Gonca Ozcelik, Erhan Kırtay

Ege University
Textile Engineering Department
35100 Bornova, İzmir, Turkey
E-mail: gonca.ozcelik@ege.edu.tr
E-mail: kirtay@egenet.com.tr

Examination of the Influence of Selected Fibre Properties on Yarn Neppiness

Abstract
Yarn neppiness, one of the most important aspects of cotton yarn quality, has significant influences on the downstream processes; therefore it should be well controlled. In this study, in order to examine the changes in nep count during the production of yarn, cotton materials from different origins have been investigated at some parts of the production line of carded yarn. Moreover, to predict of the yarn nep count from fibre properties measured by HVI and AFIS instruments, the regression equations were obtained by means of multiple regression analysis. In order to see the validity of each equation, the correlations between the measured and estimated yarn nep counts were obtained.

Key words: *cotton, fibre neps, yarn neps, AFIS, HVI, regression analysis.*

Introduction

In today's highly competitive and global textile market, product quality has become of paramount importance. In order to produce high-quality cotton yarns which will in turn produce high-quality woven & knitted fabrics and end products, emphasis must be placed on the quality and processing of cotton fibres [1].

There is a direct correlation between the quality of raw materials and the end products. The lower quality of cotton fibres means the lower quality of yarn produced from such a raw material. High-quality cotton blends are superior with respect to properties such as length, fineness, elongation, and brightness, sufficiently mature and without any trash particles, and displaying a high capacity of spinning consistency.

Starting from harvesting, cotton is exposed to numerous processes. Mechanical outer actions during yarn manufacturing cause significant changes of almost all the properties of processed cotton. Such mechanical actions and processing conditions cause increases in short fibre content, nep formation, a decrease in fibre strength, and problems such as cotton stickiness. Therefore, these matters result in the fibre quality and economical value decreasing.

One of the most important fibre parameters that causes a decrease of cotton quality is neps; a nep can be defined as "a small knot of entangled fibres consisting entirely of fibres (i.e. a fibre neps) or of foreign matter (i.e. a seed-coat fragment) entangled with fibres" [1].

Neps in a yarn are defined as "point agglomerations of fibres entangled into yarn causing the increase of yarn diameter". The number of neps in cotton yarn depends on two main factors: the characteristics of the raw material used for the yarn production, and the conditions of the technological process in the spinning mill [2].

The opening and cleaning processes in the blow room line are the operations in which the formation of mechanical neps takes place, as well as fibre damage. In today's spinning market, together with the increment in demand for cleaner cotton and the increased prices paid for the cleaner cotton, cotton fibres are exposed to two or more stages of lint cleaning in the ginning process, which improves the cotton grade and removes foreign materials from cotton. However, the lint cleaners tend to break seed-coat fragments into very small fragments to reduce fibre length, and it becomes very difficult to remove them in opening and cleaning lines. Therefore in order to clean the fibres from these fragments sufficiently, mechanical treatments in the blow room line become more exhaustive. During the opening and cleaning processes, for removing trash and dust particles from cotton, beating, drawing and rolling motions take place, and these actions cause neps formation. Furthermore, the pneumatic transport of fibres between particular machines in the technological line cause an increment in the number of neps, as the more open fibre stream means increased tendencies of fibres to form neps. Therefore it can be stated that regular air stream and clean air circulation are significant in these preliminary processes.

Problems with neps

Neps in cotton lint cause short, thick places in yarns, resulting in uneven fabric appearance. Often, erratic fibre orientation in these areas can cause weak places in yarns. This can lead to a loss of spinning efficiency, weaving and knitting machine stoppage and fabric defects.

While manufacturing knitted fabric, when transferring yarns from bobbins to knitting needles, neps in yarns can block the holes of yarn guides and needle hooks, resulting in yarns breaking. Therefore, the knitted fabric produced will have a hole, which minimises the value of the product.

Neps on the surface of a fabric can cause undyed or unprinted spots during dyeing or printing. The most disturbing effect of these white spots is that they cannot be recognised until dyeing or printing. This problem becomes very troublesome, especially when dealing with dark colours. Neps sometimes contain immature fibres, which are usually weaker than normal fibres. This weakness can lead to fibre fragments breaking off, which creates excessive fibre dust fly and lint deposits.

