CORRECTION OF COLOUR VALUES OF WOVEN FABRICS USING CHANGES TO CONSTRUCTIONAL PARAMETERS

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Abstract

In practice it happens very frequently that yarn of certain fineness, which creates desired colour effect on the woven fabrics surface, is not available. In consequence an available yarn of different fineness has to be used instead, which can be observed on the woven fabrics as a colour deviation compared with the desired effect. The aim of this research is the possibility of colour values corrections of woven fabrics by changes of constructional parameters. Simulations of woven fabrics are used for this purpose. In the case described weft the yarn of higher fineness is substituted by the yarn of lower fineness and equal colour values. Three possible ways of colour values correction by changes of constructional parameters of the woven fabric are presented. In the first case, the colour difference is corrected by increase of the weft threads density, the second way of correction consists in the change of warp yarn fineness, and the third in decreasing of warp threads density. The basic purpose of all the three types of correction is the equally change of warp and weft contents in one colour rapport of the woven structure. In the experimental part of our work, the colour values L, a* and b*, and colour differences DE*ab are investigated theoretically (using calculations on the basis of theoretical defined fractions, and L*, a*, and b* values of yarns), as well as spectrophotometrically, on the basis of printouts of simulations of woven fabrics prepared with the use of Arahne CAD system. Two ways of determination of colour values of simulations and three types of corrections are evaluated in the conclusions. It was find out that the correction with the increase of weft thread density is the most successful, and the DE*ab values are minimal.*

Keywords

colour correction, colour differences colourimetry, woven fabric, constructional parameters

1. Introduction

Usage of colorimetry in the textile industry has improved the quality and precision of dyers' and printers' work. More objective estimation has minimised misunderstandings between the manufacturers of textiles and their clients. Unfortunately colorimetry is much less used when fabrics are made of multicolour threads than when yarns and fabrics are dyed or printed. When multicolour threads are used for patterning, the particular colour effects of a woven fabric depend on combinations of thread colours and must be measured. Moreover, the constructional parameters of woven structure, namely thread density, fineness and weave, can strengthen or reduce the colour effect on the surface [1].

When two or more colour threads are used in warp and weft pattern, the colour effect of the entire fabrics is caused by optical mixing of light reflected from the surfaces of warp and weft threads and by the influence of foundation. In this case, optical mixing can be just partly explained as additive colour mixing, because the colour surfaces are not light emitting objects, but only its converters [2].

Moreover, the relation between the colour values of different colours and their size must be carefully considered. When two colours are placed close to each other, their influence can be explained by the terms of contrast and harmony. The differences between colours are explained by the contrast. Quantitative contrast means that the size of the two colour surfaces are different, and as a consequence the contribution of reflected light from different areas differ from each other. We can find this type of contrast on the woven structures, where, the surface of warp threads differ from weft threads surface due to different density and fineness. Taking into account colour values of warp and weft, the most interesting are complementary colour contrasts and colour harmony. Complementary colours lie on the opposite side of the colour circle, and their sum of reflected light give an unsaturated colour, which can be observed as a greyish hue on the fabric. On the other hand, the close position of two harmonic colours of similar colour values, on the instant pour into one colour effect by visualisation [3, 4].

However, when differently coloured threads with the contribution of changes to constructional parameters give uniform colour values to the entire fabric surface, the usage of colorimetry may contribute considerably to improving the quality of products, which in turn would result in a reduced number of claims [5].

The aim of this research is to enable corrections to colour values of woven fabrics by changing the constructional parameters. It was assumed that when a yarn of a certain fineness was not available, it was substituted with a yarn of lower fineness. The different thread fineness caused colour deviations between two fabrics, and to this end our experimental work aimed to find out whether the changes of other constructional parameters (density) could correct differences in colour effects on fabric surfaces.

2. Theoretical Part

2.1. Theoretical Calculation of Colour Values of a Fabric Made of Differently Coloured Threads

The warp and weft threads' interlacing point can be divided into three surfaces which differ in colour and construction: the warp thread surface, the weft thread surface and the spacing between the threads, as shown in Figure 1 [1].

