(REFEREED RESEARCH)

COLOR MATCHING IN TWO COLOR MELANGE FIBER BLENDS BY STEARNS – NOECHEL MODEL

İKİ RENKLİ MELANJ ELYAF KARIŞIMLARINDA STEARNS-NOECHEL MODELİNE GÖRE RENK EŞLEME

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ABSTRACT

Melange color is a color effect obtained by mixing of fibers in different colors before the blend. One of the biggest problems encountered in the work of mélange colors in textile is that, not accurate estimation of fiber colors provides desired color. In this study estimating the mélange color pre-production, yellow, red and blue colors used in the viscose and polyester fibers. These fibers in different ratios and two colors mixed and 165 mélange-colored bands were obtained. Color values of these bands, measured in the spectrophotometer were expressed in CIELab 1976 (D65 illuminant and 10o standard observer) unit. Stearns – Noechel model has been the basis for color forecasting. To calculate the model M, in the coefficient, a new approach was developed. A different M coefficient was calculated for all wavelengths in each mix, 400-700 nm (10nm intervals) range. The color calculations are performed, using the M coefficients. The average color difference between the measured color values and calculated color values was found as 1.15 CIELab units. This result suggests that in the fiber blend estimating the colors of the Stearns - Noechel model might be a sufficient result.

Key Words: Melange, reflectance, Viscose, Polyester, Color, Stearns-Noechel.

ÖZET

Melanj renk, farklı renklerdeki liflerin harmandan önce karıştırılması ile elde edilen bir renk efektidir. Tekstilde melanj renk çalışmalarında karşılaşılan en büyük problemlerden birisi istenilen rengi sağlayacak elyaf renklerinin doğru tahmin edilememesidir. Bu çalışmada, melanj rengin üretim öncesi tahmin edilebilmesi için sarı, kırmızı ve mavi renklerde viskon ve polyester elyafı kullanılmıştır. Bu elyaflar farklı oranlarda ve iki renkli olmak üzere karıştırılmış ve 165 adet melanj renkli şerit elde edilmiştir. Bu şeritlerin spektrofotometrede ölçülen renk değerleri CIELab 1976 (D65 illuminant ve 10o standart gözlemci) biriminde ifade edilmiştir. Renk tahmini için Stearns-Noechel modeli esas alınmıştır. Modeldeki M katsayısının hesaplanması için yeni bir yaklaşım geliştirilmiştir. Bu yaklaşım sonucu her karışımda, 400-700nm (10nm aralıklarla) aralığındaki bütün dalgaboyları için farklı bir M katsayısı hesaplanmıştır. Bulunan M katsayıları kullanılarak renk hesapları yapılmıştır. Ölçülen renk değerleri ile hesaplanan bu renk değerleri arasındaki ortalama renk farklığı 1.15 CIELab birimi olarak bulunmuştur. Bu sonuç elyaf karışımlarında Stearns – Noechel modelinin renk tahmininde yeterli sonuçları verebileceğini göstermektedir.

Anahtar Kelimeler: Melanj, Reflektans, Viskon, Polyester, Renk, Stearns-Noechel.

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1. INTRODUCTION

Melange color studies, widely used and have an important place in textile industry has come to the fore with different effects and widely used. Melange is a variety of effects derived from a different color mixture of fiber colors, uncertain multi-tone. Place of use of fabrics, mélange colored yarn, depending on fashion are increasing. Knitting, tricoting and weaving are often used in these fields.

To produce colored mélange products, fibers in different colors before the blend is mixed and then mixed the color effect are achieved. In this mixture, one of the biggest problems is not obtaining desired color of mélange. Estimating the color of colored fibers in the mix for given the color standards will provide a huge benefit for the textile industry.

Kubelka - Munk theory is widely used to describe the color of fabric and tens of different commercial software applications. However, in the estimating of the color of the mélange-colored fibers, the desired results can not be taken, by this theory (1). Therefore, many scientific studies have been done on this issue to describe the behavior of color the fibers in the mélange of color mixing using various experimental and quasi experimental methods. Stearns – Noechel model is one of the most important of these studies.

In this study, a new method was developed to predict the fiber colors of the Stearns – Noechel used model for calculating the coefficient of M, in the mélange-colored fiber blends. For each mixture, obtained with M coefficients depending on the wavelength and color value of 165 polyester and viscose mélange of colorful band studied to be estimated. Reflectances of prepared 165 bands were measured in spectrophotometer. Then M coefficients are determined the result closest to the measured reflectance values using the Stearns – Noechel model. Measurement results has been tested using CIELab 1976 (D65 illuminant and 10^o standard observer) color difference formula.

