# Investigating the RoCos Core Spun Compact Yarn Properties

Parvaneh Kheirkhah Barzoki, Morteza Vadood, and Majid Safar Johari

*Abstract*— **in this research, the core-spun compact yarns using RoCos roller have been produced and the effects of some factors including filament yarn pre-tension, yarn count and type of sheath fibers were investigated. 56 core-spun compact yarns were produced based on the different combination of controllable factors. The core yarn for all samples was nylon filament. In the next step, physical and mechanical properties of samples including tensile properties, hairiness, unevenness and abrasion resistance were investigated and the best core-compact yarn was determined. The statistically analyses have been applied on the obtained data and also the yarn properties were modeled by multiple linear regression analysis. The results showed that all controllable factors had a significant effect on measured yarn properties, except for pre-tension which had no significant effect in the case of yarn evenness. The yarn samples with polyester/viscose sheath fiber exhibited superior physical and mechanical properties compared with samples with cotton sheath fibres. Additionally for the case of comparison, a siro-core yarn was produced according to the controllable parameters of best core-spun compact yarn and it was observed that the properties of core-spun compact yarn is better than those of siro-core spun yarn.**

*Keywords:* **core-spun compact yarn, cotton and polyester sheath fibres, multiple linear regression, physical and mechanical properties, siro-core yarns**

## I. Introduction

Core spun yarns have a structure in which one of the components, usually a synthetic filament, is covered by another component, which is a staple fiber sheath. The main aim of using the core spun yarn is to combine the advantage of different properties of both components [1]. The production of core spun yarns has continuously grown since about the middle of the sixties [2]. Many studies have been performed in this filed and some researchers have studied the effect of spinning parameters to improve core yarn properties. Louis *et al.* [3] presented a modified ring spinning system combined with an air jet to increase the formation of sheath fibers. Some researchers employed a modified method using ring spinning frame to produce yarns with nylon and polyester filaments as core and cotton as wrap [4, 5]. The obtained results indicated the modified method produces yarns with significantly improvement in strength compared with 100% cotton, cotton/nylon or cotton/polyester blends yarns. Jou *et al.* [6] designed a device to produce core spun yarns with capability of filament charging and separating multi filament yarns. Xu *et al.* [7] introduced Embeddable and Locatable spinning system with capability of locating filaments and staple fibers. Pourahmad and Johari [8] devised a three-strand modified method (TSMM) based on modifications on siro spinning system to improve physical and mechanical properties of core-spun yarns. In this method by feeding one core filament into each sheath fibers, the produced yarn would be more uniform and the enhanced structure of core-spun yarns typically results in improved physical and mechanical properties. Brunk [2] reported that produced yarns by compact spinning method in comparison with ring core-spun yarns show higher evenness and more resistance against abrasion. Moreover, Pourahmad and Johari [9] in another work compared the characteristics of different core spun yarns. Balasubramanian and Bhatnagar [10] studied effects of twist, pre-tension, and feed positions of the core filament on properties of core-spun yarns. Yuan *et al.* [11] studied the effects of changing compound spinning conditions such as the tension ratio between filaments and staple fibers, the position where the filaments were fed into the staple fibers, and the twist factor on the structure of core-spun yarns. Despite the variety of reported researches, the lack of information on the properties of RoCos core spun yarns highlights the need for further investigations. In this research, it was attempted to present a comprehensive study on the physical and mechanical properties of core spun yarns. Therefore, the effect of some important spinning parameters, such as filament pre-tension, yarn count and type of sheath fibers, were investigated on the properties of RoCos core spun yarns namely tenacity, elongation percentage at breakage, hairiness, unevenness (CV%) and abrasion resistance. Moreover, it was tried to model the relation between the measured properties and selected parameters. Finally the properties of compact-core yarn were compared with siro-core yarn produced with the same materials.

