Helena Gabrijelčič
Oddelek za tekstilstvo, Naravoslovnotehniška fakulteta, Univerza v Ljubljani

Barva in optični pojavi na tkanini

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Izvleček

Namen preglednega članka je sistematično predstaviti in opisati najpomembnejše dejavnike, pojave in lastnosti, ki sodelujejo pri nastanku barve na tkaninah. V prvem delu so predstavljeni nekateri optični pojavi (refleksija, absorpcija, sipanje), ki so poleg opazovalca in svetlobnega vira pogoj za dojemanje barve preje in tkanine. Osrednji del članka vključuje opis vpliva konstrukcijskih parametrov na optične pojave in posledično barvo preje in tkanine. Predstavljene so primarne lastnosti vlaken, preje in tkanin, ki povzročajo naravno obarvanost in s katerimi ustvarjamo enostavne barvno-teksturne učinke: surovinska sestava vlaken, vrsta in oblika preje, konstrukcijski parametri tkanine (gostota, vezava, presevanje v tkanini). Pregled je nadgrajen z opisom kompozicijskih lastnosti, s katerimi dosegamo zahtevnejše barvne in reliefne učinke. Tu so vključeni: barvno sosledje, razmerje med številom osnovnih in votkovnih veznih točk, razporeditev veznih točk, pojav presevanja, flotiranje niti, posebni reliefni učinki, barvno oblikovanje in odnos med barvami, ki s konstrukcijo sooblikujejo končni videz tkanega izdelka.

Ključne besede: tkanina, preja, barva, optični pojavi, konstrukcijske lastnosti

Abstract

The purpose of the scientific review paper is to systematically present and describe the most significant factors and parameters, which influence the colour of woven fabrics. In the first part, optical phenomena, such as refraction, reflection, absorption, and scattering, are described. These phenomena are necessary, beside the observer and a light source, for visual sensation of the colour of threads and woven fabrics. The main part of the paper deals with the influence of constructional parameters on the colour of threads and woven fabrics. Primary parameters of fibres, threads and fabrics, such as raw material, type and shape of yarn, constructional parameters (thread spacing, weave, reflectance) are presented. With these parameters, simple colour and texturing effects can be achieved. Furthermore, the review gives the description of some methods and compositional parameters, which enable complex colour effects. In that part, the paper analyses colour repeat, ratio of the number of warp to weft interlacing points, distribution of interlacing points, foundation reflectance, thread floating, special texturing effects, colour design, and the

Vodilni avtor/*Corresponding Author:*
dr. Helena Gabrijelčič
tel.: +386 1 200 32 78
e-mail: helena.gabrijelcic@ntf.uni-lj.si

relationship between different colours (contrast, harmony), which coupled with the construction, participate in creation of final visual appearance of woven fabrics.

Key words: woven fabric, threads, constructional parameters, colour, optical phenomena

1 Introduction

Fabrics differ by raw material, constructional parameters, application, and visual characteristics. Constructional parameters of a fabric, and their values, which are limited by the used raw materials, determine the application and appearance of woven products. A textile product can function as a complete unit only if the mentioned parameters have been carefully designed.

The initial relationship between products and users is established on the basis of visual sensation, and depends on the buyer's subjective taste. From technological aspect, the appearance of a product is treated as an additional property, and as such it is practically ignored when technical textiles are concerned. On the contrary, with clothing and decorative textiles, the appearance is a key factor, which considerably influences the buyer's attitude towards a certain product. The overall visual image of a product is created by its properties, such as colour, texture, design, as well as the dimensions and arrangement of its patterns.

The colour of textile material is attributed to the colours of constituent fibres, yarns, and textile products, as well as to certain complex phenomena that occur at the same time. Certain parameters and phenomena, which influence the colour of textiles, and, consequently, optical phenomena that occur on an untreated textile surface, are of entirely natural origin, such as natural colour, texture, and surface parameters (yarn parameters). In the first place, these are the phenomena occurring between threads in flat textile products (threads interlacing, weave, thread spacing), which change the primary structure of threads and yarns and, consequently, optical phenomena on and/or in textile material. If only the set of natural colours was available, the selection of colours would be rather modest; that is why textiles are additionally treated in order to enlarge

1 Uvod

Tkanine se med seboj razlikujejo po surovinski sestavi, konstrukcijskih parametrih, namenu uporabe in vizualnih lastnostih. Konstrukcijski parametri tkanine in njihove vrednosti so omejeni glede na surovinsko sestavo, sami pa potem definirajo možnosti uporabe in tudi vizualne lastnosti tkanega izdelka. Tekstilni izdelek deluje celovito le v primeru, ko so omenjeni parametri skrbno načrtovani.