Stearns – Noechel Model

Stearns and Noechel developed a model for fine mixed wool in published research in 1944. In this model, the M coefficient was found at 0:15 (2) (Equation 1).

$$F(R)=\frac{1-R}{\left[M(R-0.001)+0.01\right]} \quad (1)$$

Here “R” is reflectance; “M” is the dimensionless constants.

Davidson and Taylor by mixing black and white acrylic fibers in solution dyed, found the M coefficient in Stearns - Noechel model most suitable as a 0.25 (3). In his study, Burlone, comparing the some mix of fibers by mathematical perspective, proposed color matching equations and found M coefficient in Stearns - Noechel model as 0.11 for nylon fibers (4). Aspland and Zhou tried to estimate a mixture of black and white colors of polyester fibers and proposed M coefficient in Stearns - Noechel model as 0.189 (5). Rong and Feng, in studies, used Stearns - Noechel model and proposed a new method to calculate the M empirical constants. With this method, they found M constant as 0.09 and used as a constant value (2). Philips has developed a new formula for calculating M coefficient in Stearns - Noechel model by the statistical analysis. In the formula M constant as linear depend on wavelength as shown Equation 2 (6).

$$M=\frac{1}{1000}(0.12\lambda+42.75) \quad (2)$$

λ = Wavelength; nm units.

$$F(R_{mix,\lambda})=\sum_i x_i F(R_{i,\lambda}) \quad (3)$$

$$\sum_i x_i = 1 \quad (4)$$

Here,

***$R_{mix,\lambda}$*:** color reflectance of the mixture prepared according to wavelength,

***x_i*:** ith fiber mixture ratio (in terms of fractions)

Equation 5 in this study, the assumption of the hypothesis is to be used for two-color mixing.

$$F(R_{mix})=x_1F(R_1)+x_2F(R_2) \quad (5)$$

Also, the fiber mixture ratio of the total must be equal to 1.

$$x_1+x_2=1$$

Coefficient M

The study, a new approach was found for calculation of M dimensionless coefficient used in Equation 1, different from literatures. In the studies, the M coefficient was accepted a constant value regardless of mixing and color. In this study, for every color and every mixture, every 10nm increasing between 400-700nm wavelengths a separate coefficient of M, was accepted. M coefficients was changed in each wavelength with an increase of 0.0001 between 0.0001 and 2, F(R) function was calculated by replacing each M value in Equation 1. Thus, Equation 1, for each mixture and each color, 20000 times was calculated. This function of the R-value for each color, pre-measured and defined, is a constant value. For each mixture, including the same wavelength, the calculated F(R) values replacing in Equation 5 F(R_{mix}) function of the mixture is calculated. From 400nm to 700nm up for each wavelength, the selected value for M, the value of RSS1 (Residual Sum of Squares) is calculated by correlation between ratio of mixture and calculated F(R_{mix}) value. Then RSS2 (Residual Sum of Squares) is calculated by correlation between F(R_{mix}) value as measured directly from a mixture and ratio of mixture. Calculate the average of these two values (Equation 6).

$$Average=\frac{RSS1+RSS2}{2} \quad (6)$$

In these values, the smallest average value of M which, as the current M value, is recorded. F(R) is calculated with saved M coefficients, using Equation 1.

Tristimulus Values

To express the color as numerically; light source, object and observer should be defined as numeric. Light source, with the values Spectral Energy Distribution (SED), the properties of objects, % reflectance values and the properties of the Standard Observer is defined as color matching functions (color-sensitivity values) (7).

$$X=k\sum_{400}^{700}E_\lambda \bar{x}_\lambda R_\lambda \quad (7)$$

$$Y=k\sum_{400}^{700}E_\lambda \bar{y}_\lambda R_\lambda \quad (8)$$

$$Z=k\sum_{400}^{700}E_\lambda \bar{z}_\lambda R_\lambda \quad (9)$$

Here,

X, Y, and Z: tristimulus values of the color

$\bar{x}_\lambda, \bar{y}_\lambda$ *ve* $\bar{z}_\lambda$:Standard observer values (fixed)

E_λ :SED values of the light source (constant)

R_λ :Reflectance value (in terms of fractions)

k :Normalizing factor.

$$k=\frac{100}{\sum E_\lambda \bar{y}_\lambda} \quad (10)$$

“λ”, suggests that these values change the depending the wavelength.

