The effect of dyeing tubes' structure on the colour difference of yarns

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ABSTRACT – REZUMAT

The effect of dyeing tubes' structure on the colour difference of yarns

In the study, the effect of the structure of the dyeing tubes used in bobbin dyeing on the colour difference of the yarns was investigated. For this purpose, dyeing was done using 5 dyeing tubes with different dye permeability. Yarn samples were taken from the inner, middle and outer winding layers of the dyed bobbins. The colour difference of the yarns was measured with a spectrophotometer. It was observed that as the dye permeability of the dyeing tubes increased, the colour difference decreased and a more homogeneous dyeing was obtained. When the bobbins were evaluated in terms of diameter, it was seen that the colour difference was at least in the middle diameter. As the dye permeability increased, the colour distribution along the bobbin diameter became more homogeneous. In addition, it was determined that the colour difference decreased in fine yarn and high winding density.

Keywords: *bobbin dyeing, dyeing tubes, useful surface coefficient, winding density, colour difference value (ΔE)*

Influența structurii tuburilor de vopsire asupra diferenței de culoare a firelor

În studiu, a fost investigată influența structurii tuburilor de vopsire utilizate în vopsirea bobinelor asupra diferenței de culoare a firelor. În acest scop, vopsirea s-a realizat folosind 5 tuburi de vopsire cu permeabilitate diferită a coloranților. Au fost prelevate mostre de fire din straturile de înfășurare interioare, mijlocii și exterioare ale bobinelor vopsite. Diferența de culoare a firelor a fost măsurată cu un spectrofotometru. S-a observat că pe măsură ce permeabilitatea la colorant a tuburilor de vopsire a crescut, diferența de culoare a scăzut și s-a obținut o vopsire mai omogenă. Când bobinele au fost evaluate din punct de vedere al diametrului, s-a evidenţiat că diferența de culoare s-a observat cel mai puțin în diametrul mijlociu. Pe măsură ce permeabilitatea coloranților a crescut, distribuția culorii de-a lungul diametrului bobinei a devenit mai omogenă. În plus, s-a evidenţiat că diferența de culoare a scăzut în cazul firelor fine și cu o densitate mare de înfășurare.

Cuvinte-cheie: *vopsirea bobinelor, tuburi de vopsire, coeficient de suprafață util, densitate de înfășurare, valoarea diferenței de culoare (ΔE)*

INTRODUCTION

Dying the yarns in bobbins is a more suitable method in terms of technical and economic compared to other dyeing methods. The positive aspects of this method are that the yarns can be sent to the weaving without any additional processing after dyeing, that large lots can be dyed at once, that it can work at low chemical substance ratios, and that all kinds of fibres can be dyed with all kinds of dyestuffs in HT type boilers. Various parameters affect the dyeing of yarns in bobbin form. These parameters are related to dyeing (type and quality of dyestuff used, temperature of dyeing solution, circulation rate and method of dyeing solution, pumping pressure, technical parameters of dyeing device), those related to the quality of the winding structure of the bobbins (density, unevenness), structure of the tubes are grouped as (the shape of the tubes face, the shape and number of the holes in its face, and the size of the area of the holes) [1].

In a study examining some dyeing parameters affecting the dyeing process of yarns, it is said that unidirectional dye solution flow causes uneven dyeing. For smooth and optimum dyeing results, inside-out and outside-in circulation of the dyeing solution should be provided [2]. Pump speed affects the painting's unevenness. In bobbin dyeing, pump speed and circulation time should be adjusted according to yarn count and bobbin density [3, 4]. In the mathematical model developed by Guelli Ulson de Souza et al., the dye concentration in the dyeing bath liquid outside the bobbin, the dye concentration in the bath liquid surrounding the yarn but inside the bobbin and the dye concentration in the yarn were defined. The mathematical model has been shown to have good accuracy when compared with the experimental results. Thus, the consumption of dyes and other auxiliary materials required for the dyeing process will be minimized [5]. Mancusi et al. described the bobbin dyeing process with a set of time-dependent partial differential equations that govern the convection, distribution and adsorption of dye in the dyebath and along the bobbin threads. The flow direction inside the bobbins was periodically reversed and investigated by applying periodic forcing. It has been stated that the periodic change in the flow direction does not affect the regime profile. Still, the reverse process plays an important role in the dye distribution at the beginning and provides a better dye distribution [6].