Začetno razmerje, ki se vzpostavi med izdelkom in uporabnikom, temelji na vizualnem dojemanju in je odvisno od subjektivnega okusa kupca. Videz izdelka se s tehnološkega vidika obravnava kot dodatna lastnost tkanin, zato se pri tehničnih tekstilijah lastnosti videza skorajda ne obravnavajo. Nasprotno je pri tekstilijah za oblačilno in dekorativno uporabo videz vodilni dejavnik, ki vpliva na kupčev odnos do izdelka. Celostno vizualno podobo oblikujejo lastnosti kot barva, tekstura, oblika izdelka ter dimenzije in razporeditev vzorcev na njem.

Barva tekstilnega materiala je posledica barvnih lastnosti tekstilnih vlaken, preje in tekstilnega izdelka ter sočasnega delovanja kompleksnih pojavov. Nekatere lastnosti in pojavi, ki vplivajo na barvo tekstilij, so popolnoma naravnega izvora: naravna obarvanost, tekstura in lastnosti površine (lastnosti preje) ter posledično vsi optični pojavi na neobdelani tekstilni površini. Na prvo mesto lahko tu postavimo vse pojave med nitmi v ploskih tekstilnih izdelkih (prepletanje niti, vezava, gostota niti), ki spremenijo primarno strukturo preje in vlaken ter s tem tudi optične pojave na/v tekstiliji. Če bi lahko izbirali samo med naravnim naborom barv, bi imeli precej majhno izbiro, zato tekstilije dodatno obdelujemo in s tem precej povečamo barvno paleto na tekstilnem materialu. Dodatna obdelava lahko vključuje kemijsko in mehansko obdelavo tekstilnega materiala (tiskanje, barvanje, mehanske apreture), ki tako ali drugače vpliva na optične in spektralne pojave na/v tekstiliji.

Kompleksnost pojava barve na tekstilijah potrjuje dejstvo, da je nemogoče opisati skupni barvni učinek na vzorcu z eno samo merilno metodo (spektrofotometrija, goniometrija itd.). Potrebno je sodelovanje več merilnih in analitičnih postopkov, s katerimi sočasno opišemo spektralne in optične lastnosti tekstilije ter psihofizično dojemanje človeka ob opazovanju barve tekstilije. Med brskanjem po domači in tuji literaturi zasledimo raziskave, ki opisujejo, kakšne barvno-optične učinke dosežemo z različnim prepletanjem osnovnih in votkovnih niti enake barve ter kombiniranjem niti različnih barv [1, 2, 3, 4, 5, 6]. Te raziskave največkrat obravnavajo tematiko z oblikovalskega vidika, numerični in analitični pristopi pa so nekoliko zapostavljeni. V nekaterih raziskavah je analiza tudi poglobljena, saj predstavlja lego barv večbarvnih tkanin v primerjavi z izhodiščnimi barvami osnovnih in votkovnih niti v barvnem prostoru ter numerično ovrednoti in napoveduje skupni barvni učinek tkanine, sestavljene iz osnovnih in *the selection of colours on textile materials. Additional treatment either chemical or mechanical (printing, dyeing, mechanical finishes) influences in one or another way optical and spectral phenomena on and/or in textile materials.*

The complexity of colour phenomenon on textiles is confirmed by the fact that it is impossible to describe the entire colour effect on a pattern with only one measurement method (spectrophotometry, goniometry, etc.). Several measurement and analytical procedures have to be combined in order to be able to describe spectral and optical properties of textile material, and the psychophysical sensation of its colour. There are several researches mentioned in home and foreign literature, which describe the colour-optical effects that can be achieved by different interlacing of warp and weft threads of the same colour, and by combining threads of different colours [1, 2, 3, 4, 5, 6]. In most cases, these researches deal with this subject from the aspect of design, whereas numerical and analytical approaches are more or less ignored. Only few researches provide in-depth analyses of the position of colours of multicolour fabrics in colour space in comparison with the original colours of warp and weft threads, and numerical evaluation and prediction of final colour effect of a fabric manufactured from differently coloured warp and weft threads [7, 8, 9, 10]. In these researches, colour metrics was used in a different, not standardized manner, which offered quite a new insight into the issue of colour creation and its visual sensation on fabrics.

2 Optical phenomena on fabric

There are three factors that influence the perception and appearance of the colour of a woven product (Figure 1) [11, 12, 13]:

- *the light source transmitting rays onto the observed surface,*
- *the optical-reflective properties of material, and*
- *the observer and responsiveness of his eye.*

The colour of a textile object (fibre, yarn, flat textile product), which is seen by the eye, depends on its chemical and physical composition, and its structure. When light contacts the surface of a material, a portion is reflected from

votkovnih niti različnih barv [7, 8, 9, 10]. V teh raziskavah je bila barvna metrika uporabljena na drugačen, nestandardiziran način, ki ponuja nov vpogled v problematiko nastanka in dojemanja barve na tkaninah.

2 Optični pojavi na tkanini

Na dojemanje in videz barve tkanega izdelka vplivajo trije dejavniki (slika 1) [11, 12, 13]:

- svetlobni vir, katerega svetlobno sevanje pada na opazovano površino,
- optično-refleksijske lastnosti materiala in
- opazovalec in odzivnost njegovega očesa.