CIELab System

CIE (Commission Internationale de l'Eclairage, International Lighting Commission) has defined a system that was calculated from tristimulus values X, Y and Z in 1976, in the form of three-coordinate as L *, a * and b and is called CIELab system (8). L * describes brightness, a * describes red-green, b * describes yellow-blue, with C *describes a point distant from the neutral point, the color saturation (vitality), the rotation speed h is used to the color tones.

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$$L^* = 116(Y/Y_n)^{1/3} - 16 \qquad Y/Y_n > 0.008856 \qquad (11)$$

$$a^* = 500\left[(X/X_n)^{1/3} - (Y/Y_n)^{1/3}\right] \qquad X/X_n > 0.008856 \qquad (12)$$

$$b^* = 200\left[(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}\right] \qquad Z/Z_n > 0.008856 \qquad (13)$$

If value is equal to or less then 0.008856 the following formula applies:

$$L^* = 903.3(Y/Y_n) \qquad Y/Y_n \leq 0.008856 \qquad (14)$$

Calculating of a * and b * values is done with the help of the following formula in case of X/X_n, Y/Y_n, Z/Z_n equal or less than 0.008856.

$$a^* = 500[f(X/X_n) - f(Y/Y_n)] \qquad (15)$$

$$b^* = 200[f(Y/Y_n) - f(Z/Z_n)] \qquad (16)$$

Here,

$$f(X/X_n) = 7.787(X/X_n) + 16/116 \qquad X/X_n \leq 0.008856 \qquad (17)$$

$$f(Y/Y_n) = 7.787(Y/Y_n) + 16/116 \qquad Y/Y_n \leq 0.008856 \qquad (18)$$

$$f(Z/Z_n) = 7.787(Z/Z_n) + 16/116 \qquad Z/Z_n \leq 0.008856 \qquad (19)$$

X_n, Y_n and Z_n are tristimulus values of light source used in measurement and fixed (9).

Color Differences

Color difference denominated in units of CIELab, is calculated using the following formula (10):

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \qquad (20)$$

Here Δ shows the difference.

2. EXPERIMENTAL STUDY

2.1. Materials

In the study; as material colors of, yellow, red and blue types of viscose and polyester fibers was used. The properties of these fibers are given in Table 1.

Table 1. Fiber properties

Colors	Viscose Fiber			Polyester Fiber		
	Finesse	Length	Label	Finesse	Length	Label
Blue	1,7 dtex	40 mm	Lenzing	1.7 dtex	38 mm	Sasa
Red	1.7 dtex	38 mm	Lenzing	1.7 dtex	38 mm	Sasa
Yellow	1.7 dtex	40 mm	Lenzing	1.7 dtex	38 mm	Sasa

2.2. Preparation of mixed fiber

Fiber blends was built with the device Trash Analyser with Microdust SDL MDTA Rotor Attachment 3. To obtain a homogeneous color, fiber has been spent 3 times in the machine. The weight of each mixture of fiber, 5 grams. Viscose and polyester fibers, with different colors binary mixture, blend in 15 total 165 pieces of colorful band, were obtained (Table 2). Mixture ratio ranges were identified as (0, 10, 20, ..., 100) (Table 3).

Table 2. Prepared blends

Blend Number	Mixture Code	Mixture Name	Number of Mixture (Item)
1	PV_RB	Red Polyester / Blue Viscose	1……11
2	PV_RY	Red Polyester / Yellow Viscose	1……11
3	PV_RR	Red Polyester / Red Viscose	1……11
4	PV_BB	Blue Polyester / Blue Viscose	1……11
5	PV_BY	Blue Polyester / Yellow Viscose	1……11
6	PV_BR	Blue Polyester / Red Viscose	1……11
7	PV_YB	Yellow Polyester / Blue Viscose	1……11
8	PV_YY	Yellow Polyester / Yellow Viscose	1……11
9	PV_YR	Yellow Polyester / Red Viscose	1……11
10	PP_RY	Red Polyester / Yellow Polyester	1……11
11	PP_RB	Red Polyester / Blue Polyester	1……11
12	PP_BY	Blue Polyester / Yellow Polyester	1……11
13	VV_RY	Red Viscose / Yellow Viscose	1……11
14	VV_RB	Red Viscose / Blue Viscose	1……11
15	VV_BY	Blue Viscose / Yellow Viscose	1……11
		Total	**165**

