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The Effects Of Oe-Rotor Spinning Parameters On Yarn Properties Produced From Recycled/Virgin Cotton Fibers Blend

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Abstract

The environmental load problem of the cotton fiber such as amount of water and pesticides used in the agricultural sector, the main raw material of the textile and apparel industry, obligates the extension of the fiber's life cycle. In order to ensure the sustainability of resources, efficient use of natural supplies and evaluation of recyclable wastes are required. However information lacking is the one of barriers in recycling and processing of cotton. In this study, open-end rotor yarns (OE-Rotor) were spun from the blends of recycled cotton fibers obtained from pre-consumer cotton products (r-CO) and the virgin cotton (C) fibers with 50/50 ratios. The effects of production parameters (rotor type, navel type and torque type) on yarn properties were examined. According to the results the effect of the production parameters on all measured yarn properties except tenacity values, is statistically significant. It was concluded that 50/50 r-CO/C open-end rotor yarn samples producing by rotor type with narrowest groove, spiral navel type without notch and green torque type without twist stopping effect, led to lower unevenness, hairiness, IPI and higher breaking elongation.

Article Info

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Keywords

Pre-Consumer Textile Waste, Virgin Cotton, Recycled Cotton, Open-End Rotor Yarn

Highlights

Use of recycled cotton fiber in open-end rotor yarn production and determination of process parameters.

GERİ DÖNÜŞÜM PAMUK/PAMUK ELYAF KARIŞIMINDAN ÜRETİLEN OE-ROTOR İPLİK ÖZELLİKLERİ ÜZERİNDE İPLİK PARAMETRELERİNİN ETKİLERİ

Özet

Tekstil ve konfeksiyon sektörünün ana hammaddesi olan pamuk lifinin çevresel yük sorunu, lifin yaşam döngüsünün uzamasını zorunlu kılmaktadır. Ancak bilgi eksikliği, pamuğun geri dönüşümü ve işlenmesindeki engellerden biridir. Bu çalışmada, tüketim öncesi pamuk ürünlerinden (r-CO) elde edilen geri dönüştürülmüş pamuk lifleri ile işlenmemiş pamuk (C) liflerinin 50/50 oranlarında karışımlarından Open-end rotor iplikleri (OE-Rotor) eğrilmiştir. Üretim parametrelerinin (rotor tipi, navel tipi ve tork tipi) iplik özelliklerine etkileri incelenmiştir. Elde edilen sonuçlara göre, üretim parametrelerinin mukavemet değerleri dışında ölçülen tüm iplik özellikleri üzerindeki etkisi istatistiksel olarak anlamlıdır. En dar yivli rotor tipi, çentiksiz spiral navel tipi ve büküm durdurma etkisi olmayan yeşil tork tipi ile üretilen 50/50 r-CO/C open-end rotor iplik numunelerinin daha düşük düzgünsüzlük, tüylülük, IPI ve daha yüksek kopma uzaması değerleri gösterdiği tespit edilmiştir.

Anahtar Kelimeler

Tüketici Öncesi Tekstil Atıkları, Pamuk, Geri Dönüşüm Pamuk, Open-End Rotor İplik

Öne Çıkanlar

Geri dönüşüm pamuk elyafının open-end rotor iplik üretiminde kullanımı ve proses parametrelerinin belirlenmesi.