Barva tekstilnih objektov (vlaken, preje, ploskih tekstilnih izdelkov), ki jo oko zazna, je odvisna od kemijske in fizikalne sestave ter strukture. Pri stiku svetlobe z materialom se del svetlobe odbije od površine oz. reflektira, del pa se vpije oz. absorbira v material. Barva predmeta je odvisna od razmerja teh deležev. Slika 1 prikazuje pojav refleksije, absorpcije, loma in sipanja svetlobe v vlaknatem tekstilnem materialu. Del vpadnega žarka I_0 se v točki stika s površino A odbije kot reflektirani žarek I_r, del pa prodre v vlakno tekstilne strukture in se pri tem lomi – I_l (žarek B). Žarek pri lomu svetlobe spremeni kot gibanja glede na normalo, saj je tekstilni material gostejši medij od zraka v okolici. Ko žarek v točki B zapusti vlakno in se giblje po vmesnem zraku, se naklon gibanja ponovno spremeni, in sicer tako, da je vzporeden žarku vpadle svetlobe. Pri prehodu skozi vlakna, ki sledijo, se proces lomljenja svetlobnega žarka ponovi. Jakost svetlobe se pri tem zmanjšuje zaradi absorpcije v molekule barvila – I_a in sipanja na manjših strukturnih delcih – I_s. Prepuščena svetloba zapusti vlaknati material kot prepuščeni oz. transmitirani žarek – I_t pod enakim kotom glede na normalo, kot ga je imela vpadla svetloba. Vpadla svetloba svetlobnega vira I_0 je tako vsota reflektirane I_r, absorbirane I_a, sipane I_s in transmitirane I_t svetlobe, kot prikazuje enačba (1) [11, 12]:

$$I_0 = I_r + I_a + I_s + I_t \quad (1)$$

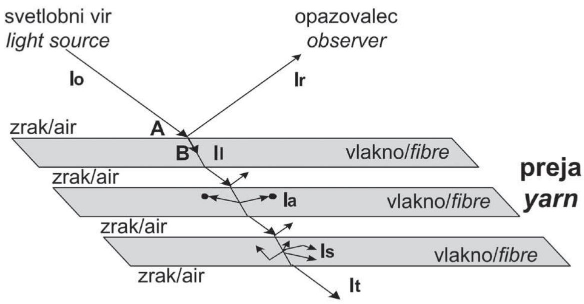


Figure 1: Reflection, absorption, refraction, scattering, and transmittance of light in textile material

the surface, and a portion is absorbed by the surface. The colour of the object depends on the relation between these two portions. Figure 1 presents the phenomenon of reflection, absorption, refraction, and scattering of the light in a fibrous textile material. In the light – surface contact point A, a portion of incident light ray I_0 *is reflected as* I_r*, and a portion penetrates into the fibre of the textile structure and refracts as* I_l *(ray B). At the light refraction, the ray changes the angle of its travel in view of the normal because textile material is a denser medium than the surrounding air. When the ray leaves fibre in point B, and travels through the intermediary air, the inclination of its travel changes again and becomes parallel to the incident light ray. At the passage through following fibres, the process of the light ray refraction is repeated. The light intensity is decreasing as a result of the light absorption into the molecules of dyestuff-*I_a *and its scattering on smaller structural parts-*I_s*. The transmitted light leaves fibrous material as transmitted ray-*I_t *at the same angle in view of the normal at which the incident light entered the surface. Incident light* I_0 *is therefore a sum of reflected light* I_r*, absorbed light* I_a*, scattered light* I_s*, and transmitted light* I_t *as is presented by Equation 1 [11, 12].*

At optical perception of the light, it is the reflected light, which is particularly important as it reaches the eye and induces visual sensation of colour.

2.1 Reflection

The portion of the light, which does not refract into the object, reflects from its surface, and reaches the eye. Photons, which fall on the smooth surface of material, reflect from it by changing the direction of movement. In the case of smooth surface, the angle of reflection is the same as the angle of incidence, and in the case of unsmooth surface, this angle is different.

The light, which will reflect from the surface between materials 1 and 2 with different indexes of refraction, can be expressed according to Fresnel law as a reflection factor by Equation 2 where ρ is the reflection factor of non-polarized light, and n is the relationship between indexes of refraction of materials 1 and 2 $(n = n_2 : n_1)$ *[12].*

Pri optičnem zaznavanju svetlobe je pomembna predvsem reflektirana svetloba, saj slednja doseže oko in sproži zaznavo barve.

2.1 Refleksija

Delež svetlobe, ki se ne lomi v telo, se od telesa odbija – reflektira in doseže naše oko. Fotoni, ki padejo na gladko površino materiala, se od nje odbijejo, tako da spremenijo smer gibanja. V primeru gladke površine je kot odboja enak vpadnemu kotu, v primeru negladke površine pa sta kota različna.