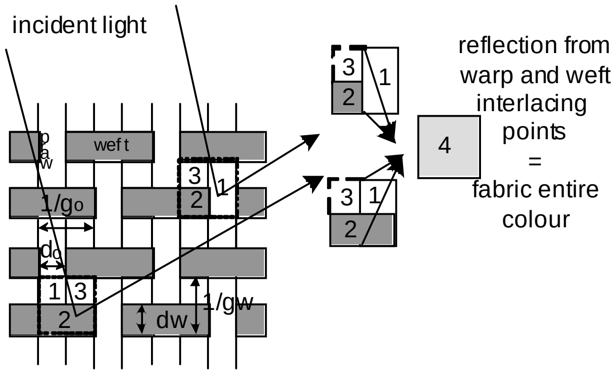

Figure 1. Schematic view of a fabric with individual colour surfaces of warp – 1, weft – 2, inter-thread spacing – 3, and final colour effect of the woven fabric - 4

On the basis of the thread diameter , the thread density and the weave, the fractions of individual colour threads in the pattern are calculated by using the following equation [2]:

$$Ui = \frac{u_{on,ot} \cdot n_{ot,oi} + u_{on,wt} \cdot n_{wt,oi}}{n_{oi}} + \frac{u_{wn,ot} \cdot n_{ot,wi} + u_{wn,wt} \cdot n_{wt,wi}}{n_{wi}} \qquad (1)$$

where n is the number of all points in a colour repeat; $u_{on,ot}$ is the content of the warp thread colour in the warp interlacing point; $n_{ot,oi}$ is the number of the warp points on i colour warp threads; $u_{on,wt}$ is the content of the warp thread colour in the weft interlacing point; $n_{wt,oi}$ is the number of the weft points on i colour warp threads; n_{oi} is the sum of the warp and the weft points on i colour warp threads = $n_{ot,oi}+n_{wt,oi}$; $u_{wn,ot}$ is the content of the weft thread colour in the warp interlacing point; $n_{ot,wi}$ is the number of the warp points on i colour; $u_{wn,wt}$ is the content of the weft thread colour in the weft interlacing point; $n_{wt,wi}$ is the number of the weft points on i colour wefts; n_{wi} is the number of the warp and the weft points on i colour wefts = $n_{ot,wi}+n_{wt,wi}$.

The colour differences between the standard woven fabric and the fabric made of multicolour threads are calculated by using the following equation [5,6]:

$$\Delta E^{*}{}_{ab} = \sqrt{(\sum_{i-1}^{n}(a^{*}{}_{i}U_{i}) - a^{*}{}_{s})^{2} + (\sum_{i-1}^{n}(b^{*}{}_{i}U_{i}) - b^{*}{}_{s})^{2} + (\sum_{i-1}^{n}(L^{*}{}_{i}U_{i}) - L^{*}{}_{s})^{2}} \qquad (2)$$

where a^*_v, b^*_v and L^*_v are colour values of the pattern; a^*_s, b^*_s and L^*_s are the colour values of the standard fabric; a^*_i, b^*_i and L^*_i are the colour values of the *i* component; U_i is the fraction of the *i* component in a colour repeat.

2.2. The Influence of Constructional Parameters on the Size of Colour Components

The effect of the increase of threads fineness and its density is presented in Figure 2. The dimensions of colour components change as a consequence of changes in relation between constructional parameters.

On the left side of Figure 2 the original warp and weft points are presented. With the increase of warp or weft fineness the fraction of these threads increases which causes a smaller surface of other thread system and of the foundation. The size of colour repeat remains constant. In the second case, the increase of density causes the change of repeat dimensions. The fraction is higher for the thread system with increased density, and reduced for the other. Finally, due to different relations between colour components in the colour repeat, four different colour effects can be observed on the right side of the figure [7].

