izr. prof. dr. **Krste Dimitrovski**, uni. dipl. inž.
Helena Gabrijelčič, univ. dipl. inž.
Univerza v Ljubljani, Naravoslovnotehniška fakulteta, Oddelek za tekstilstvo, Snežniška 5, SI-1000 Ljubljana;
e-pošta: krste.dimitrovski@ntftex.uni-lj.si; helena.gabrijelcic@ntftex.uni-lj.si

Assoc ***Prof Krste Dimitrovski**, DSc*
***Helena Gabrijelčič**, BSc*
Faculty of Natural Sciences and Technology, Department of Textiles, Snežniška 5, SI-1000 Ljubljana, Slovenia;
e-mail: krste.dimitrovski@ntftex.uni-lj.si; helena.gabrijelcic@ntftex.uni-lj.si

Izvirni znanstveni članek
Original Scientific Paper

Napovedovanje barvnih vrednosti žakarskih tkanin

Predicting of Colour Values of Jacquard Fabrics

Žakarske tkanine imajo na površini različno velike, poljubno oblikovane vzorce. Slednji se med sabo razlikujejo po strukturi – vezavi, če so izdelani iz različno obarvanih niti, pa tudi po barvi. Sodobni CAD sistemi omogočajo simulacijo videza površine žakarskih tkanin na zaslonu in njihov iztis na papir pred samim procesom tkanja. Zaradi različnih kakovosti simulacij, različnih tipov tiskalnikov in ne vedno natančno zajetih konstrukcijskih parametrov tkanine, prihaja do razlik med barvnimi vrednostmi iztiskanih simulacij in tkanin. V prispevku so prikazani teoretični izračuni za napovedovanje barvnih vrednosti žakarskih tkanin. Ocenjene so bile razlike med izračunanimi in s spektrofotometrom izmerjenimi barvnimi vrednostmi simulacij in realnih tkanin.

Analizirana je bila žakarska tkanina s štirimi barvnimi efekti na licni in hrbtni strani. Na začetku so bile izvedene spektrofotometrične meritve barvnih vrednosti osnovnih in votkovnih niti. Na podlagi teh vrednosti in znanih konstrukcijskih parametrov tkanine so bili izdelani teoretični izračuni barvnih vrednosti v posameznih efektih žakarske tkanine. Izdelana je bila računalniška simulacija z enakimi konstrukcijskimi parametri. Primerjane so bile teoretično napovedane – izračunane barvne vrednosti, izmerjene barvne vrednosti simulacij in realnih tkanin.

***Ključne besede:** žakarska tkanina, simulacija tkanin, barvna metrika, teoretično računanje barvnih vrednosti tkanin, barvne razlike*

Jacquard fabrics have the patterns of different sizes and various designs on their surface. These patterns differ in structure – the weave and also in colour if they are made of differently coloured threads. Modern CAD systems enable simulation of a Jacquard fabric surface on computer monitor and its printout prior to weaving. However, due to varying quality of simulations, different types of printers and not always precisely determined constructional parameters of a fabric, differences between the colour values of the printed simulations and the colour values of the real fabrics occur.

In this paper theoretical calculations for predicting the colour values of Jacquard fabrics are presented. The differences between the calculated colour values and the colour values of the simulations and of the real fabrics measured spectrophotometrically are estimated. First of all spectrophotometric measurements of the colour values of the used threads were carried out. Then, theoretical calculations of the colour values in particular effects of a Jacquard fabric were made on the basis of these values and known constructional parameters. A computer simulation was made with the same constructional parameters. The theoretically predicted – the calculated colour values, the measured colour values of the simulations and of the real fabrics were compared.

***Keywords:** woven fabrics, simulations, colorimetry, colour values predicting, colour differences*

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1.0 UVOD

Žakarske tkanine imajo na svoji površini različno velike in poljubno oblikovane vzorce, ki so vidni zaradi različnih barv in strukture. Barva vzorca na tkanini je odvisna od različno obarvanih niti, njihove kombinacije in različne strukture na površini vzorca. Čeprav računalniški CAD sistemi, podprti s standardiziranimi

1.0 INTRODUCTION

On their surface Jacquard fabrics have the patterns of different sizes and various designs which become visible through their different structure. The colour of such patterns depends upon the colour of the threads involved, their combination and different structure on the pattern surface. Although modern CAD systems, supported by barvnimi bazami podatkov, omogočajo čedalje boljšo ponazoritev tkanih vzorcev tako na zaslonu kot na papirju, prihaja do odstopanj barvnih vrednosti na zaslonu, simulacijah in tkanini [1].

Odstopanja so posledica:

• **Različne stopnje kakovosti programske opreme.** Različni CAD sistemi različno uspešno simulirajo videz površine tkanine. To se zlasti nanaša na žakarske, vzorčne tkanine, kjer se ustrezni barvni efekti na licu tkanine dosegajo z različno vezavo in kombinacijo barvnih niti na površini tkanine. Struktura – vezava teh tkanin je pogosto kompleksna in večslojna. Niti, ki ne sodelujejo na površini, so skrite v notranjosti ali na hrbtni strani tkanine. Te niti so nato le toliko vidne, kolikor dopušča razmak med nitmi, ki se prepletajo na licu. Temu primeren je vpliv njihove barve na barvne vrednosti površine tkanine. Ta v realnosti obstaja in je toliko večji, čim manjša je pokritost z nitmi na licu tkanine. Ravno v tem segmentu se barvne simulacije najbolj razlikujejo od realnih tkanin, saj slednje praviloma pokažejo delček skoraj vsake niti v strukturi taknine, tudi tistih, ki se pri realnih tkaninah sploh ne vidijo in tvorijo hrbtno stran tkanine. To seveda pomeni dodaten vpliv njihovih barvnih vrednosti na barvne vrednosti vzorčnega efekta, ki je simuliran in posledica tega je odstopanje od realnega.

• **Različne kakovosti strojne opreme.** Kakovost tiskalnikov in nastavitve barv tako na zaslonu kot pri tiskalniku se v praksi razlikujejo, kar lahko povzroča odstopanja od realnih barvnih vrednosti.

• **Neidentičnosti konstrukcijskih parametrov na zaslonu in v simulaciji s parametri realne tkanine.** Pri konstrukcijskih parametrih je najbolj pogosta napaka pri premeru preje, kjer računalnik za simulacijo upošteva teoretični premer preje na podlagi njegovega titra (ta je idealno enakomeren in okrogel) in vitja preje, ne upošteva pa v zadostni meri surovine in vrste preje (predivna preja, filamentna preja, teksturirana preja, sukana preja ...) ter načina predenja (prstanska, rotorska, air jet). Glede na omenjeno in tehnološke dejavnike (različne napetosti osnove in votka) se v realni tkanini premeri prej različno deformirajo in s tem zavzamejo različno površino v posameznem vzorčnem efektu. Od tega so odvisne barvne vrednosti, ki jih bodo niti prispevale k barvnim vrednostim lica tkanine. Nekoliko manjši je vpliv vezave, kjer se ne da primerno simulirati ukrivljanja in prekrivanja niti zlasti pri ekstremnih gostotah. Najmanjši vpliv je pri gostoti osnove in votka, kjer je možnost napake samo pri omejevanju gostot navzgor, ki jih simulacija dopušča, v realnosti pa niso dosegljive.

• **Barvnih razlik pri določanju barvnih vrednosti s spektrofotometrom.** Spektrofotometrično merjenje barvnih vrednosti popolnoma ploskih simulacij tkanine se na papirju razlikuje od vrednosti »tridimenzio-

standardised colour databases, provide better and better simulation of woven patterns on computer monitor and on paper, deviations of the colour values of such simulations from real fabrics still occur [1].

These deviations result from:

• ***Different quality of software.*** *Various CAD systems differently, more or less successfully, simulate the appearance of a fabric surface. This applies particularly to Jacquard fabrics where desired colour effects on the fabric face are achieved by different weave and by combination of coloured threads on the fabric surface. The structure of these fabrics – the weave is often complex and multi-layer. The threads that do not appear on surface are concealed inside fabric or on its back side. These threads are visible only to the extent permitted by the spacing between the threads interlacing on the face, and influence the colour values of a fabric surface accordingly. This influence is the higher the smaller is the coverage with threads on the face. This is the segment in which colour simulations differ the most from real fabrics because they always reveal at least a small part of almost every thread involved in the fabric structure, even of those on the back side of a fabric which are not visible in real fabrics. Of course, this means an additional influence upon the colour values of a simulated pattern effect and hence a deviation from a real one.*

• ***Different quality of hardware.*** *The quality of printers and the setting of colours on computer monitor and in printer differ in practice, which may result in deviations from the real colour values.*

• ***Non-identity of the constructional parameters on computer monitor and simulation and those of a real fabric.*** *A mistake most frequently occurs in the diameter of the thread. Namely, to make a simulation a computer most frequently takes into account the theoretical diameter of the thread on the basis of its fineness (ideally uniform and round) and the number of twists but not enough the material and the type of the thread (spinning thread, filament thread, textured thread, worsted thread...) as well as the spinning method (ring spinning, OE-spinning, air jet spinning). Due to the above mentioned factors and some technological factors (different warp and weft tensions) the diameters of the threads in a real fabric deform differently so that the threads occupy differently large areas in a particular effect. This determines the amount of the colour values, which will be contributed by these threads to the colour values on the face of a fabric. The influence of the weave where it is impossible to simulate bowing and overlapping particularly at extreme densities is slightly lower. It is the lowest at the warp and weft density where the mistake can occur only at uplimiting of the densities which are admitted by simulation but are not achievable in reality.*

• ***Differences in the colour values measurements by spectrophotometer.*** *Spectrophotometrical measurements* nalne« površine tkanin in niti. To je razvidno iz tega, da ima iztis simulacij prej drugačne barvne vrednosti kot realne preje, kljub temu, da so bile v računalnik vnešene izmerjene barvne vrednosti realnih prej.