Materials and methods

In this study, in order to make a prognosis of the nep content in the finished yarn based on the raw material properties, and to investigate the changes in neps content of the fibre stream during yarn manufacturing, an experimental study was carried out in a Turkish spinning mill on a carded yarn production line.

The first aim of this study was to determine the relationship between the cotton fibre properties measured by HVI (High Volume Instrument), AFIS (Advanced Fibre Information System) instruments and the amount of yarn neps, and the second was to examine the changes in nep amount during the production stages. As raw material, cotton fibre, which is commonly used in the textile industry

Table 1. Cotton blends used in the study, taken from the carded production line.

Blend number	Blend Composition
1	100% Uzbek
2	100% Turkish (Aegean)
3	100% Turkish (Diyarbakır)
4	100% Turkish (Hatay)
5	100% Greece
6	100% African
7	50% Uzbek – 50% Turkish (Aegean)
8	60% Uzbek – 40% Greece
9	70% Greece – 30% Iranian
10	59% Turkish (Aegean) – 24% African – 17% Turkish (Hatay)
11	64% Uzbek – 25% Turkish (Aegean) – 11% African

in Turkey and worldwide, was utilised, and cotton blends were selected from the types processed in spinning mills.

In the first part of the study, in order to determine the changes of the neps and seed coat neps during yarn manufacturing, 11 different cotton blends consisting of different ratios of the Greek, Aegean, African, Uzbek and Turkish (Diyarbakir and Hatay) cottons were examined (see Table 1). It should be noted that the geographic denotations indicate a particular cotton batch and do not characterise in general the cotton of the particular country.

The processing stages in the yarn production line, where the nep count of the material is measured, are given in Table 2. In the second part of the study, to predict yarn neps by means of fibre properties, the AFIS and HVI data of 30 cotton blends were used, and by using these values, a multiple regression analysis was carried out with the SPSS statistical program.

The parameter to be predicted in the study, yarn neps, was considered as a dependent variable (y), and the fibre properties were dealt with as independent variables. Besides, as it is known from proceeding studies that there is a close correlation between yarn count (linear density) and yarn neps, yarn count was also included in the regression analysis. With the regression analysis, we tried to obtain the highest regression coefficient of determination (R^2).

The fibre properties were measured with the following principles and instruments:
- measurement of fibre bundle (HVI – High Volume Instrument)
- measurement of single fibres (AFIS – Advanced Fibre Information System)

In this respect, regression analyses were done separately for each set of data taken from the instruments. However, yarn count was added for both analyses. Also, measurement of yarn neps was carried out with a Uster Tester 3 instrument.

The fibre parameters measured by the HVI instrument and included in the regression analyses are as follows:
- 2.5% span length, mm
- 2.5% span length CV, %
- Uniformity index, %
- Fibre strength, cN/tex
- Fibre elongation, %
- Fibre fineness, microner

The fibre parameters measured by the AFIS system and included in the regression analyses are as follows:
- Short fibre content by number, %
- Fibre fineness, mtex
- Immature fibre content, %
- Fibre maturity
- Nep number, count/g
- Seed-coat nep number, count/g
- Dust number, count/g
- Trash number, count/g
- Visible foreign material, %

After the regression analyses, a stepwise regression procedure was applied to determine the independent variables which effectively made the maximum contribution to the coefficient of determination. In this method, starting from the independent variable providing the maximum contribution, the increment in the coefficient of determination was calculated by the contribution of the other independent variables in turn. With the aid of this method, it is possible to determine the most important fibre properties that influence yarn nep formation.

Table 2. Process stages at which the cotton samples were taken.

Carded yarn production line	
Bale	
Opening and cleaning line	Cleaning (CVT3) Opening (Tuftomat) Dust separator (Dustex)
Carding machine	Card mat Card sliver
1st passage draw frame machine 2nd passage draw frame machine	Sliver from the 1st passage draw frame Sliver from the 2nd passage draw frame

Results and discussion

Examining the effect of process stages on nep content

By using the AFIS system, starting from the bale, the important fibre parameters of each semi-product and end product of yarn manufacturing can be measured, and so each processing stage can be controlled. The role of machines in handling fibres has become more critical because of the nature of today's machinery. Accordingly, the absence of close monitoring of the process may result in significant changes in fibre characteristics. Specifically, fibres are likely to be damaged; nepped and fine trash is likely to cling to the fibres [4].