In a study examining the winding structure in the dyeing of yarns in bobbins, the rise angle of the yarn during winding, the winding cross angle, the winding density, the type and count of the wound yarn, the winding type, the shape and dimensions of the winding structure were determined as the important parameters that determine the winding structure. It is shown that when the yarn tension increases during winding, the bobbin density increases, the variation of the winding stiffness along the diameter of the bobbin decreases linearly, and the winding stiffness is higher at the edges of the bobbin compared to the middle [7]. Belforte et al. determined the winding angle and yarn tension as basic parameters during the winding process. Higher winding angle values help maintain the bobbin shape. Higher yarn tension values ensure that the package shape is maintained after the dyeing cycle. It has also been shown that applying a variable tension during the winding process is not beneficial [8]. Colour values were measured by dyeing the bobbins wound at a certain winding density, winding pressure, winding speed and winding angle values. It has been determined that the degree of colour uptake in these regions is different by winding the yarns at different tensions in the inner-middle and outer regions of the bobbin [9]. Soft hardness values of dyeing bobbins are important in terms of dyeing efficiency and errors in bobbin dyeing based on inside-out and outside-in solution circulation. The winding density varies along the length and diameter of the bobbin. Density increases along its length at the edges of the bobbin relative to its middle part, and along its diameter, with the inner diameter of the bobbin relative to its outer diameter. Abdelkader studied the variation of density along the length of the bobbin. He made recommendations for reducing the density variation [10]. The quality of the winding process is an important factor affecting the yarn dyeing quality and efficiency. Çalhan et al. designed a system to provide high-quality and reproducible staining. For this, they used 3D printing and image processing techniques. With the designed system, the bobbin winding densities were calculated, the difference between the windings was determined and production was started [11]. The structure and properties of the yarns produced with different spinning systems affect the colour efficiency in bobbin dyeing. Özdemir and Oğulata produced ring compact, open-end rotor and vortex (MVS) yarns in different yarn counts by using 100% cotton from the same blend. They measured the hardness values by obtaining dyeing bobbins with a constant density (370 g/dm^3) from the yarns. They stated that the stiffness of dyeing bobbins formed with vortex yarns is lower than ring, compact and rotor bobbins. It has also been shown that the effect of the spinning system on the package stiffness is statistically highly effective. In other words, the bobbin stiffness values of the yarns produced according to different spinning systems, which are wound at the same density value, are different. For this reason, it has been concluded that, in addition to the bobbin density, the bobbin hardness value is an important parameter for smooth and easier circulation of the solution, reaching the desired colour values, and preventing dyeing errors such as inner-middle-outside colour difference [12, 13]. Özdemir and Oğulata investigated the effects of different structures and properties of yarns produced by ring, compact, rotor and air-jet (vortex) spinning systems on the bobbin dyeing colour efficiency. For this, bobbins formed by winding on perforated plastic dyeing tubes according to the soft winding principle with a density of 370 g/dm^3 were dyed. It has been shown that under the same conditions, vortex and rotor yarns can be dyed darker than ring and compact yarns [14]. Özdemir and Oğulata tried to determine the relationship between dyeing differences and parameters affecting dyeing unevenness. The parameters affecting the colour difference values in bobbin dyeing were considered as material parameters (yarn count, bobbin density) and machine parameters (pump rotation, circulation time and temperature gradient). The colour difference values of the bobbin were estimated by performing linear multiple regression analysis with these parameters. In the dyeing and analysis results, it was observed that the colour difference values of the bobbins wound with thin threads were lower than those of thick threads. In addition, it was determined that the colour difference values increased as the bobbin density increased [15].

