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Bakır Tel İçeren Kompozit İpliklerin Fiziksel Özellikleri Üzerine Karşılaştırmalı Bir Çalışma

A Comparative Study on the Physical Properties of Hybrid Yarns Containing Copper Wire

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Araştırma Makalesi / Research Article

A COMPARATIVE STUDY ON THE PHYSICAL PROPERTIES OF HYBRID YARNS CONTAINING COPPER WIRE

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ABSTRACT: Some problems occur especially in respect of wearing and aesthetic comfort, when different metals are used, bare or hybrid yarn form to produce functional fabrics. The aim of this study is to investigate the physical properties of hybrid yarns containing copper wire which are produced with 5 different production methods at three different twist levels. In this study, tenacity, breaking elongation and Young modulus values of hybrid yarns were evaluated comparatively. Also copper visibility ratio (CVR) values of hybrid yarns on the fabric surface were determined by using image thresholding method in CIELab color space.

Keywords: Copper wire, hybrid yarn, image processing, thresholding method, functional fabric.

BAKIR TEL İÇEREN KOMPOZİT İPLİKLERİN FİZİKSEL ÖZELLİKLERİ ÜZERİNE KARŞILAŞTIRMALI BİR ÇALIŞMA

ÖZET: Fonksiyonel kumaşların üretiminde metal teller, çıplak ya da kompozit iplik formunda kullanıldıklarında, özellikle giyim ve estetik konforla ilgili çeşitli problemlere neden olmaktadır. Bu çalışmanın amacı, üç farklı büküm/sarım seviyesinde, beş farklı üretim tekniği ile üretilmiş bakır tel içerikli kompozit ipliklerin fiziksel özelliklerinin değerlendirilmesidir. Çalışmada üretilen farklı tiplerdeki kompozit ipliklerin özgül gerilme, kopma uzaması, Young modülü değerleri karşılaştırmalı olarak incelenmiştir. Ayrıca, kompozit ipliklerin kumaş yüzeyindeki bakır görünürlük oranı değerleri CIELab renk uzayında görüntü eşikleme metodu kullanılarak belirlenmiştir.

Anahtar Kelimeler: Bakır tel, kompozit iplik, görüntü işleme, eşikleme yöntemi, fonksiyonel kumaş.

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1. INTRODUCTION

Nowadays, new types of yarns having different appearance and properties are being used instead of conventional yarns to be able to create higher added value for fabrics. Conductivity in fabrics is essential for functional clothing since electrical conductivity provides pathways to carry information or energy for various functions [1]. Hybrid yarns are yarn structures which are developed to benefit from the properties of two or more different components at the same time. Hybrid yarns containing copper wire are used in order to provide conductivity of fabrics which are produced for functional clothing.

Hybrid yarns containing metal wire are used in two main areas. The first usage area is basically for decorative purposes as a fancy yarn, whereas the other usage area is for functional purposes as a technical yarn. Hybrid yarns containing metal wire, which are used to avoid static electricity to protect against electromagnetic radiation and to transmit the electric current in the fabric structures, can be evaluated in the second group [2].

The common metal wires used in textiles are stainless steel, silver and copper wires. Even though it is possible to use 100 % metal wire in fabric structure, the usage of 100 % bare metal wire in fabric manufacturing, cause various problems in related with efficiency of processes, aesthetics and lifetime of products. Therefore, hybrid yarns which consist of metal wires combined with synthetic or natural fibres with different methods are preferred for fabric production.

The aim of this study is to evaluate the effects of yarn production method and number of twist on the some physical properties of hybrid yarns. Initially, different hybrid yarns containing copper wire, were produced with the five different production methods and three different twist levels, then some physical properties such as tenacity, breaking elongation, modulus and copper visibility ratio (CVR) of hybrid yarns were investigated.

2. MATERIALS AND METHODS

In this study, 15 different types of hybrid yarns containing copper wire, were produced with 5 different production methods as cross wound covering with double yarn (CWD), twisting with single yarn (TS), covering with single yarn (CS), twisting with double yarn (TD), covering with double yarn (CD), and with 3 different twist levels as 200 T/m, 250 T/m and 300 T/m using Ağteks ‘‘Directwist-2B’’ machine. The delivery speed of Directwist-2B machine was set of 24 m/minute, during the production of hybrid yarns. For the production of hybrid yarns, Ne 25/1, Ne 50/1 ring-spun cotton yarns and 50 micron (Ne 33/1) copper wire were used. Final count measurements of all yarns and hybrid yarns were performed according to Standard TS 244 EN ISO 2060. Hybrid yarns’ codes and production parameters are summarized in Table 1.

