INFLUENCE OF NEPS ON ROTOR SPUN YARN STRENGTH

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Abstract

To the yarn manufacturer, the presence of neps in the yarn has always been a concern in terms of the nep's impact on the yarn appearance and dyeability. Until recently neps have not been studied in terms of their possible influence on yarn strength and breaking frequency. It has been the influence of cotton fiber properties of strength, length, and fineness, on rotor spun yarn strength that has been well documented. The aim of this study is to determine if neps have an influence on rotor spun yarn strength. Using commercially processed 19s count 100% cotton yarn for the study, yarn was examined for the presence of neps along the yarn length. Once identified, the nep was removed from the yarn strand at the center of an 18 inch sample length. The sample contained only one nep within it's specified length. Once collected the neps were examined an classified into four treatment groups. These groups were based on the type of nep; fibrous or seed coat, and location; outside the yarn structure or inside the yarn structure. A control yarn sample was collected that did not have a nep within it's yarn length. This sample was used for comparative analysis. Yarn samples were broken on a Instron Tensile Tester at a continuous rate of extension. The mean maximum breaking load was analyzed using the two sample T-test. Variances of the maximum breaking load was analyzed using the two sample F-test. Breaking distances from the nep point were measured and percent frequency graphs were generated for each nep group. Three replications of the study were performed. Results of the data analysis demonstrated that neps within the yarn structure, whether fibrous or seed coat, had no statistically significant influence on breaking load means or variance. Fibrous neps and seed coat neps inside the yarn structure did demonstrate a higher percentage of breaks at the nep point, suggesting that the neps in these two groups created weak places in the yarn structure.

Introduction

The increase in global competition has challenged the textile industry to reduce manufacturing costs, while improving production and quality. With the advent of higher production weaving and knitting machines, the yarn manufacturers are continually being challenged to provide high quality yarns. These yarns must be able to withstand the high stress levels induced by increased production rates. This demand for stronger yarns translates to a need for better understanding of the raw materials and their effects on yarn strength. The influence of cotton fiber properties such as, strength, length, and fineness, on yarn strength and quality has been well documented. Still, spinning breaks and ends down during weaving continue to occur, suggesting that other factors are contributing to weaknesses in the yarn structure.

The increasing demand for raw cotton fiber, has required the cotton producers to further mechanize their harvesting practices. This has resulted in more leaf, trash and bark becoming mixed in with the raw seed cotton. In order for the producer to receive a good price for his cotton, these impurities must be removed. As a consequence, the ginning process have become more aggressive, resulting in an increase in fiber entanglements (neps), and seed coat fragments in the raw cotton. It is the hypothesis of this study that these neps and seed coat fragments are one of the contributing factors influencing yarn strength.

Neps and seed coat fragments have been present in cotton yarn for many years. And traditionally their influence has been on yarn appearance and fabric dyeability. Yarns are given an appearance rating based on their evenness and frequency of neps along the yarn length. An increase frequency of neps would down grade the yarn, resulting in a decrease in yarn quality. Seed coat fragments also detract from the yarn quality. Such fragments account for more than 27% of imperfections found in yarns. Because there are usually fibers attached to these seed coat fragments, these fibers can become entangled and result in seed coat neps. In a recent study done by Herbert et. al., they found 13% of all neps contained seed coat fragments.

The dyeability problems concerning neps has to do with their fiber composition. Neps are primarily made up of immature fibers. These immature fibers have thin cell walls and therefore have a low bending rigidity. This results in a high tendency to become snarled and entangled.

The cell wall thickness is determined by the layering of cellulose during fiber cell maturation. If this layering in incomplete the cell walls will be thin. It is the presence of the cellulose, and it's chemical composition, that results in the dye up take that occurs on cotton fibers. The greater the amount of cellulose the better the dye takes to the fiber and the deeper the color. Because of the immature fibers present in the nep structure, it doesn't take the dye. This results in white specks in the fabrics.

Advances in fiber and yarn testing methods have provided an opportunity to investigate the possibility of neps impacting other yarn quality indicators. In particular, yarn strength and yarn strength variation. Because the strength of any yarn is dependent on the weakest point, any increase in yarn variation will result in a weaker structure. Controlling for strength variation will also decrease manufacturing costs. By keeping a low variability about the mean yarn strength the manufacturer can lower the mean

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strength without having weak places below the control limits. Lowering the mean strength requirements means being able to buy lower grade raw materials, which translates into a decrease in cost. With 50% - 70% of manufacturing costs going toward the purchase of the raw material, finding the causes of mean strength variation becomes paramount.