In order to examine the changes in nep count in cotton during processing, cotton samples taken from different stages of the blow room line for 11 different cotton blends were tested with the AFIS system (see Figure 1). In the cotton blends observed, the fibre nep content ranges from 81 count/g to 264 count/g. As can be seen from Figure 5, the minimum nep content belongs to the fourth cotton blend, i.e. 100% Turkish cotton (Hatay), whereas the maximum nep content belongs to the fifth cotton blend, 100% Greek cotton. An increment in nep number from the bale to the dust separator is observed. Generally, the reason for this increment is external mechanical factors, which are connected with actions of the machine's working elements on the fibres, as well as by the pneumatic transport of fibres between particular machines.

The next machine after the blow room line in yarn manufacturing is the carding machine, which is also called the 'heart of the spinning mill'. To evaluate the carding performances and select the optimum card settings, the NRE% (nep removal efficiency) should be monitored. The NRE shows the relation between input material, card mat, and the output material, card sliver [4].

Zelleweger Uster reported that a 70% nep reduction by card is low, 80% is average and 90% is high. The nep removal effi-

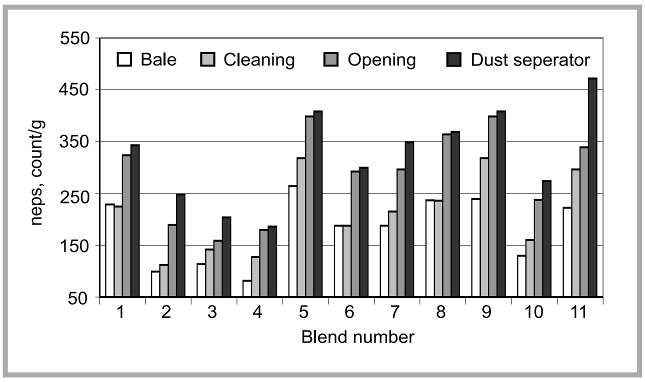

Figure 1. *The changes in nep content in cotton during the blow room line.*

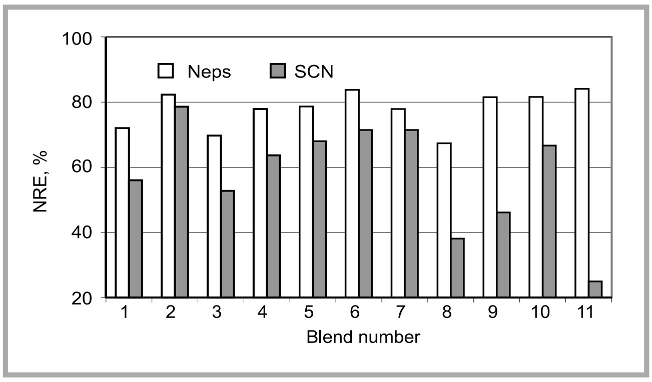

Figure 3. *Average fibre and seed-coat nep removal efficiencies (NRE %) of the carding machines.*