Table 1. The production methods, contents and twist levels of the samples

Yarn Code	Production Method	Content	T/m
1A	CWD	Ne 50 Co/Ne 50 Co/M	200
1B	CWD	Ne 50 Co/Ne 50 Co/M	250
1C	CWD	Ne 50 Co/Ne 50 Co/M	300
2A	TS	Ne 25 Co/M	200
2B	TS	Ne 25 Co/M	250
2C	TS	Ne 25 Co/M	300
3A	CS	Ne 25 Co/M	200
3B	CS	Ne 25 Co/M	250
3C	CS	Ne 25 Co/M	300
4A	TD	Ne 50 Co/Ne 50 Co/M	200
4B	TD	Ne 50 Co/Ne 50 Co/M	250
4C	TD	Ne 50 Co/Ne 50 Co/M	300
5A	CD	Ne 50 Co/Ne 50 Co/M	200
5B	CD	Ne 50 Co/Ne 50 Co/M	250
5C	CD	Ne 50 Co/Ne 50 Co/M	300

CO: cotton, M: metal wire (Ne 33/1 copper wire)

Sample yarns were photographed with an Olympus SZ61 stereo microscope using BABSOFT digital image processing software. The longitudinal views and the models of the yarns produced with 5 different production methods at the twist level of 250 T/m are given in Figure 1.

Tensile tests were performed on the Instron tensile tester (Model 4411) according to Standard TS 245 EN ISO 2062. 10 tests were performed for each hybrid yarn types. Test parameters were applied as 250 mm distance between jaws and test speed was 250 mm/minute. Besides technical performance, also aesthetical performance is very important for the hybrid yarns containing copper wire.

The study related with aesthetic performance of hybrid yarns was carried out in the form of knitted fabric. During the formation of knot structure, metal wire of hybrid yarn which is normally invisible can become visible. Therefore, the visibility of copper wire of hybrid yarns which were produced with the different production techniques and twist levels, was evaluated in the fabric form.For this reason, supreme knit structured fabrics were fabricated from hybrid yarns on sample sock knitting machine. To determine the CVR of hybrid yarns on the surface of supreme knit fabric, image thresholding method was used in CIELab color space.

An image is a two dimensional function of the light and composed of pixels. This function is shown as f(x,y). Here "x" and "y" are the cartesian coordinates and the numerical value at (x,y) point is the brightness value or the gray level intensity value of the image at the corresponding point. Each element of this numeric index or matrix is called the image element or pixel (pixel= picture element). A numerical image is often sampled with a rectangular pixel series. Every pixel has a certain coordinate (x,y) on the image. The intensity value of a pixel represents the color of that pixel. Image thresholding is used to convert the image into a "binary" image in which pixels are considered as black or white [3].

Thresholding is one of the important processes of image processing. It is especially used to make the dark and light areas of the object distinct. It also contains editing the image which is split to pixels, until the image at binary structure. Thresholding is simply locating the pixel values on the image instead of defining them according to certain values. Thus, the background of the object and the silhouette of the object can be exposed [4].

The obvious and the only way of distinguishing the object from the background is to choose the T (thresholding) which distinguishes the models. Otherwise, the point will be defined as a point of the background. In other words, threshold image g (x,y) can be defined as in equation (1) [5].

$$g(x,y)=\begin{cases}1, & if \quad f(x,y)\geq T\\ 0, & if \quad f(x,y)<T\end{cases} \qquad (1)$$

RGB (red-green-blue) color space can be thought as a three-dimensional space which has coordinate axis; those are red, green and blue. The desired colors are defined as the coordinates of these three colors. The coordinates of CMYK color space which is composed of 4 main colors, represent cyan, magenta, yellow and black colors. XYZ color space is defined by CIE (Comission Internationale de L'Eclairege, International Commission on Illumination) and it shows the ratio of three reference colors as X, Y, Z to generate a color.

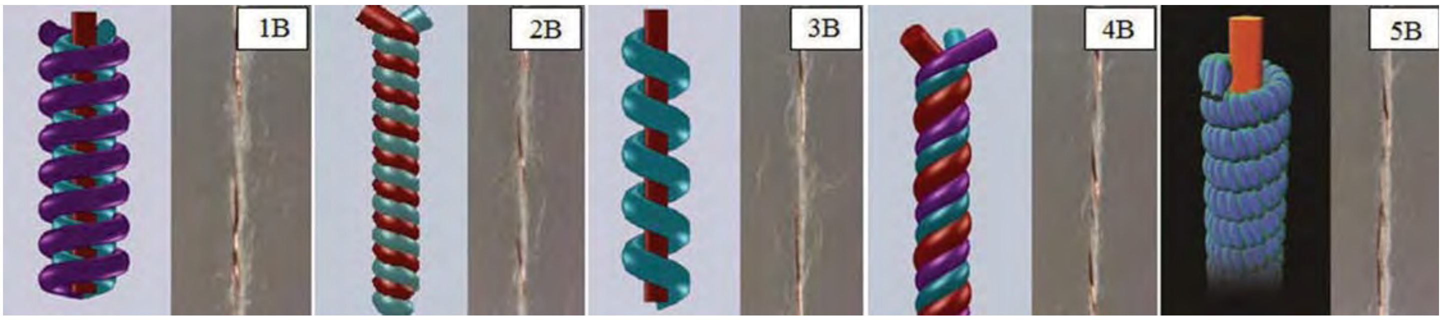

Figure 1. Models and longitudinal views of different yarns produced with 250 T/m

CIELab color space was chosen the standard color space for various areas and today it is used in many applications. CIELab color space is constructed on the non-linear compression of the CIE XYZ color space coordinates. In CIELab color space, L* component defines the approximate brightness of the color and “a” and “b” components define the color [6]. Opposite to the RGB and CMYK color models, Lab color is designed for modeling the human view in a better way. CIELab defines all the colors which can be seen by human eye [7].