Influence of Neps in Rotor Spun Yarn

It has been well documented in the literature as far back as 1933, that neps influence the quality and appearance of yarn and the fabric made from that yarn. Pearson states that "the presence of neps in yarn produces fabric imperfections, and does not dye properly resulting in white specks". The effect of poor dyeability of neps due to their composition of immature fibers has been extensively researched and documented. Neps including seed coat fragments are often referred to as imperfections that detract from the yarn appearance resulting in a down grading of the yarn when tested against the standard yarn boards for grade and appearance. Mangialardi stated that neps and seed coat fragments make up the majority of small imperfections found in all yarns. In the literature the impact of neps and seed coat fragments has been in the area of imperfections in yarn appearance and yarn evenness.

Few publications discussed neps and or seed coat fragments impact on rotor spun yarn strength. Mangialardi quoted a study done at Texas Tech University on the causes of broken ends at the rotor spinning frame. They found that seed coat fragments were the major cause of ends down at spinning. In another article by Sasser, concerning an objective measure of neps by AFIS, he stated: "Neps in cotton are usually associated with a lower yarn strength and less uniform yarn". The third article which is the most recent, published in 1995 by Jones et. al., looked at the impact of seed coat neps in yarn manufacturing. In this study two carding conditions were chosen based on the best and worst seed coat nep removal performances achieved from different processing conditions that were studied. These two conditions were:

- Process A: Flat spacing - 0.008 in
  Flat speed - 5 in/min
  Throughput - 100 lbs/hr
- Process B: Flat spacing - 0.014 in
  Flat speed - 9.75 in/min
  Throughput - 120 lbs/hr

Portions of nine bales were each run through both processes and three rotor spun yarn counts (10s, 20s, & 30s Ne) were made from each process. The yarns were then tested for yarn strength, appearance, and imperfections (thick places, thin places and neps). The card slivers were tested on the AFIS and found an overall drop in seed coat neps by 50% and fibrous neps by 65% for process A. They found that yarn strength and appearance increased in process A for all three yarn counts. Nep count from the Uster Evenness Tester showed a higher count for process A for the 10s and 30s count and no difference for the 20s count.

Objective

The main objectives of this study were:

a. to identify and isolate neps within the yarn structure,
b. to categorize the neps in terms of type; fibrous or seed coat, and location; inside or outside the yarn structure,
c. to determine if neps have an influence on the strength of rotor spun yarn.

The following parameters were used in analyzing the nep's influence on yarn strength.

1. Means for maximum breaking load in grams force at break, for all sample yarns.
2. Variation of the mean maximum breaking load in grams force at break, for all sample yarns.
3. Breaking frequency of the yarn samples at the nep point.

Experimental

Experimental Design

A completely randomized design was selected for this experiment. The experimental design for this study consisted of five groups. Each group consisted of 19s count open-end yarn, eighteen inches in length. The five groups had the following characteristics:

1. Control yarn - no nep outside or inside the yarn structure (CY)
2. Fiber nep outside the yarn structure (FNO)
3. Fiber nep inside the yarn structure (FNI)
4. Seed coat nep outside the yarn structure (SCNO)
5. Seed coat nep inside the yarn structure (SCNI)

The number of samples for each group was forty five, with fifteen samples each, coming from three different spindle sites. Three replications of the experiment were performed.

Tests and Methods

Raw Materials

The 100% cotton yarns used in this study came from a local yarn spinner. They were commercially processed from a thirty six bale mix laydown consisting of upland variety cotton, grown in various regions in the United States. Each replication was drawn from a separate mix laydown. The replications were processed on the same equipment. To insure that the yarn used in the study was from the raw material tested, the processing line was emptied and cleaned prior to processing of the test cotton.