Svetlobo, ki se bo odbila od površine med materialoma 1 in 2 z različnima lomnima količnikoma, lahko podamo s Fresnelovim zakonom v obliki refleksijskega faktorja z enačbo (2), kjer je ρ refleksijski faktor nepolarizirane svetlobe in n razmerje lomnih količnikov materialov 1 in 2 $(n = n_2 : n_1)$ [12].

$$r = \frac{(n-1)^2}{(n+1)^2} \tag{2}$$

Barva predmeta, ki jo vidimo, ustreza delu vidnega spektra svetlobe, kjer ima refleksija maksimalno vrednost. Svetloba, ki se od predmeta odbija, je pri tem nasprotna oz. komplementarna absor-

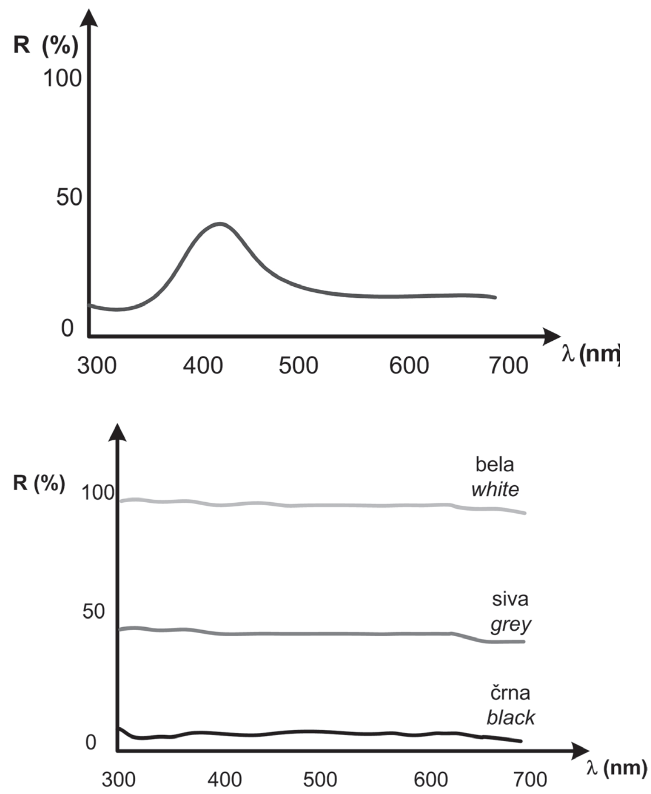


Figure 2: Reflection curves of saturated blue surface, and unsaturated white, grey and black surfaces

The colour of an object, which is seen by the eye, corresponds to the part of the light visible spectrum in which reflection reaches its peak. The light, which reflects from the object, is opposite, i.e. complementary to the absorbed wavelengths. The object, which is seen as blue, absorbs wavelengths of the yellow part, and reflects the light of the blue part of visible spectrum. In practice, the value of the reflected light is expressed as a portion of the incident light that is reflected from the surface. Thus, the portions of the reflected light (R) are presented in the form of reflection curves. With regard to the shape of reflection curves, colours are either chromatic (saturated) or achromatic (unsaturated). Chromatic colours have the reflection peak in the visible part of electromagnetic radiation range, whereas achromatic colours have almost constant value of reflection at all wavelengths from 360 to 700 nm. The reflection curve of a fabric that is seen as blue (a), and the reflection curves of achromatic colours (b) are presented in Figure 2.

Light reflection depends on the surface of textile material, and influences the perception of its colour lightness and saturation. In general, reflection depends on three parameters of a surface: brilliance, texture, and lustre. Brilliance has influence on colour lightness and saturation. A surface with higher brilliance looks, in dependence of the angle of viewing, darker than a mat surface from which the light scatters. Namely, scattering decreases the intensity of the reflected ray so that, for example, a black object looks lighter. Texture of a surface is connected with brilliance – a more prominent texture exhibits less brilliance. The third parameter is lustre, which characterizes selective mirror-like reflection of the light. At contact with the surface, a portion of the light reflects from randomly distributed particles. Spectral composition of the reflected light depends on the type and properties of these particles. The light, which does not reflect from the surface, penetrates into the material where it is selectively absorbed and partly reflected back towards the observer. Perception of the colour depends on the angle of viewing; the light, which reaches the eye, changes when the position of the observed object is changed [14].

biranim valovnim dolžinam. Telo, ki ga zaznavamo kot modro, absorbira valovne dolžine rumenega dela, odbija pa svetlobo modrega dela vidnega spektra. V praksi se vrednost reflektirane svetlobe podaja kot delež vpadle svetlobe, ki se je odbil od površine. Deleži odbite – reflektirane svetlobe (R) se tako prikazujejo v obliki refleksijskih krivulj. Glede na obliko refleksijske krivulje ločimo kromatske (nasičene) in nekromatske oz. akromatske (nenasičene) barve. Kromatske barve imajo v vidnem delu elektromagnetnega spektra maksimum refleksije, nekromatske barve pa imajo pri vseh valovnih dolžinah od 360 do 700 nm skoraj konstantno vrednost refleksije. Refleksijsko krivuljo tkanine, ki jo vidimo kot modro (a), in refleksijske krivulje akromatskih barv (b) predstavlja slika 2.