R: Red **B:** Blue **Y:** Yellow **V:** Viscose **P:** Polyester

Table 3. Fiber mixture ratio

Fiber Type	Fiber Ratios in the Mixture (%)										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1. Fiber	0	10	20	30	40	50	60	70	80	90	100
2. Fiber	100	90	80	70	60	50	40	30	20	10	0

2.3. Color Measurement

In color measurement of prepared mélange colorful stripes, the Minolta 3600 D spectrophotometer was used. From 30 points (10 nm each between 400nm and 700 nm) reflectance values were measured and recorded. Reflectance brightness component (specular component) is included. In measurements, representative the sample was sensitive. For example, during the measurement non-strict protruding fibers are used. To ensure sufficient accuracy 25.4 mm which was the largest measuring range in spectrophotometer was chosen. In experimental, glass was not used to keep samples or cover. For all measured samples, from different regions, at least 10 reads were taken at random and carefully until the color difference, <0.2 CIELab 1976 (D65 light source and observer 10^o). Measurements that are larger than 0.2 (CIELab 1976) between the measured values and the average of previously measured of color difference have not been evaluated. The averages of the other values were recorded as correct reflectance values.

3. RESULTS

To achieve optimum results in the equation Noechel depends on M coefficient. In study, according to new method developed a to calculate the M coefficient, for each mix; a separate M coefficient was calculated in each wavelength (Table 4)

Table 4. Calculated M coefficients

WL	Blend Number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
400	0.212	0.308	0.842	0.481	0.463	0.158	0.187	0.224	0.846	0.178	0.746	0.126	0.252	0.114	0.114
410	0.150	0.366	0.111	0.251	0.339	0.031	0.197	0.278	0.229	0.183	0.281	0.202	0.292	0.814	0.337
420	0.146	0.157	0.126	0.380	0.254	0.672	0.109	0.415	0.275	0.187	0.286	0.822	0.131	0.211	0.369
430	0.668	0.371	0.092	0.501	0.206	0.439	0.069	0.447	0.907	0.103	0.317	0.623	0.770	0.727	0.094
440	0.889	0.002	0.326	0.235	0.249	0.170	0.497	0.430	0.149	0.255	0.325	0.224	0.760	0.785	0.035
450	0.223	0.147	0.296	0.104	0.327	0.357	0.175	0.417	0.972	0.203	0.350	0.203	0.845	0.789	0.109
460	0.314	0.375	0.002	0.258	0.136	0.691	0.173	0.119	0.964	0.166	0.347	0.119	0.272	0.087	0.034
470	0.361	0.138	0.375	0.156	0.363	0.103	0.172	0.191	0.307	0.173	0.344	0.198	0.782	0.267	0.182
480	0.305	0.202	0.257	0.328	0.248	0.022	0.179	0.304	0.276	0.189	0.434	0.220	0.792	0.363	0.085
490	0.170	0.024	0.327	0.299	0.316	0.353	0.184	0.265	0.223	0.168	0.211	0.144	0.994	0.026	0.021
500	0.179	0.142	0.474	0.023	0.782	0.545	0.165	0.241	0.200	0.148	0.127	0.129	0.780	0.380	0.102
510	0.353	0.228	0.024	0.201	0.659	0.454	0.159	0.246	0.200	0.144	0.451	0.128	0.110	0.268	0.197
520	0.415	0.209	0.251	0.226	0.200	0.366	0.159	0.257	0.200	0.141	0.587	0.130	0.387	0.308	0.297
530	0.122	0.192	0.052	0.359	0.116	0.177	0.161	0.268	0.200	0.138	0.664	0.133	0.410	0.015	0.019
540	0.158	0.136	0.532	0.524	0.359	0.303	0.161	0.272	0.200	0.132	0.337	0.136	0.556	0.068	0.164
550	0.556	0.572	0.507	0.633	0.209	0.603	0.162	0.271	0.200	0.131	0.243	0.138	0.352	0.336	0.171
560	0.575	0.137	0.529	0.415	0.165	0.583	0.163	0.272	0.200	0.130	0.134	0.141	0.425	0.021	0.410
570	0.496	0.186	0.000	0.213	0.163	0.729	0.165	0.278	0.200	0.129	0.451	0.144	0.380	0.251	0.408
580	0.235	0.187	0.488	0.754	0.161	0.537	0.167	0.283	0.218	0.131	0.235	0.145	0.286	0.129	0.044
590	0.216	0.183	0.867	0.237	0.341	0.215	0.169	0.607	0.583	0.190	0.195	0.146	0.776	0.030	0.043
600	0.200	0.192	0.073	0.253	0.339	0.054	0.173	0.387	0.450	0.135	0.174	0.149	0.060	0.073	0.027
610	0.186	0.393	0.854	0.260	0.155	0.055	0.176	0.498	0.703	0.138	0.161	0.150	0.058	0.074	0.447
620	0.185	0.344	0.845	0.471	0.515	0.057	0.178	0.893	0.846	0.194	0.153	0.150	0.063	0.079	0.380
630	0.185	0.332	0.898	0.867	0.331	0.056	0.181	0.459	0.473	0.103	0.150	0.149	0.066	0.083	0.451
640	0.188	0.324	0.788	0.842	0.119	0.055	0.184	0.204	0.436	1.305	0.145	0.147	0.068	0.085	0.389
650	0.192	0.330	0.745	0.754	0.441	0.056	0.190	0.378	0.462	0.183	0.144	0.147	0.072	0.087	0.455
660	0.196	0.334	0.924	0.718	0.216	0.058	0.192	0.703	0.440	0.120	0.144	0.146	0.076	0.089	0.265
670	0.202	0.344	0.655	0.689	0.211	0.061	0.197	0.245	0.957	1.830	0.144	0.146	0.080	0.091	0.044
680	0.207	0.356	0.877	0.678	0.161	0.064	0.201	0.355	0.470	0.182	0.146	0.147	0.085	0.094	0.407
690	0.216	0.363	0.856	0.568	0.158	0.066	0.206	0.470	0.429	0.193	0.146	0.146	0.089	0.097	0.366
700	0.242	0.379	0.759	0.396	0.546	0.067	0.225	0.454	0.474	0.193	0.148	0.146	0.093	0.101	0.282