Definition of Nep Categories

The four nep groups were designed to categorize the nep according to type and location with respect to the yarn structure. These groups were defined as follows:

1. Fiber Nep Outside (FNO) **-** fibrous mass of entangled fibers located on the surface of the yarn structure.

2. Fiber Nep Inside (FNI) - fibrous mass of entangled fibers located inside and or attached to, the yarn core structure.
3. Seed Coat Nep Outside (SCNO) - fibrous mass of entangled fibers attached to a seed coat fragment located on the surface of the yarn structure.
4. Seed Coat Nep Inside (SCNI) - fibrous mass of entangled fibers attached to a seed coat fragment located inside and or attached to, the yarn core structure.

The fifth group was the control yarn. This yarn had the same characteristics as the other four groups, but did not include a nep structure within the sample length. By controlling the other variables that impact yarn strength in this manner, neps became the single independent variable being studied.

Nep Identification

The nep structures on the yarn were identified using black and white image analysis equipment. This equipment used the Optimas 402 Image Analysis Software, to present the yarn image to a computer screen for analysis. Calibration of the system was performed according to the Optimas Manual. The yarn was run in a continuous motion across the viewing lens by way of a hand controlled manual winder. This maintained tension in the yarn which prevented a loss of twist, and also decreased manual manipulation of the yarn during the viewing process. Once a nep was identified, an eighteen inch length of yarn was cut from he continuous yarn strand. The yarn sample was cut with the nep in the center of the sample length. Prior to cutting the sample, the sample length was inspected for leaf, bark, trash, and other neps. If found within this sample length, the sample was discarded. The samples were then mounted on eleven by fourteen inch black paper with tape. Placing the nep in the center, a ten inch gauge length was marked on the yarn samples. This gauge length represented the standard length used when performing stress strain tests on the Instron tensile testing machine. The yarn samples were mounted in a consistent manner to avoid biasing the study.

Specimen Testing Procedure

The stress strain measurements were obtained on an Instron 4502 tensile testing machine which was interfaced with a personal computer and printer. The measurements obtained from this test were the load in grams at break, and the breaking distance from the nep. Each sample was mounted in a consistent manner, with the yarn processed prior to the nep always placed in the upper jaws, and the yarn processed after the nep, placed in the lower jaws. Precaution was taken to avoid any change in the yarn twist. The nep was positioned in the middle of the gauge length at what would be called the zero point. The test was performed according to ASTM D2256, and the maximum load values in grams, for each sample was recorded by computer. The distance at break was determined by measuring the distance in millimeters from the top jaw to the break.

Computation and Data Analysis

The maximum load values and breaking distance from the nep were obtained on all five groups, the following statistical analysis was performed. A two sample T-test was done between the control group and each nep group, for breaking load. The null hypothesis was that the mean values were all the same. F-tests were performed between the control group and each nep group for breaking load to determine if their variances were different. Breaking frequency graphs were done on the distance of break from the nep to determine if more breaks occurred at or near the nep site.

Results and Discussion

Graphs of the means of the four nep groups in comparison to the control for breaking load are presented in Figure 1. Graphs of the variances for the four nep groups in comparison to the control for breaking load are presented in Figure 2.

Two Sample T-test

The two sample T-test compared each nep group to the control group. From this analysis of the breaking load in grams force to break, the FNI group, in replication one, was statistically different from the control group. With the mean value for the FNI group being 324.20 grams and the Control group mean value being 339.78 grams. All other means were not statistically different for the other groups across the three replications. Table 1 presents the results of the analysis, looking at the p-values for all three replications. This difference in means for one group, in only one replication was not sufficient to suggest that fiber neps within the yarn structure had any effect on the mean breaking strength of the yarn.

Two Sample F-test for Variance

The two sample F-test was used to determine if there was a difference in the variances between the four nep groups and the control group, for breaking load. Each nep group was compared against the control group. It was expected that the presence of the nep within the yarn structure would result in an increase in the variability in breaking load. The results from this analysis, looking at the p-values, can be found in Table 2. For the breaking load parameter, the variances were not statistically different for all groups, across the three replications. The p-values continued to be greater than the alpha level of .05. This suggests that neps do not significantly influence the yarn strength by causing a greater variability in the breaking strength values.

Breaking Frequency at the Nep Point

It has been demonstrated that yarns break at their weakest point. By determining the frequency of breaks at the nep point, it can be ascertained whether neps do indeed influence the yarn's strength. The presence of the nep in the yarn structure would undoubtedly result in a weak place in the yarn, thereby causing an increase in breaks at the nep point. The frequency of breaks along the sample gauge length, in 10 mm increments, were calculated and presented in a graph for each treatment group. Figures 3-7 show the breaking frequency distributions for replication one.