Refleksija svetlobe na tekstilnem materialu je odvisna od površine materiala ter vpliva na dojemanje svetlosti in nasičenosti njegove barve. Refleksija je tako na splošno odvisna od treh lastnosti površine: sijaja, teksture in leska.

Opazimo lahko vpliv sijaja materiala na svetlost in nasičenost barve površine. Površina z večjim sijajem je videti – odvisno od zornega kota opazovanja – temnejša kot mat površina, na kateri se svetloba sipa. Sipanje namreč oslabi jakost odbitega žarka, tako da je npr. črn objekt videti svetlejši. Tekstura površine je povezana s sijajem, saj ima izrazitejša tekstura za posledico manj sijaja. Tretja lastnost pa je lesk, ki označuje selektivni zrcalni odboj svetlobe. Del svetlobe se pri stiku s površino odbije od naključno razporejenih delcev. Spektralna sestava odbite svetlobe je pri tem odvisna od vrste in lastnosti delcev. Svetloba, ki se ne odbije, prodre v material ter se tam selektivno absorbira in delno reflektira nazaj do opazovalca. Dojemanje barve materiala je pri tem odvisno od kota opazovanja, v oko vpadla svetloba pa se spreminja s spreminjanjem lege objekta [14].

Na sliki 3 [15] so v odvisnosti od gladkosti površine prikazani štirje tipi odboja vpadle svetlobe. V primeru A je predstavljen difuzni odboj svetlobe, kjer je videz neodvisen od kota opazovanja. V pri-

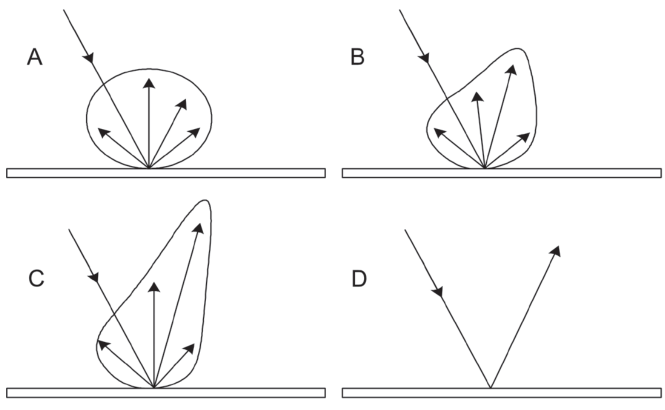


Figure 3: Orientation of reflected light at contact with different surfaces

Figure 3 presents, in dependence of the smoothness of the surface, four types of the incident light reflection. In case A, diffusive reflection of the light is presented; in that case the appearance of the surface is independent of the angle of viewing. In cases B and C, the increased smoothness of the surface results in the orientation of the reflected light in a particular direction. Material D is perfectly smooth with the angle of light reflection being identical to the angle of light incidence. The surface is lustrous, and its appearance depends on the angle of viewing.

From textile fibres, a bigger portion of the light reflects diffusively – from natural fibres due to scattering on the surface of microfilaments, and from synthetic fibres due to the particles of titanium dioxide [13].

Since all phenomena that accompany the reflection of the incident light can be present on textile materials, it is highly important that the appropriate method of colour measurement is selected. Standardized measurement methods, which are used in colorimetry, recommend elimination of the phenomenon of lustre on textile materials, however, the user may decide otherwise [15]. Likewise spectrophotometric curves are used to define the colour of an object, goniometric curves can be used to define the surface parameters of an object. Goniometer is a complex optical device that measures the quantity of the reflected light under various angles of viewing. The measurement methods can be different, either with fixed angle of illumination and by changing the angle of the object's position, or by changing both angles, i.e. the angle of illumination and the angle of the object's position [14].

2.2 Light refraction

During penetration into material, the incident light refracts and changes the angle of its travel in view of the perpendicular. This phenomenon occurs due to different densities of materials and, consequently, different indexes of refraction [12, 13].

Refraction of light ray I_0 at passage from one material to another is presented in Figure 4.

The relationship between the indexes of refraction of two materials n_1 and n_2 is calculated on the basis the relationship between the angles of

merih B in C se povečana gladkost kaže kot usmerjenost reflektirane svetlobe v določeno smer. Material D je popolnoma gladek, zato je odbojni kot svetlobe popolnoma enak vpadnemu kotu. Površina je lesketajoča in njen videz odvisen od kota opazovanja.

Na tekstilnih vlaknih se večji delež svetlobe odbije difuzno, in sicer na naravnih vlaknih zaradi sipanja na površini mikrofibrilov, na sintetičnih pa zaradi delcev titanovega dioksida [13].