In a study in which the structure of the tubes in the dyeing of the yarns in bobbins was examined, the amount of energy consumed by dyeing at different pressures was examined. When the pump pressure is increased, more energy is consumed. Considering the colour values, it has been shown that dyeing with tubes with high paint permeability will reduce the pump pressure and save energy [16]. Fettahov et al. reported that the amount of dyestuff can be reduced by 10–15 % by using tubes with a high dye permeable area [17]. In addition, it has been shown that the colour difference along the winding diameter is lower in tubes with high dye permeability [18, 19]. Mahmudova states that the amount of yarn waste also decreases in dyeing made with tubes with a high dye permeable area [19].

Dyeing tubes differ according to the material they are produced, their shapes, sizes, the structure of the face, as well as the shapes, sizes and placement of the holes on the face. Plastic and steel tubes according to the material they are produced, conical and cylindrical tubes according to their shapes, rectangular, square, triangle, circle, ellipse and other geometric shaped perforated tubes according to the shapes of the holes on the face, tubes with equal and uneven distribution according to the placement of the holes on the face, can be classified as smooth and ribbed tubes according to their form [1, 20]. When the literature is examined, it has been seen that there are few studies investigating the structure of dyeing tubes. Unlike other studies, for the first time, experiments were carried out using 5 dyeing tubes with different dye permeability. Thus, the effect of the structure of the dyeing tubes on the dyeing of the yarns in bobbin form was examined in a systematic and detailed way, contributing to the literature.

MATERIAL AND METHOD

Material

The bobbins made of 100% cotton yarns of Ne 30 and Ne 50 from the same blend were dyed with reactive dyestuff. Bobbins were formed by winding on 5 dyeing tubes with different dye permeable areas. The dyeing tubes used in the study are shown in figure 1.

Fig. 1. The dyeing tubes used in the study

The useful surface coefficient (USC), which expresses the paint permeability of the tubes, was calculated with the help of equations 1 and 2 given in the study of Fettahov et al. [1]:

$$USC = \frac{SD}{SG} \quad (1)$$

$$USC\% = 100 \cdot \frac{SD}{SG} \quad (2)$$

where *SD* is the sum of the hole areas on the tube's face and *SG* is the general area where the tube's face is covered with wrap.

Again, considering the dyeing tubes classification made in the same study, the dyeing tubes used were classified (table 1).

In bobbin dyeing, cylindrical tubes with smooth surfaces and uniformly hole-distributed plastic material, indicated by number 1, are mostly used. In rib tubes indicated with numbers 2 and 3, the wound yarn does not sit directly on the holes. A certain gap remains between the tubes and the lower surface of the winding and the contact area of the dyeing with the winding face increases. The flex tube shown with the number 4 consists of two layers of surfaces, and therefore, the dye solution passing through the first layer with a large gap can easily pass to the yarn wound on the second layer. The high-performance plastic dyeing tube, numbered 5, is the dyeing tube with patent number EP 2083106 A1, produced by increasing the surface transfer area [21].

Table 1

CLASSIFICATION OF DYEING TUBES

Number	Dyeing tubes type	Useful surface coefficient	
		Ratio	Percentage
1	Smooth plastic cylindrical tube	0.44	44
2	Circular rib plastic cylindrical tube	0.34	34
3	Plastic conical tube with ribs along its length	0.30	30
4	Flex tube	0.68	68
5	High-performance plastic dyeing tube	0.82	82

Method

Before the dyeing process, dyeing bobbins were created by soft winding at a fixed bobbin density (0.36 g/cm^3 and 0.40 g/cm^3) using two different counted yarns. At this stage, the SSM TW2-W Digicone cross-winding machine was used. All of the test bobbins have the same diameter and were prepared as 15 cm. The yarn count parameter can affect colour difference values. For this reason, the averages of the number values of the yarns wound on the tubes were compared and it was tested whether the difference between the averages was significant at a certain confidence level. For this purpose, one-way analysis of variance was performed. The results of the analysis are given in table 2. As can be seen from the table, the differences between the levels of the yarn count factor are not statistically significant ($P>0.05$).