The graphs for the Control group, across all replications, showed a fairly even proportion of breaks along the sample gauge length. Therefore, there was not a concentration of breaks in one area, suggesting an influence from the yarn. This also demonstrated that there was not a machine bias to break more frequently at a certain place along the gauge length.

For the FNO group the distribution of breaks along the gauge length was fairly even. Much like that of the control. This was demonstrated in all three replications, suggesting that the fiber nep outside the yarn structure did not have an influence on the yarn strength. Although in replication three there was an 11% frequency of breaks around the nep point, this was also seen at the 90 mm mark above the nep point.

In the case of the FNI group, in all three replications, there was a significant increase in the percent of breaks around the nep point. These breaks occurred at the nep point, or within 5 mm on either side of the nep. Breaking frequencies of 20%, 22% and 16% around the nep point were seen in the three replications respectively. When examining the means of the maximum breaking load for these breaks, they are below the average mean for all forty five samples by a significant margin. This was demonstrated for replication one and three. This increase in percent breaks at the nep point suggests that the fiber nep within the yarn structure is having an effect on the yarn strength. The presence of the fibrous entanglement in the yarn structure is creating a weak place in the yarn.

The proportion of breaks for the SCNO group in replications one and two, demonstrated no significant effect on strength of the seed coat fragment outside the yarn structure. In replication one the percent breaks were 9% with 11% breaks at the -60 mm gauge length. For replication two the breaks at the nep point were 13%, only slightly higher than other areas that showed 11% and 9%. No significant increase in the proportion of breaks at the nep point was seen in these two replications. This was what would be expected if the seed coat was outside the yarn structure. In replication three, the percentage of breaks at the nep point was 22%. A significant increase of breaks occurred at the nep point. This would suggest that the seed coat fragment is playing a role in affecting the strength of the yarn structure. Although the seed coat fragment is identified as outside the nep, the size of the fragment, as well as it's possible penetration into the yarn structure could be causing an effect on the yarn structure.

A significant increase in breaking frequency at the nep point was seen in the SCNI group. This increase in frequency was demonstrated across all replications one, two and three, with percentages of 16%, 22% and 27%, respectively. The next highest frequency was 11%, that occurred at the -90 mm gauge length. These results could be due to the seed coat neps being inside the yarn structure. The presence of seed coat fragments within the yarn structure effects the ability of the yarn to handle stress, resulting in creation of a weak place at the nep point. In fact, the mean breaking strength at the nep point for all three replications was well below the mean for the entire sample in this group. This suggests that the seed coat nep does in fact affect the yarn strength, by creating weaknesses in the yarn structure.

Conclusions

In studying the effect of neps on yarn strength in rotor spun yarn, three criteria were used. First the mean of the maximum load at break, for each nep group was analyzed. These values in themselves identify the average stress-strain characteristics of the yarn. If there is a defect (nep) introduced into the yarn structure that effects it's strength, it is expected that these values would be impacted. This impact or change in mean values would only effect the processability of the yarn if they fell below the processing requirements set for that yarn. The mean values, themselves, are not sufficient in determining the effect of neps on yarn strength. What has become more critical is the variation that occurs around the means. That is why variation was the second criteria used in this study.

An increase in the variance about the means, suggests that the nep introduced in the yarn is creating breaks at both the upper and lower ends of the normal distribution curve. Some breaking values will be higher, but some will be lower. It is these lower values that affect the yarn strength and processability. If these low strength values fall below the processing parameters, the yarn will break, making it unsatisfactory for that application.

By keeping the variance narrow about the mean, the mean strength values can be lowered without having a detrimental effect on the yarn processability. Lowering the mean strength values by using low cost raw fibers, can have a profitable impact for the yarn manufacturer. When your variation is wide about the mean, the mean strength values might have to be increased to compensate for the strength values at the lower end of the distribution. This means buying higher grade raw materials than is really necessary in order to process a viable yarn.