1. Introduction

The cotton fiber is the most preferred natural fiber and its annual production worldwide is about 26 million mt in 2019 [1], while regenerated cellulose fiber production is only between one-sixth and one-fifth of cotton volume [2]. The amount of water used in cotton fiber production is more than 57% of the total amount of water used in the agricultural sector and it requires 20000 L of water to grow 1 kg of Cotton [3]. In addition, the amount of pesticides used in cotton farming is about a quarter of the total amount of pesticides used in the agricultural sector [4, 5]. The high environmental load of the cotton fiber, necessitates to extend the life cycle of the cotton fiber.[6, 7] Both natural and synthetic fibers obtained by conventional production methods, stay behind in the sustainability ranking and fibers produced by recycled or organic production methods are more environmentally friendly [8]. The life cycle impact assessment results shows that environmental impacts of recycled cotton yarns are far less than those of virgin cotton yarns, except for climate change and water depletion [9]. Nowadays low recycling rates are acquired from short staple fibers [10]. Textile wastes are classified as pre-consumer and post-consumer wastes [10,11]. Pre-consumer wastes include noil from blow-room and card, yarn waste, selvedge, fabrics and not worn garments generated during production. Post-consumer textile waste contains products which have completed life cycle and is no longer useful for the consumer in both function and aesthetics. Products that are reasonably in better conditions in these wastes, are sold to low-income countries as second-hand clothing. Post-consumer and pre-consumer wastes converted into raw materials by chemical, mechanical or thermal recycling methods [3, 12]. Mechanical recycling process is a system that is processed several times in a mechanical recycling machine, after separating textile waste according to the fiber composition, condition, color and other properties [13-15]. Unopened or partially opened yarns and fabric pieces, short staple length and non-uniformity fibers that can be found in recycled fiber blends, limit working with them in terms of yarn count and quality. In order to compensate for the quality loss of the recycled material and to produce yarn with finer counts, recycle fibers is preferred to use with the virgin material such as virgin cotton, polyester [11, 16-22]. When the studies on the recycling of textile wastes was searched, open-end rotor yarns from pre-consumer wastes mostly generated in ginning machines, blowroom and card units were investigated in different studies such as the optimization of various rotor spinning production parameters in of cotton yarn produced from the ginning process waste [22], effects of some navel properties on rotor yarn spun from 100% cotton waste [23], comparison of mechanical properties of cotton mélange yarn manufactured by adding waste to blow room or draw frame [24], the effect of cotton wastes on the rotor yarn quality [25], effect of reused cotton fibres on the quality of conventional ring and OE-rotor yarns [26], predicting the properties of cotton/waste blended rotor yarn, using taguchi OA experimental design [27], comparison of properties of open-end rotor yarn from yarn waste [28], examination of yarn properties of open-end rotor yarns with different production parameters (rotor speed, opening roller speed, twist) from recycled yarn waste [29]. Furthermore, in the literature, there are studies investigating properties of yarns from pre-consumer cotton knitted textile wastes [11], open-end yarns and fabrics from denim waste [30], recycled yarn and single jersey fabric from fabric scraps of ready-to-wear products [31]. Textile mills have little experience about production of yarn containing recycled cotton. In the study, it is aimed to create know-how for textile mills related to the production of yarns containing recycled cotton. Furthermore, it is targeted to spread the applications of recycling in textile by contributing to the literature on recycling and processing of cotton. In the study, the yarn production potential of recycled pre-consumer textile waste is investigated. Afterwards, the investigation was carried out to determine the effects of production parameters (rotor type, navel type and torque type) specified by the spinning mill as the most effective parameters in the production of open-end yarns on yarn properties such as unevenness, hairiness, imperfection indicator, tenacity and breaking elongation.

2. Materials and Method

2.1. Materials

In the study, 18 different types of OE-Rotor yarns were spun from the blends of recycled cotton and virgin cotton fibers with 50/50 ratios (Figure 1). In the study, 100% Urfa cotton was used as virgin cotton. Properties of the cotton was tested by an Uster HVI 900, and the results were Recycled cotton fibers (r-CO) were made from pre-consumer cotton products obtained mostly from fabrics and not worn garments generated during production. Recycled cotton and virgin cotton blends were mixed in the blow-room during production of open-end rotor yarns. The properties of virgin cotton (CO) and recycled cotton (r-CO) fibers used in the production of 18 types of Open-End Rotor yarn were determined by Uster HVI (High Volume Instrument) device (Table 1). From Table 1 it is seen that the tenacity, breaking elongation, uniformity index and upper half mean length values of the recycled cotton fiber are lower than that of the virgin cotton fiber.