Kot dodatek tem načinom bolj ali manj uspešnega napovedovanja barvnih vrednosti na površini žakarskih tkanin je bil na NTF-Oddelek za tekstilstvo razvit način računanja slednjih iz znanih barvnih vrednosti uporabljenih niti in konstrukcijskih parametrih v vseh delih (efektih, vzorcih) tkanine [2].

Prispevek se v največji meri nanaša na oceno napake med izračunanimi barvnimi vrednostmi tkanine in izmerjenimi barvnimi vrednostmi simulacije tkanine v primerjavi z izmerjenimi barvnimi vrednostmi realne tkanine s popolnoma enakimi parametri. Za objektivno oceno velikosti omenjene napake, izražene v barvnih vrednostih, je bila uporabljena iz barvne metrike znana veličina ΔE^*_{ab}, s katero se podaja barvna razlika med dvema barvama v CIE L*a*b* barvnem prostoru.

of the colour values of fully flat fabric simulations on paper differ from the values of a »3D« surface of fabrics and threads. This is noticeable in the simulations printouts the colour values of which differ from those of real thread despite the fact that the measured colour values of real threads have been entered into computer.

Additionally to those more or less successful methods of predicting colour values on Jacquard fabrics surface a method for calculating these colour values from the known colour values of the used threads and the constructional parameters in all segments (effects, patterns) of a fabric has been developed [2] at the Faculty of Natural Sciences, the Textiles Department in Ljubljana, Slovenia.

*The paper focuses to the estimation of deviation of the calculated fabric colour values and the measured fabric simulation colour values from the measured colour values of a real fabric with identical parameters. For objective estimation the parameter ΔE^*_{ab}, which is used in colorimetry for expressing the difference between two colours in the CIE L*a*b* colour space, was used.*

2.0 TEORETIČNI DEL

2.1 Barvne vrednosti in barvna odstopanja

Sodobno pojmovanje barv temelji na treh veličinah, s katerimi se vsako barvo natančno opiše in umesti na določeno mesto izbranega barvnega sistema. Tri veličine so barvni ton – h_{ab} (*hue*), nasičenost – C^*_{ab} (*chroma, saturation*) in svetlost – L* (*lightness*).

CIE L*a*b* barvni prostor je eden izmed najbolj uporabljenih barvnih sistemov v tekstilstvu. Zasnovan je na pravokotnem triosnem koordinatnem sistemu: L*: črno-bela os, a*: rdeče-zelena os, b*: rumeno-modra os. S temi osmi se določa položaj barve v barvnem prostoru [3]. Samo koordinata L* ima fizikalni pomen svetlosti barve, C^*_{ab} – nasičenost in h_{ab} – barvni ton pa se izračunavata po enačbah (1) in (2):

2.0 THEORETICAL PART

2.1 Colour Values and Colour Deviations

Contemporary comprehension of colours is based upon three parameters which precisely describe and position each colour within a selected colour system. The three parameters are: hue – h_{ab}, chroma – C^*_{ab} and lightness – L. The CIE L*a*b* colour space is one of the mostly used colour systems in textile technology. It is conceived on a right-angled triaxial coordinate system: L* – black-white axis, a* – red-green axis, b* – yellow-blue axis which determine the position of a colour within the colour space [3]. Only the coordinate L* has a physical meaning of colour lightness while C^*_{ab} (chroma) and h_{ab} (hue) are calculated by using equations (1) and (2):*

$$C^*_{ab} = \sqrt{(a^*)^2 + (b^*)^2} \tag{1}$$

$$h_{ab} = \arctan(b^*/a^*) \tag{2}$$

Iz matematično opisanih barvnih vrednosti je možno izražanje razlike v barvnih vrednostih ΔE^*_{ab}, ki se izračunava na podlagi enačb (3) in (4):

From the mathematically described colour values it is possible to mathematically express the difference in colour values ΔE^*_{ab} which is calculated by using equations:

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \tag{3}$$

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta C^*_{ab})^2 + (\Delta H^*_{ab})^2} \tag{4}$$

kjer je $\Delta H^*_{ab} = C^*_{ab}\, \Delta h_{ab}\, (\pi/180)$, Δa^*, Δb^*, ΔL^*, Δh_{ab} in C^*_{ab} pa imajo vrednosti, ki ustrezajo njihovemu fizikalno-matematičnemu pomenu.

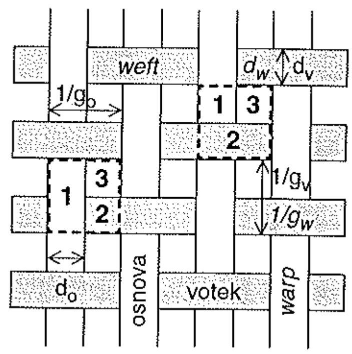
where $\Delta H^*_{ab} = C^*_{ab}\, \Delta h_{ab}\, (\pi/180)$ and Δa^*, Δb^*, ΔL^* and Δh_{ab} have the values that correspond to their physical and mathematical meaning.

2.2 Teoretično računanje barvnih vrednosti tkanine iz različno obarvanih niti

Vezna točka osnovnih in votkovnih niti je lahko razčlenjena na tri barvno in konstrukcijsko različne površine: osnovne, votkovne niti ter prostora med nitmi, kot je prikazano na sliki 1 [4].

2.2 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 is shown in Figure 1 [4].



Slika 1: Shematični videz tkanine s posameznimi barvnimi površinami osnove – 1, votka – 2 in prostora med nitmi – 3, kjer sta d_o in d_v premera osnovnih in votkovnih niti ter $1/g_o$ in $1/g_v$ prostora med osnovnimi in votkovnimi nitmi.

Figure 1. *Schematic view of a fabric with individual colour surfaces of warp – 1, weft – 2 and inter-thread spacing – 3.*

Velikost površine votkovne in osnovne vezne točke se lahko izračuna po enačbi (5):

$$P_{o,v} = \frac{1}{g_o} \cdot \frac{1}{g_v} \qquad (5)$$

kjer sta g_o in g_v gostoti osnovnih in votkovnih niti, medtem ko se delež U posamezne komponente i v določenem raportu izračuna po enačbi (6):

$$U_i = \frac{n_{oi} + n_{vi}}{n} \qquad (6)$$

kjer sta n_{oi} in n_{vi} števili osnovnih in votkovnih točk barve i, n pa je število vseh točk v barvnem raportu.

Če se osnovno vezno točko obravnava kot barvno površino iz treh komponent, se lahko delež posameznih barvnih komponent v barvnem zaporedju izračuna s pomočjo enačb (7), (8) in (9):

$$P_{1o} = d_o \cdot \frac{1}{g_v} \qquad (7)$$

$$P_{2o} = d_v \cdot \left(\frac{1}{g_o} - d_o\right) \qquad (8)$$

$$P_{3o} = \left(\frac{1}{g_o} - d_o\right) \cdot \left(\frac{1}{g_v} - d_v\right) \qquad (9)$$

kjer so:

– d_o, d_v – premer osnovne in votkovne niti;

So far the size of the surface of individual warp and weft points has been calculated by using equation (5):

$$P_{o,w} = \frac{1}{g_o} \cdot \frac{1}{g_w} \qquad (5)$$

where g_o and g_w is the density of the warp and the weft threads, while the colour content of i component in a repeat unit is:

$$U_i = \frac{n_{oi} + n_{wi}}{n} \qquad (6)$$

where n_{oi} and n_{wi} is the number of the warp and the weft points of i colour and n the total number of points in a colour repeat.

If a warp interlacing point is considered as a colour surface made up of three components, the content of individual colour components in a colour repeat of a fabric will be calculated by using the following equations:

$$P_{1o} = d_o \cdot \frac{1}{g_w} \qquad (7)$$

$$P_{2o} = d_w \cdot \left(\frac{1}{g_o} - d_o\right) \qquad (8)$$

$$P_{3o} = \left(\frac{1}{g_o} - d_o\right) \cdot \left(\frac{1}{g_w} - d_w\right) \qquad (9)$$

where:

– d_o, d_w is the diameter of the warp, the weft threads;

- g_o, g_v – gostota osnovnih in votkovnih niti;
- p_{1o} – površina osnovne niti v osnovni vezni točki;
- p_{2o} – površina votkovne niti v osnovni vezni točki in
- p_{3o} – površina prostora med nitmi v osnovni vezni točki.

