(REFEREED RESEARCH)

EFFECT OF SELECTED PARAMETERS ON COLOR DIFFERENCE AT DYEING OF COTTON PACKAGES WOUND FROM RING SPUN YARNS

PAMUKLU RİNG İPLİK BOBİNLERİNİN BOYAMASINDA SEÇİLMİŞ PARAMETRELERİNİN RENK FARKINA ETKİSİ

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ABSTRACT

In this study, %100 combed ring yarns with different yarn counts, which were used from the same raw material blend were produced and wound to different package densities. Bobbins were dyed with C.I. Reactive Black 5 (4 %). Here, the yarn count, package density, pump rotation, circulation time (in-out) and gradient of temperature are selecting parameters that can affect levelness of dyeing. The color difference (DE) of the dyed yarn was measured in two different zones of each packages internal and external zone to determine the levelness of dyeing. Linear multiple regression methods were used for the estimation of relation between the parameters and color differences. In the result of statistical study, goodness of adjusted R2 (coefficient of multiple determination) values were observed. Furthermore, analysis of variance showed that equations were significant at significance level ($p<0.01$).

Key Words: Ring spun yarn, Package dyeing, Package dyeing parameters, Color difference, Regression analysis.

ÖZET

Çalışmada aynı harmandan alınmış %100 pamuk kullanılarak, farklı iplik numaralarında ring iplikleri üretilmiştir. İplikler farklı yoğunluklarda sarılarak, boyama bobinleri oluşturulmuştur. Bobinler % 4 konsantrasyonda, C.I. Reactive Black 5 boyarmaddesiyle boyanmıştır. İplik numarası, bobin yoğunluğu, pompa devri, sirkülasyon süresi (iç-dış) ve sıcaklık yükselmesi, boyamanın düzgünlüğüne etki edebilecek parametreler olarak seçilmiştir. Lineer çoklu regresyon modelleri kullanılarak, boyama farkları ve seçilmiş parametreler arasındaki ilişki tespit edilmeye çalışılmıştır. İstatistiksel çalışma sonucunda, yüksek sayılabilecek düzeltilmiş determinasyon katsayısı (adjusted R2) değerlerine ulaşılmıştır. Ayrıca varyans analizi sonucunda bulunan eşitliklerin 0,01 (%99) anlamlılık seviyesinde anlamlı olduğu bulunmuştur.

Anahtar Kelimeler: Ring iplik, Bobin boyama, Bobin boyama parametreleri, Renk farkı, Regresyon analizi.

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1. INTRODUCTION

Yarn dyeing can be done with the yarn in skeins, the yarns wrapped on packages or the yarn wound on warp beams (1). Package dyeing provides the textile industry with an opportunity to color yarn at the latest possible stage prior to fabric manufacture. This is of prime importance if the dyer is to respond rapidly to changes in fashion and consumer demands (2). Package dyeing has accelerated for last years by the increase of demand for colored and patterned fabrics. Because, Yarn-dyed fabrics can use different areas such as jacquard or dobby fabrics, woven and knit. In addition, fastness to wearing of yarn-dyed fabrics can better than other fabrics which are dyed with different dyeing methods (3,4).

Package dyeing in textile finishing is more preferred comparing to other yarn dyeing methods because of advanced capacity of production and easy application of subsequent processes. On the other hand, solving the problems that might appear during dying is very difficult. The package will have no good uniformity of color where the internal, centre and external parts of dyed bobbins is possible during the dyeing because of deformity of yarn. Nevertheless, levelness and faulty dyeing can occur because of poor yarn properties, insufficient machinery and equipment, wrong selection for yarn dye tubes, non-uniform package density and winding profile, using of wrong dye, auxiliaries, process and dyer or personnel errors (5,6).