Table 2

RESULTS OF ANALYSIS OF VARIANCE

Factor	Dependent variable	Mean	P
Bobbin (Ne 30)	Count	29.50	0.537
Bobbin (Ne 50)	Count	50.35	0.461

The dyeing of the bobbins was carried out in the Thies brand HT bobbin dyeing machine with a machine capacity of five bobbins. By keeping the dyeing parameters constant, the dyeing process was repeated 3 times for each group and a total of 60 bobbins were dyed. The dyeing prescription is given in table 3 and the dyeing graph is given in figure 2.

After drying, all samples were conditioned under standard atmospheric conditions (20±2 °C and 65±2% humidity) so that moisture differences do not cause incorrect evaluations in the colour value. In bobbin dyeing, dyeing evenness is evaluated by measuring the colours of the yarns taken from different diameters of the bobbin. For this reason, the colour difference value was measured along the diameter of the

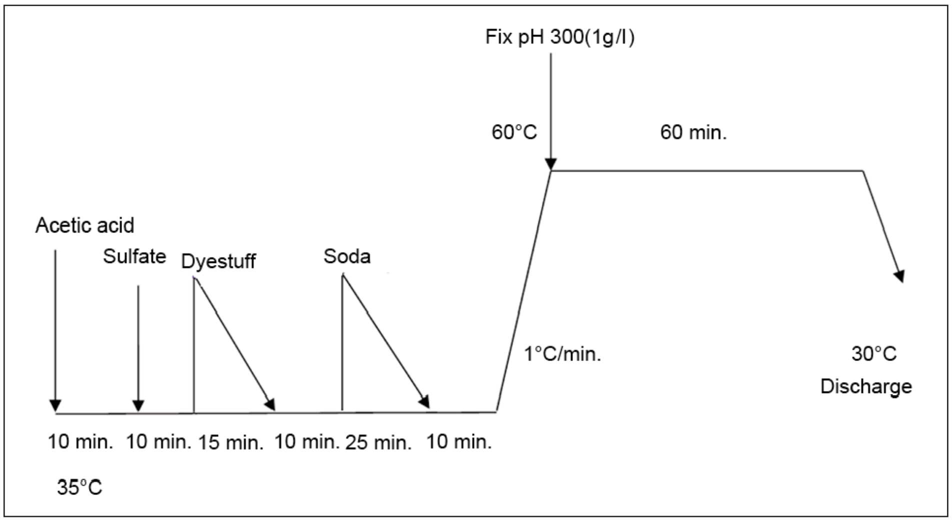


Fig. 2. Green colour dyeing graph

(7 cm), middle (9.5 cm) and outer (12 cm) diameters. It was observed that the highest average colour difference value in Ne 30 and Ne 50 yarns was obtained with the dyeing tube with a useful surface coefficient of 0.30 in both winding densities, and the lowest average colour difference value with 0.82. At a winding density of 0.36 g/cm^3, the average colour difference value of the 3rd tube is 1.49 times the average of the 5th tube. At a winding density of 0.4 g/cm^3, the average colour difference value of the 3rd tube is 1.87 times higher than the average colour difference value of the 5th tube. In addition, the average colour difference value of the bobbins formed with Ne 50 thread is lower than the bobbins formed with Ne 30 thread. When the colour difference values of the yarns wrapped on all tubes with different dye permeability were compared, it was seen that fine yarns were dyed more homogeneously.

The change graph of the average colour difference depending on the useful surface coefficient of the tubes was obtained with the Microsoft Excel program (figure 3 and 4). As can be seen, the average colour difference decreases as the useful surface coefficient increases. It is seen that the average colour difference values of the bobbins at 0.40 g/cm^3 winding density obtained with Ne 30 yarn are lower than the colour difference values of the bobbins at 0.36 g/cm^3 winding density (figure 3). It is seen that the average colour difference values of the bobbins at 0.40 g/cm^3 winding density obtained with Ne 50 yarn are lower than the colour difference values of the bobbins at 0.36 g/cm^3 winding density (figure 4). When the bobbin winding density increases, the unevenness of the