## II. Material and methods

The data was collected from the published work [12]. The database (56 datasets) contains the properties of core-spun compact yarns and their corresponding tenacity, elongation, hairiness and abrasion resistance. The properties of yarns are filament pre-tension (25, 50, 75, 100, 125, 160 and 180 g), yarn count (41.5, 43.5, 48 and 59 tex) and sheath fibers (cotton and polyester/viscose). Moreover in this study, the corresponding yarn unevenness (CV%) was measured by the Uster Tester III using ASTM D6612 on 125 m of yarns at the test speed of 25 m $min^{-1}$ (each test was repeated 10 times). The siro-core spun yarns can be produced by feeding the core yarn before the delivery roller in conventional siro spinning system [8]. In

P. K. Barzoki and M. S. Johari are with the Department of Textile Engineering, Amirkabir University of Technology, Tehran, Iran. M. Vadood is with the Department of Textile Engineering, Yazd University, Yazd, Iran. Correspondence should be addressed to M. Vadood (E-mail: mortezavadood@yazd.ac.ir).

this study, siro-core spun yarns were produced to compare with RoCos core spun yarns which are explained in the next section.

## III. Results and Discussion

In this section, the effect of controllable factors on core-spun compact spun yarn properties was investigated and then results were statistically analyzed using MANOVA method. One of the most applicable methods to study the influence of several parameters on a specified response at the same time is a multivariate analysis of variance (MANOVA). At 95% confidence interval, if the calculated P-value is less than 5%, the corresponding parameter has significant effect on the response. To investigate the relation between properties of core-spun compact yarn and controllable factors, the multiple linear regression method has been applied.

### *A. Tenacity*

In this part, the effect of controllable factors on tenacity of core-compact spun yarns was investigated. As can be seen in Table I, all parameters have significant effect on the tenacity. Moreover according to Figs. 1 and 2, with increasing of the filament pre-tension, regardless of yarn count and type of the sheath fiber, strength increases too. But when pre-tension increases more than 125 g, yarn strength decreases which can be attributed to the fact that filaments are broken in pre-tension higher than 125 g. Considering research works by Pourahmad and Johari [9] with increasing filament pre-tension, the filament is migrated to the center of the yarn and it will have a better axis arrangement, so more contribution to the yarn strength is achieved. At low pre-tension, the core filament is not fully coaxial with yarn axis and consequently the yarn enjoys the less strength contribution of filament.

TABLE I
The Statistical Results of MANOVA Test at 95% Confidence Interval for Tenacity

| source | SSE | Df | MSE | F | P-value |
|---|---|---|---|---|---|
| yarn count | 13.24 | 3 | 4.41 | 2.84 | 0.04 |
| filament pre-tension | 67.75 | 6 | 11.29 | 7.27 | 0.00 |
| type of sheath fiber | 1995.47 | 1 | 1995.47 | 1155.68 | 0.00 |
| error | 69.91 | 45 | 1.55 | - | - |
| total | 1946.37 | 55 | - | - | - |

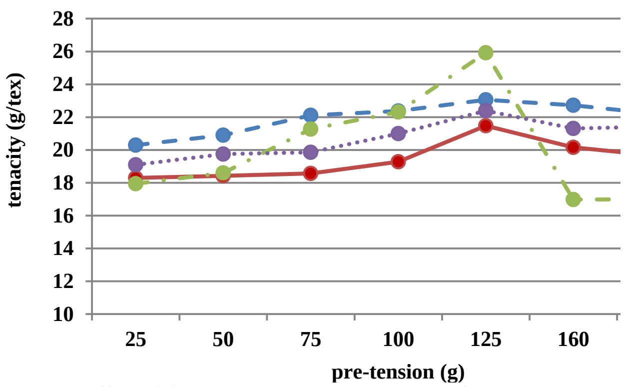

Fig. 1. The effect of filament pre-tension on tenacity of polyester/viscose core-spun compact yarn.