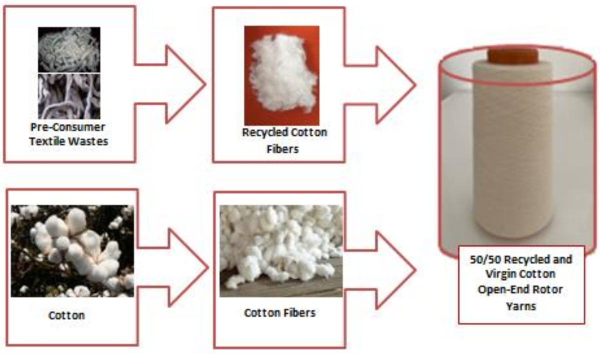


Figure 1. The production of the yarns from virgin cotton and recycled cotton fibers.

Table 1. Properties of virgin cotton and recycled cotton fibers.

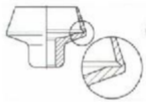
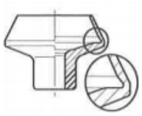
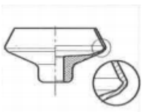
Quality Parameters	Symbol	CO	r-CO
Micronaire (µg/in)	Mic.	4.34	4.33
Tenacity (gr/tex)	Str.	35.3	27.55
Elongation (%)	El.	7.9	6.75
Upper Half Mean Length (mm)	UHML	29.92	25.34
Uniformity Index (%)	UI	84.7	73.55
Short Fiber Index (%)	SFI	7.6	20.15
Brightness (%)	Rd	73.6	74.05
Yellowness	(+b)	7.7	6.7

2.2. Method

Yarn samples have different process parameters such as rotor types (T, TT, U), navel types (4 notch, 6 notch+spiral, spiral) and torque types (green, white) in order to investigate effects of process parameters on yarn properties (Table 2). T, TT, U rotor types are used in the study. Rotor types have boronized-diamond coated (BD), 40 mm groove diameter, different groove shapes (T, TT or U). U and T rotor types have the widest and the narrowest rotor groove, respectively and TT is medium level in terms of rotor groove width As seen in Table 2. While the strength of the yarns produced with rotors with narrow groove geometry is high and their hairiness is low; these rotors are very sensitive to pollution. Instead, rotors with wide grooves have less tendency to contamination and have self-cleaning properties; however, the quality values of the yarns produced with these rotors are low. 4 notch, 6 notch+spiral, spiral navel types are used in the study. Green torque stops do not have bridges and twist stopping effect, white torque stops have 3 bridges and light twist stopping effect (Table 2). Torque stop and navels are parameters that affect spinning stability in yarn production. The spirals in the navels improve the spinning stability by increasing the surface pressure and false twist effect. Torque stop should use in case of twist reduction and possible subsequent loss of spinning stability. Especially for spinning fine yarn and when using small-diameter rotors, also when spinning yarns from inferior-quality raw materials. The production of yarn samples was carried out by the Saurer Schlafhorst Autocoro 9 model open-end rotor spinning machine. All the yarn samples were produced with the following spinning conditions: Ne 9/1 yarn count, Ne 0.110 sliver count, 590 T/m twist, 90000 rpm rotor speed, 9200 rpm opening roller speed and 40 mm rotor diameter.

The strength and breaking elongation measurements of OE-Rotor yarns were conducted on the Uster Tensojet 4 device based on the TS 245 EN ISO 2062 standard. The unevenness, hairiness and imperfection indicator (thick place +50%, thin place -50% and neps +280%) measurements of the yarn samples were conducted on the Uster Tester 4 device according to ISO 16549. For each yarn sample, five tests were performed and the averages were reported. Samples were conditioned at least for 24 hours in an atmosphere of 20±2 ºC and 65±2% relative humidity, in order to adjust humidity balance, before measurements. Three-way replicated analysis of variance method (ANOVA), was used to analyze whether there was a difference between factor levels or not by means of SPSS 22 statistical package program at 95% confidence interval. If the p value is less than 0.05, it means that the difference is statistically significant. The means were compared by Student Newman-Keuls (SNK) tests.