There are studies about technological developments in yarn dyeing is well known. Chakraborty and Sharma reported that the package dyeing machine is based on "optimised differential measuring" system which is controlled by variable pump rotation and differential pressure should adjust depending upon the density of packages for an efficient dyeing process (7). Tsui investigated the effect of some machine parameters on even package dyeing. It is explained that driving the dye liquor in a single flow direction causes an uneven dyeing effect. To avoid such unwanted dyeing results, dyeing machine used to allow dye liquor flows through both inside-out and outside-in directions to obtain optimum even dyeing results

(8). Balmford and Moussalli explained that cotton yarns wound at a density of 450 g/dm^3 using the precision winding can be safely dyed without being disturbed (9). In the AATCC Symposium, Jackson emphasized that flow is the most important parameter affecting the quality of dyed yarn. Flow rates must be consistent for comparable yarns. If flow is insufficient, unlevel dyeing can result. Increasing the flow can sometimes reduce or eliminate unlevelness (10).

When dye houses and their dyeing processes were investigated, it was come out that some machine parameters and yarn (package) properties affected the dyeing results directly. Unfortunately, parameters such as pump rotation, circulation time, gradient of temperature, yarn number and package densities haven't been taken in to consideration for pretreatment and dyeing. Accordingly, dyeing experiments were used for seeing the effect of the parameters on dyeing results. It was applied statistical methods and models, the color differences (DE) could be predicted using parameters.

2. MATERIAL AND METHOD

In this work, 100 % combed conventional ring yarns producing the same lot of Aegean cotton fibers were spun on ring spinning machine (Rieter model G30) at different yarn count of Ne 30 (19.69 tex), Ne 40 (14.77 tex) and Ne 50 (11.8 tex) respectively. All yarns were spun with a suitable twist factor for woven fabrics and got one hundred sixty two (162) conventional ring packages with different yarn counts. After that they were wound to perforated plastic dye tubes (cones) according to principle of loose winding (package density; 350, 370 and 390 gr/dm^3) for obtaining soft dye packages under the mill conditions.

The cotton packages were dyed under laboratory conditions in a laboratory-type sample package-dyeing machine (Thermal HT) at 20:1 liquor ratio after suitable pre-treatment processes. For the pre-treatment processes at 96 ^oC, it was used 4 g/L sodium hydroxide, 1 g/L wetting and washing agent and 7.8 g/L anti-ion. In the dyeing experiments, the samples were dyed with vinylsulphone type C.I. Reactive Black 5 at 4 % owf dyestuff. The black dyeing was chosen to minimize the reflectance of the dyed packages. It were used 70 g/L sodium chloride (salt), the beginning condition, 1 g/L wetting and washing agent and 7.8 g/L anti-ion at the beginning condition (30 ^oC). Afterwards in dyeing condition (60 ^oC), 20 g/L soda (sodium carbonate) was added in the dyeing tank. 1 g/L detergent was used for washing. The pH was adjusted to 5-5.5 by 0.25 g/L acetic acid and 2 g/L avivage was used for finishing process. Conditions of washing and avivage processes are given Table 1 and dyeing diagrams are given in Figure 1. The dyed packages were dehydrated with a centrifugal hydro-extractor and dried with a high frequency drier.

Table 1. Conditions of washing and avivage packages

Last treatmant	Temperature (^oC)	Gradient (^oC/min.)	Time (min.)
Cold wash with running tap water	---	---	20
Heat washing	70	1.5	10
Boiling washing (1 g/L agent)	98	---	10
Heat washing	70	---	10
Cold wash with running tap water	---	---	30
Avivage (2 g/L) Acetic Acid (0.25 g/L) (pH 5-5.5)	50	---	25

In this study, both material parameters such as the yarn number, package density and machine parameters such as pump rotation, circulation time and gradient of temperature are investigated, since these parameters can affect the levelness of dyeing. In addition to this, details of these parameters are given in Table 2.

Yarn samples to be tested were taken from the internal and external parts of dyed packages. These two parts were compared with respect to color uniformity. Two reflectance measurements were performed on each sample package. The average of measurements was calculated as the reflectance values by the color measurement software and using in calculating the coordinates (L, a and b), DE and ΔL according to CIELAB (1976).