Na tekstilnem materialu so lahko prisotni vsi pojavi, ki spremljajo odboj vpadle svetlobe, zato je zelo pomembno definirati ustrezen način merjenja barve. Standardizirani načini merjenja, ki se uporabljajo v barvni metriki, priporočajo izključitev pojava leska na tekstilnem materialu, vendar se uporabnik glede na svoje potrebe lahko odloči drugače [15]. Podobno kot uporabljamo spektrofotometrično krivuljo za definicijo barve predmeta, lahko z goniometrično krivuljo definiramo njegove površinske lastnosti. Goniometer je kompleksna optična naprava, ki meri količino reflektirane svetlobe pod različnimi koti opazovanja. Načini merjenja so lahko različni, in sicer s fiksnim kotom osvetljevanja svetlobnega vira in spreminjanjem kota lege objekta ali s spreminjanjem obeh kotov, tako osvetljevanja kot lege objekta [14].

2.2 Lom svetlobe

Ko vpadla svetloba prodira v material, se lomi in pri tem spremeni naklon gibanja glede na pravokotnico. Vzrok pojava so različne optične gostote materialov in posledično različni lomni količniki [12, 13].

Lom svetlobnega žarka I_0 pri prehodu iz enega materiala v drugega prikazuje slika 4.

Razmerje lomnih količnikov dveh materialov n_1 in n_2 se izračuna iz razmerja kotov potovanja svetlobe v dveh materialih po enačbi (3), kjer je θ_1 vpadni kot in θ_2 lomni kot. [12]

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1} \quad (3)$$

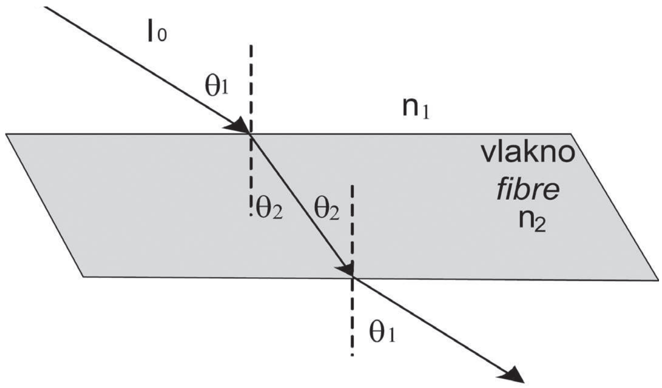


Figure 4: Refraction of light ray at its passage through material with parallel surfaces

the light travel through two materials by using Equation 3 where θ_1 is the angle of incidence, and θ_2 is the angle of refraction [12]:

2.3 Light absorption

Light absorption is the capability of a material to absorb the light of certain wavelengths. All materials are capable of absorbing the waves of ultraviolet, visible or infrared spectrum of electromagnetic radiation. However, only the materials, which absorb the waves within visible light spectrum can be perceived by the eye as coloured. The fact that materials absorb light can be understood only if various types of energy of particles are known.

Molecules possess the rotational energy as a result of their rotation around the gravity centre, the vibrational energy as a result of shrinking and bending of chemical bonds, and the electronic energy as a result of movement of electrons around the atomic nucleus, i.e. their passing over to a higher electronic level. These phenomena are presented in Figure 5 [11].

Molecules absorb only the light of such wavelengths within UV and visible spectrum, the energy of which corresponds to the difference in the energy between two energy levels of electrons in molecules. Incitement of electrons from the initial into the incited state follows. Lower energy and the light with higher wavelengths (IR and micro waves) are required for rotational and vibrational change.

The portion of the absorbed light is determined experimentally by using Lambert-Beer law according to which the absorption of light A by the particles of a dyestuff in a solution depends on dye concentration c (mol/l), length l of path passed by the light (m, cm), and extinction factor ε, as is shown by Equation 4 [11, 13]. It is evident that absorption also depends on value T, i.e. the degree of transmission or the portion of the transmitted light.

A disadvantage of Lambert-Beer law is that it can be used only for the light of specified wavelengths (monochromatic light), and for the materials in which scattering is not present.

2.4 Scattering

A portion of the light striking textile material passes through it due to spaces existing be-

2.3 Absorpcija svetlobe

Absorpcija je sposobnost materiala, da vpije svetlobo določene valovne dolžine. Vsi materiali imajo sposobnost absorbirati valovanje ultravijoličnega, vidnega ali infrardečega področja elektromagnetnega valovanja. Vendar pa lahko samo tiste materiale, ki absorbirajo v področju vidne svetlobe, človeško oko zazna kot obarvane. Razumevanje dejstva, da snovi absorbirajo svetlobo, je mogoče le ob poznavanju različnih vrst energije delcev.

Molekule posedujejo rotacijsko energijo zaradi vrtenja okoli težišča, vibracijsko-nihajno energijo zaradi krčenja in upogibanja kemijskih vezi ter elektronsko energijo zaradi gibanja elektronov okoli atomskega jedra oz. prehajanja na višji elektronski nivo. Opisane pojave prikazuje slika 5 [11].