Indeks $_o$ se nanaša na osnovno vezno točko, indeks $_1$ se nanaša na površino osnovne niti v vezni točki, indeks $_2$ na površino votkovne niti v vezni točki in indeks $_3$ na površino prostora med nitmi v določeni vezni točki. Deleži posameznih barvnih površin v osnovni vezni točki se izračunajo iz razmerja enačb (7) in (5), (8) in (5) ter (9) in (5). Enačbe (7), (8) in (9) za površine osnove – 1, votka – 2 in prostora med nitmi – 3, so v primeru votkovne vezne točke primerno prirejene. Deleže posameznih barvnih površin v votkovni vezni točki pa se izračuna na podoben način kot v osnovni vezni točki.

Na podlagi premera niti, gostote in vezave se izračunajo deleži osnovnih barvnih niti U_{io} in votkovnih niti druge barve U_{iv} v vzorcu po enačbah (10) in (11):

$$U_{io} = \frac{u_{on,\,ot} \cdot n_{ot,\,oi} + u_{on,\,vt} \cdot n_{vt,\,oi}}{n_{oi}} \qquad (10)$$

$$U_{iv} = \frac{u_{vn,\,ot} \cdot n_{ot,\,vi} + u_{vn,\,vt} \cdot n_{vt,\,vi}}{n_{vi}} \qquad (11)$$

kjer so:

- $u_{on,ot}$ – delež barve osnovne niti v osnovni vezni točki;
- $n_{ot,oi}$ – število osnovnih točk na osnovnih nitih i-te barve;
- $u_{on,vt}$ – delež barve osnovne niti v votkovni vezni točki;
- $n_{vt,oi}$ – število votkovnih točk na osnovnih nitih i-te barve;
- n_{oi} – vsota osnovnih in votkovnih točk na osnovnih nitih i-te barve = $n_{ot,oi}+n_{vt,oi}$;
- $u_{vn,ot}$ – delež barve votkovne niti v osnovni vezni točki;
- $n_{ot,vi}$ – število osnovnih točk na votkih i-te barve;
- $u_{vn,vt}$ – delež votkovne niti v votkovni točki;
- $n_{vt,vi}$ – število votkovnih točk na votkih i-te barve;
- n_{vi} – število osnovnih in votkovnih točk na votkih i-te barve = $n_{ot,vi} + n_{vt,vi}$.

Računanje barvnih vrednosti L*, a* in b* na površini žakarske tkanine z i barvnimi komponentami poteka po enačbah (12), (13) in (14):

- *g_o, g_w is the density of the warp, the weft threads;*
- *p_{1o} is the surface of the warp thread in the warp interlacing point;*
- *p_{2o} is the surface of the weft thread in the warp interlacing point and*
- *p_{3o} is the foundation reflectance surface in the warp, the weft interlacing point.*

Index $_o$ applies to the warp interlacing point. Index $_1$ applies to the surface of the warp thread in the interlacing point, index $_2$ to the surface of the weft thread in the interlacing point and index$_3$ to the surface between the threads. The contents of individual surfaces in the warp interlacing point are calculated from the ratio between equation (7) and (5), (8) and (5) and (9) and (5). Equations (7) and (8) for the surfaces 1-warp and 2-weft in the weft interlacing point are accordingly adjusted. The rest is the same as in the case of the warp interlacing point.

On the basis of the diameter of the thread, the threads density and the weave the fractions of warp colour threads U_{io} and weft colour threads of different colour U_{iw} in the pattern are calculated by using the following equation (10) and (11):

$$U_{io} = \frac{u_{on,\,ot} \cdot n_{ot,\,oi} + u_{on,\,wt} \cdot n_{wt,\,oi}}{n_{oi}} \qquad (10)$$

$$U_{iw} = \frac{u_{wn,\,ot} \cdot n_{ot,\,wi} + u_{wn,\,wt} \cdot n_{wt,\,wi}}{n_{wi}} \qquad (11)$$

where:

- $u_{on,ot}$ *is the fraction 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 fraction 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 fraction 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 fraction 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 = $n_{ot,wi}+n_{wt,wi}$.*

Equations (12), (13) and (14) show the calculation of colour values L, a* in b* on surface of jacquard woven fabrics with i colour components:*

$$a^*_v = \sum_{i-1}^{n} (a^*_i\, U_i) \qquad (12)$$

$$b^*_v = \sum_{i-1}^{n} (b^*_i\, U_i) \qquad (13)$$

$$L^*_v = \sum_{i-1}^{n} (L^*_i\, U_i) \qquad (14)$$

Računanje barvnih razlik tako poteka po naslednji enačbi [2]:

$$\Delta E^*_{ab} = \sqrt{(\sum_{i-1}^{n}(a^*_i U_i) - a^*_s)^2 + (\sum_{i-1}^{n}(b^*_i U_i) - b^*_s)^2 + (\sum_{i-1}^{n}(L^*_i U_i) - L^*_s)^2} \qquad (15)$$

kjer so

- a^*_v, b^*_v in L^*_v barvne vrednosti vzorca;
- a^*_s, b^*_s in L^*_s barvne vrednosti standardne tkanine;
- a^*_i, b^*_i in L^*_i barvne vrednosti i-te komponente tkanine;
- U_i delež i-te komponente v barvnem raportu.

3.0 EKSPERIMENTALNI DEL

V eksperimentalnem delu so bile najprej izmerjene barvne vrednosti štirih prej na spektrofotometru. Iz teh niti je bila pri konstantni gostoti osnove in votka stkana žakarska tkanina z dvema sistemoma osnove in dvema sistemoma votka. Tkanina je imela štiri efekte na licu in štiri na hrbtu v različnih vezavah in različnih kombinacijah osnovnih in votkovnih niti. V nadaljevanju so posamezni efekti na tkanini podajani kot vzorec od 1 do 4 na licni strani in od 5 do 8 na hrbtni strani tkanine. Na podlagi določenih barvnih in konstrukcijskih parametrov tkanine so bile izdelane računalniške simulacije v CAD sistemu Arahne [5]. Iztisi simulacij so bili narejeni na tiskalniku Epson Stylus Pro XL, 720 dpi. S pomočjo barvnih vrednosti prej iz preglednic 3 in 4 ter konstrukcijskih parametrov tkanine iz preglednice 5 so bile teoretično določene barvne vrednosti žakarske tkanine v posameznem efektu s pomočjo enačb (10), (11), (12), (13) in (14). Izmerjene so bile barvne vrednosti simulacij in tkanin ter izračunane barvne razlike med izračunanimi vrednostmi, simulacijami in realno tkanino s pomočjo enačb (3) in (15).

3.1 Priprava vzorcev

Gostota osnove in votka je bila pri vseh vzorcih enaka in sicer po osnovi g_0=32 niti/cm, po votku g_v= 29.5 niti/cm. Ostali konstrukcijski parametri pripravljenih vzorcev so podani v preglednici 1.

4.0 REZULTATI MERITEV

4.1 Rezultati optičnih meritev premera preje

Premer preje je bil določen na tri različne načine:

- s pomočjo zveze med teoretičnim premerom preje in njenim titrom, ki jo upošteva računalnik in ga bomo v bodoče na kratko imenovali teoretični premer preje;

Colour differences are calculated by using the following equation [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 i component;*
- U_i *is the fraction of i component in a colour repeat.*

3.0 EXPERIMENTAL PART

First of all the colour values of four threads were measured on spectrophotometer. Then, these threads were woven at constant warp and weft threads density into a Jacquard fabric with two warp systems and two weft systems. The fabric had four effects on the face and four effects on the back in different weaves and different combinations of the warp and weft threads. The four effects will be referred to as patterns 1 to 4 (face) and 5 to 8 (back). Simultaneously, computer simulations were made by using the Arahne CAD system [5]. The simulations were printed out on paper with the printer Epson Stylus Pro XL, 720 dpi. The colour values of the simulations and the fabrics were measured with DataColor SpectraFlash SF 600Plus-CT (D65) and calculated using equation (11), (12), (13) and (14) on the basis of colour values of threads (Table 3 and 4) and constructional parameters (Table 2 and 5).