WL: Wavelength (λ ; nm)

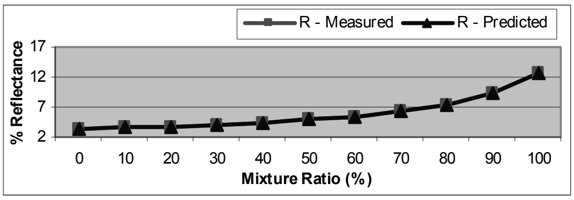
Between the measured and calculated M coefficients of the prepared mixtures of fiber and the predicted reflectance values, % error of the average are given in Table 5. The mixture of the highest average% error is a mixture the yellow polyester / yellow viscose (PV_YY) with 6.3464 (average wavelength). The mixture of the lowest average error % is a mixture of a red polyester / blue viscose (PV_RB), with 1.0167. In general, the differences between measured and calculated reflectance values were low up.

Table 5. According to the wavelength of the fiber blend between the measured and predicted reflectance values of the mean value of errors%

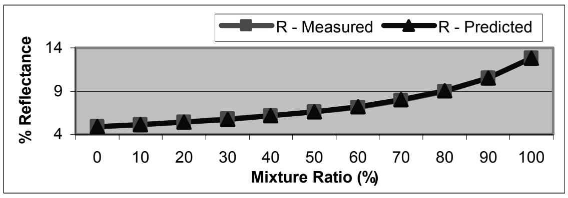
WL	% Error Mean Values According to Harman Type														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
400	0.923	6.753	1.580	0.649	1.555	1.260	7.190	1.349	7.847	4.115	3.083	1.001	0.848	1.346	1.096
410	0.600	7.411	2.183	0.607	1.791	1.172	3.284	13.072	4.685	2.299	2.571	4.923	0.534	0.975	2.065
420	0.957	6.536	2.548	0.605	2.145	1.364	4.518	6.930	4.036	1.482	1.948	1.432	0.573	1.222	4.140
430	0.819	4.983	2.019	0.599	2.275	1.308	4.928	3.805	4.483	2.021	1.243	1.235	0.502	1.590	4.280
440	0.588	3.189	0.923	0.582	2.631	1.566	4.844	2.553	4.700	1.760	1.142	1.424	0.479	1.040	3.575
450	0.620	1.479	0.827	0.563	2.271	1.444	5.210	2.186	4.761	1.690	1.034	1.475	0.582	0.840	2.494
460	0.689	0.575	0.756	0.716	1.923	1.592	4.724	2.232	4.740	1.366	1.336	1.465	0.869	0.840	1.434
470	0.740	0.463	0.726	0.842	1.672	1.660	4.940	2.509	4.960	1.788	1.987	1.849	0.809	0.979	0.851
480	0.826	1.068	1.059	0.656	1.213	1.428	6.789	1.672	11.047	1.179	1.466	8.280	1.147	1.060	1.164
490	1.245	1.606	0.982	0.839	1.380	1.779	1.585	1.268	2.325	0.574	1.588	0.920	1.058	0.973	1.732
500	1.188	1.480	1.612	0.768	1.750	1.510	1.283	1.229	2.385	0.561	0.954	1.012	0.674	1.151	1.943
510	1.741	1.423	1.161	0.951	1.585	1.846	1.159	1.289	2.753	0.549	1.206	1.134	0.743	1.181	1.320
520	1.442	1.288	0.482	1.332	1.670	2.051	1.264	1.345	2.641	0.620	1.008	1.165	1.755	1.127	1.097