Table 2. Codes and process parameters of yarn samples.

Code	Rotor Type (R)		Navel Type (N)		Torque Type (T)	
1	T		4 notch		Green	
2	T		6 notch+spiral		White	
3	T		Spiral	4 notch	Green	
4	T	T	4 notch		White	
5	T		6 notch+spiral		Green	Green
6	T		Spiral		White	
7	TT		4 notch		Green	
8	TT		6 notch+spiral		White	
9	TT	TT	Spiral	6 notch+spiral	Green	
10	TT		4 notch		White	
11	TT		6 notch+spiral		Green	
12	TT		Spiral		White	
13	U		4 notch		Green	
14	U		6 notch+spiral		White	White
15	U	U	Spiral	Spiral	Green	
16	U		4 notch		White	
17	U		6 notch+spiral		Green	
18	U		Spiral		White	

3. Results and Discussion

Average values of unevenness, hairiness, imperfection indicator (IPI), tenacity and breaking elongation of yarn samples are illustrated in Figures 2–6. Analysis variance results (ANOVA) of yarn samples is seen in Table 3. * is the mean difference is significant at a 95% confidence level.

Table 3. Analysis of variance results for yarn sample production parameters

Parameters	CVm (%)		Hairiness (H)		IPI		RKM (kgf*Nm)		Breaking Elongation (%)	
	Sig.	**F**	**Sig.**	**F**	**Sig.**	**F**	**Sig.**	**F**	**Sig.**	**F**
R	0.000*	176950.833	0.000*	186.617	0.000*	39.620	0.571	0.565	0.000*	34.571
N	0.000*	159.828	0.000*	439.463	0.000*	12.660	0.633	0.461	0.000*	35.124
T	0.000*	19.760	0.000*	37.801	0.001*	11.348	0.987	0.000	0.000*	21.725
R*N	0.000*	14.064	0.006*	3.982	0.006*	3.936	0.383	1.059	0.605	0.506
R*T	0.002*	4.835	0.003*	6.215	0.044*	3.270	0.977	0.024	0.419	0.990
N*T	0.134	2.068	0.225	1.523	0.061	2.907	0.988	0.012	0.790	0.237
R*N*T	0.234	1.484	0.348	1.133	0.011	3.524	0.927	0.219	0.934	0.207

R: Rotor Type, N: Navel Type, T: Torque.

Yarn unevenness

Yarn unevenness (CVm) could be defined as the variation in a yarn's weight per unit length. According to Table 3, rotor, navel and torque type are statistically significant factor on CVm and by considering the F-value, it is clear that the rotor type shows more influence on CVm than the navel type and torque type. For the unevenness results in Figure 2, yarn samples producing by U rotor type have higher unevenness values compared to yarn samples producing by T or TT rotor types. Because T and TT rotor types have narrow rotor groove, enables tighter packing of the fibers in the yarn [32]. Furthermore, yarn samples producing by spiral navel type have lower unevenness values. In previous studies, while it has been observed that the quality of the yarns decreases with the increase of the number of notches in the navel [33], yarn quality properties are positively affected because it is exposed to less friction in spiral form navels [34]. Yarn samples produced by green torque type which have no twist-stop effect and bridge, have lower unevenness values. This situation may be explained by lower yarn-material friction than white torque which have twist-stop effect and 3 bridges.

Table 4 shows the SNK test results for measured properties of yarn samples. In the interpretation of SNK results, abbreviations a, b, c, d, and e represent factor level; factor levels that have the same letters are not different from each other at a significance level of 0.05. The results of SNK confirmed the significant influences of these parameters on CVm results. SNK results in Table 4 show that the CVm results are separated into two different groups in terms of the rotor types and torque types, three different groups in terms of the navel types.