3.1 The Preparation of Patterns

The warp and weft density was the same in all patterns, i.e. g_o = *32 threads per cm by warp and* g_w = *29.5 threads per cm by weft. Other constructional parameters are presented in Table 1.*

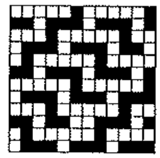
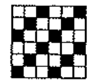
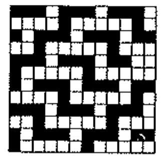
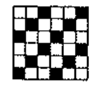
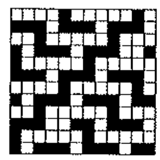
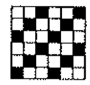
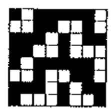
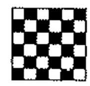
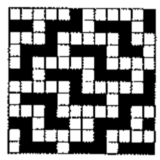
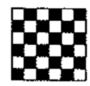
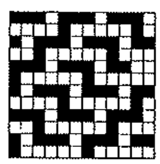
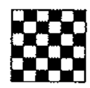
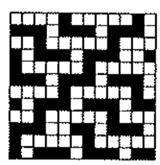
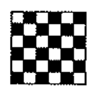
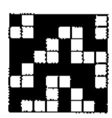
4.0 RESULTS OF MEASUREMENT

4.1 Results of Optical Measurement of Diameter of Thread

The diameter of the thread was determined in three different ways. The first way was by means of the relation between the theoretical diameter of the thread and its fineness which is taken into account by computer and which will be referred to as the theoretical diameter of the thread. The second way was optical determination of

Preglednica 1: Konstrukcijski parametri prej in vzorcev tkanin

Table 1. *Constructional parameters of threads and patterns*

	Preja – osnova / *Thread – Warp*	Preja – votek *Thread-Weft*	Vezava *Weave*	Vezava v zg. plasti Weave in top layer
1	**preja / *Thread* 1 – zelena / *green*:** poliester / *Polyester*, 40 tex	**preja / *Thread* 4 – rdeča / *red*:** poliester / *Polyester*, 40 tex		lice / *Face* keper / *Twill weave* 
2	**preja / *Thread* 2 bela / *white*:** poliester / *Polyester*, 40 tex	**preja / *Thread* 3 – bela / *white*:** bombaž / *Cotton*, 58 x 2tex, 830 Z		lice / *Face* keper / *Twill weave* 
3	**preja / *Thread* 2 – bela / *white*:** poliester / *Polyester*, 40 tex	**preja / *Thread* 4 – rdeča / *red*:** poliester / *Polyester*, 40 tex		lice / *Face* keper / *Twill weave* 
4	**preja / *Thread* 1 – zelena / *green*:** poliester / *Polyester*, 40 tex **preja / *Thread* 2 – bela / *white*:** poliester / *Polyester*, 40 tex	**preja / *Thread* 3 – bela / *white*:** bombaž / *Cotton*, 58 x 2tex, 830 Z		lice / *Face* platno / *Plain weave* 
5	**preja / *Thread* 1 – zelena / *green*:** poliester / *Polyester*, 40 tex **preja / *Thread* 2 – bela / *white*:** poliester / *Polyester*, 40 tex	**preja / *Thread* 3 – bela / *white*:** bombaž / *Cotton*, 58 x 2tex, 830 Z		hrbet / *Back*  platno / *Plain weave*
6	**preja / *Thread* 1 – zelena / *green*:** poliester / *Polyester*, 40 tex **preja / *Thread* 2 – bela / *white*:** poliester, 40 tex	**preja / *Thread* 4 – rdeča / *red*:** poliester / *Polyester*, 40 tex		hrbet / *Back*  platno / *Plain weave*
7	**preja / *Thread* 1 – zelena / *green*:** poliester / *Polyester*, 40 tex **preja / *Thread* 2 – bela / *white*:** poliester, 40 tex	**preja / *Thread* 3 – bela / *white*:** bombaž / *Cotton*, 58 x 2tex, 830 Z		hrbet / *Back*  platno / *Plain weave*
8	**preja / *Thread* 1 – zelena / *green*:** poliester / *Polyester*, 40 tex	**preja / *Thread* 4 – rdeča / *red*:** poliester / *Polyester*, 40 tex		hrbet / *Back*  rips 4/2 / *Repp weave 4/2*

- z optičnim določanjem premera prosto ležeče preje, ki je bila izvlečena iz tkanine;
- z optičnimi meritvami na površini tkanine.

Med prepletanjem niti se namreč preja glede na obliko in svojo strukturo različno deformira, multifilamentna preja z majhnim številom zavojev se tako bistveno bolj splošči od konvencionalne predivne preje in s tem spremeni svoj premer. Pod vplivom vezave in gostote se ta premer poveča in prispeva k drugačnim barvnim

the diameter in free state of the thread pulled out of the fabric. The third way was determination by optical measurement on the fabric surface. Namely, during interlacing the thread deforms differently in dependence of its shape and structure; multifilament thread with low number of twists flattens significantly more than conventional spinning thread and, consequently, changes its diameter. Under the influence of the weave and the density this diameter increases and contributes to different colour values of the fabric. The results of fifty optical mea-

vrednostim tkanine. V preglednici 2 so podani rezultati petdesetih optičnih meritev preje, izvedenih na samih nitih, odparanih iz tkanine in na površini tkanine na prevezovalnih točkah s pomočjo mikroskopa.

surements of the thread carried out on individual threads torn off the fabric and on the fabric surface at the interlacing points by using microscope are presented in Table 2.

Preglednica 2: Teoretični in optično merjeni premeri prej istega titra v različnih strukturah vzorca s sipanjem (S) in koeficientom variacije (CV).

Table 2. *Theoretically and optically measured diameters of threads of same fineness in different pattern structures with scattering (S) and coefficient of variation (CV).*

Premer preje / *Thread diameter*		**Osnova / *Warp***		**Votek / *Weft***	
		Preja 1 – zelena / *Thread 1-green*	**Preja 2 – bela / *Thread 2-white***	**Preja 3 – bela / *Thread 3-white***	**Preja 4 – rdeča / *Thread 4-red***
Teoretični / *Comp.*	d (mm)	0.351	0.351	0.591	0.351
Prosto / *Free state*	d (mm)	0.478	0.459	0.547	0.475
	S (mm)	0.085	0.084	0.089	0.072
	CV (%)	17.83	18.24	16.25	15.22
Vzorec / *Pattern* 1	d (mm)	0.557			0.588
	S (mm)	0.057			0.069
	CV (%)	10.26			11.72
Vzorec / *Pattern* 2	d (mm)		0.449	0.604	
	S (mm)		0.05	0.06	
	CV (%)		11.13	10.01	
Vzorec / *Pattern* 3	d (mm)		0.510		0.58
	S (mm)		0.063		0.089
	CV (%)		12.37		13.38
Vzorec / *Pattern* 4	d (mm)	0.418	0.418	0.611	
	S (mm)	0.052	0.052	0.07	
	CV (%)	12.50	12.50	11.61	
Vzorec / *Pattern* 5	d (mm)	0.462	0.462	0.625	
	S (mm)	0.045	0.045	0.071	
	CV (%)	9.67	9.67	11.34	
Vzorec / *Pattern* 6	d (mm)	0.545	0.545		0.523
	S (mm)	0.074	0.074		0.048
	CV (%)	13.53	13.53		9.10
Vzorec / *Pattern* 7	d (mm)	0.447	0.447	0.606	
	S (mm)	0.048	0.048	0.065	
	CV (%)	10.70	10.70	10.76	
Vzorec / *Pattern* 8	d (mm)	0.459		0.617	
	S (mm)	0.052		0.083	
	CV (%)	11.37		13.46	

4.2 Rezultati meritev barvnih vrednosti prej

Meritve barvnih vrednosti prej so bile izvedene na spektrofotometru DataColor SpectraFlash SF 600Plus-CT (D65). Izmerjene so bile barvne vrednosti realnih prej (preglednica 3) in vrednosti računalniških iztisov prej (preglednica 4).

4.2 Results of Measurement of Colour Values of Threads

The measurements of the colour values of the threads were carried out on DataColor SpectraFlash SF 600Plus-CT (D65). The colour values of the real threads (Table 3) and the values of the computer printouts (Table 4) were measured.

Preglednica 3: Izmerjene L*, a* in b* ter izračunane h_{ab} in C^*_{ab} barvne vrednosti realnih prej.

Table 3. *Measured L*, a* and b* and calculated h_{ab} and C^*_{ab} colour values of real threads*

Barvna vrednost / *Colour Value*	Preja 1 – zelena / *Thread 1 – green*	Preja 2 – bela / *Thread 2 – white*	Preja 3 – bela / *Thread 3 – white*	Preja 4 – rdeča / *Thread 4 – red*
L*	52.86	87.69	85.24	29.92
a*	–3.63	2.33	2.63	45.47
b*	17.17	10.87	16.94	12.19
h_{ab}(°)	281.94	77.90	81.18	15.01
C^*_{ab}	17.55	11.12	17.14	47.07

Preglednica 4: Izmerjene L*, a* in b* in izračunane h_{ab} in C^*_{ab} barvne vrednosti računalniških iztisov prej ter odstopanja le-teh od barvnih vrednosti realnih prej ΔE^*_{ab}

Table 4. *Measured L*, a* and b* and calculated h_{ab} and C^*_{ab} colour values of computer printouts and their deviation from colour values of real threads ΔE^*_{ab}*

Barvna vrednost / *Colour Value*	Preja 1 – zelena / *Thread 1 – green*	Preja 2 – bela / *Thread 2 – white*	Preja 3 – bela / *Thread 3 – white*	Preja 4 – rdeča / *Thread 4 – red*
L*	52.27	85.49	83.03	36.51
a*	–3.98	1.41	1.15	28.69
b*	11.78	2.24	9.67	6.69
h_{ab}(°)	288.67	57.81	83.22	13.13
C^*_{ab}	2.65	12.43	9.74	29.46
ΔE^*_{ab}	5.43	8.95	7.74	18.84

4.3 Računanje deležev posameznih komponent (prej) v vzorcih

V preglednici 5 so podani premer preje, gostota niti in deleži posameznih barvnih komponent v določenem vzorcu tkanine.