Molekula absorbira svetlobo samo takšnih valovnih dolžin ultravijoličnega in vidnega področja, katerih energija ustreza energijski razliki dveh energijskih nivojev elektrona v molekuli. Sledi vzbujanje elektronov iz osnovnega v vzbujeno stanje. Za rotacijsko in vibracijsko spremembo je potrebna manjša energija in svetloba z večjimi valovnimi dolžinami valovanja (IR- in mikrovalovi).

Delež absorbirane svetlobe določimo eksperimentalno s pomočjo Lambert-Beerovega zakona, ki določa, da je absorpcija svetlobe A na delcih barvila v raztopini odvisna od koncentracije barvila c (mol/l), dolžine poti l, ki jo svetloba prepotuje (m, cm), in ekstinkcijskega koeficienta ε, kot prikazuje enačba (4) [11, 13]. Sledi, da je absorpcija odvisna tudi od vrednosti T, ki pomeni stopnjo transmisije oz. delež prepuščene svetlobe.

$$A = log\left(\frac{1}{T}\right) = \varepsilon \cdot c \cdot l \qquad (4)$$

Pomanjkljivost Lambert-Beerovega zakona je omejitev uporabe, saj velja le v primeru svetlobe določene valovne dolžine (monokromatska svetloba) in za snovi, v katerih ni prisotno sipanje.

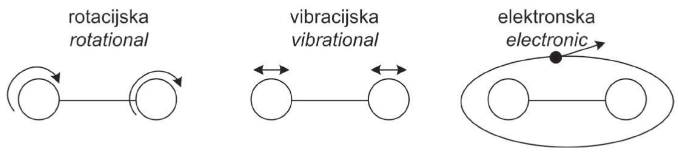


Figure 5: Energy in molecules

2.4 Sipanje

Del svetlobe, ki pade na tekstilni material, prehaja skozi tkanino zaradi prostorov med osnovnimi in votkovnimi nitmi ter prostorov med vlakni. Do pojava sipanja pride, če so delci, ob katere trči svetloba, dovolj majhni v primerjavi z valovno dolžino vpadle svetlobe. Ocenjuje se, da mora biti velikost delcev, ki povzročajo sipanje, manjša od ene desetine velikosti valovne dolžine vpadle svetlobe [12]. Zaradi pojava sipanja se pri prehodu svetlobe skozi *tween warp and weft threads, and between fibres. The phenomenon of scattering occurs only if the particles, which the light hits against, are small enough in comparison with the incident light wavelength. It is estimated that the size of the particles, which induces scattering should be smaller than one tenth of the size of the incident light wavelength [12]. As a result of scattering, the intensity of the ray decreases during the light passing through the fabric in dependence of the properties of the scattering centres in the fabric.*

Likewise Lambert-Beer law, such decreased intensity of the light ray can be expressed by Equation 5 where I_t is the light ray intensity after passing through material, I_0 is the incident light intensity, l is the distance passed by the light ray in material, and α_s is the experimentally determined coefficient of scattering for the material [12].

Figure 6 presents scattering of the incident ray in the fibre of warp and weft threads.

2.5 Light absorption and scattering

On opaque materials, three phenomena occur, which influence the colour formation or its appearance: absorption, scattering, and reflection. Their interdependence can be expressed by Kubelka-Munk Equation 6, which includes absorption coefficient K, coefficient of scattering S, and reflection R. Value K/S expresses the so-called colouration of an object [12, 13].

Final form of Kubelka-Munk Equation has been derived from the analyses of the absorption, scattering, and reflection phenomena on a thin layer of dyestuff applied on substrate. Disadvantages of this Equation are that it can be used only for monochromatic light, that it ignores loss of the light over edges and total reflection on the surface, and that it simplifies the distribution of dye particles as being uniform and without any interactions.

3 Constructional parameters and colour of fabric

The phenomenon of colour on a woven product cannot be attributed exclusively to the above optical phenomena. There are many other parameters, which influence the overall perception of colour. First of all, the colour values of constituent threads, which define the hue of a

tkanino jakost žarka zmanjša, kar je odvisno od lastnosti centrov sipanja v tkanini.

Podobno kot Lambert-Beerov zakon se lahko moč oslabljenega svetlobnega žarka zaradi sipanja zapiše z enačbo (5), kjer je I_t jakost svetlobnega žarka po potovanju skozi material, I_0 jakost vpadle svetlobe, l razdalja, ki jo žarek prepotuje v snovi, in α_s eksperimentalno dobljen koeficient sipanja za določen material [12].

$$I_t = I_0 \exp(-\alpha_s \cdot l) \quad (5)$$

Na sliki 6 je prikazano sipanje vpadlega žarka v vlaknu osnovnih in votkovnih niti.