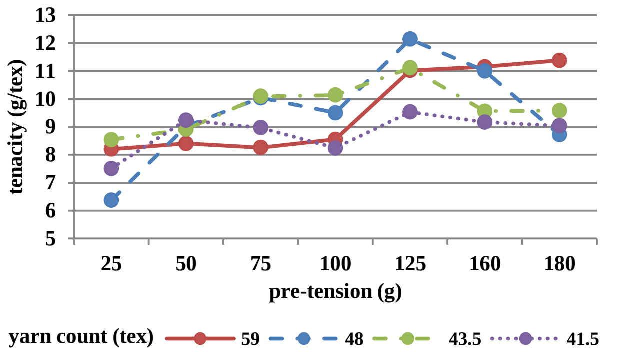

Fig. 2. The effect of filament pre-tension on tenacity of cotton core-spun compact yarn.

The results of multiple linear regression analysis for yarn tenacity are as follows, Eq. (1):

$$Tenacity = -4.34 + 0.043N + 0.015T + 11.3F \quad (1)$$
$$S = 1.49,\ R-value = 94\%$$

where $N$, $T$, $F$ and $S$ are yarn count, filament pre-tension, type of sheath fiber (1: cotton, 0: polyester/viscose), and standard error, respectively.

TABLE II
The statistical results of MANOVA test at 95% confidence interval for elongation

| source | SSE | Df | MSE | F | P-value |
|---|---|---|---|---|---|
| yarn count | 39.46 | 3 | 13.15 | 2.94 | 0.04 |
| filament pre-tension | 113.18 | 6 | 18.46 | 4.21 | 0.00 |
| type of sheath fiber | 2520.81 | 1 | 2520.81 | 563.01 | 0.00 |
| error | 201.48 | 45 | 4.48 | - | - |
| total | 2874.93 | 55 | - | - | - |

### *B. Percentage of Elongation*

Table II indicates that all parameters are effective on elongation. Moreover, Figs. 3 and 4 show that regardless of yarn count and type of sheath fiber there is an upward trend between pre-tension and the percentage of elongation. Better axis arrangement of the filament at high pre-tension leads to an increase in the elongation of yarn, and consequently at low pre-tension the filament has less contribution to the elongation of the core-compact spun yarn.

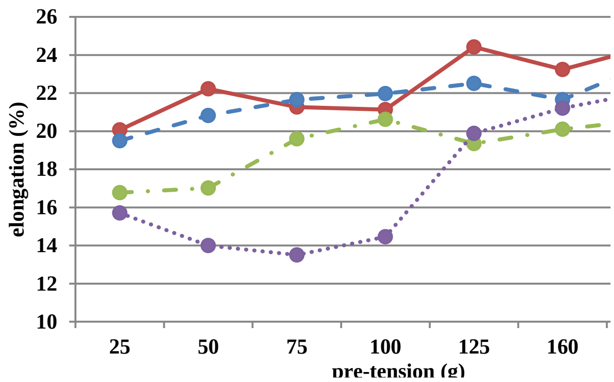

Fig. 3. The effect of filament pre-tension on elongation of polyester/viscose core-spun compact yarn.

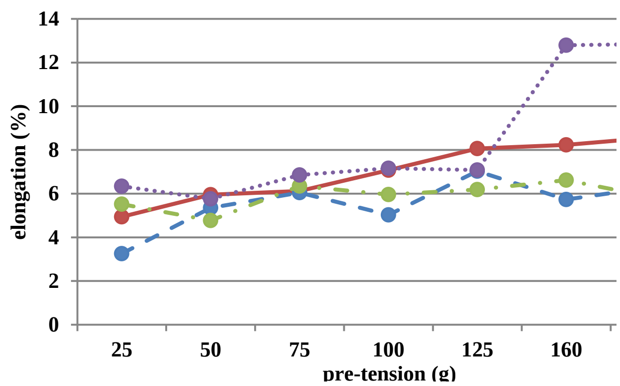


Fig. 4. The effect of filament pre–tension on elongation of cotton core-spun compact yarn.