The determination of copper visibility ratio on the fabric surface was done with thresholding method based on CIELab color space. Also RGB space was tried for image processing but it was not successful since the copper image could not be processed properly. The fabric samples were photographed with an Olympus SZ61 stereo microscope by using BABSOFT image processing software, to be able to calculate the CVR value on the fabric samples.

The obtained sample fabric images were processed with MATLAB software and CVR values for each fabric sample were found. At this stage, the images obtained at RGB color space were converted to CIELab color space as default. There is not a simple formula for the conversion between RGB and L*, a*, b* values because RGB color model is device dependent. First of all, RGB values must be converted to a certain absolute color space such as sRGB or AdobeRGB. These settings are also device dependent. But by permitting the conversion of the data first to CIE XYZ color space, then to CIELab color space, the data obtained from the conversion will be independent from device. The images at the L*, a*, b* components of only one image of the 1A coded sample fabric given in Figure 2. The “a” component image was used for the algorithm since the copper is more evident as it can be seen in Figure 2.

For the start-up image with MxN dimension, the processes given in Figure 3 were done respectively.

The ratio of copper image area to the total image area on the fabric surface is defined as copper visibility ratio (CVR). Equations (2) and (3) were used to calculate the CVR value on the fabric surface.

$$B(x,y) = \begin{cases} 1, & if \quad f^{a^*}(x,y) \geq T \\ 0, & if \quad f^{a^*}(x,y) < T \end{cases} \qquad (2)$$

$$\text{CVR }(\%) = \frac{\sum_X^M \sum_Y^N B(x,y)}{MN} 100 \qquad (3)$$

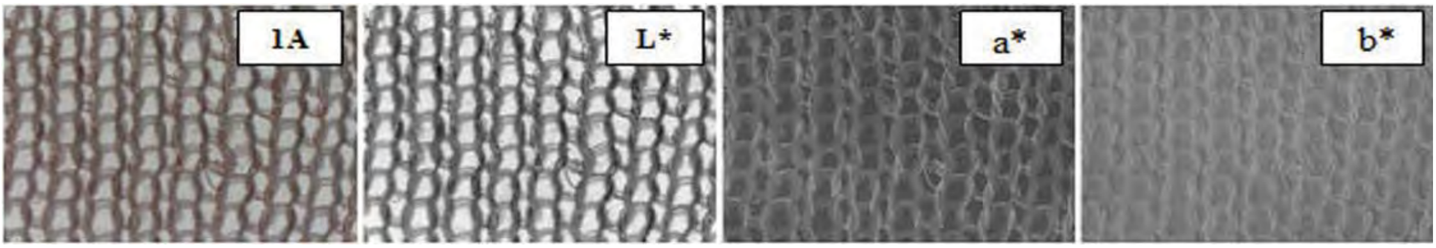

Figure 2. Original image 1A and L*, a*, b* components at CIELab space of image 1A

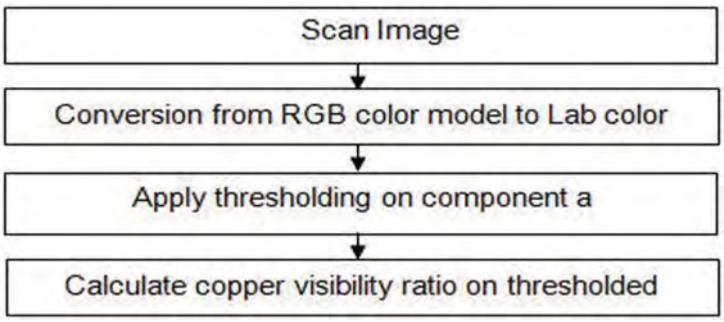

Figure 3. Used method to determine CVR of hybrid yarns on the fabric surface

Here, "f" exponential defines the value of the "a" image at (x, y) coordinates in component "a*" at CIELab space, B(x, y) defines the threshold mode of component "a" and "T" is the threshold value.

Histogram is the graphical representation of the pixel values on the image. This is called the image histogram. Image histogram shows the values of the pixels by determining the pixels on each point of the image. The histogram of the "a" component of image 1A is shown in Figure 4.