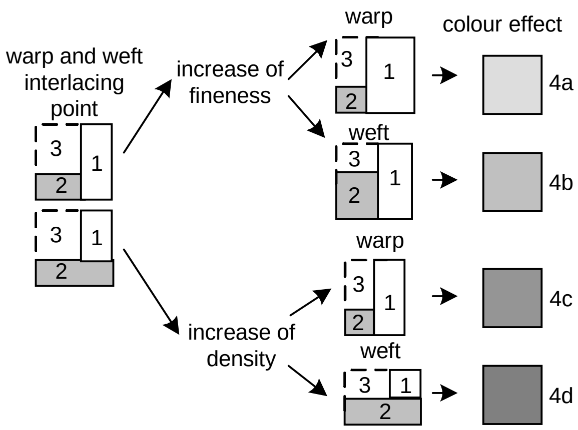

Figure 2. Change of the thread density and fineness in the warp and weft interlacing points: 1-warp, 2-weft, 3-foundation, 4.a-d- different colour effects

3. Experimental part

In the experimental part, computer simulations of woven fabrics were made with the Arahne CAD system [8]. The simulations were printed out on paper with the Epson Stylus Pro XL 720 dpi printer. The colour values of the simulations and fabrics were measured with DataColor SpectraFlash SF 600Plus-CT (D65). The warp threads were red, the weft threads were blue by the first group of fabric simulations and yellow by the second group. The colour of foundation (space between threads) was white. In Table 1, the colour values L*, a*, b*, h_{ab} and C^*_{ab} of the warp, weft and foundation are presented.

Table 1. Colour values L*, a*, b*, h_{ab} and C^*_{ab} of warp, weft and foundation

Colour values	Warp	Weft		Foundation
	Red	Blue	Yellow	White
L*	46,1	41,91	82,59	94,04
a*	48,09	-5,56	2,74	3,74
b*	19,24	-44,77	70,41	-12,55
h_{ab} (°)	21,81	262,92	87,77	286,59
C^*_{ab}	51,79	45,11	70,46	13,09

Table 2. Thread diameter, density and fractions of warp (o), weft (w) and foundation (f) by different constructional parameters of threads

Pattern	Fineness (tex)		Diameter (cm)		Density (thread/cm)		Fraction		
	Tt_o	Tt_w	d_o	d_w	g_o	g_w	U_o	U_w	U_f
1	27	27	0.0289	0.0289	27.00	27.00	0.476	0.476	0.048
2	27	24	0.0289	0.0272	27.00	27.00	0.494	0.448	0.058
3	27	24	0.0289	0.0272	27.00	28.50	0.478	0.473	0.049
4	24	24	0.0272	0.0272	27.00	27.00	0.465	0.465	0.071
5	27	24	0.0289	0.0272	26.00	27.00	0.475	0.458	0.066

Table 3. Theoretically calculated and spectrophotometrically determined colour values and ΔE^*_{ab} values of red/blue and red/yellow patterns