Table 3

REACTIVE DYESTUFF DYEING PRESCRIPTION				
Colour	**Dyestuff**	**Dyestuff (%)**	**Salt (g/l)**	**Soda (g/l)**
Green	Levafix yellow CA Levafix red CA Levafix blue CA	0.66 0.025 0.78	40	12

bobbin in the study. To be able to measure the colour, first of all, the yarns were wound on cardboards at constant tension, in equal amounts, in a parallel and homogeneous manner. For this, two samples were taken on cardboard papers from the inner, middle and outer winding layers of the middle part of the dyed bobbins according to their length. In the colour difference measurement, the colour value in the outer diameter of the bobbin was accepted as a reference for all bobbins and colour difference values were determined accordingly. Colour measurements were calculated under D65 daylight according to the CIELab formula [22]. Datacolor brand spectrophotometer was used in the study. Microsoft Excel program was used to evaluate the obtained colour differences.

RESULTS AND DISCUSSION

Bobbins formed by wrapping the useful surface coefficient on different tubes were dyed and the colour difference values were measured. Table 4 shows the colour difference values of the bobbins wrapped with Ne 30 yarns in two different densities and the colour difference values of the bobbins wrapped with Ne 50 yarns in two different densities. The colour difference value was measured at different diameters of the bobbins, the inner

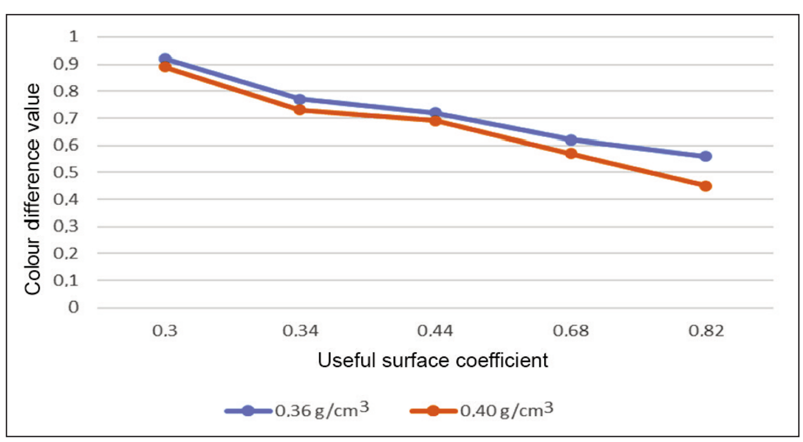


Fig. 3. Change of average colour difference value depending on useful surface coefficient at different winding densities with Ne 30 yarn

Table 4

COLOUR DIFFERENCE VALUES OF DYEING WITH DIFFERENT DYEING TUBES				
Useful surface ratio	**Winding density (g/cm^3)**	**Bobbin diameter (cm)**	**Colour difference ΔE** (Ne 30 yarn count)	**Colour difference ΔE** (Ne 50 yarn count)
0.44	0.36	7	0.73	0.68
		9.5	0.65	0.55
		12	0.80	0.61
0.34	0.36	7	1.03	0.72
		9.5	0.53	0.54
		12	0.75	0.70
0.30	0.36	7	0.86	0.96
		9.5	0.76	0.50
		12	1.14	0.70
0.68	0.36	7	0.68	0.68
		9.5	0.59	0.40
		12	0.61	0.48
0.82	0.36	7	0.57	0.43
		9.5	0.52	0.36
		12	0.60	0.46
0.44	0.40	7	0.69	0.59
		9.5	0.60	0.49
		12	0.76	0.62
0.34	0.40	7	0.98	0.61
		9.5	0.49	0.53
		12	0.70	0.67
0.30	0.40	7	0.82	0.66
		9.5	0.73	0.59
		12	1.11	0.81
0.68	0.40	7	0.56	0.51
		9.5	0.53	0.42
		12	0.63	0.56
0.82	0.40	7	0.46	0.38
		9.5	0.40	0.33
		12	0.49	0.44

winding can be reduced. It is thought that this situation leads to more homogeneous dyeing at a winding density of 0.40 g/cm^3.