4.3 Calculation of fractions of Individual Components (Threads) in Patterns

Table 5 presents the diameter of the thread, the threads density and the fractions of individual colour components in a particular pattern of the fabric.

Preglednica 5: Vrednosti konstrukcijskih parametrov in deležev posameznih komponent U_o-osnove, U_v-votka in U_{po}- prostora med nitmi v vzorcih od 1 do 8

Table 5. *Values of constructional parameters and fractions of individual components (U_i) in patterns, U_o -warp, U_w -weft, U_{sp} -space between threads.*

Vzorci / *Pattern*	Osnova / *Warp*				Votek / *weft*				Prostor med nitmi / *Spacing between threads*
	Preja / *Thread*	d_o (mm)	g_o (niti/cm)	U_o	Preja / *Thread*	d_v / d_w (mm)	g_v / g_w (niti/cm) / (thread/cm)	U_v / U_w	U_{po} / U_{sp}
1	zelena / *green*	0.557	16	0.376	rdeč / *red*	0.588	14.75	0.609	0.015
2	bela / *white*	0.449	16	0.350	bela / *white*	0.604	14.75	0.623	0.027
3	bela / *white*	0.510	16	0.350	rdeč / *red*	0.580	14.75	0.623	0.027
4	bela / *white*	0.418	16	0.275	bel / *white*	0.611	14.75	0.599	0.033
	zelena / *green*	0.418	16	0.093					
5	bela / *white*	0.462	16	0.269	bel / *white*	0.625	14.75	0.695	0.020
	zelena / *green*	0.462	16	0.016					
6	zelena / *green*	0.545	16	0.399	rdeč / *red*	0.523	14.75	0.548	0.029
	bela / *white*	0.545	16	0.024					
7	zelena / *green*	0.447	16	0.273	bela / *white*	0.606	14.75	0.681	0.030
	bela / *white*	0.447	16	0.016					
8	zelena / *green*	0.459	16	0.400	rdeč / *red*	0.617	14.75	0.576	0.024

4.4 Rezultati merjenih in izračunanih barvnih vrednosti površine tkanin

Preglednica 6 prikazuje vrednosti merjenih in izračunanih barvnih vrednosti tkanin in simulacij, kjer pomeni MBVT – merjene barvne vrednosti tkanine, MBVS – merjene barvne vrednosti simulacije s premerom niti merjenim na tkanini, RBVP1 – izračunane barvne vrednosti s premerom niti, merjenim na tkanini ter L*a*b* vrednostmi realnih prej in RBVP2 – izračunane barvne vrednosti s premerom niti, merjenim na tkanini, ter L*a*b* vrednostmi računalniških iztisov prej.

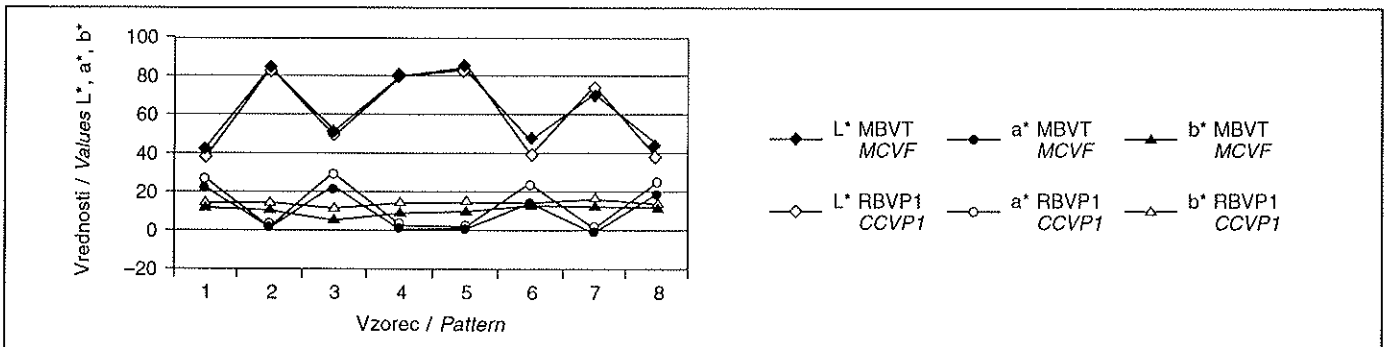
4.3 Results of Measured and Calculated Colour Values of Fabrics Surfaces

*Table 6 presents the values of the measured and calculated colour values of the fabrics and simulations where MCVF means the colour values of the fabric, MCVS the measured colour values of the simulation with the on-fabric measured diameter of the thread, CCVP1 the calculated colour values with the on-fabric measured diameter of the thread and L*a*b* values of the real threads and CCVP2 the calculated colour values with the on-surface measured diameter of the thread and L*a*b* values of the computer printouts.*

Preglednica 6: Izmerjene in izračunane barvne vrednosti tkanin in simulacij

Table 6. *Measured and calculated colour values of fabrics and simulations*

		Vzorec / *Pattern*							
		1	2	3	4	5	6	7	8
MBVT / *MCVF*	L*	41.79	83.32	51.41	79.61	82.34	46.42	70.83	44.01
	a*	21.58	1.17	22.42	0.67	0.90	13.77	−1.10	18.69
	b*	12.14	10.71	5.44	9.35	9.90	12.90	12.52	12.08
	h_{ab}(°)	29.36	83.77	13.63	85.90	84.81	43.13	275.02	32.87
	C^*_{ab}	24.67	10.77	23.07	9.37	9.94	18.87	12.57	22.25
MBVS / *MCVS*	L*	40.70	81.15	54.99	78.65	82.22	45.16	70.30	45.53
	a*	16.13	1.90	16.70	2.20	1.22	7.95	−0.62	13.44
	b*	9.02	9.56	6.39	9.39	8.65	9.47	12.75	9.69
	h_{ab}(°)	29.21	78.74	20.90	76.87	81.97	49.98	272.78	35.79
	C^*_{ab}	18.48	9.74	17.88	9.64	8.76	12.36	12.76	16.56
RBVP1 / *CCVP1*	L*	38.11	83.34	49.38	80.04	83.68	39.52	73.87	38.38
	a*	26.36	2.46	29.14	1.88	2.39	23.49	0.84	24.73
	b*	13.89	14.65	11.4	14.72	14.97	13.78	16.39	13.89
	h_{ab}(°)	27.79	80.47	21.37	82.72	80.93	30.39	87.07	29.32
	C^*_{ab}	29.79	14.86	31.29	14.84	15.16	27.23	16.41	28.36
RBVP2 / *CCVP2*	L*	41.91	81.19	52.71	78.05	81.53	42.84	72.17	41.94
	a*	15.99	1.19	18.36	0.71	1.11	14.14	−0.28	14.93
	b*	8.51	7.21	4.95	7.49	7.51	8.41	9.83	8.57
	h_{ab}(°)	28.02	80.62	15.09	84.58	81.59	30.74	271.63	29.86
	C^*_{ab}	18.11	7.31	19.02	7.52	7.59	16.45	9.83	17.21

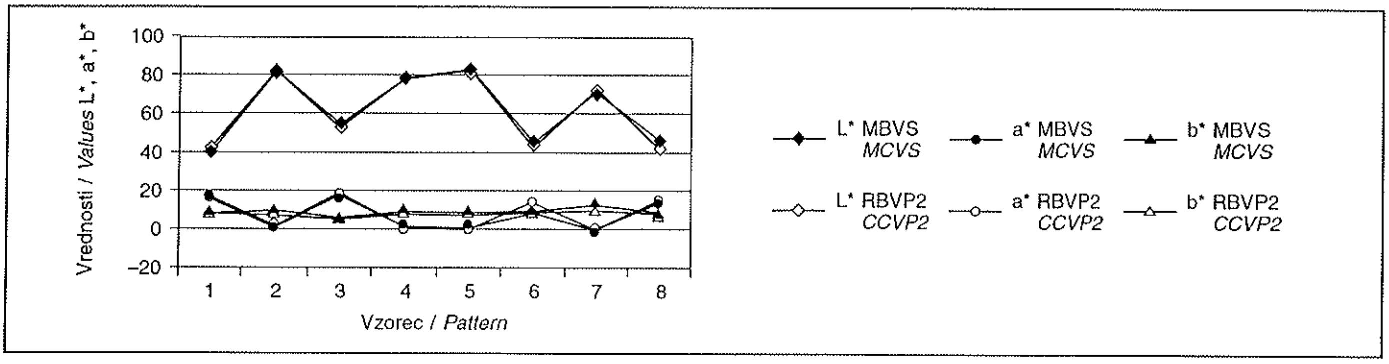


Slika 2: Grafični prikaz barvnih vrednosti L*, a* in b* za vzorce od 1 do 8 med merjenimi vrednostmi dejanske tkanine (MBVT) in računanimi barvnimi vrednostmi s premerom niti, merjenim na tkanini, ter L*, a*, b* vrednostmi realnih prej (RBVP1).