BLUE weft					
Theoretically calculated					
Colour values	1	2	3	4	5
	Tt_o=27, Tt_w=27	Tt_o=27, Tt_w=24	Tt_o=27, Tt_w=24	Tt_o=24, Tt_w=24	Tt_o=27, Tt_w=24
	g_o=27, g_w=27	g_o=27, g_w=27	g_o=27, g_w=28.5	g_o=27, g_w=27	g_o=26, g_w=27
L*	44.05	44.78	44.14	45.18	45.01
a*	20.89	21.99	21.02	20.46	21.03
b*	-6.37	-4.95	-6.22	-5.99	-5.59
h_{ab} (°)	343.04	347.31	343.52	343.68	345.11
C^*_{ab}	21.84	22.54	21.92	21.32	21.76
ΔE*ab	0.00	1.94	0.21	1.27	1.24
Spectrophotometrically determined					
L*	35.68	36.04	35.62	35.98	36.05
a*	9.95	11.26	9.87	9.89	10.43
b*	-18.57	-17.64	-18.49	-18.71	-18.23
h_{ab} (°)	298.18	302.55	298.09	297.86	299.78
C^*_{ab}	21.07	20.93	20.96	21.16	21.00
ΔE*ab	0.00	1.64	0.13	0.34	0.69
YELLOW weft					
Theoretically calculated					
Colour values	1	2	3	4	5
	Tt_o=27, Tt_w=27	Tt_o=27, Tt_w=24	Tt_o=27, Tt_w=24	Tt_o=24, Tt_w=24	Tt_o=27, Tt_w=24
	g_o=27, g_w=27	g_o=27, g_w=27	g_o=27, g_w=28.5	g_o=27, g_w=27	g_o=26, g_w=27
L*	64.52	64.05	64.48	65.19	64.72
a*	24.59	25.48	24.69	24.09	24.6
b*	42.12	40.41	41.94	40.83	40.63
h_{ab} (°)	59.72	57.77	59.51	59.46	58.81
C^*_{ab}	48.77	47.77	48.67	47.41	47.50
ΔE*ab	0.00	1.99	0.21	1.54	1.50
Spectrophotometrically determined					
L*	60.89	60.23	60.63	61.66	61.29
a*	28.85	29.93	29.16	28.17	28.49
b*	40.69	38.81	40.19	39.02	38.97
h_{ab} (°)	54.66	52.36	54.04	54.17	53.83
C^*_{ab}	49.88	49.01	49.65	48.13	48.27
ΔE*ab	0.00	2.26	0.64	1.96	1.79

Five simulations of woven structure with different constructional parameter were prepared. The constructional parameters of standard woven fabric-pattern 1 were as follows: fineness of warp and weft threads Tt_o = Tt_w = 27tex and thread density g_o =g_w =27 threads/cm. In pattern 2, the weft fineness was changed to 24 threads/cm, and the thread density and colour remained the same. With pattern 3, the colour difference was corrected by increasing the weft threads' density; in pattern 4, the correction was made by changing the warp yarn fineness, and in pattern 5, by decreasing the warp threads' density. The constructional parameters and fractions are presented in Table 2. The symbols d_o and d_w are the diameters of warp and weft thread (mm), g_o and g_w are the densities of warp and weft threads and U_o, U_w and U_f are the fractions of warp, weft and foundation in one colour repeat of woven fabric.

The colour values of the simulations and fabrics were determined:

- theoretically, with calculations on the basis of the theoretically defined fractions and the L*, a* and b* values of the yarns used (equation (1)) and
- spectrophotometrically, on the printouts of simulations of woven fabrics.

Finally, colour deviations ΔE^*_{ab} between colour values of planned woven fabric-pattern 1 and woven fabrics with changed constructional parameters (2-5) were calculated and the correction of colour values using changes of constructional parameters was objectively investigate.

4. Results of measurements

The colour values of red and blue patterns with ΔE^*_{ab} values are presented in Table 3, with theoretically calculated and spectrophotometrically determined colour values of simulations.

5. Discussion

In the experimental work, two different colours of weft threads were used, blue and yellow. These colours were chosen because they are located in different parts of the CIE L*a*b* colour system. Blue has a very high negative value of colour parameter b* (-44,77), whereas yellow is located at the opposite end of the colour system, where there are high positive values of b* colour parameter (70,41). Woven fabrics with equal constructional parameters in the warp and weft system (g_o=g_w=27 threads/cm, Tt_o=Tt_w=27 tex) should be made. The desired colour effect was supposed to be achieved on the surface of the simulation of woven fabrics with such constructional parameters and colour values of threads. However it wasassumed that weft yarn of fineness 27 tex was not available, and thus it was replaced with threads of lower fineness 24 tex. Different fineness of weft threads caused certain colour deviation in comparison with the desired effect as a decrease of chroma, because of the bigger fraction of space between threads and the change in hue angle in the direction of the red axis. This was because in the woven construction with weft fineness of 24 tex, the red warp threads have a higher fraction in colour repeat (Table 2) and a greater influence on the colour effect of the surface.