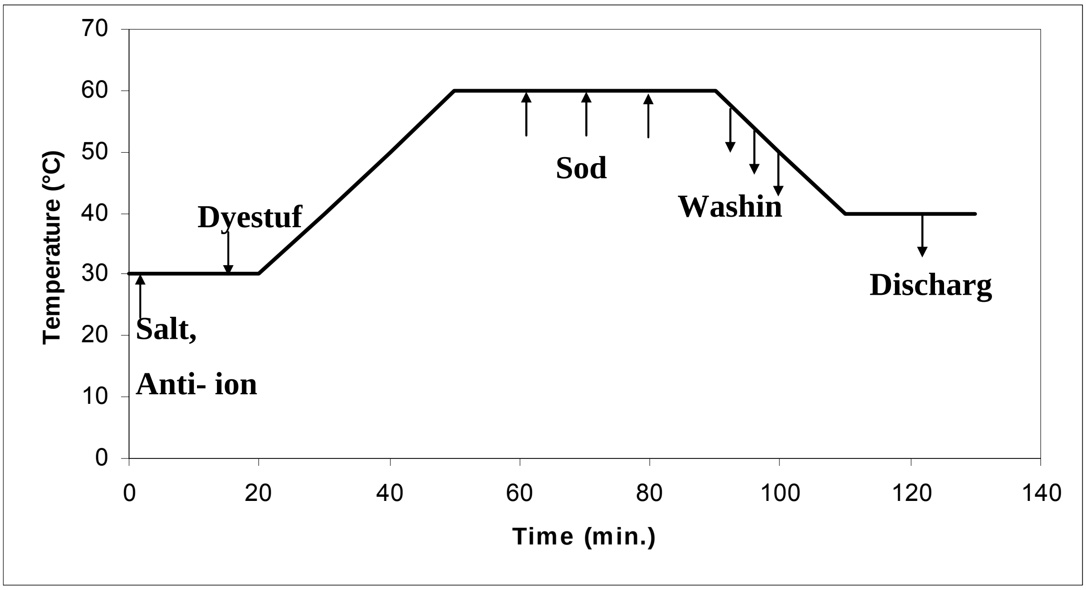

Figure 1. Reactive dyeing diagrams

Table 2. Details of dyeing parameters

Material Parameters		Machine Parameters			Number of Experiments
Yarn Number (Ne)	D: Package Density (g/dm^3)	P: Pump Rotation (Max: 2850 rpm)	G: Gradient ($^oC/min.$)	C: Circulation Time (in-out) (min.)	
30/1	350	1140, 1425, 1710	0.5, 1	4/6, 5/5, 6/4	18
	370	1140, 1425, 1710	0.5, 1	4/6, 5/5, 6/4	18
	390	1140, 1425, 1710	0.5, 1	4/6, 5/5, 6/4	18
40/1	350	1140, 1425, 1710	0.5, 1	4/6, 5/5, 6/4	18
	370	1140, 1425, 1710	0.5, 1	4/6, 5/5, 6/4	18
	390	1140, 1425, 1710	0.5, 1	4/6, 5/5, 6/4	18
50/1	350	1140, 1425, 1710	0.5, 1	4/6, 5/5, 6/4	18
	370	1140, 1425, 1710	0.5, 1	4/6, 5/5, 6/4	18
	390	1140, 1425, 1710	0.5, 1	4/6, 5/5, 6/4	18
				Total	**162**

Table 3. Model summary, Anova, Regression coefficients, t-values and significance level of t- values of our linear regression model for color difference (DE)

R	R Square (R^2)	Adjusted R Square	Std. Error of the Estimate	Anova	
				F	Sig.
0,927	0,860	0,855	0,2175	170,271	0,000