Figure 2. *Graph presenting colour values L*, a* and b* for patterns 1 to 8 of measured colour values of real fabric (MCVF) and calculated colour values with the thread diameter measured on the fabric and L*, a*, b* colour values of the rael threads (CCVP1).*

Na sliki 2 je grafično prikazana primerjava barvnih vrednosti L*, a* in b* med vzorcema MBVT in RBVP1, na sliki 3 pa je grafična primerjava barvnih vrednosti L*, a* in b* med vzorcema MBVS in RBVP2.

Figure 2 presents grafical comparison of colour values L, a* and b* between patterns MCVF in CCVP1 and figure 3 presents grafical comparison of colour values L*, a* in b* between patterns MCVS in CCVP2.*



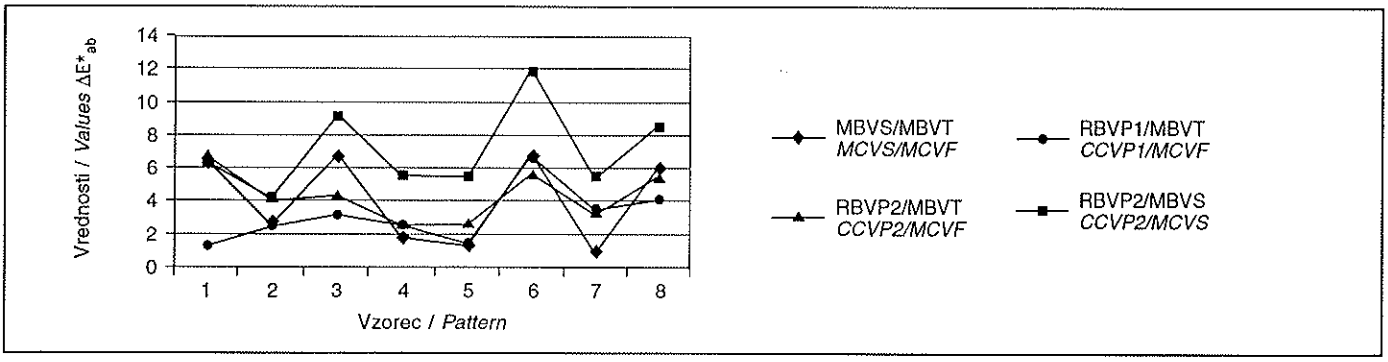
Slika 3: Grafični prikaz barvnih vrednosti L*, a* in b* za vzorce od 1 do 8 med merjenimi vrednostmi simulacije (MBVS) in računanimi barvnimi vrednostmi s premerom niti, merjenim na tkanini, ter L*, a*, b* vrednostmi računalniških izpisov (RBVP2).

***Figure 3.** Graph presenting colour values L*, a* and b* for patterns 1 to 8 of measured colour values of simulation (MCVS) and calculated colour values with the thread diameter measured on the fabric and L*, a*, b* colour values of computer printouts (CCVP2).*

Na podlagi meritev, prikazanih v preglednici 6, so bila po enačbi (3) in (14) izračunana barvna odstopanja ΔE^*_{ab}. Pri tem so bile v prvem primeru za osnovo primerjave vzete kot standard vrednosti realne tkanine, ki so bile nato primerjane z vrednostmi simulacije in vrednostmi, dobljenimi z računanjem. V drugem primeru je bila izvedena primerjava med barvnimi vrednostmi simulacije in računsko določenimi barvnimi vrednostmi tkanin, pri čemer so bile kot barvne vrednosti posameznih prej vzete barvne vrednosti, izmerjene iz računalniških iztisov. Slednje je prikazano v preglednici 7 in na sliki 4, kjer pomeni MBVT – merjene barvne vrednosti dejanske tkanine, MBVS – merjene barvne vrednosti simulacije s premerom niti, merjenim na tkanini, RBVP1 – izračunane barvne vrednosti s premerom niti, merjenim na tkanini, ter L*a*b* vred-

On the basis of the measurements presented in Table 6 and by using equation (3) and (14) colour deviations ΔE^*_{ab} were calculated. In the first case the values of the real fabric were taken as a standard and were compared with the values of the simulation and the values determined by calculation. In the second case the comparison between the colour values of the simulation and the calculated colour values was carried out by taking into account the colour values of individual threads such as were measured from the computer printouts.

*The results are presented in Table 7 and in Figure 4 where MCVF means the measured colour values of a fabric, MCVS the measured colour values of simulation with the on-fabric measured diameter of the threads, CCVP1 the calculated colour values with the on-fabric measured diameter of the threads and L*a*b* values of*



Slika 4: Grafični prikaz barvnih odstopanj ΔE^*_{ab} za vzorce od 1 do 8 med merjenimi barvnimi vrednostmi simulacij (MBVS) in realne tkanine (MBVT) ter izračunanimi barvnimi vrednostmi iz računalniških (RBVP2) in realnih prej (RBVP1) in realne tkanine.

***Figure 4.** Graph presenting colour deviations ΔE^*_{ab} between the measured colour values of simulations and those of real fabric and between the colour values calculated from computer and real threads and those of real fabric for patterns 1 to 8.*

nostmi realnih prej (preglednica 3) in RBVP2 – izračunane barvne vrednosti s premerom niti, merjenim na tkanini, ter L*a*b* vrednostmi računalniških iztisov prej (preglednica 4).

*the real threads (Table 3) and CCVP2 the calculated colour values with the on-fabric measured diameter of the threads and L*a*b* values of the computer printouts (Table 4).*

Preglednica 7: Barvna odstopanja ΔE^*_{ab}

Table 7. *Colour deviations ΔE^*_{ab}*

	Vzorec / *Pattern*							
	1	2	3	4	5	6	7	8
MBVS/ MBVT / *MCVS/MCVF*	6.37	2.56	6.81	1.81	1.29	6.87	0.75	5.96
RBVP1/MBVT / *CCVP1/MCVF*	6.28	4.15	9.21	5.52	5.45	11.95	5.29	8.45
RBVP2/MBVT / *CCVP2/MCVF*	6.67	4.09	4.29	2.42	2.53	5.75	3.11	5.54
RBVP2/MBVS / *CCVP2/MCVS*	1.32	2.45	3.17	2.49	1.34	6.69	3.48	4.05

5.0 RAZPRAVA O REZULTATIH

Iz rezultatov eksperimentalnega dela je razvidno, da je napovedovanje barvnih vrednosti žakarskih tkanin možno ob upoštevanju določenih odstopanj. Kot je že omenjeno v uvodnem delu, je simulacija najprimernejši vizualni način prikaza videza žakarske tkanine še pred samim postopkom izdelave le-te. Upoštevati pa je potrebno določene omejitve, zaradi katerih lahko barvni videz simulacije tkanine odstopa od realne tkanine.

5.1 Vpliv premera preje

V preglednicah 2 in 5 so podani premeri vseh štirih prej v osmih vzorcih tkanine. Iz rezultatov je razvidno, da se premer posamezne preje spreminja glede na to, v kateri vezavi veže z drugim sistemom, in glede na vrsto preje, s katero veže. Preja v osnovi je multifilamentna in se v vzorcih, ko se prepleta z bombažnim votkom, bolj stisne v primerjavi z vzorci, ko veže z multifilamentnim poliesternim votkom. Pri prevezovanju z bombažnim votkom se premeri preje v osnovi spreminjajo od 0,418 do 0,462 mm, in so torej manjši kot v primeru prepletanja z multifilamentnimi votki, ko se premeri gibljejo od 0,510 do 0,557 mm. Pri tem lahko opazimo tudi, da so premeri osnovnih niti v primeru vzorcev v keprovi in ripsovi vezavi v povprečju nekoliko večji kot premeri osnovnih niti v platnovi vezavi, za kar lahko najdemo vzrok v večjem številu prevezovalnih točk niti v platnovi vezavi.

Za votkovne niti spremembe niso tako očitne. Razvidno je le, da so premeri multifilamentnih votkov manjši od premera bombažnih votkov, vendar večji od premerov osnovnih niti, čeprav gre za prejo enakih konstrukcijskih parametrov. Razlago za to lahko poiščemo v različni gostoti osnovnih in votkovnih niti na končnem izdelku. Gostota osnovnih niti je namreč 32 niti/cm, votkovnih pa 29,5 niti/cm.

5.0 DISCUSSION

The results of experimental work reveal that predicting of the colour values of Jacquard fabrics is possible with certain deviations to be taken into account. As already mentioned simulation is the most suitable way to visualise a Jacquard fabric prior to manufacture. However, certain limitations which can lead to deviation of the colour appearance of a fabric simulation from a real fabric, should be taken into account.