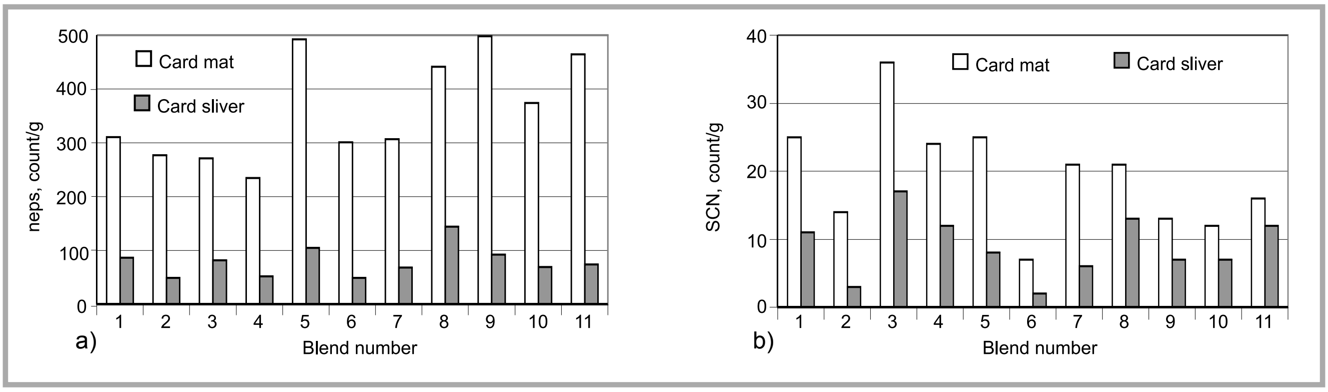

Figure 2. *The changes in a) nep and b) seed-coat nep content (count/g) in card mat and sliver.*

ciency (NRE) of a carding machine can be calculated by the following equation:

$$NRE\ (\%) = \frac{N_{feed} - N_{del}}{N_{feed}} .100$$

where:

N_{feed} = the neps number in the feeding web, neps count/g

N_{del} = the neps number in the delivered sliver, neps count/g

In Figure 2, the average nep and seed-coat nep numbers of the card mats and slivers are presented. It can be stated from the results that a considerable reduction of the fibre and seed-coat nep number occurs in carding machines.

On the basis of the results presented, it can be stated that the nep removal efficiency of the carding machines used for 11 different blends ranges from 67% to 84%, whereas for seed-coat neps, the removal efficiency varies between 25% and 79% (Figure 3). Regarding the nep removal efficiency, it can be stated that carding machines are much more effective at removing fibre neps than seed-coat neps. In Table 1, the origins of the cottons were given. Among these 11 blends, 6 of them contain only one type of cotton; the other 5 blends are mixtures of 2 or 3 types of cotton. In order to see the effect of the difference in cotton origins clearly, the changes in nep content in cotton while processing these 6 cotton types are presented in Figure 4.

Although the origins and ginning conditions of the cottons are different and the neps content of the raw material ranges from 81 count/g to 262 count/g,

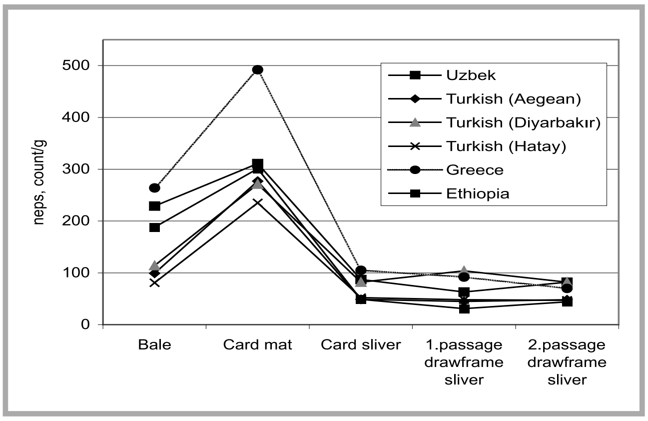

Figure 4. *Changes in nep content of fibre stream during carded yarn manufacturing.*

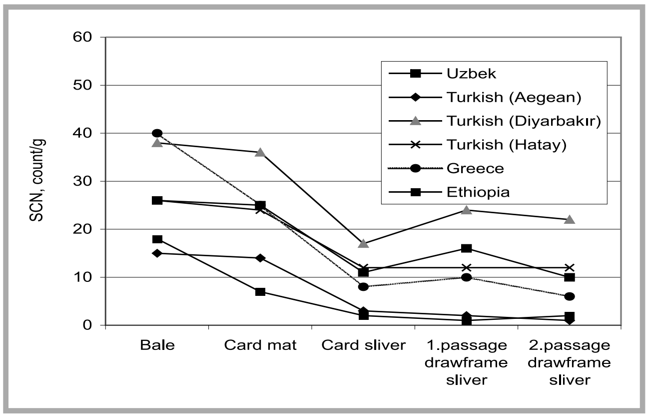

Figure 5. *Changes in seed-coat nep content of fibre stream during carded yarn manufacturing.*