530	0.918	1.388	1.087	1.846	1.248	2.435	1.400	1.220	2.603	0.679	1.555	1.307	2.770	0.938	0.827
540	0.811	1.523	1.441	1.471	1.234	2.140	1.413	1.193	2.753	0.803	1.698	1.264	3.050	1.125	1.075
550	1.429	1.669	1.817	1.055	1.187	1.751	1.388	1.232	2.800	0.800	2.440	1.269	3.017	1.187	1.413
560	2.495	1.688	3.370	1.514	1.202	2.027	1.427	1.363	2.559	0.941	2.901	1.349	3.727	1.035	1.995
570	5.542	1.129	8.174	1.970	1.282	2.129	1.672	1.454	1.948	1.105	4.522	1.470	4.446	1.354	2.781
580	0.546	0.538	0.547	1.928	1.233	1.197	1.932	1.619	1.020	1.305	0.502	1.552	1.417	2.191	3.107
590	0.589	0.554	2.048	1.659	1.139	3.380	1.901	13.998	3.344	9.364	0.475	1.519	0.662	6.654	3.112
600	0.713	2.787	1.430	2.780	1.479	0.941	2.079	13.523	7.764	3.613	0.629	1.726	0.543	1.138	4.295
610	0.677	0.470	1.321	2.945	1.286	0.871	2.111	13.395	8.927	1.184	0.729	1.732	0.647	1.193	4.551
620	0.589	0.500	2.239	3.597	1.319	0.940	2.069	13.146	8.601	0.508	0.667	1.739	0.629	1.190	4.948
630	0.716	0.516	2.526	4.580	1.161	0.948	2.108	12.600	8.329	0.726	0.739	1.732	0.608	1.202	5.564
640	0.619	0.524	1.872	4.400	1.180	0.950	1.988	12.464	8.415	0.848	0.614	1.558	0.667	1.243	5.712
650	0.801	0.543	0.451	6.023	1.220	0.825	2.115	11.912	7.920	0.935	0.690	1.685	0.679	1.301	6.448
660	0.592	0.533	1.484	6.652	1.254	0.894	1.871	11.839	6.320	0.953	0.659	1.555	0.850	1.523	6.385
670	0.638	0.533	2.951	6.064	1.337	1.185	1.975	11.484	4.533	0.954	0.594	1.558	1.275	1.815	6.139
680	0.552	0.518	3.820	5.499	1.248	1.432	1.786	11.210	3.114	0.939	0.666	1.674	1.671	2.152	6.022
690	0.480	0.531	4.158	4.938	1.366	1.726	1.677	11.041	2.295	0.950	0.616	1.616	2.114	2.448	4.914
700	0.434	0.528	4.102	2.964	1.254	1.898	1.647	10.600	1.909	1.003	0.597	1.543	2.398	2.703	2.598

WL: wavelength (λ ; nm)

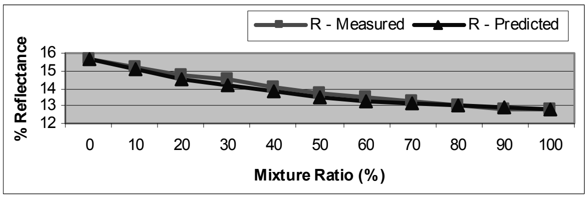
For 15 prepared blends reflectance values measured by spectrophotometer and calculated M coefficients predicted reflectance values were compare in Figure 1. In all graphs it is seen that results which are very close friends of the measured reflectance values can be estimated.