According to the Figure 4, the threshold value to be applied in this study is estimated by trial and error. Threshold values (T) of 130, 136 and 142 are applied to the "a" component of the input image and only copper images are obtained (Figure 5a). In Figure 5b, detected coppers fused with the original input images are also visualized to evaluate the performance of different "T" values. According to the visual results given in Figure 5, threshold value of 136 is suitable for the best output.

In order to evaluate the effect of yarn production method and number of twist on CVR of hybrid yarns, each sample fabrics were photographed fifteen times with the Olympus SZ61 stereo microscope.

All measured values were also statistically analyzed with two-way repeated measures analysis of variance (ANOVA) method. The mean differences of subgroups were also compared by Student-Newman-Keuls (SNK) test at 95 % significant level in the COSTAT statistical package.

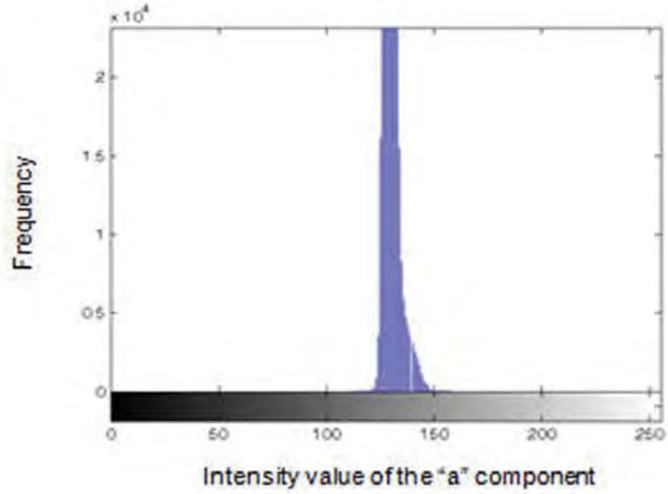

Figure 4. Image histogram

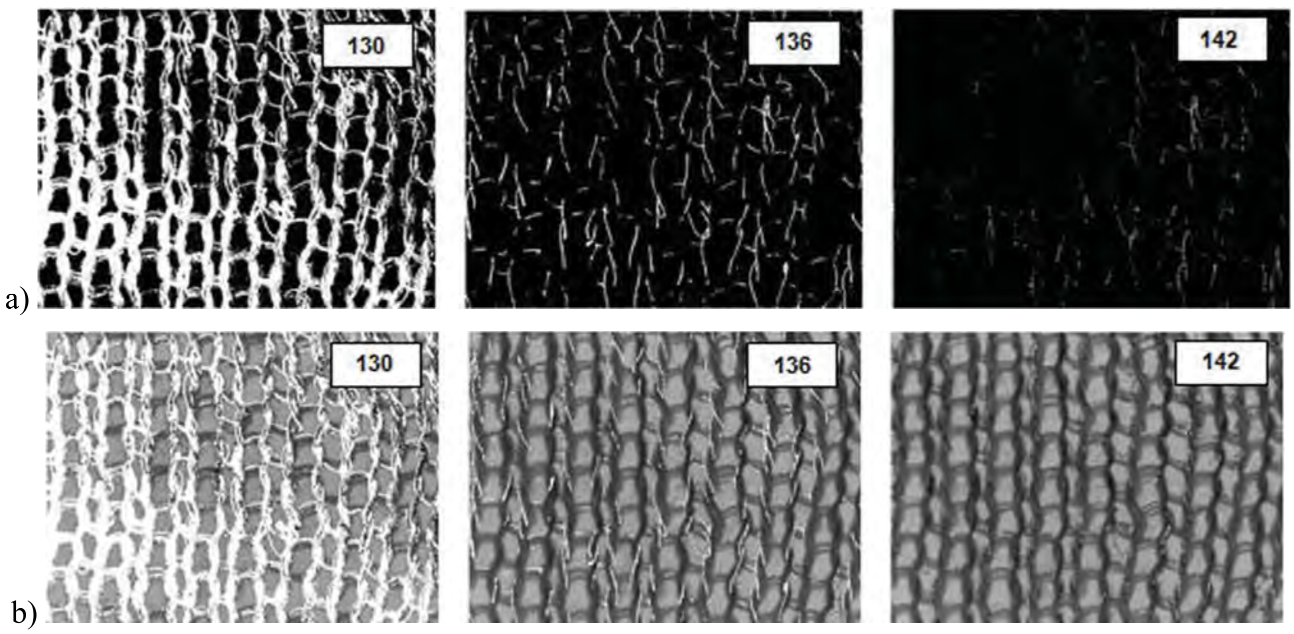

Figure 5. a) Only copper images obtained at threshold values (T) of 130, 136 and 142 b) Image samples of detected coppers fused with the original input images

3. RESULTS AND DISCUSSIONS

The average of the yarn count, tenacity, breaking elongation and Young modulus of the hybrid yarns are given in Table 2.