Independent variables					
	Count (Ne)	Density (D)	Gradient (G)	Circulation time (C)	Pump Rot. (P)
b*	-0,016	0,001696	0,149	0,07346	0,00002944
t	-7,252	4,736	2,090	3,457	0,382
Sig.	0,000	0,000	0,038	0,001	0,703

The reflectance of the samples was scanned over the range $400 \leq \lambda \leq 700$ nm in a spectrometer (Color Eye 3000, ICS-Texicon Co., U.S.A.) at intervals of $\lambda = 20$ nm with a Commission Internationale de l'Eclairage (CIE) standard illuminant D_{65} and an observer angle of 10^o. The standard illuminant D_{65} shows the relative spectral power distribution of day light with a color temperature of 6500 K. The spectral power distribution of daylight has been measured in a laboratory, and standard illuminant D_{65} is used to describe the color of a sample when illuminated by daylight.

Color difference (DE) between the internal, center and external parts of dyed packages with equation 1:

$$DE = \left[(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2\right]^{1/2} \quad (1)$$

Where L is the lightness, a is the chroma index on the red-green axis, and b is the chroma index on the yellow blue axis in the CIELAB color system [11].

The multiple regression method was selected for establishing the relationships between color difference and selected dyeing parameters (yarn number, package density, pump rotation, gradient value and circulation time). For this purpose, dyeing parameters are selected as independent variables and color difference is used as dependent variable in this analysis. The statistical test indicated that there was a scarcely linear relationship between package parameters and color differences. Therefore a linear multiple regression analysis method was chosen for our study in order to establish a quantitative relationship of color differences with respect to yarn count, package density, circulation time, pump rotation and gradient of temperature. Statistical analyses were performed using the SPSS 11.5 program.

3. RESULTS AND DISCUSSION

Table 3 shows model summary, anova results, the regression coefficient of variables, the t-values and significance level of each variable for color difference. Model's coefficient of multiple determination, and adjusted R^2 show that the predictive power of the model is high. Analysis of variance showed that equations were significant at the α = 0.01 significance level. A negative correlation was found between color difference and yarn count. While package density, circulation time and gradient of temperature are other parameters that can have a significant influence on color difference, the effect of pump rotation was insignificant influence on color difference.

$$DE=-0{,}016*Ne+0{,}001696*D+0{,}149*G+0{,}07346*C+0{,}00002944*P \quad (2)$$

According to model, while the yarn number increases, color difference (DE) values might be decrease. This case may cause decreasing of the yarn diameter and hairiness value of yarn. However, while the circulation time, gradient of temperature and circulation time increase, color difference (DE) values increase. Because, depend on pump rotation, increasing the package density (amount of the yarn in package) can be made difficult the circulation in dyeing treatment. Flow direction is controlled by a timer in the package dyeing machine. The setting will depend on the fiber, yarn properties, package density and machine systems. The outside-in flow must be set to run for more exposure time because the outside of the package is so much larger than the inside. Furthermore, according to equation 2, the circulation time from inside to outside flow must be chosen lower than time from outside to inside flow for suitable color difference values. If values of gradient decreases total dyeing time and cost of production increase in the textile dyeing processes. However, if it increases, color defects like as color difference are might be increase. The thesis is confirmed with our regression model.

Figure 2 shows the scatter plot of predicted values experimental values and regression line of our model for color difference.

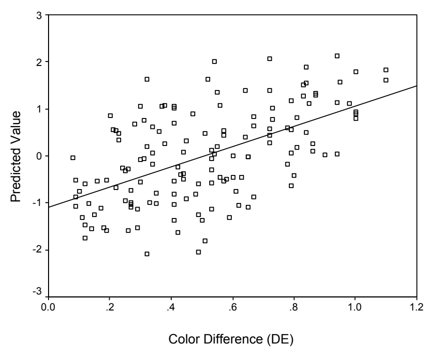

Figure 2. Experimental and predicted values of color difference (DE)