The results of regression analysis for the elongation are as follows, Eq. (2):

$$Elongation = -4.03 - 0.264N + 0.027T + 13.4F$$
$$S = 2.01,\ R - value = 92\% \qquad (2)$$

*C. Hairiness*

According to the statically analysis (Table III), hairiness is influenced by all parameters. Figs. 5 and 6 indicate that with increasing the filament pre-tension, yarn hairiness increases and this phenomenon is more intensive in the case of cotton rather than polyester/viscose core-spun compact yarn. With raising filament pre-tension the core filament tends to be positioned in the inner areas of the yarn and hence is completely covered with sheath fibers as shown in Fig. 7. In this situation, the fibers located on the surface of yarn body are connected with core fibers weakly and there is less control on surface fibers. Hence, surface fibers become a part of hairiness and in this way hairiness increases at high levels of filament pre-tension.

TABLE III
THE STATISTICAL RESULTS OF MANOVA TEST AT 95% CONFIDENCE INTERVAL FOR HAIRINESS

| source | SSE | Df | MSE | F | P-value |
|---|---|---|---|---|---|
| yarn count | 295.8 | 3 | 98.62 | 7.29 | 0.00 |
| filament pre-tension | 603.39 | 6 | 100.57 | 7.43 | 0.00 |
| type of sheath fiber | 1874.11 | 1 | 1874.11 | 138.47 | 0.00 |
| error | 609.05 | 45 | 13.53 | - | - |
| total | 3382.42 | 55 | - | - | - |

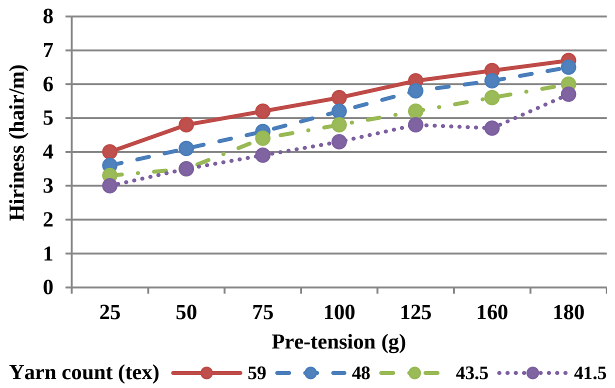


Fig. 5. The effect of filament pre–tension on hairiness of polyester/viscose core-spun compact yarn.

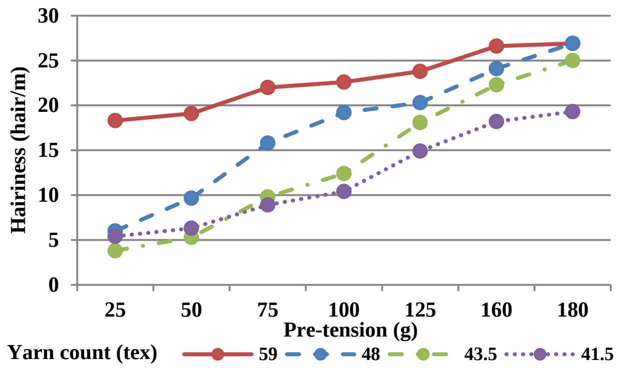


Fig. 6. The effect of filament pre–tension on hairiness of cotton core-spun compact yarn.

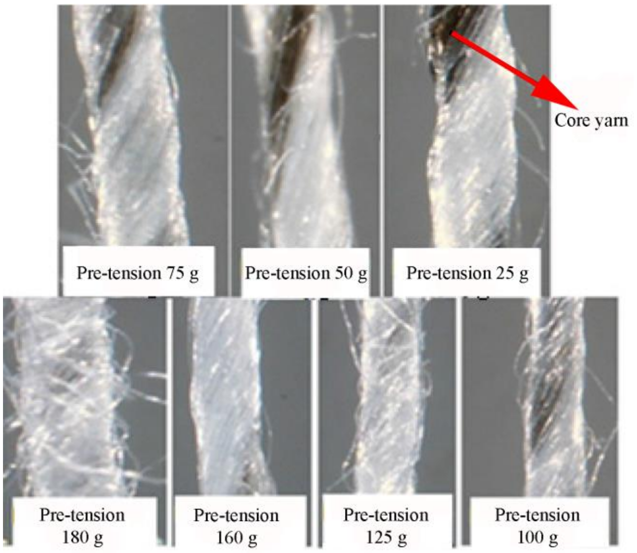


Fig. 7. Longitudinal pictures of core-spun compact yarn at different filament pre-tension.