According to Table 2, it is seen that the tenacity values of copper containing hybrid yarns are lower than that of Ne 50 and Ne 25 cotton yarns. The effect of the production method and the change in the twist level, on the tenacity of the yarns is shown graphically in Figure 6. As seen in Figure 6, it was found that the tenacity values of the yarns produced with CD method for all twist levels were higher than that of the other hybrid yarns.

According to the ANOVA results, it was found that the production method, twist level and the interaction of these two factors have significant influence on the tenacity of the hybrid yarns. According to SNK test results, the difference between tenacity values of hybrid yarns produced by TS and TD methods was statistically insignificant whereas the difference between tenacity values of hybrid yarns produced by CWD, CS and CD methods was statistically significant. The highest tenacity values were obtained from the yarns produced with CD method. This was followed by the yarns produced with TS, TD, CWD and CS methods respectively. Also, it was found that the difference between tenacity values of hybrid yarns produced by using different twist levels were statistically significant (Table 3).

Table 2. Some physical properties of 100% cotton yarns (Ne25, Ne 50), copper wire (M) and hybrid yarns

Yarn Code	Yarn Count (Ne)	%CV	Tenacity (cN/tex)	%CV	Breaking Elongation %	%CV	Young Modulus (cN/tex)	%CV
Ne 25	25	*4.4*	14	*7.7*	7.1	*11.6*	270	*17.4*
Ne 50	50	*13.5*	17.9	*8.9*	6.8	*6.1*	360	*14.5*
M	33	*1.3*	5.0	*5.9*	29.7	*7.2*	812	*46.5*
1A	13.7	*1.5*	5.8	*9.3*	4.1	*25.3*	205	*15.3*
1B	13.5	*0.9*	7.6	*11.4*	5.6	*27.4*	205	*19.3*
1C	14.1	*1.1*	8.0	*8.54*	6.7	*28.6*	157	*10.2*
2A	14.1	*1.6*	8.0	*7.3*	5.2	*8.9*	279	*10.8*
2B	14.3	*1.0*	8.2	*6.9*	5.7	*13.5*	245	*28.1*
2C	14.5	*2.6*	7.9	*3.6*	6.2	*9.0*	226	*22.9*
3A	14.5	*2.2*	6.2	*11.9*	5.2	*23.1*	221	*31.9*
3B	14.5	*2.3*	6.7	*7.9*	5.2	*9.5*	246	*24.3*
3C	14.2	*1.4*	5.2	*30.4*	4.2	*26.6*	252	*16.8*
4A	14.5	*0.8*	7.1	*9.4*	4.2	*11.7*	298	*12.9*
4B	14.2	*11*	8.7	*5.0*	5.2	*6.0*	279	*10.0*
4C	14.3	*1.4*	8.2	*3.7*	4.6	*6.0*	320	*9.4*
5A	13.7	*1.9*	9.9	*3.7*	5.6	*2.8*	321	*22.7*
5B	14.1	*1.5*	10	*3.3*	5.4	*3.5*	304	*16.5*
5C	14.1	*1.5*	10.1	*10.3*	5.6	*6.1*	262	*13.2*

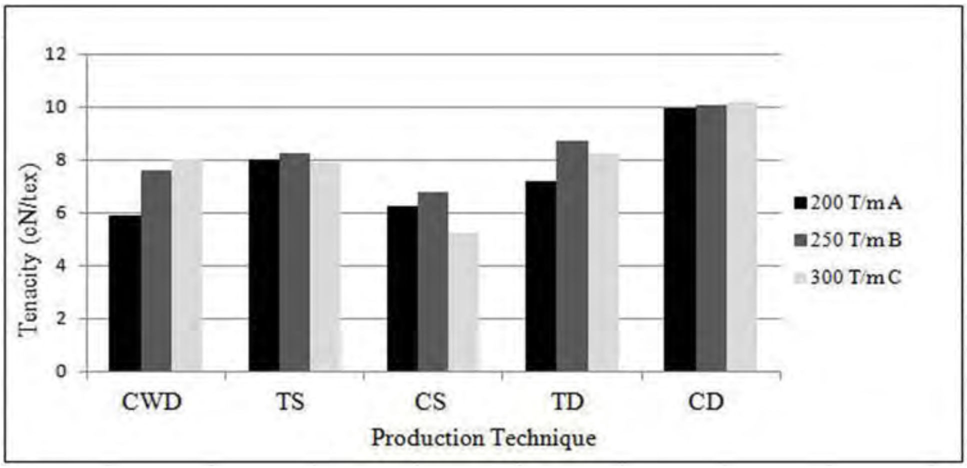

Figure 6. Tenacity values for different hybrid yarns

The effects of the production method and twist level on the breaking elongation are given in Figure 7. As seen in Figure 7, hybrid yarn produced with CWD method at the twist level of 300 T/m shows the highest breaking elongation when compared with other hybrid yarns.