Douglas, in his article on “Quality Characteristics of Cotton Fibers”, gave an excellent illustration of the importance of controlling yarn variability when it comes to weaving. Given three yarns with the same mean breaking tenacity of 14 cN/tex, and breaking force coefficients of variation (CV) of 11%, 13%, and 15%. He demonstrated that as you increase the weaving speeds you also increase the stress on the yarns which results in an increase in the weft breaking frequency per 100,000 picks. Comparing these weft breaks, he found that at 700 p.p.m loom speed, the 11% CV yarn had 2 weft breaks per 100,000 picks. The 13% CV yarn had 10 weft breaks per 100,000 picks. And the 15% CV yarn was unable to perform at that loom speed. He stated that: "A difference in the coefficient of variation of as little as 2% will determine whether a particular yarn can be processed or not, even if the mean breaking tenacity remains the same. A minor improvement in the coefficient of variation value of breaking force can have a substantially positive effect on the running behavior of a yarn during weaving."

The third criteria used in this study was breaking frequency at the nep site. An increase in breaking frequency at or near the location of the nep, suggests that the nep in some way is having an effect on the yarn's ability to handle a stress. The creation of a weak point in the yarn structure does have a detrimental effect on yarn processability. Work done by Davydov et. al. found that cyclic extension, similar to that experienced by warp yarns on a loom, produced changes in the initial breaking probability. This was especially true in the initial stages, and the largest changes were seen in the weaker sections of the yarn structure. In the strong sections, repeated extensions produced virtually no variations in the yarn strength. Further work done by Piciotto and Hersh, confirmed this weak link effect during repeated cycles of stress and relaxation.

From the results of the analysis of these three criteria, it can be stated that neps in the yarn structure did not have a statistically significant influence on the strength of the yarn. This was demonstrated by the fact that the means and variances for breaking load did not change. But the increase in breaking frequency seen in the FNI and SCNI group demonstrates that the presence of a nep in the yarn structure does create a weak point in the yarn. The creation of this weak point does impact the processability of yarns that must withstand cyclic extension behavior, like that experienced by warp yarns in weaving.

Summary

The influence of fibrous neps and seed coat neps located inside the yarn, on the yarn strength of rotor spun yarn has been established by this study. Because of these findings, neps do not have to be considered as an input variable when looking at yarn strength. But their impact on the yarn structure with the formation of weak points cannot be under stated. For the industry, the presence of neps in the yarn is still significance, because of their effect on yarn appearance, dyeability, and the creation of weak points in the yarn. The fact that neps do create weak points in the yarn, suggests that further study needs to be done into the mechanism of failure created by the nep in the yarn structure. Working with the producers and ginners to improve the processing of the raw cotton, is essential to decreasing the quantity of neps in the raw material. Advances in cotton testing systems, like the new seed coat identification module for the AFIS, the Microwatcher for nep identification, and the Microvision Video System that can do cross sectional analysis, will help the industry gain more understanding of their raw material characteristics and how these characteristics impact yarn performance and quality.

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Table 1. P-Values for T-Test of the Mean Breaking Load (α= .05)

	Control/FNO	Control/FN I	Control/SCN O	Control/SCNI
1	0.1897	**0.0139***	0.2714	0.2366
2	0.3031	0.3240	0.7044	0.2544
3	0.3748	0.0527	0.3767	0.2055

* Values in bold are statistically significant

Table 2. P-Values for F-Test of the Mean Breaking Load (α = .05)

	Control/FNO	Control/FNI	Control/SCNO	Control/SCNI
1	0.2174	0.4348	0.1534	0.2459
2	0.2346	0.3052	0.3710	0.1219
3	0.2649	0.4468	0.4125	0.2114

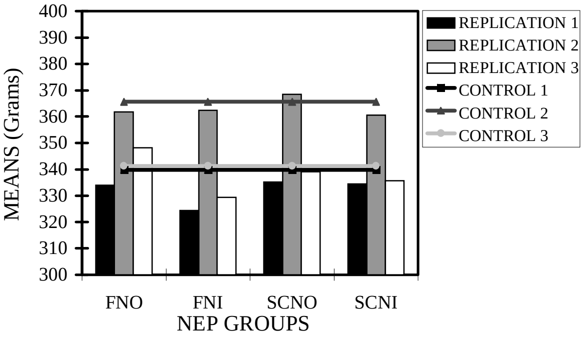

Figure 1. Breaking Load Means for the Five Groups (Including the Control) Over Three Replications