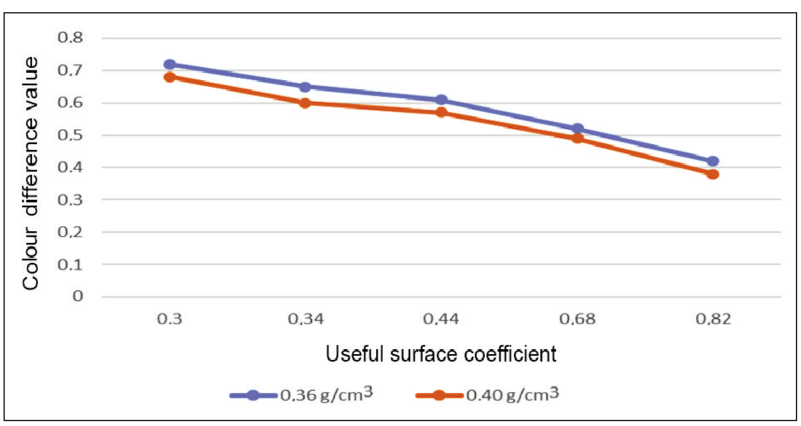
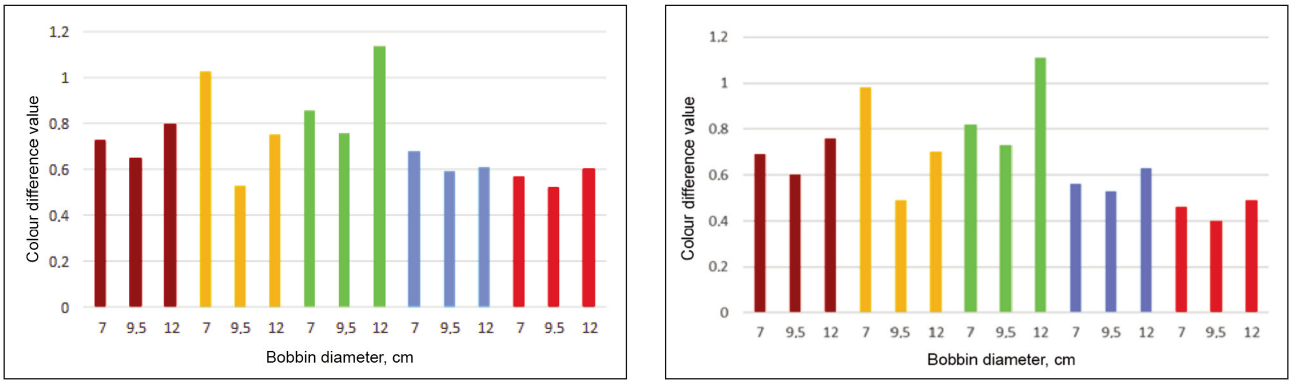


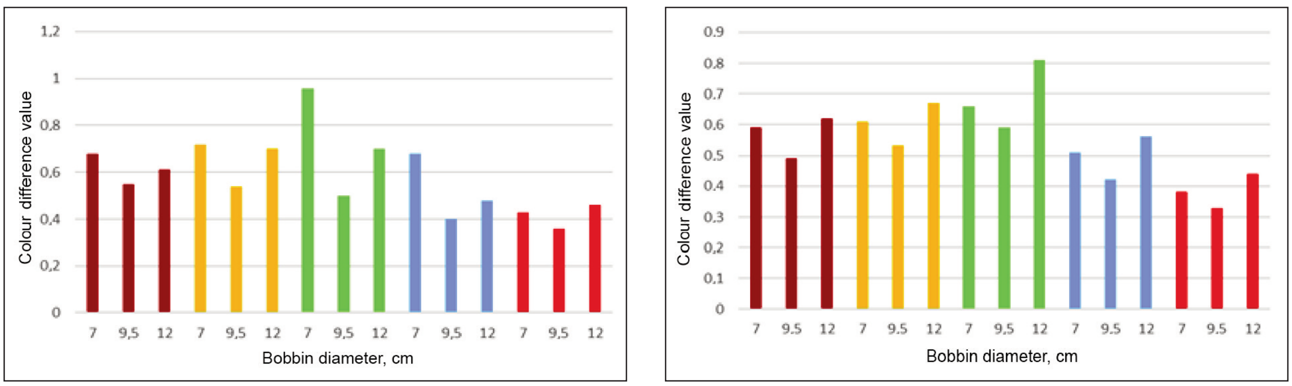
Fig. 4. Change of average colour difference value depending on useful surface coefficient at different winding densities with Ne 50 yarn