Table 3. SNK table for the tenacity values of the hybrid yarns

Factor	Factor Levels	Tenacity (cN/Tex)
Production Technique	CWD	7.16 c
	TS	8.06 b
	CS	6.06 d
	TD	8.05 b
	CD	9.97 a
Twist level (T/m)	200	7.46 c
	250	8.27 a
	300	7.84 b

According to the ANOVA results, it was found that the production method, twist level and the interaction of these two factors have statistically significant influence on the breaking elongation of the yarns. According to SNK test results, the difference between breaking elongation values of hybrid yarns produced by CWD, TS, CD methods were found to be statistically insignificant. Therewithal, it was found that there was not statistically significant difference between breaking elongation values of hybrid yarns produced by CS and TD methods. On the other hand, breaking elongation values of hybrid yarns produced by CWD, TS, CD methods were statistically higher than that of CS and TD methods (Table 4).

The difference between breaking elongation values of hybrid yarns produced with the twist levels of 250 T/m and 300 T/m were found to be statistically insignificant. Moreover, the breaking elongation values of hybrid yarns produced with 200 T/m twist level were found to be significantly lower than that of hybrid yarns produced with other twist levels (Table 4)

The Young modulus for different hybrid yarns is given in Figure 8. Hybrid yarn produced with TD method at the twist level of 300 T/m shows the highest Young modulus value when compared with the other yarns.

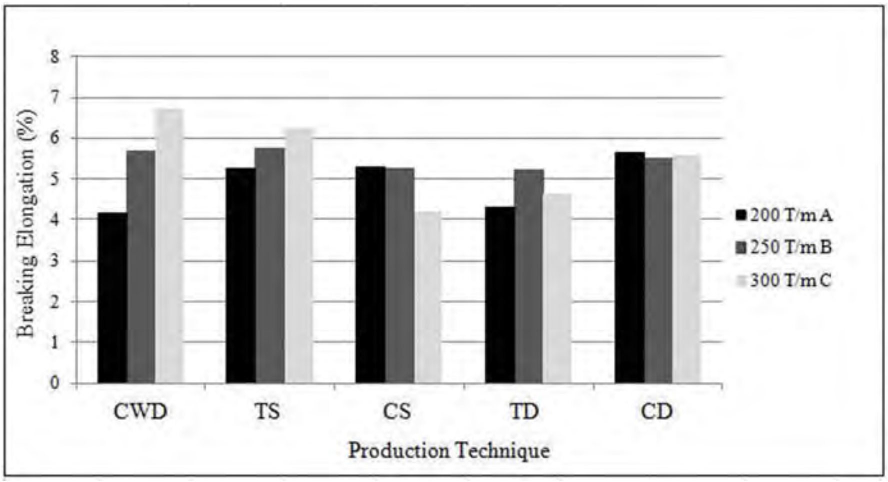

Figure 7. Breaking elongation values for different hybrid yarns

Table 4. SNK table for the breaking elongation values of the hybrid yarns

Factor	Factor Levels	Breaking Elongation (%)
Production Technique	CWD	5.52 a
	TS	5.75 a
	CS	4.92 b
	TD	4.68 b
	CD	5.54 a
Twist Level (T/m)	200	4.89 b
	250	5.47 a
	300	5.48 a

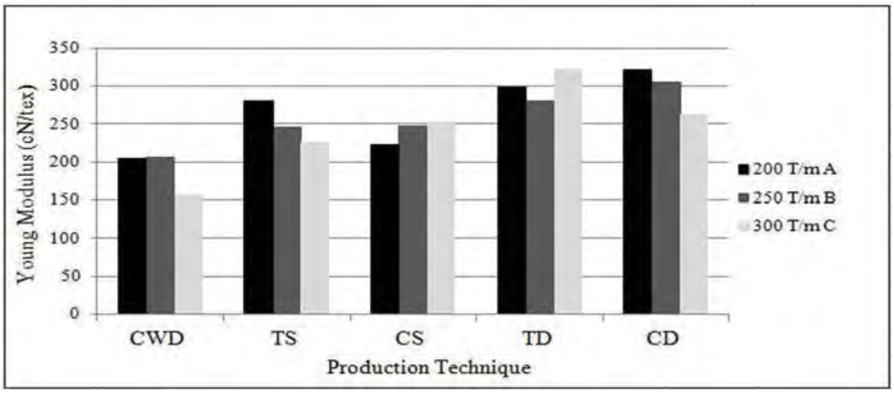

Figure 8. Young modulus for different hybrid yarns

According to the ANOVA results, it was found that the production method and the intersection of production method and twist level factors statistically have significant influence on the Young modulus of the hybrid yarns.

As seen in Table 5, the difference between Young modulus values of hybrid yarns produced by TS, CS and TD, CD methods were statistically insignificant. Also, whereas the highest Young modulus values were obtained from the yarns produced with TD method, the lowest Young modulus values were obtained from the yarns produced with CWD method (Table 5).