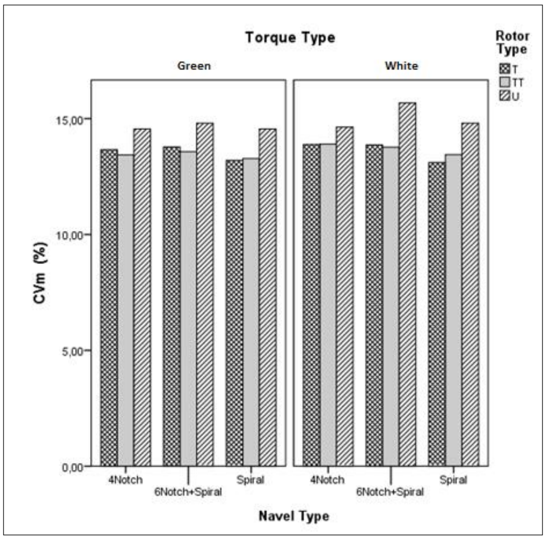


Figure 2. Effect of rotor types, navel types and torque stops on CVm values.

Table 4. SNK test results for measured properties of yarn samples.

	CVm (%)	**Hairiness (H)**	**IPI**	**Breaking Elongation (%)**
Rotor Type				
T	13.59a	4.89a	104.14a	5.27a
TT	13.57a	5.34b	124.68a	4.86b
U	14.84b	6.87c	229.45b	4.80b
Navel Type				
4 notch	14.01a	6.20a	144.53a	4.92a
6 notch+Spiral	14.24b	6.99b	194.19b	4.80a
Spiral	13.73c	3.92c	119.56a	5.20b
Torque Type				
Green	13.87a	5.43a	131.99a	5.12a
White	14.12b	5.97b	173.53b	4.82b

Hairiness

The hairiness index H refers to the ratio of the total length of the fiber ends protruding from the yarn surface to the measured yarn length. High hairiness variations have a negative effect on the appearance of the fabric. According to Table 3, rotor, navel and torque type are statistically significant factor on hairiness and by considering the F-value, it is clear that the navel type shows more influence on hairiness than the rotor type and torque type. For the hairiness results in Figure 3, yarn samples producing by T rotor type, have partially lower values than the other yarn samples as in CVm results. It is a fact that in narrow grooved rotor types, yarns with low hairiness rate similar to ring yarn are obtained, and in wide grooved rotors more bulky and more hairy yarns are obtained. Also, yarn samples producing by spiral navel type, have lower hairiness values than the other yarn samples. It is thought that higher hairiness values in the other yarn samples (by 4 notch and 6 notch+Spiral) is due to increasing in the number of notch [21, 35, 36]. In previous studies, it has been determined that the yarn quality properties are positively affected as the yarn is exposed to less friction in spiral form navels [34, 37]. Lower hairiness values are observed in yarns spun by green torque which have no twist-stop effect and bridge. This situation may be explained by lower yarn-material friction than white torque which have twist-stop effect and 3 bridges. The results of SNK confirmed the significant influences of these parameters on hairiness results. SNK results in Table 4 show that the hairiness results are separated into three different groups in terms of the rotor types and navel types, two different groups in terms of the torque type.

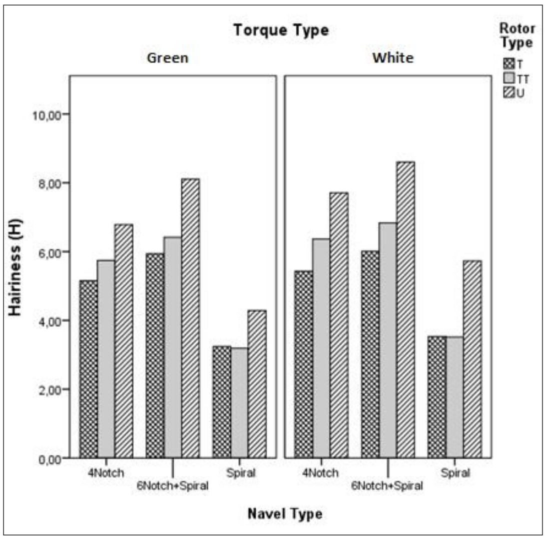


Figure 3. Effect of rotor types, navel types and torque stops on hairiness values.