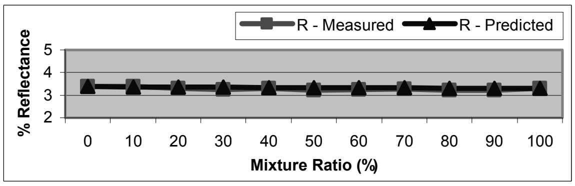
Red Polyester / Blue Viscose



Red Polyester / Yellow Viscose



Red Polyester / Red Viscose



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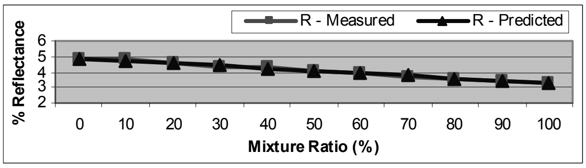

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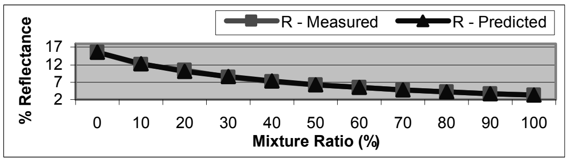
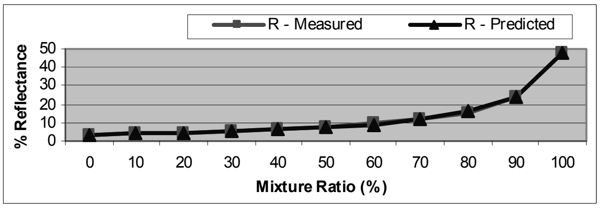
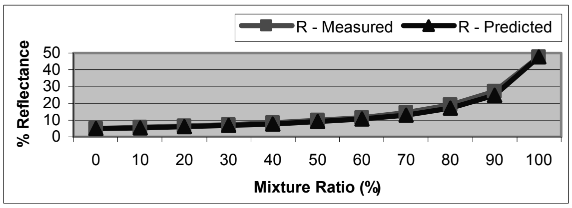


Blue Polyester / Red Viscose



Yellow Polyester / Blue Viscose



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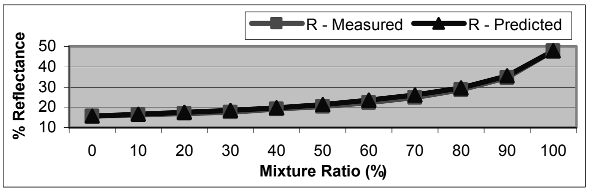
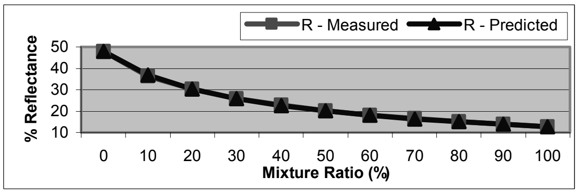
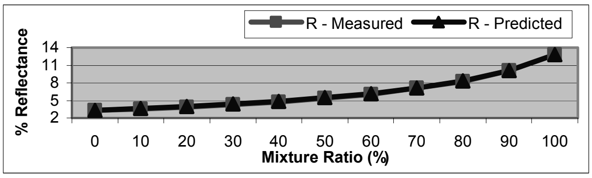