5.1 Influence of Diameter of Thread

In Tables 2 and 5 the diameters of all four threads in eight patterns are presented. The results show that the diameter of an individual thread varies in dependence of the weave in which it interlaces with the other system and of the type of the thread with which it interlaces. The thread in the warp is multifilament and it shrinks more in the patterns in which it interlaces with a cotton weft than in the patterns with a multifilament polyester weft. When interlacing with a cotton weft the diameters of the thread in the warp vary from 0.418 to 0.462 while in the case of interlacing with multifilament wefts the diameters vary from 0.459 to 0.557 mm. Furthermore, the diameters of the warp threads are slightly bigger in the twill and repp weave than in the plain weave. The reason can be higher number of the threads interlacing points in the plain weave.

As to the weft threads the changes are not so noticeable. The diameters of multifilament polyester wefts are smaller than those of cotton wefts but bigger than the diameters of the warp threads although the thread of identical constructional parameters is used. This phenomenon can be explained by different density of the warp and the weft threads on a finished product. Namely, the density of the warp threads is 32 threads per cm and of the weft ones 29.5 threads per cm.

5.2 Vpliv deležev U_i

Na podlagi praktičnih meritev premera preje na tkanini so bili izračunani deleži U_i posameznih barvnih komponent v raportu vezave v skladu z enačbo (10). Pri tem je razvidno, da so premer, gostota niti in vezava osnove in votka odločilni dejavniki, ki vplivajo na velikost posamezne barvne površine. Pri primerjavi deležev U_i iz preglednice 5 lahko vidimo, da se deleži za osnovne niti U_o gibljejo od 28,9 % pri vzorcu 7 do 42,3 % pri vzorcu 6. Deleži votkovnih niti U_v pa se gibljejo od 54,8 % pri vzorcu 6, do 68,1 % pri vzorcu 7. Deleži presevanja podloge se gibljejo od 1,5 % pri vzorcu 1 do 3,3 % pri vzorcu 3. Ker dosegajo deleži osnovnih niti do približno 40 % in deleži votkovnih niti okrog 60 %, sledi, da je barvni efekt na tkanini bolj odvisen od barve votkovnih niti kot od barve osnovnih niti.

5.3 Vpliv barvnih vrednosti niti

Uspešnost predvidevanja in simuliranja barvnih vrednosti na površini žakarskih tkanin je odvisna od vhodnih podatkov. Poleg že omenjenih konstrukcijskih parametrov so pomembne barvne vrednosti niti, ki tvorijo efekt na površini tkanine. V preglednicah 3 in 4 so tako podane izmerjene barvne vrednosti L*, a* in b* ter izračunane barvne vrednosti h_{ab} in C^*_{ab} realnih prej (preglednica 3) in računalniško iztiskanih prej (preglednica 4). Pri tem je potrebno povedati, da so računalniški izpisi prej nastali tako, da so bile kot podatek v računalnik vnesene izmerjene vrednosti realnih prej. Omenjene barve so bile nato iztiskane, izpisi teh pa so bili nato spektrofotometrično izmerjeni in prikazani v preglednici 4. Kot je iz njih razvidno, se barvne vrednosti realnih prej in njihovih računalniških iztisov precej razlikujejo, in sicer od ΔE^*_{ab} 5,43 pri zeleni preji – 1 do 18,84 pri rdeči preji – 4. Že tovrstna odstopanja so podlaga za odstopanja barvnih vrednosti tkanih površin.

5.4 Barvna odstopanja

Na slikah 2 in 3 sta prikazani primerjavi merjenih barvnih vrednosti L*, a* in b* dejanske tkanine (MBVT) in računanih barvnih vrednosti z L*, a* in b* barvnimi vrednostmi dejanskih prej (RBVP1) ter merjenih barvnih vrednosti L*, a* in b* simulacije in računanih barvnih vrednosti simulacije z L*, a* in b* vrednostmi računalniških iztisov prej (RBVP2). Iz krivulj slik je razvidno, da je napovedovanje L*, a* in b* vrednosti uspešnejše v primeru simulacij, saj se krivulji MBVS in RBVP2 na sliki 3 bolj ujemajo v primerjavi krivulj MBVT in RBVP1 na sliki 2. Barvne vrednosti L*, a* in b*

5.2 Influence of Fractions U_i

On the basis of practical measurements of the diameter of the thread and by using equation (10) the fractions U_i of individual colour components in a weave repeat have been calculated. It is evident that the diameter, the threads density and the weave are the most important factors that influence the size of individual colour surface. Table 5 shows that the fraction of the warp thread U_o varies from 28.9% in pattern 7 to 42.3% in pattern 6. The fraction of the weft threads U_w varies from 54.8% in pattern 6 to 68.1% in pattern 7. The fraction of the foundation reflectance ranges from 1.5% in pattern 1 to 3.3% in pattern 3. Since the fraction of the warp threads reaches about 40% and the fraction of the weft threads about 60% it can be concluded that the colour effect of the fabric depends more on the colour of the weft threads than on the colour of the warp threads.

5.3 Influence of Colour Values of Threads

How successful predicting and simulating of colour values on the surface of Jacquard fabrics will be depends upon the input data. Beside the above mentioned constructional parameters the colour values of the threads that produce the effect on the fabric surface are important. Tables 3 and 4 present the measured colour values L, a* and b* and the calculated colour values h_{ab} and C^*_{ab} of the real (Table 3) and of the computer printed out threads (Table 4). It should be mentioned that the printouts were created so that the measured values of the real threads (Table 3) were entered into computer, the colours were then printed and the printouts spectrophotometrically measured and the results presented in Table 4. As can be seen the colour values of the real threads and their computer printouts differ considerably – from ΔE^*_{ab} 5.43 (green thread No.1) to 18.84 (red thread No.4). Such differences are already the basis for deviation of the colour values of woven surfaces.*

5.4 Colour Deviations

In Fig. 2 and 3 the measured colour values L, a* and b* of the real fabric (MCVF) and the calculated colour values are compared with the colour values L*, a* and b* of the real threads (CCVP1) and the measured colour values L*, a* and b* of the simulation and the calculated colour values of the simulation are compered with the values L*, a* and b* of the computer printouts of the threads (CCVP2). The curves show that predicting of the values L*, a* and b* is more successful in the case of simulations, namely, the curves MCVS and CCVP2 in Fig. 3 match better than the curves MCVF and CCVP1 in Fig. 2. The colour values L*, a* and b* of the simulation MCVS* simulacije MBVS in računane vrednosti RBVP2 se v primeru vzorcev 1, 2, 4 in 5 skoraj prekrivajo, kar kaže na uspešno računsko predvidevanje teh vrednosti. Na sliki 2 so ujemanja med krivuljami MBVT in RBVP1 manjša, pri čemer lahko opazimo večjo podobnost barvnih vrednosti L* med vzorci MBVT in RBVP1 in manjše ujemanje med barvnimi vrednostmi a* in b*.

V preglednici 7 so podane štiri skupine vrednosti barvnih odstopanj ΔE^*_{ab} za vseh osem vzorcev. V prvi skupini so bile izračunane barvne razlike simulacij in realnih tkanin (MBVS/MBVT), v drugi skupini pa razlike izračunanih barvnih vrednosti tkanin z barvnimi vrednostmi realnih prej in realnih tkanin (RBVP1/MBVT). Tretja skupina podaja barvna odstopanja izračunanih barvnih vrednosti tkanin z računalniškimi barvnimi vrednostmi prej v primerjavi z realnimi tkaninami (RBVP2/MBVT) in četrta primerja izračunane vrednosti tkanin z računalniškimi barvnimi vrednostmi prej ter merjene vrednosti simulacij (RBVP2/MBVS).

Iz vrednosti ΔE^*_{ab} v preglednici 7 se lahko vidi, da so barvna odstopanja vseh osmih vzorcev manjša, ko so v votku bele bombažne niti v primerjavi z rdečim multifilamentnim votkom. To velja tako za simulacije kot za izračunane vrednosti. Slednje je razvidno tudi iz slike 4, kjer so pri 3. in 6. vzorcu (rdeč votek v efektu) vrednosti ΔE^*_{ab} velike tako za simulirane tkanine kot za izračunane barvne vrednosti tkanine. Predvidevanje barvnih vrednosti površin rdečih barvnih tonov je torej manj natančno kot predvidevanje drugih barvnih tonov.

Primerjava vrednosti ΔE^*_{ab} vseh štirih skupin kaže, da so barvna odstopanja med izračunanimi barvnimi vrednostmi iz realnih prej v primerjavi z merjenimi barvnimi vrednostmi realnih prej najvišja, medtem ko so barvna odstopanja med izračunanimi in merjenimi barvnimi vrednostmi simulacij manjša. Slednje lahko razložimo z načinom predvidevanja barvnih vrednosti žakarskih površin in načinom izračunavanja deležev barvnih vrednosti površin na vzorcih. Iz enačb (5) do (9) je razvidno, da so sicer upoštevani konstrukcijski parametri prej (debelina, gostota), vendar v geometrijskem smislu. Ta način bolj ustreza simulacijam, kjer je barvna površina predstavljena na ploski površini in manj realnim tkaninam, kjer imajo niti poleg dveh dimenzij – dolžine in širine, še tretjo – debelino, ki se pri geometrijskem računanju površine posamezne niti v vezni točki ne upošteva.