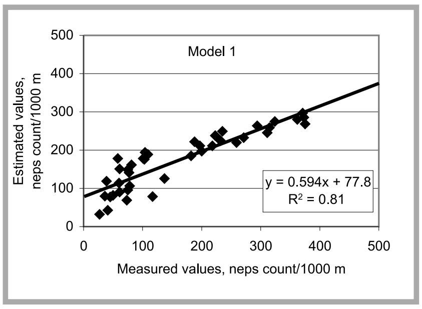

Figure 6. *The comparison of the measured nep count and the estimated values, with the fibre properties measured by HVI (the enter method).*

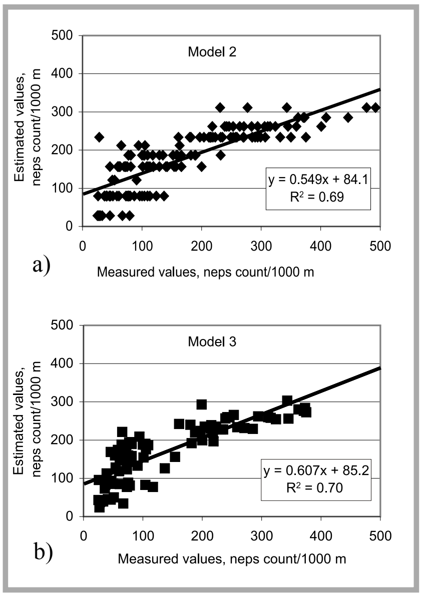

Figure 7. *The comparison of measured nep count and the estimated values with the fibre properties measured by HVI (stepwise method); a) model 2 and b) model 3.*

the changes in nep content during yarn manufacturing stages are similar. In all blends, preliminary treatment of cotton in the opening and cleaning lines causes an increment in the nep number. In the carding process, a significant decrease in the level of neps takes place.

For drawing and mixing the card slivers, the 1st and 2nd passage draw-frame machines are used after the carding process. On the basis of the results, as can be seen from Figure 4 and 5, it can be stated that there is no significant change in the nep and seed-coat nep content at this stage of production. The reason for the slight changes in nep content may arise from the doubling process, because several card slivers containing different amount of neps are gathered and drawn together. But however, the 2nd passage draw-frame sliver, the raw material of which contains a higher nep content, also includes many more neps.

Prediction of yarn neps with fibre properties

In the second part of the study, cotton yarns whose counts (linear densities) range from 33 tex to 16 tex were produced on a carded yarn manufacturing line. In order to predict yarn neps by using the fibre parameters measured by the HVI and AFIS systems, multivariate regression analyses were carried out. Yarn neps measured by the Uster Tester instrument were considered as dependent-variable (y), and the yarn count and fibre parameters measured by the HVI and AFIS systems were considered as independent variables (x). The regression equations were derived separately for both the HVI and AFIS fibre parameters.

Since the regression equations consist of so many fibre parameters, in order to determine the most effective independent variables which make the maximum contributions to the prediction of yarn neps, a stepwise regression procedure was applied.

In Table 3, the regression equations derived from HVI data are presented.

As a result of the regression analyses with HVI parameters, 3 different models for estimating yarn neps have been derived. For controlling the appropriateness of the regression equations, variance analyses were carried out; for a significance coefficient of $\alpha = 0.05$, the calculated F and p values have been found to be significant.

The regression coefficient of determination (R^2), which is calculated by the method's enter where all fibre parameters are included in the equation, is established as 75.0%. In order to verify the proposed theoretical equations, the number of estimated yarn neps has been determined by using fibre parameters. The correlation between the estimated values that were calculated from the first regression equation and the real values obtained as results of yarn measurement by the Uster Tester has been established as 81.03%, (Figure 6).

As a result of the stepwise method which determines the most effective property for yarn nep prediction, 2 different models were obtained. In the first model, where the only parameter contributing the regression equation is yarn count, the regression coefficient of determination is found as 69.3%. On the basis of this result, it can be stated that yarn count is the most important factor for predicting yarn neps. It has been found that the finer the yarn, the more yarn neps occur, so there is a positive correlation. In the second model, besides yarn count, the uniformity index of fibres has been found to be significant, and the regression coefficient of determination is found as 74.2%. The correlation between the estimated values calculated from the 2nd regression equation and real values has been found as 68.93%; whereas the correlation between the estimated values calculated from the

Table 3. *Regression equations derived from fibre parameters measured by HVI instrument; N_y – yarn neps, T_t – linear density (yarn count), l_s – spun length, l_s CV – spun length CV, T – tenacity, e – elongation, I_u – uniformity index, D – dust, F – fineness.*