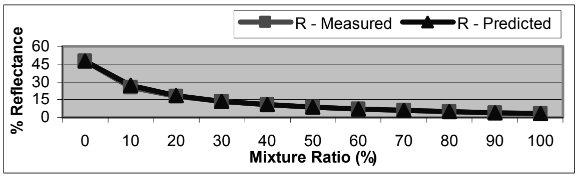
Yellow Polyester / Red Viscose



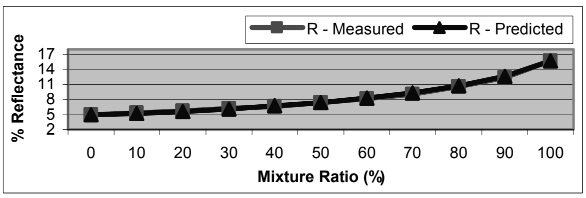
Red Polyester / Yellow Polyester



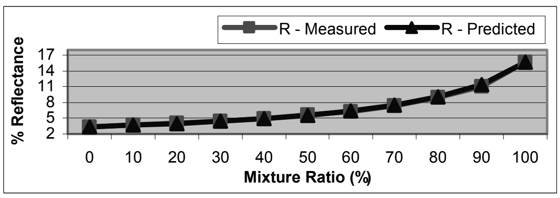
Red Polyester / Blue Polyester



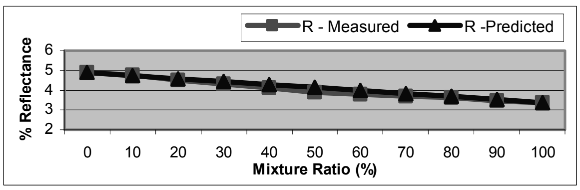
Blue Polyester / Yellow Polyester



Red Viscose / Yellow Viscose



Red Viscose / Blue Viscose



Blue Viscose / Yellow Viscose

Figure 1. Comparing to measured and predicted reflectance values of mixtures

Color differences was calculated using the formula CIELab 1976 (D65 illuminant and 10° standard observer). By using measured reflectance values and M coefficients in Table 4, color differences (ΔE) between the equation Stearns – Noechel and calculated reflectance values are shown in Table 6. Moreover, color information as L *, a *, b *, C * and h is given. It is observed that in PV_RY, PV_BY, PV_YY and PP_RY mixture color becomes dark; in other mixtures it becomes light. In PV_BR, PV_YB, PV_YY, PP_RY, PP_RB and VV_RY mixtures, the color were shifted from red to green while the other mixtures were shifted from green to red. In all blends; colors shifted from blue to yellow on average**.** In addition, color saturation, a slight increase has occurred. Average difference between measured and estimated total color values is a unit of ΔE = 1.1505 CIELab. The highest difference was obtained from the unit ΔE = 4.4052 CIELab and a yellow polyester / yellow viscose (PV_YY) mixture. The color differences in other blends of polyester used yellow were higher. In mixtures, in general, ΔE was less than 1 out which can be accepted as the limit.

Table 6. The average values of difference between measured and calculated color values of fiber blends

Mixture Name	The average value of color differences					
	ΔL*	**Δa***	**Δb***	**ΔC***	**ΔH**	**ΔE**
PV_RB	0.0669	0.0585	0.2582	-0.1258	0.2210	0.3279
PV_RY	-0.1678	0.4297	-0.8296	-0.3086	0.8466	0.9589
PV_RR	0.2706	0.2291	0.3055	0.3221	0.2142	0.4965
PV_BB	0.2109	0.2014	0.2629	-0.2270	0.2411	0.4113
PV_BY	-0.0367	0.4045	-0.4687	-0.3158	0.3656	0.6664
PV_BR	0.1020	-0.3233	-0.0422	-0.3113	0.0963	0.4561
PV_YB	0.2639	-0.2674	1.5597	1.1484	0.6242	1.7328
PV_YY	-0.9790	-3.6254	-2.0843	-1.4851	3.9106	4.4052
PV_YR	0.4787	3.1900	1.5485	3.1145	1.6691	3.6589
PP_RY	-0.2349	-0.4564	-0.0326	-0.1610	0.4372	0.8768
PP_RB	0.2154	-0.1772	-0.0156	-0.1797	0.0907	0.3268
PP_BY	0.3120	0.0228	0.4383	0.4660	0.2528	0.6845
VV_RY	0.1673	-0.4185	0.4013	-0.0734	0.5666	0.6297
VV_RB	0.0038	0.3976	-0.0569	0.3318	0.2122	0.4772
VV_BY	0.2241	1.0793	-0.1460	-0.1253	1.0602	1.1479

P: Polyester **V:** Viscose R**:** Red Y**:** Yellow B**:** Blue

4. CONCLUSION

In study, the Stearns – Noechel model was based on and a new method was developed for calculating the M coefficient in the model. M coefficients calculated with this new method were used for estimating the color of 165 unit mélange-colored band. The coefficient of M in Stearns – Noechel model depends on the final color of the mixture. Previous studies were usually made calculating only one M coefficient. In this study, the M coefficient was calculated separately for each mixture and each wavelength. By calculating the color difference between measured color values and estimated color values based on new method, were expressed CIELab 1976 (D65 light source and observer 10°). Average color difference is 1.15 CIELab units. This result shows that the new method, developed for calculating the coefficient M in Stearns - Noechel model, in the mélange of color mixing, and can estimate the color values in sufficient accuracy.

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