Imperfection Indicator

The imperfection indicator (IPI) of the yarns is expressed as the sum of the thin place, thick place and neps count in 1000 meters of yarn. According to Table 3, rotor, navel and torque type are statistically significant factors on IPI and by considering the F-value, it is clear that the rotor type shows more influence on IPI than the navel type and torque type. For the IPI results in Figure 4, yarn samples produced by U rotor type have higher values than the other yarn samples (by T and TT) as CVM values. One of the most important factors affecting hairiness is the degree of friction between the yarn and the rotor parts [38]. Buharalı et al. observed that the increase in hairiness leads to an increase in the amount of unevenness and neps [36]. Also, yarn samples produced by 6 notch+spiral navel type have higher IPI values than the other yarn samples because of exposing to more friction than the others during production. As the number of notches increase, it is seen that the IPI values of yarn samples increase like the hairiness and unevenness values [34, 36]. Lower IPI values are observed in yarns spun by green torque which have no bridge and twist-stop effect. This situation may be explained by lower yarn-material friction than white torque which have twist-stop effect and 3 bridges as hairiness and unevenness values. The results of SNK confirmed the significant influences of these parameters on IPI results. SNK results show that the IPI results are separated into two different groups in terms of the rotor types, navel types and torque types.

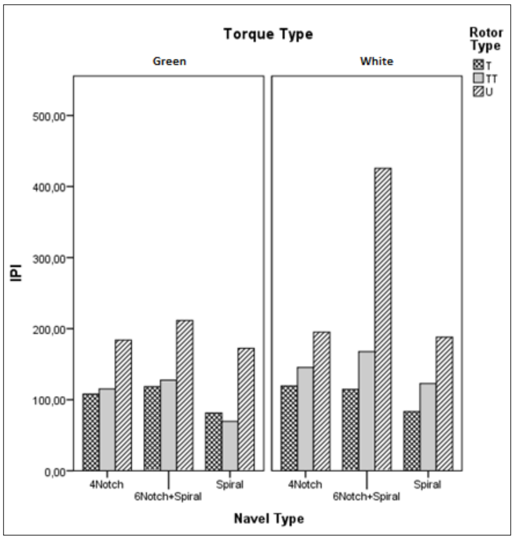


Figure 4. Effect of rotor types, navel types and torque stops on IPI values.

Rkm (Breaking kilometer)

Rkm is widely used for yarn breaking strength and it expresses kilometers of the length in which the yarn breaks in its own weight in the vertical position. Rkm is mainly depend on twist level and yarn count. According to Table 3, rotor, navel and torque type are not statistically significant factor on RKM. For the Rkm results in Figure 5, yarn samples producing by T rotor type have higher values than the other yarn samples (by TT and U). Also, yarn samples produced by spiral navel type have higher values than the other yarn samples. Yarn samples produced by white torque type have higher Rkm values. But, effect of these parameters on Rkm results were found to be statistically insignificant according to results of ANOVA ($p>0.05$). As the yarn count and twist degree, which are the most effective parameters on the Rkm values, do not change, it is an expected result that the mentioned yarn production parameters do not affect the Rkm values.

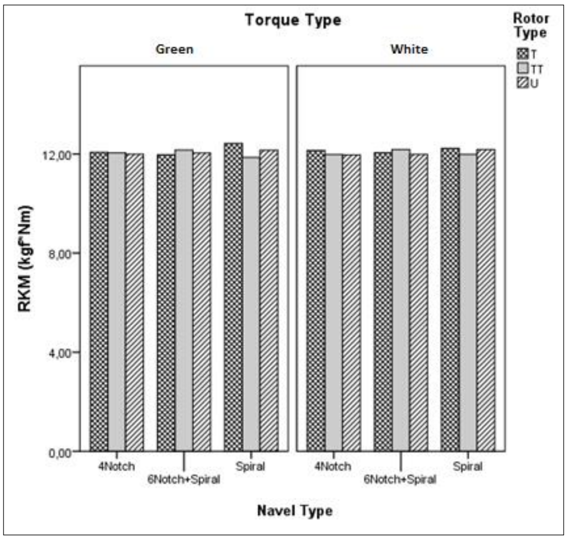


Figure 5. Effect of rotor types, navel types and torque stops on RKM values.