Regression equations determined by HVI data			Regression coefficient of determination (R^2), %
Enter method	$N_y = 3169 – 14.5\ T_t + 6.12 \cdot 2.5\%\ l_s – 22.9 \cdot 2.5\%\ l_s\ CV +$ $– 29.3\ T – 44.8\ e – 15.0\ I_u - 69.6\ F$	(1)	75.0
Stepwise method	$N_y = 542.6 – 15.7\ T_t$	(2)	69.3
	$N_y = 2084 – 14.9\ T_t – 18.8\ I_u$	(3)	74.2

Table 4. *Regression equations derived from fibre parameters measured by AFIS instrument; N_y – yarn neps, T_t – linear density (yarn count, D – dust, F – fineness, N_f – fibre neps, SFC – short fibre content, SCN – seat coat neps, VFM – visible fibre matter, IFC – immature fiber content, M – maturity, T_r -trash.*

Regression equations determined by AFIS data			Regression coefficient of determination (R^2), %
Enter Method	$N_y = 728.6 – 16.7\ T_t – 8.28\ SFC – 1.94\ IFC – 423\ M +$ $+ 2.05\ F + 0.27\ N_f – 2.30\ SCN – 8.43 \cdot 10^2\ D +$ $– 1.32\ T_r + 76.7\ VFM$	(4)	69.8
Stepwise Method	$N_y = 588.9 – 14.4\ T_t$	(5)	63.3
	$N_y = 133.3 – 16.7\ T_t + 786\ M$	(6)	66.8
	$N_y = 114.7 – 16.7\ T_t + 562\ M – 0.069\ SFC$	(7)	67.9

3rd equation and real values has been found as 69.67% (see Figure 7).

By using the AFIS system (Advanced Fibre Information System) based on single fibre measurement, several fibre properties were measured and regression analyses carried out. In Table 4, the regression equations derived from AFIS data are presented.

As a result of the regression analyses carried out with AFIS parameters, 4 different models for estimating yarn neps have been derived. In order to control the appropriateness of the regression equations, variance analyses were carried out. According to the significance coefficient of $\alpha = 0.05$, the calculated F and p values have been found to be significant. In this respect, the regression between the yarn neps and fibre properties obtained from the AFIS system can be considered as significant.

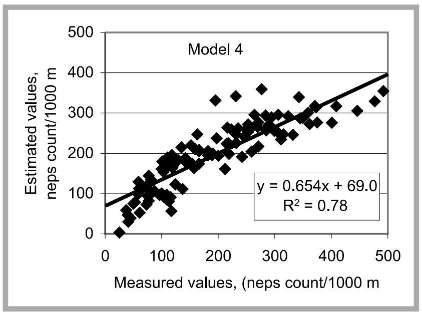

Figure 8. The comparison of measured nep count and the estimated values with the fibre properties measured by AFIS (the enter method).

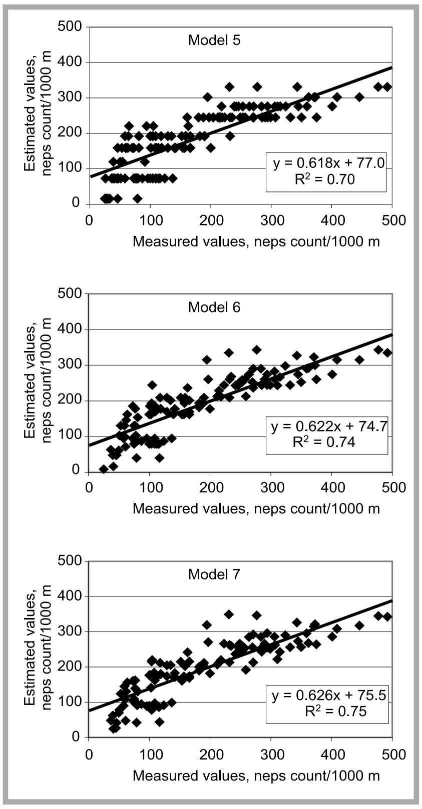

Figure 9. The comparison of measured nep count and estimated values with the fibre properties measured by AFIS (the stepwise method).

