. It helps to understand the product before producing it. We can save from raw material, labor and energy by using estimation tools. There are studies producing/using estimating equations in textile field. The simplest way for this can be regression analysis. It was used to analyse the effects of fiber properties on yarn properties in different systems, such as: ring spinning, siro spinning and open-end rotor spinning and also it was used for predicting fabric properties [1-7]. This study deals with the effects of HVI fiber properties on compact-spun yarns’ IPI fault results.

2. Method
In this study we used 11 types of cotton blends in the production. HVI and AFIS results confirmed that there are significant differences between fiber properties of these cotton blends. The main purpose of this study was to use fiber properties as predictors and find out information about our produced
compact-spun yarns. So, we used Rieter K45 compact spinning machine to spin compact yarns from 11 different blend cotton rovings. We named those rovings as H1 to H11. In production same machine parameters were used for different rovings and the production was carried out on same spindles. For each cotton blend, 4 different yarn counts (Ne40, Ne 50, Ne 60 and Ne 70) and 3 different twist coefficients (\(\alpha e 3.8\), \(\alpha e 4.3\) and \(\alpha e 4.8\)) were produced. Each yarn type had 10 cops of compact yarns. After the production, yarns were conditioned at 20\(\pm\)2 °C and 65\(\pm\)3 RH. After conditioning, yarns were subjected to unevenness, tenacity and twist tests.

Uster Tester 5 was used for determining unevenness, hairiness, thick places, thin places and neps results of yarns. 10 cops was used for each yarn type and for each one of them 1000 meters of test length was used. We used Uster Tensorapid 4 for tenacity tests. This test was also done for 10 cops for each yarn type. Also 10 tests were done for each cop. At the end we had 100 tenacity and breaking elongation results for each yarn type. Twist tests were carried out by using Zweigle D315.

3. Results

Initially, results gathered from yarn tests were used in ANOVA to understand the difference between groups. Thin places (-50%) results were not normally distributed so nonparametric tests were done to this feature. So, thick places (+50%) and neps (+200%) results were used in ANOVA and test results of this analysis are given on table 1. According to these results, we can say that the difference between cotton blends for thick places and neps counts are statistically significant. Moreover, non-parametric Kruskal-Wallis test confirmed that difference between the thin places (-50%) results of cotton blends are statistically significant.

Table 1. ANOVA Results for Thick Places (+50%) and Neps (+200%)

| Yarn Properties | F     | Significance |
|-----------------|-------|--------------|
| Thick Places (+50%) | 176,902 | .000         |
| Neps (+200%)    | 189,323 | .000         |

Table 2. Kruskal-Wallis Test for Thin Places (-50%)

| Hypothesis Test Summary |
|-------------------------|
| Null Hypothesis         |
| Test                    |
| Sig.                    |
| Decision                |
| The distribution of Thin Places (+50%) is the same across categories of Cotton Blend. | Independent Samples Kruskal-Wallis Test | .000 | Reject the null hypothesis |

Regression Analysis was carried out for thick places (+50%) and neps (+200%) results for better understanding the effects of fiber properties on them and for building a prediction equation in which HVI fiber properties will be predictors. But first of all, we investigated correlation between the properties we wanted to use as predictors. The results of tests showed that micronaire had high correlation with maturity (pearson correlation coefficient=0.931) and strength had high correlation with length (pearson correlation coefficient=0.956). Therefore we did not use maturity and strength results in our regression analysis. GRETL software was used for regression analysis. Ordinary least squares method was used for analysis. Coefficients and t values and p values for thick places are given in Table 3.
Table 3 Regression coefficients, t-values and significance level of t-values of linear regression model for Thick Places (+50%)

| Coefficient | t-value | p-value  |
|-------------|---------|----------|
| const       | 406,147 | 22,7435  | <0.00001 |
| Len         | -14,7707 | -26,5440 | <0.00001 |
| Elg         | -13,1735 | -4,5233  | <0.00001 |
| +b          | 15,2349  | 26,8167  | <0.00001 |
| Yarn Count (Ne) | 1,51993 | 33,5495  | <0.00001 |
| Mic         | -18,1359 | -9,0257  | <0.00001 |

The results show that thick place count on yarn decreases with the increase of fiber length, elongation and micronaire. It increases with finer yarns and higher yellowness value. R^2 value of this analysis is 0.73. This means we can build a prediction equation that allows us calculate thick places of yarn before production which has accuracy of 73%. The equation is:

\[
\text{Thick places (1/km)} = 406,147 + 1,51993 \cdot \text{Yarn Count (Ne)} + 15,2349 \cdot (+b) - 18,1359 \cdot \text{Mic} - 14,7707 \cdot \text{Len} - 13,1735 \cdot \text{Elg}
\]

Observed and predicted values of thick places (+50%) are given in Figure 1.

The results of regression analysis which was carried out for neps results of yarns show that neps count of yarn decreases with the increase of fiber length, elongation and micronaire (Table 4). It increases with finer yarns and higher yellowness and Uniformity index values. R^2 value of this analysis is 0.74. This means we can build a prediction equation that allows us calculate thick places of yarn before production which has accuracy of 74%. The equation is:

\[
\text{Neps (1/km)} = -246,164 + 2,64004 \cdot \text{Yarn Count (Ne)} + 28,4664 \cdot (+b) + 13,0783 \cdot \text{Unf} - 40,7572 \cdot \text{Mic} - 31,7594 \cdot \text{Len} - 13,484 \cdot \text{Elg}
\]

Figure 1 Predicted- Observed values for Thick Places (+50%)
Table 4 Regression coefficients, t-values and significance level of t-values of linear regression model for Neps (+200%)

|        | Coefficient | t-value | p-value   |
|--------|-------------|---------|-----------|
| const  | -246,164    | -2,0075 | 0,04493   |
| Len    | -31,7594    | 28,6570 | <0,00001  |
| Elg    | -13,484     | -3,1005 | 0,00198   |
| b      | 28,4664     | 26,9594 | <0,00001  |
| Yarn Count (Ne) | 2,64004 | 36,7702 | <0,00001  |
| Mic    | -40,7572    | -9,8379 | <0,00001  |
| Unf    | 13,0783     | 7,9466  | <0,00001  |

Observed and predicted values of neps (+200%) are given in Figure 2.

4. Conclusion
In this study, we have aimed to predict thick places and neps of cotton compact-spun yarns by using HVI fiber properties as predictors. Two equations we have got from analysis and their $R^2$ values are given in Table 5.

Table 5 Regression equations and $R^2$ values for Thick Places (+50%) and Neps (+200%)

| Yarn Properties | Regression equation                                      | $R^2$ | Adj $R^2$ |
|-----------------|---------------------------------------------------------|-------|-----------|
| Thick Places (+50%) | 406,147 +1,51993.Yarn Count (Ne) + 15,2349.(+b) – 18,1359.Mic – 14,7707.Len -13,1735.Elg | 0,73  | 0,73      |
| Neps (+200%)    | -246,164+2,64004.Yarn Count (Ne) + 28,4664.(+b) +13,0783.Unf -40,7572.Mic -31,7594.Len -13,484.Elg | 0,74  | 0,74      |
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