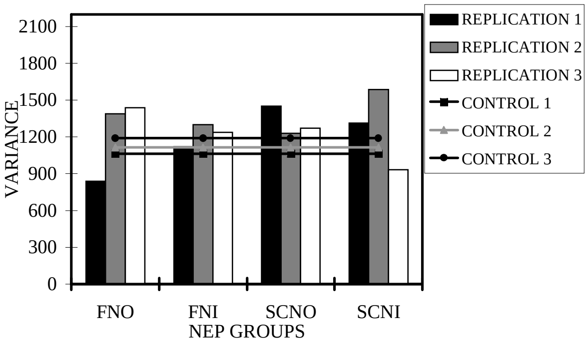

Figure 2. Breaking Load Variances for the Five Groups (Including the Control) Over Three Replications

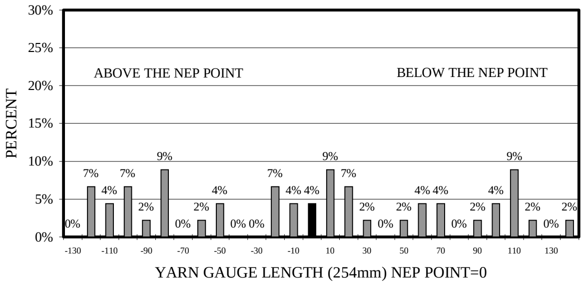

Figure 3. Percent of Breaks along the 254mm Yarn Length for the Control Yarn, Replication 1.

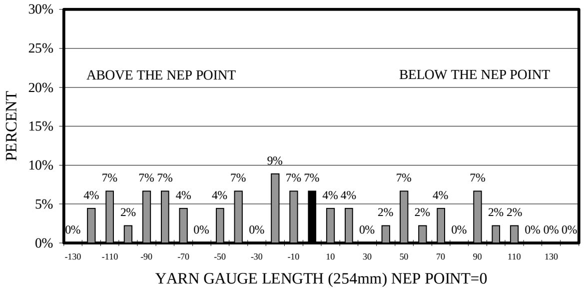

Figure 4. Percent of Breaks along the 254mm Yarn Length for the FNO Yarn, Replication 1.

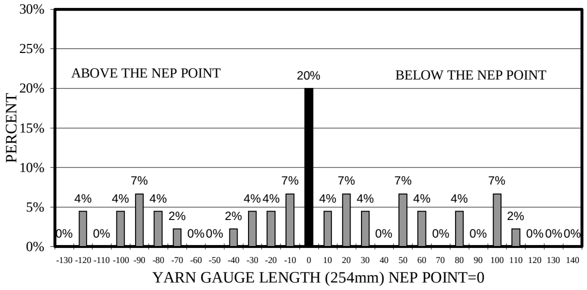

Figure 5. Percent of Breaks along the 254mm Yarn Length for the FNI Yarn, Replication 1.

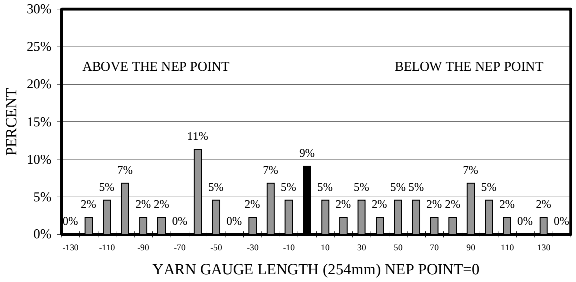

Figure 6. Percent of Breaks along the 254mm Yarn Length for the SCNO Yarn, Replication 1.

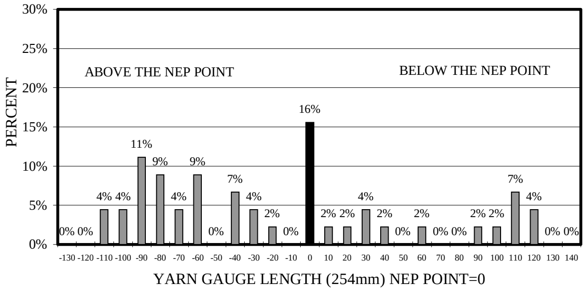

Figure 7. Percent of Breaks along the 254mm Yarn Length for the SCNI Yarn, Replication 1.