In figure 5, colour difference changes are seen along the diameters of Ne 30 yarn bobbins, which are wound on each tube in two different densities. In figure 6, colour difference changes are seen along the diameters of Ne 50 yarn bobbins, which are wound in two different densities on each tube. In the figures, bobbins formed with the number 1 tube are shown in claret red. the bobbins formed with the number 2 tube in yellow. the bobbins formed with the number 3 tube in green, the bobbins formed with the number 4 tube in blue, and the bobbins formed with the number 5 tube in red. When all the bobbins are evaluated, it can be said that the colour difference seen in the outer diameter is higher than the inner



a *b*

Fig. 5. Colour difference change according to the diameter of the bobbins on different tubes: *a* – Yarn count: Ne 30, density: 0.36 g/cm^3; *b* – Yarn count: Ne 30, density: 0.40 g/cm^3



a *b*

Fig. 6. Colour difference change according to the diameter of the bobbins on different tubes: *a* – Yarn count: Ne 50, density: 0.36 g/cm^3; *b* – Yarn count: Ne 50, density: 0.40 g/cm^3

diameter. It was also observed that the colour difference was at least 9.5 cm in diameter.

CONCLUSIONS

The quality of the bobbin winding structure (density. evenness) and the structure of the dyeing tube (the shape of the tube's face, the shape and number of the holes on the face, and the size of the hole area) are important in terms of ensuring that the dye solution is evenly distributed throughout the winding. In the study, bobbin dyeing was carried out by wrapping yarns with different numbers, 0.36 g/cm^3 and 0.40 g/cm^3 winding density, on different dye permeability tubes. The dye permeability of the dyeing tubes used was determined by the useful surface coefficients. The lowest useful surface coefficient was found to be 0.30, and the highest coefficient was 0.82.

The 2.7-fold difference in dye permeability affected the colour distribution. It was observed that as the dye permeability increased, the colour difference decreased and a more homogeneous dyeing was obtained. It is thought that the dyeing efficiency can be increased and the use of dyestuffs can be reduced when the yarns are dyed with dyeing tubes, which have a higher ability to pass the dye solution. Thus, production costs will also be reduced.

It was observed that the colour difference values of the bobbins obtained with Ne 50 yarns were lower than those obtained with Ne 30 yarns. The colour difference decreased when the yarn was thinner. As the yarn gets thinner, the cotton of the same weight is spread over a larger area. Thus, since there will be fewer fibres per unit area, the dye solution will penetrate the yarn more easily. This provides a more homogeneous dyeing. The colour difference values of the dyeing made with a winding density of 0.40 g/cm^3 obtained with Ne 30 and Ne 50 yarns are lower than the dyeing made with a winding density of 0.36 g/cm^3. The bobbins were dyed more homogeneously in the dyeing parameters studied, with a winding density of 0.40 g/cm^3. It is thought that this is because the increase in density may reduce the unevenness of the winding. As a result of the evaluation of the samples taken from the inner, middle and outer diameters of the bobbins, it was seen that the average colour difference values were different from each other. When the colour difference between the inner, middle and outer diameters of all bobbins wound with Ne 30 and Ne 50 yarns in two different winding densities is evaluated, it was observed that the colour difference in the middle diameter was the lowest. In addition, it was determined that the colour difference seen in the outer diameter was higher than the inner diameter. The density of the winding layers of the bobbin varies depending on the pressure of layers of yarn. Depending on this situation, while there is a more balanced density change in the middle diameter, the density tends to decrease in the outer diameter. The obtained colour difference value results were related to the density variation between the winding layers. By dyeing with tubes with different dye permeability, the amount of dyestuff usage can be compared in later studies and the effect on the cost can be calculated.

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