The results of applying multiple linear regression analysis on hairiness data are given in Eq. (3).

$$Hairiness = 37.6 - 0.775N + 0.062T - 11.6F$$
$$S = 3.43,\ R - value = 81\% \qquad (3)$$

*D. Unevenness (CV %)*

It can be observed in Table IV that the filament pre-tension does not have significant effect on unevenness (CV%) but yarn count and type of sheath fiber show a significant effect. According to Figs. 8 and 9, by increasing yarn count, unevenness (CV%) decreases. It can be attributed to the fact that in higher yarn count, as yarn is thicker; the yarn defects are better covered. Moreover, based on Martindale's theory [13] unevenness (CV%) value for a thicker yarn is less than thinner one with lower count since the number of fibres in yarn cross-section is decreased. This is obviously observed in Fig. 9.

Using multiple linear regression analysis lead to the following results, Eq. (4).

$$CV\,\% = 8.21 + 0.190N + 0.011T - 2.59F$$
$$S = 0.63,\ R - value = 85\% \qquad (4)$$

TABLE IV
THE STATISTICAL RESULTS OF MANOVA TEST AT 95% CONFIDENCE INTERVAL FOR UNEVENNESS (CV%)

| source | SSE | Df | MSE | F | P-value |
|---|---|---|---|---|---|
| yarn count | 18.223 | 3 | 6.07 | 14.47 | 0.00 |
| filament pre-tension | 20.392 | 6 | 3.39 | 8.1 | 0.051 |
| type of sheath fiber | 94.017 | 1 | 94.01 | 223.94 | 0.00 |
| error | 18.892 | 45 | 0.42 | - | - |
| total | 151.524 | 55 | - | - | - |

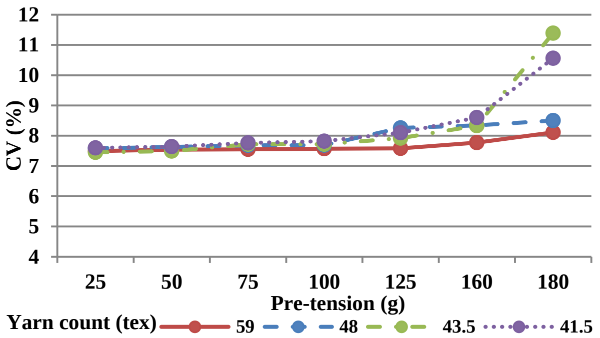


Fig. 8. The effect of filament pre–tension on CV% of polyester/viscose core-spun compact yarn.

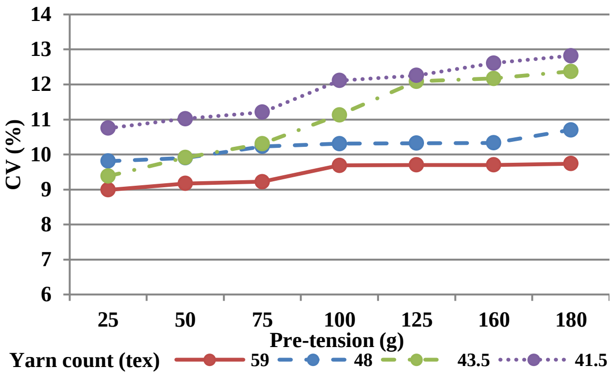


Fig. 9. The effect of filament pre–tension on unevenness (CV% ) of cotton core-spun compact yarn.

*E. Abrasion Resistance*

Table V proves that all considered parameters are effective on the abrasion resistance. Furthermore, Figs. 10 and 11 illustrate that polyester/viscose samples at pre-tension of 100 g have the best abrasion resistance and for cotton ones the best results were obtained in pre-tension of 180 g.