CVR values on the surface of the hybrid yarn knitted fabric were determined by using image thresholding method in CIELab color space. According to the ANOVA results, it was found that the production method, twist level and the intersection of these two factors have statistically significant influence on the CVR values of hybrid yarns. The CVR values for different hybrid yarns are given in Figure 9.

The difference between average CVR value of hybrid yarns produced with the twist levels of 200 T/m and 250 T/m were found to be statistically insignificant (Table 6). On the other hand, the CVR value of hybrid yarns produced with the twist level of 300 T/m was statistically lower than that of hybrid yarns produced with other twist levels as seen in Table 6.

Table 5. SNK table for the young modulus values of the hybrid yarns

Factor	Factor Levels	Young Modulus (cN/Tex)
Production Technique	CWD	189 c
	TS	250 b
	CS	235 b
	TD	299 a
	CD	296 a
Twist Level (T/m)	200	265 a
	250	253 a
	300	244 a

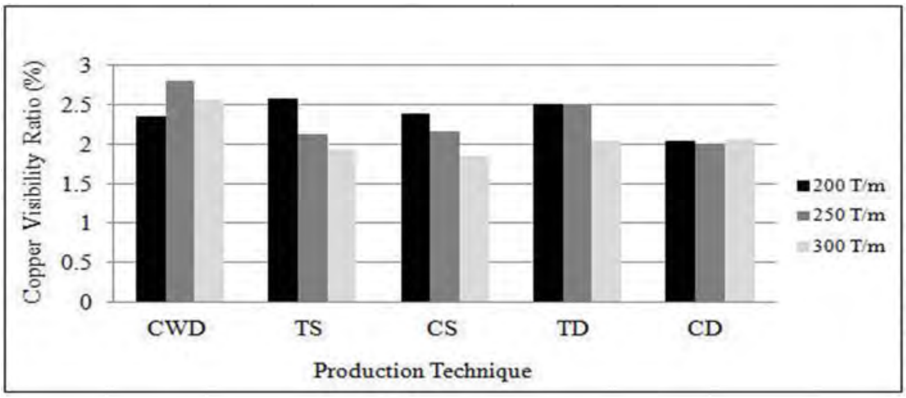

Figure 9. CVR values for different hybrid yarns

Table 6. SNK table for CVR (%) values of the hybrid yarns

Factor	Factor Levels	CVR (%)
Production Technique	CWD	2.57 a
	TS	2.34 b
	CS	2.20 c
	TD	2.13 cd
	CD	2.02 d
Twist Level (T/m)	200	2.37 a
	250	2.30 a
	300	2.08 b

The highest CVR value was obtained from hybrid yarns produced with CWD method (Figure 9). The images of the samples knitted from CWD hybrid yarns are given in Figure 10. Image samples of only copper wire which were obtained from the result of thresholding belonging to samples knitted from CWD hybrid yarns are given in Figure 11.

The lowest CVR value was obtained from the sample fabrics knitted from the hybrid yarns produced with CD method. The photos of the samples knitted from CD hybrid yarns are given in Figure 12. Image samples of only copper as the result of thresholding of samples knitted from CD hybrid yarns are also given in Figure 13.

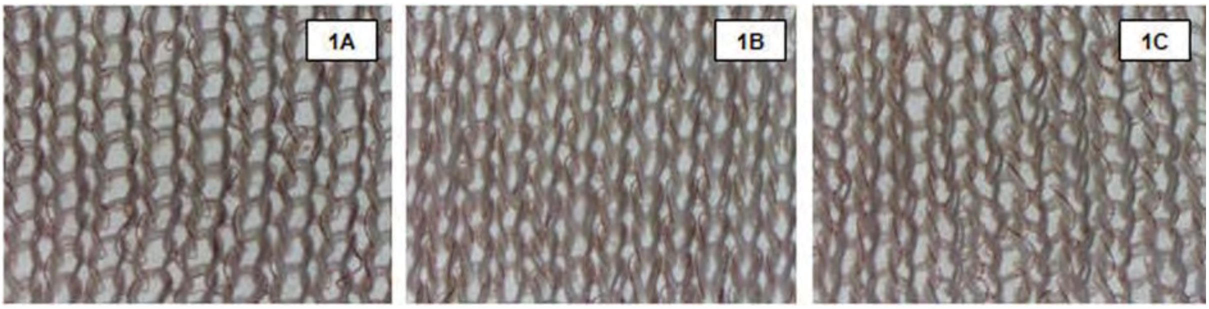

Figure 10. The images of the fabrics knitted from hybrid yarns produced with CWD method