In the table, it can be observed that the fraction of single-colour component (warp, weft, and foundation) changes with the change of the thread fineness and density. The fractions U_o, U_w and U_f of pattern 2 differ considerably from those of the fractions of pattern 1, which was taken as the standard. This caused high colour differences between patterns 1 and 2, as can be observed in table 3. For the blue weft colour ΔE^*_{ab}, the value between patterns 1 and 2 is 1.94 by theoretical calculation and 1.64 by spectrophotometrically measured colour values, while for the yellow weft these values were 1.99 and 2.26.

The aim of the research is to explore the possibility of correcting colour by changing constructional parameters. Patterns 3-5 were designed with this aim in mind. By these patterns, changes to constructional parameters were carried out in order to correct the fractions of colour components, so that they would be closer to the fractions of the standard pattern. These can be seen in Table 3, where patterns 3-5 have fractions U_o, U_w and U_f more similar to fabric 1 in comparison with pattern 2. So, the colours of warp and weft threads have a similar influence on the colour of the simulation. The consequence is that by theoretical calculations, the ΔE^*_{ab} values between patterns 3-5 and 1 are lower in comparison with those between fabrics 1 and 2. In the case of blue weft, the ΔE^*_{ab} values of the theoretically determined colour values between pattern 1 and the patterns with changed fineness or density 3-5 range from 0.21 to 1.24, and in the case of the yellow weft from 0.21 to 1.50. Moreover, the success of colour corrections achieved by changing constructional parameters is proved with

ΔE^*_{ab} colour deviations between spectrophotometrically determined colour values. In this case, the ΔE^*_{ab} values range from 0.13 to 0.69 by the blue weft, and from 0.64 to 1.79 by the yellow weft.

In Table 3, it is evident that the colour corrections using changes to constructional parameters are effective in both colours of weft threads, blue and yellow. The lowest ΔE^*_{ab} values are present between patterns 3 and 1 by spectrophotometrically determined colour values, so when lower fineness of weft thread (24 tex) is corrected with higher density weft threads (28.5 threads/cm). The same results give us the theoretical predictions of colour values, which by pattern 3 in fact predict the closest fraction values to pattern 1 ($U_{o1}= U_{w1}=$ 0.476, $U_{o3}=$ 0.478, $U_{w3}=$ 0.473) and give us the lowest colour deviations.

On the other hand, the patterns with blue and yellow weft show differences between theoretical calculations and spectrophotometrical measurements. The theoretical calculations of colour values predict higher colour differences between the colour values of pattern 1 and the corrected colour values of fabrics 3-5 by patterns with blue weft (theoretical: 0.21-1.94, measured: 0.13-1.64). Meanwhile, in patterns with yellow weft spectrophotometrical measurements are less successful, and the ΔE^*_{ab} values are 0.64 to 2.26 in comparison with the theoretical calculations, which give ΔE^*_{ab} values from 0.21 to 1.99.

6. Conclusions

The colour of a woven structure made of different coloured threads in the warp and weft system depends on the colour values of the threads and on the constructional parameters. On the basis of the experimental work the following conclusions can be drawn:

- changes to constructional parameters in one thread system can be substituted with changes to density or fineness in another system to achieve a similar colour effect on the woven surface;
- colour corrections can be made by changing constructional parameters;
- correction by the increase in weft threads' density is most successful with minimal ΔE^*_{ab} values in the case when colour differences are caused by lower weft thread fineness;
- theoretically predicted ΔE^*_{ab} colour differences can be compared with those which have been spectrophotometrically determined, and depend on the threads' colour.

Colour corrections using modifications to constructional parameters indicate new possibilities of usage of colorimetry in weaving technology. This enables objective estimation of colour effects due to changes in fineness, thread density and weave, as well as achievement of the desired colour values on the surface of a woven structure with the choice of proper constructional parameters.

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