Primerjava krivulj MBVS/MBVT in RBVP1/MBVT kaže, da je njihov potek precej podoben, pri prvem vzorcu pa je ΔE^*_{ab} vrednost skoraj enaka. Vrednosti ΔE^*_{ab} so v primeru računanih barvnih vrednosti z realnimi prejami v primerjavi z merjenimi vrednostmi realne tkanine višje. Tako kot simulacija prikaže barvni videz realne tkanine še pred njeno izdelavo, se lahko tudi s teoretičnim izračunavanjem predvidi barvo nastalega barvnega vzorca na površini žakarske tkanine, pri tem pa je treba upoštevati, da bo prišlo do določenih barvnih

and the calculated values CCVP2 almost overlap in the case of the patterns 1, 2, 4 and 5 which points to the successful predicting of these values by calculation. In Fig. 2 matching of the curves MCVF and CCVP1 is lower, with higher resemblance of the colour values L between the patterns MCVF and CCVP1 and lower resemblance between the colour values a* and b*.*

Table 7 presents four groups of the colour values deviations ΔE^*_{ab} for all eight patterns. In the first group the measured colour values of the simulations and the real fabrics are compared, the second group compares the calculated colour values of the fabrics with the colour values of the real threads. The third group compares the colour deviations of the colour values of the fabrics calculated from the computer colour values of the threads with the real fabrics and in the fourth group the colour values of the fabrics calculated from the computer colour values of the thread are compared with the measured values of the simulations.

The values ΔE^*_{ab} in Table 7 indicate that colour deviations of all eight patterns are lower with white threads in the weft than with red ones. This applies both to the simulations and to the calculated values. This is evident also in Fig. 4 where a high jump of the value ΔE^*_{ab} occurs in patterns 3 and 6 (red weft in the effect) for the simulated fabrics as well as for the calculated colour values of the fabric. Predicting of colour values of the surfaces in red colour shades is therefore less precise than predicting of other colour shades.

The comparison of the values ΔE^*_{ab} of all four groups shows that colour deviations between the colour values calculated from the real threads and the measured colour values of the real threads are the highest, while colour deviations between the calculated and the measured colour values of the simulations are lower. This can be explained by the nature of predicting the colour values of Jacquard surfaces and by the method of calculating the fractions of the colour values on patterns surface. Equations (5) and (9) show that the constructional parameters of the threads (thickness, density) are taken into account, but in a geometrical sense. This is more convenient for simulations where the colour surface is presented on a flat area and less convenient for real fabrics where the threads have a third dimension – the thickness additionally to two dimensions – the length and the width, which is not taken into account in geometrical calculation of an individual thread surface in the interlacing point.

The comparison of the curves MCVS/MCVF and CCVP1/MCVF shows that their course is quite similar, in the first pattern the ΔE^*_{ab} value is almost the same. The ΔE^*_{ab} values are in case of the calculated colour values with the real threads higher in comparison with the measured values of the real fabrics. Likewise the simulation which shows the colour appearance of a real fabric prior to manufacture, the colour of a Jacquard fabric pattern can be predicted by theoretical calculation by taking into odstopanj, za kar je vzrok način teoretičnega izračunavanja barvnih vrednosti.

Nadaljna primerjava barvnih odstopanj med RBVP1 in MBVT ter RBVP2 in MBVT kaže vpliv računalniško iztiskanih in realnih barvnih vrednosti prej na izračunane barvne vrednosti površin žakarskih tkanin. Razlike v poteku krivulj RBVP1/MBVT in RBVP2/MBVT so največje, ko je v votku rdeča nit ter ko je v osnovi kombiniran efekt dveh barvnih niti. To je razumljivo, saj so bila pri rdeči preji prisotna največja odstopanja barvnih vrednosti preje in samega premera preje. Poleg tega je v primerih, ko je zgornja tkanina v platno vezavi (vzorci 4, 5, 6 in 7) na prevezovalnih točkah prisotna tudi tretja obarvana nit. Slednja prispeva kot barvna komponenta svoj barvni delež k celotnemu efektu.

Analiza barvnih odstopanj ΔE^*_{ab} med računanimi barvnimi vrednostmi RBVP2 vzorcev s prejo računalniških barvnih vrednosti ter merjenimi barvnimi vrednostmi simulacij MBVS kaže, da so ta najmanjša v primerjavi z drugimi vrednostmi ΔE^*_{ab}. Iz tega se lahko sklepa, da je teoretično napovedovanje barvnih vrednosti v primeru simulacij uspešnejše v primerjavi z realno taknino. Simulacija je namreč dvodimenzionalni prikaz barvnega in konstrukcijskega videza tkanine, kjer je geometrijski način predvidevanja površine posameznega barvnega efekta najprimernejši.

6.0 ZAKLJUČKI

Teoretično izračunavanje barvnih vrednosti se lahko uporablja za predvidevanje barvnih vrednosti površin žakarskih tkanin. Pri tem je natančnost napovedovanja barvnih vrednosti v veliki meri odvisna predvsem od vrste preje. V primerih, ko gre za multifilamentno prejo z razmeroma majhnim številom zavojev, je ta podvržena razmeroma velikim deformacijam premera v prevezovalnih točkah. Deformacije so odvisne tako od vrste in karakteristik niti, s katerimi se križajo na površini tkanine, kakor tudi od drugih konstrukcijskih in tehnoloških značilnosti tkanine. Pri konstrukcijskih dejavnikih igrata odločilno vlogo gostota niti in vezava, pri tehnoloških pa napetost osnove in votka ter vdev v greben. Glede na veliko deformabilnost tovrstnih niti, variirajo tudi njihove spektrofotometrično izmerjene barvne vrednosti, kar onemogoča natančno računsko napovedovanje barvnih vrednosti stkanih površin.

Barvna odstopanja površine tkanih vzorcev (slika 4) kažejo zelo podobne spremembe v barvnih razlikah, le da so te drugačnega velikostnega reda. Pri največjih barvnih odstopanjih dosegajo ΔE^*_{ab} vrednosti tudi več kot 10. To so velika odstopanja v primerjavi s tistimi, ki so še dopustna pri barvanju in tisku, v primerjavi z barvnimi odstopanji samih niti pa se v nekaterih pri-

account certain colour deviations which result from the nature of theoretical calculation of the colour values.

A further comparison of colour deviations between CCVP1 and MCVF as well as CCVP2 and MCVF shows the influence of the computer printed and real colour values of the threads upon the calculated colour values of Jacquard fabrics surfaces. The differences in the course of the curves CCVP1/MCVF and CCVP2/MCVF are the biggest when a red thread is used in the weft and when a combined effect of bi-colour threads is used in the warp. This is understandable because the highest deviations of the colour values and of the diameter of the thread were achieved with red thread. Besides, in case of the face fabric being in plain weave a third colour thread is also present at the interlacing points which, as a third colour component, contributes to the colour value.

The analysis of colour deviations ΔE^*_{ab} between the calculated colour values CCVP2 of patterns with the thread having the computer calculated colour values and the measured colour values of the simulations MCVS shows that they are the lowest in comparison with other values ΔE^*_{ab}. It can be therefore concluded that theoretical predicting of colour values is more successful in case of simulations than in case of the real fabrics. Namely, the simulation is a 2D presentation of the colour and constructional appearance of a fabric for which a geometrical method of predicting the surface of individual colour effect is most suitable.

6.0 *CONCLUSION*

Theoretical calculation of colour values can be used for predicting the colour values of Jacquard fabrics surfaces. The accuracy of predicting greatly depends upon the type of the thread. Multifilament thread with relatively small number of twists tends to relatively big deformations of the diameter in the interlacing points. Deformations depend upon the type and the parameters of the threads with which they interlace on the fabric surface as well as upon other constructional and technological parameters of the fabric. Among constructional parameters the threads density and the weave play a key role, and among technological parameters the warp and the weft tension and reeding are most important. Due to considerable deformability of such threads their spectrophotometrically measured colour values vary as well, so that it is impossible to accurately predict the colour values of the woven surfaces.

Colour deviations of the woven patterns surface (Fig.4) show in all cases the same tendencies with differences in their extent. The ΔE^*_{ab} values reach the highest colour deviations, even over 10. These deviations are high if compared to those applied in dyeing and printing sector, but in view of colour deviations of the threads themselves they are sometimes even low. Since the inf-

merih kažejo celo kot manjša. Glede na dejstvo, da vpliv vseh konstrukcijskih parametrov tkanine na barvne vrednosti njenih površin še ni zadostno kvantitativno opredeljen, so te razlike sprejemljive. Tako računski način določanja barve tkanine kot simuliranje površine barvnih tkanin dajeta hitro in učinkovito informacijo o tem, kakšne barvne vrednosti bodo imele realne tkanine iz različno obarvanih niti pri znanih konstrukcijskih parametrih.

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luence of all constructional parameters of the fabric upon the colour values of its surfaces has not been qualitatively identified yet, these differences are acceptable. Both, the method of calculating and the method of simulating give quick and efficient information about the colour values of the real fabrics that are going to be woven from differently coloured threads at known constructional parameters.

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