The determination coefficient of the regression equation as determined by the enter method, in which all the fibre properties are included in analysis, was found to be 69.8%. In order to check the validity of this regression equation in practice, the theoretical yarn nep count was calculated by using the fibre parameters of the yarns produced. The correlation coefficient between the real and theoretical yarn nep counts (nep count per 1000 m) as calculated from the 4th equation was determined as 78.18%. The correlation between the real and theoretical values is represented in Figure 8.

As the fibre parameters included in regression equations are too difficult to calculate, in order to determine the most effective fibre properties that contribute to the regression equations more than the other parameters, a regression analysis was carried out according to the stepwise method, and 3 different equations were derived.

In the fifth model, where the only parameter contributing to the regression equation is yarn count, the regression coefficient of determination is found to be 63.3%. Similar to the regression results obtained from HVI parameters, it can be stated that yarn count is the most important factor for predicting the yarn nep number.

In the sixth regression equation, besides yarn count, fibre maturity was found to be significant for estimating the yarn neps, and the determination coefficient has been determined as 66.8%. Fibre maturity influences the tendency of fibres to entangle and form neps. Many researchers have concluded that the tendency to cotton neps increases with the increment in immature and dead fibres. Immature fibres have low rigidities and high buckling coefficients, and can therefore become entangled into neps during mechanical processes. In this study the effect of fibre maturity on yarn nep count has also been verified.

In the seventh model determined by the stepwise method, the regression equation contains yarn count, the fibre maturity ratio and also the short-fibre content. The determination coefficient of the regression equation is 67.9%. Short-fibre content in cotton means the ratio of fibres whose length is below 12.5 mm. Due to the breaking of excessively long fibres, or a lack of fibre orientation during intensive cleaning and opening of fibres, short-fibre content (SFC) increases, and indirectly the nep count will increase.

In order to verify the proposed theoretical regression equations calculated by the AFIS data, the correlation between the real and measured yarn neps counts was compared. For the 5^{th} regression equation, which includes only yarn count as an independent variable, the correlation between theoretical and real nep counts was determined as 70.20%. In the 6^{th} regression equation, of which independent variables are yarn count and fibre maturity, the correlation coefficient was determined as 74.27%, whereas in the 7^{th} regression equation which includes yarn count, fibre maturity and short-fibre content as independent variables, the correlation coefficient was found as 74.71%. The correlation between estimated and measured values is presented in Figure 9.

Summary and conclusions

In the first part of the study, cottons from 11 different origins were investigated in respect to their nep content. The neps content of raw materials was between 81 and 262 neps count/g. Turkish cottons from the Hatay region have the minimum nep amount, whereas Greek cotton have the maximum quantity. The difference in the nep content of raw cotton fibres can be explained by the fact that cottons from different origins are also subjected to different ginning conditions.

A first significant reduction in the nep content of the material takes place in carding process. In this study, with regard to fibre neps, nep removal efficiency ranged between 67% and 84%, whereas for seed-coat nep reduction this ranged between 25% and 79%. On the basis of this result, the following conclusions can be stated:

- The carding process is more effective for the removal of fibre neps compared with seed-coat neps.
- Nep removal efficiency should be calculated for each carding machines in a spinning mill; this is especially important for evaluating carding performance and selecting optimum machine settings.

In the second part of the study, in order to make a prognosis of the nep content in yarn, which considerably influences yarn quality, multivariate regression analyses have been carried out by using fibre properties measured by the HVI and AFIS instruments. As it is known from previous studies that there is a clear connection between yarn count and yarn nep content, yarn count is included both regression analyses, assessed by HVI and AFIS data. The analysis has shown that:

- yarn count makes the highest contribution to the determination coefficient of regression equations;
- to predict the number of yarn neps, the most important fibre property measured by HVI is the uniformity index, whereas maturity ratio and short fibre content are the crucial properties measured by AFIS for determining yarn neps;
- in order to estimate the yarn nep count, which may affect the yarn and therefore the end product quality significantly, both fibre properties measured with HVI and AFIS instruments can be used.
- However, in spinning mills, where both instruments are available, the fibre properties measured with HVI instruments can be a satisfactory predictor for yarn neps; also, especially as only two parameters are included in the equation and the regression coefficient of determination is higher, the third model can be used.

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