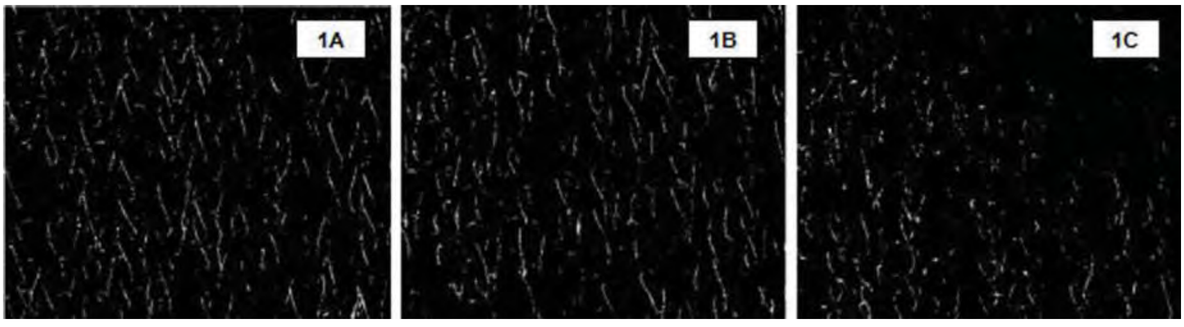

Figure 11. Image samples of only copper as the result of thresholding of fabrics knitted from CWD hybrid yarns

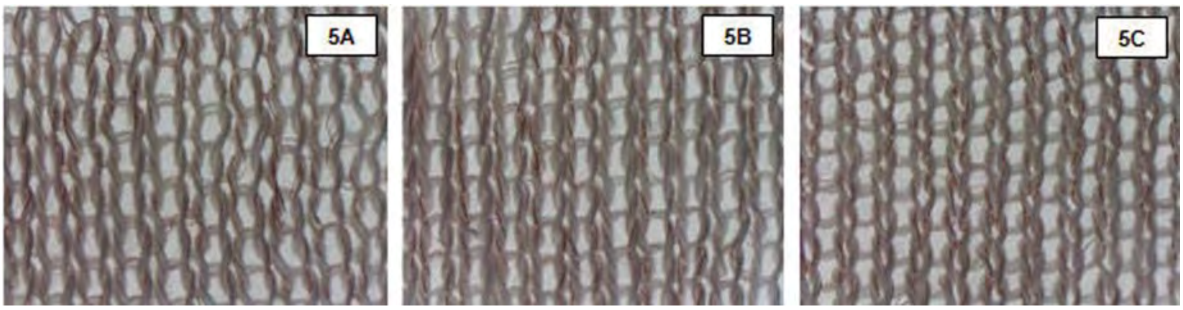

Figure 12. The photos of the samples knitted from hybrid yarns produced with CD method

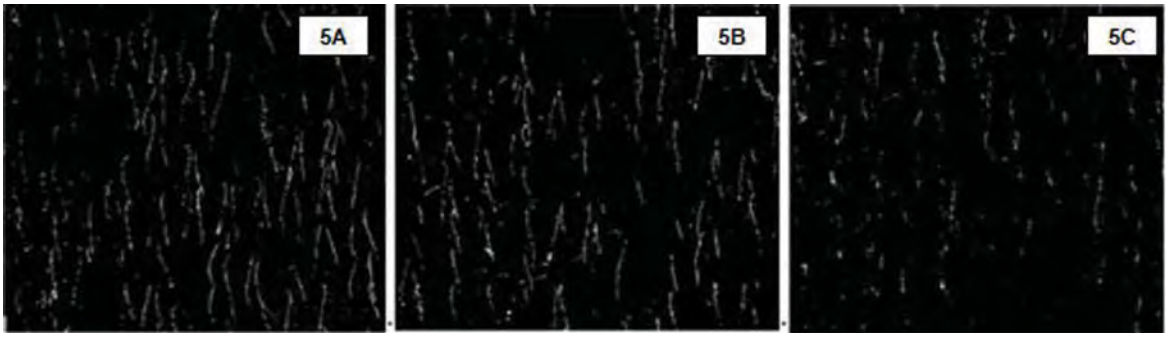

Figure 13. Image samples of only copper as the result of thresholding of fabrics knitted from CD hybrid yarns

4. CONCLUSION

According to the test results of the yarn samples, it was seen that the tenacity and breaking elongation values of hybrid yarns are lower than that of Ne 50/1 and Ne 25/1 cotton yarns. In addition, tenacity of the CD hybrid yarns was found to be statistically higher than that of other hybrid yarns. The yarn produced with CWD method at the twist level of 300 T/m shows the highest breaking elongation when compared with other hybrid yarns.

Although the tenacity and the breaking elongation values are significantly influenced with the increase of twist level, the twist level does not have any statistically meaningful effect on the Young modulus. The yarn produced with TD method at the twist level of 300 T/m shows the highest Young modulus value when compared with other hybrid yarns.

According to the data obtained from image thresholding method, the production methods and the twist levels have impact on the CVR value of the hybrid yarns. The highest CVR value was obtained from CWD hybrid yarn knitted fabric. The lowest CVR value was obtained from the fabric knitted from CD hybrid yarns. It was also seen that the CVR value of 300 T/m hybrid yarns is lower than that of 200 T/m and 250 T/m hybrid yarns.

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