Table 4 shows model summary, anova results, the regression coefficient of variebles, the t- values and significance level of each variable for lightness difference. Similarly, a negative corelation

Table 4. Model summary, Anova, Regression coefficients, t-values and significance level of t-values of our linear regression model for lightness difference (ΔL)

R	R Square (R^2)	Adjusted R Square	Std. Error of the Estimate	Anova	
				F	Sig.
0,901	0,812	0,805	0,2292	120,102	0,000

	Independent variables				
	Count (Ne)	Density (D)	Gradient (G)	Circulation time (C)	Pump Rot. (P)
b*	-0,0155	0,001353	0,152	0,07904	0,00003937
t	-6,657	2,802	2,005	3,493	0,484
Sig.	0,000	0,006	0,047	0,001	0,629

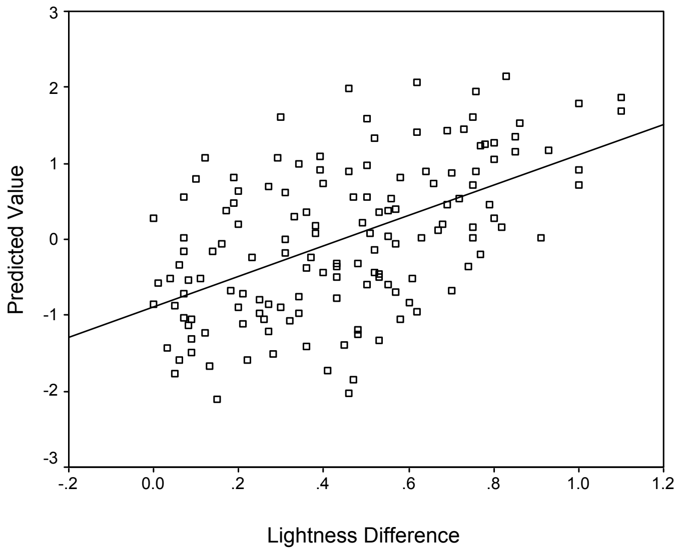

Figure 3. Experimental and predicted values of lightness difference (ΔL)

was found between lightness difference (ΔL) and yarn count. While package density, circulation time and gradient of temperature are other parameters that can have a significant influence on lightness difference, the effect of pump rotation was insignificant influence on lightness difference. Model's coefficient of multiple determination and adjusted R^2 show that the predictive power of the model is high enough.

(ΔL)= -0,0155*Ne+0,001353*D+0,152*G+ 0,07904*C+0,00003937*P (3)

According to model, while the yarn number increases, lightness difference (ΔL) values might be decrease. However, while the circulation time, gradient of temperature and circulation time increase, lightness difference (ΔL) increase. Figure 3 shows the scatter plot of predicted values experimental values and regression line of our model for lightness difference.

4. CONCLUSION

In the package dyeing process, color difference values are influenced by some material parameters (yarn number, package density) and machine parameters (pump rotation, circulation time and gradient of temperature). In this study, we tried to predict the color difference values of package with linear multiple regression analysis by using these parameters. Our models have good prediction performance. The regression coefficient R^2 values of our models are high and have greater significance.

It has been known that dyed yarns have used for shirt (checked, striped), skirt, pants and technical textile. Therefore, thick yarns usually have not been used at the yarn dyeing applications. It was estimated that packages winding with thick yarns could have been dyed easier and more uniform than thin yarns. However, results of dyeing and regression analysis indicated that color differences values of dyed packages winding with thin yarns were lower than thick yarns. This situation may be related on yarn surface and yarn diameter. If yarn number increases, hairiness and diameter decreases for cotton yarns. So, dye bath effect to yarns easier and more uniform. In addition to, package density is importantly effect on color difference. According to our model, if package density increased, color difference values increased since flow direction is forced. As another important result, circulation time from inside to outside and outside to inside flow must be set well according to some parameters such as type of fiber, yarn number and package density in the package dyeing.

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