TABLE V
THE STATISTICAL RESULTS OF MANOVA TEST AT 95% CONFIDENCE INTERVAL FOR ABRASION RESISTANCE

| source | SSE | Df | MSE | F | P-value |
|---|---|---|---|---|---|
| yarn count | 73.03 | 3 | 24.34 | 4.64 | 0.00 |
| filament pre-tension | 64.38 | 6 | 10.73 | 2.05 | 0.04 |
| type of sheath fiber | 234.88 | 1 | 234.88 | 44.78 | 0.00 |
| error | 236.05 | 45 | 5.24 | - | - |
| total | 608.36 | 55 | - | - | - |

The results of applying multiple linear regression is as follows, Eq. (5):

$$Abrasion\ resistance = 19.9 - 0.346N + 0.013T - 4.10F$$
$$S = 2.35,\ R-value = 73\% \quad (5)$$

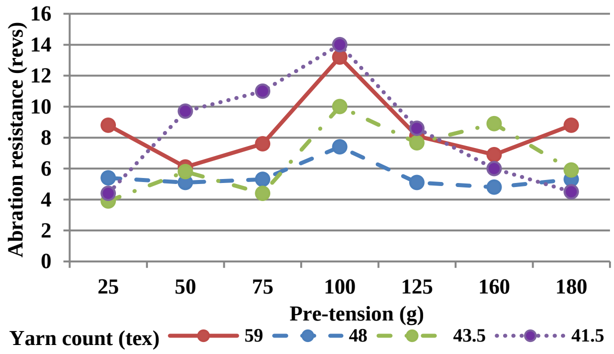


Fig. 10. The effect of filament pre–tension on abrasion resistance of polyester/viscose core-spun compact yarn.

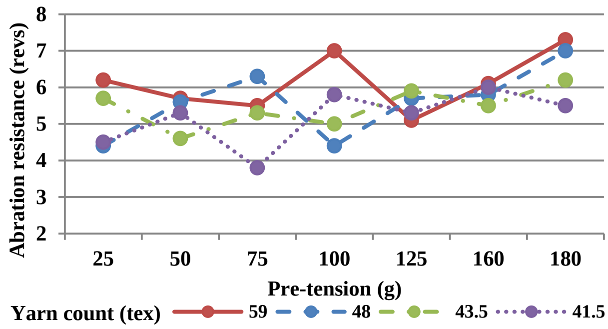


Fig. 11. The effect of filament pre–tension on abrasion resistance of cotton core-spun compact yarn.

Considering the result of different properties between yarns with different sheath fibers, two points are achieved:

- Generally compact yarns with polyester/viscose sheath fibers show higher tenacity and hairiness and lower abrasion resistance than cotton sheath fiber yarns.
- The prediction power of regression model is relatively appropriate for tenacity and elongation, Eqs. (1) and (2), but for the hairiness, unevenness (CV%) and abrasion resistance a more accurate model is needed, Eqs. (3) to (5).

Moreover, based on the Figs. 1 to 11, it can be concluded that a sample with characteristics of pre-tension 125 g, polyester-viscose sheath fiber and yarn count 43.5 tex has relatively high tenacity, elongation and abrasion resistance and low hairiness and unevenness (CV%), so this sample can be selected as the best produced core-spun compact yarn. For the case of comparison, siro-core yarns were produced by using the set of controllable parameters mentioned above for the best sample. As the strand spacing is one of the most important parameters in siro production, siro yarns were produced in four different strand spacing of 0, 4, 8 and 12 mm labeled by SI1, SI2, SI3 and SI4, respectively. It must be mentioned that the roving count and twist for all siro yarns were 1.09 Hank and 900 tpm, respectively. By comparing the properties of siro yarns, it was observed that the strand spacing of 4 mm (SI2)