Yarn Breaking Elongation

Yarn breaking elongation is the ratio of the first length of total length that occurs at the moment the yarn breaks. According to Table 3, considering the F-value rotor, navel and torque type are statistically significant factors on breaking elongation, it is clear that the navel type shows more influence on breaking elongation than the rotor type and torque type. For the breaking elongation results in Figure 6, yarn samples produced by T rotor type have higher values than the other yarn samples, as in previous study [32]. It is estimated that the yarn values are positively affected, because yarns produced with the T rotor type are exposed to less friction during production [34, 37]. Also, yarn samples produced by spiral navel type have higher values than the other yarn samples. It is estimated that this is due to the reduced friction on the yarns produced by spiral form navels [34]. Higher breaking elongation values are observed in yarns spun by green torque which have no twist-stop effect and bridge. This situation may be explained by lower yarn-material friction according to white torque which have 3 bridges and twist-stop effect. The results of SNK confirmed the significant influences of these parameters on breaking elongation results. SNK results show that the breaking elongation results are separated into two different groups in terms of the rotor types, navel types and torque types.

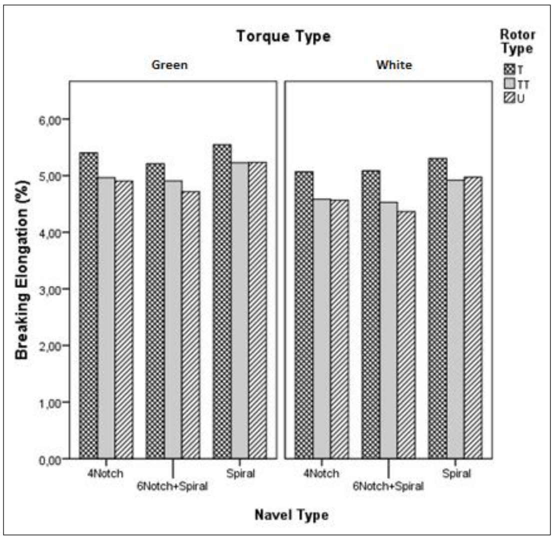


Figure 6. Effect of rotor types, navel types and torque stops on breaking elongation values.

4. Conclusion

In recent years, recycling studies, namely shift from linear to circular production, have gained great importance due to many reasons such as environmental awareness, legal requirements, limited resources, raw material costs etc. When lack of information in recycling and processing of cotton are filled, then it will be possible for the recycling process to turn into a larger market. Therefore, the social, economic and environmental destructive effects of textile industry can be reduced. In the literature there are numbers of studies made with wastes generated from from noil, opening, cleaning machines, cards, flat strips, comber noil, roving during the production. As different from common studies, in this study, pre-consumer wastes obtained mostly from fabrics and not worn garments generated during production were used. According to the analysis, it was found that the effect of the production parameters on measured yarn properties except tenacity values, is statistically significant. 50/50 r-CO/C open-end rotor yarn samples produced by T rotor type with narrowest groove, have lower unevenness, hairiness, IPI and higher breaking elongation. 50/50 r-CO/C open-end rotor yarn samples produced by spiral navel type without notch, have lower unevenness, hairiness, IPI and higher breaking elongation. As the number of notches increase, it is seen that the IPI values of yarn samples increase like the hairiness and unevenness values. 50/50 r-CO/C open-end rotor yarn samples producing by green torque type without twist stopping effect, have lower unevenness, hairiness, IPI and higher breaking elongation.

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Conflict of Interest

There is no conflict of interest regarding this article.

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