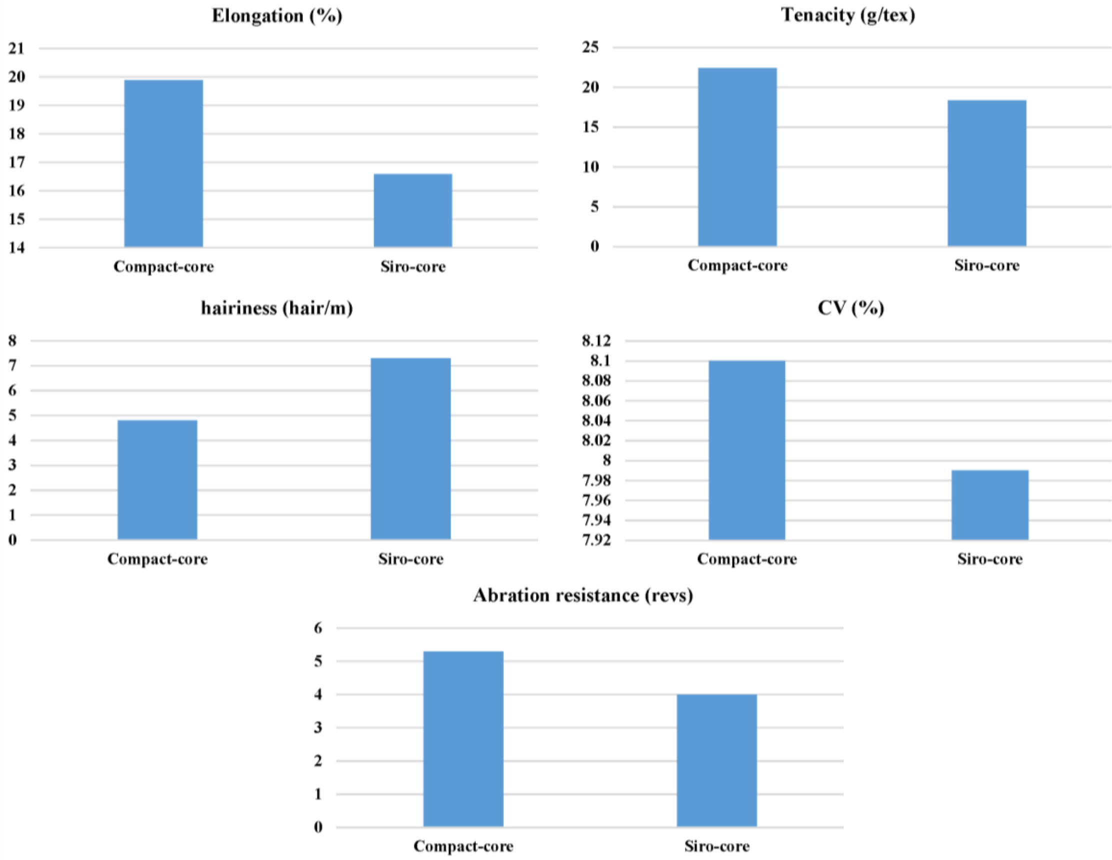


Fig. 12. Comparison of core-spun compact and Siro-core yarn properties.

produces a yarn with highest physical and mechanical properties. Fig. 12 illustrates the properties of yarns SI2 and the best core-spun compact sample. As can be seen the properties of compact-core yarn is better than siro-core one.

## IV. Conclusion

In the present paper, the effect of filament pre-tension, yarn count and type of sheath fiber on physical and mechanical properties of RoCos core-spun compact yarns were studied and multiple linear regression analysis were applied on the obtained data. Considering the result of MANOVA tests, all controllable factors were found effective on the measured properties except one case where pre-tension did not show any significant effect on the unevenness (CV%). Furthermore, the results show that with increasing filament pre-tension, hairiness and elongation percentage increase. The highest tenacity value was observed at per-tension of 125 g and the best abrasion resistance was obtained at pre-tension of 180 g and 100 g for cotton and polyester/viscose core-compact yarns, respectively. Regarding the obtained results, polyester/viscose core-compact yarns enjoy better physical and mechanical properties than cotton ones. By comparing the best compact-core and siro-core yarns produced with the same materials, it was revealed that the properties of core-spun compact yarns are better than those of Siro core yarns.

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