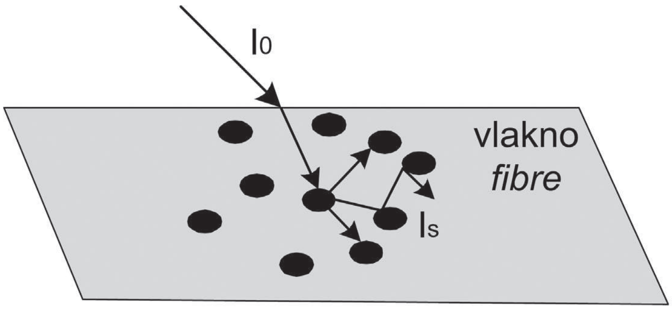


Figure 6: Scattering of light ray in fibre

2.5 Absorpcija in sipanje svetlobe

Na neprozornih materialih so istočasno prisotni trije pojavi, ki vplivajo na nastanek barve ali na njen videz: absorpcija, sipanje in refleksija. Njihovo soodvisnost lahko izrazimo s Kubelka-Munkovo enačbo (6), ki vključuje koeficient absorpcije K, koeficient sipanja S in refleksijo R. Vrednost K/S podaja t. i. obarvanost predmeta [12, 13].

$$\frac{K}{S} = \frac{(1-R)^2}{2R} \quad (6)$$

Končna oblika Kubelka-Munkove enačbe je bila v preteklosti izpeljana iz analiz pojavov absorpcije, sipanja in refleksije v tankem sloju barvila na substratu. Enačba ima nekaj pomanjkljivosti, na primer uporabo le pri monokromatski svetlobi, zanemarjanje izgube svetlobe preko robov in totalnega odboja na površini ter poenostavitev, da so delci barvila enakomerno razporejeni in med njimi ni interakcij.

3 Konstrukcijske lastnosti in barva tkanine

Pojava barve tkanega izdelka ne moremo omejiti le na optične pojave, ki so podani v prejšnjem poglavju, saj na celostno dojemanje barve vpliva še množica drugih parametrov. Najprej je seveda *woven product and, consequently, the attitude of observers. The entire colour phenomenon of a woven product can be understood only when we know all constructional parameters of yarn and fabric, as well as colour design parameters of fabric, which define:*

- *relationship between the material and the incident light: reflection, scattering, and absorption (type and material of yarns or fibres, smoothness or hairiness of the surface, relief and texture),*
- *size and proportion of individual coloured surfaces (linear density, weave, thread spacing),*
- *arrangement of colour surfaces (weave, warping and weaving pattern),*
- *overall effect of a single-colour or multicolour fabric (colour designing parameters of a fabric). [10]*

3.1 Constructional parameters of yarn

The parameters, which define the construction, properties, and appearance of yarns, are:

- *raw material,*
- *type and cross-section of fibres,*
- *type, shape, linear density, and diameter of yarn.*

3.1.1 Raw material, type and shape of fibres

At colourimetric investigation of fibres, special attention has to be paid to the properties imparted by the used raw material. Surface, dimensions, crystallinity, and shape of cross-section define light reflection and refraction (absorption and scattering) on and/or in a fibre.

By their raw material and possibilities of further processing, fibres are divided into natural (cellulose and protein), and chemically regenerated and synthetic fibres [11]. Natural fibres (cotton, silk wool) have intrinsic shape and construction, which cannot be changed in any way, the only exception are certain chemical and mechanical processes. As to chemically regenerated fibres (viscose, rayon, protein regenerated fibres), a man interferes more intensively with the properties in order to adjust them more or less to the requirements of usage. Synthetic fibres (polyesters, polyamides) involve the highest degree of technological manipulation,

treba poznati barvne vrednosti niti, ki bodo sestavljale tkani izdelek. Te definirajo barvni ton izdelka in posledično odnos, ki ga bo imel opazovalec do njega. Razumevanje celotnega pojava obarvanosti tkanega izdelka pa je mogoče šele s poznavanjem vseh konstrukcijskih lastnosti preje in tkanine ter barvno-oblikovnih lastnosti tkanine, ki definirajo:

- odnos materiala do vpadle svetlobe: refleksija, sipanje in absorpcija (vrsta in surovina preje oz. vlaken, gladkost oz. kosmatost površine, reliefnost in tekstura),
- velikost in razmerje med posameznimi barvnimi površinami (dolžinska masa, vezava, gostota niti),
- razporejenost barvnih površin (vezava, vzorec snovanja in tkanja),
- skupno učinkovanje barve enobarvne ali večbarvne tkanine (barvno-oblikovni parametri tkanine). [10]

3.1 Konstrukcijski parametri preje

Dejavniki, ki definirajo konstrukcijo, lastnosti in posledično videz preje so:

- surovinska sestava,
- vrsta in prečni prerez vlaken,
- vrsta, oblika, dolžinska masa in premer preje.

3.1.1 Surovinska sestava, vrsta in oblika vlaken

Pri barvnometričnem preučevanju vlaken moramo biti pozorni predvsem na nekaj lastnosti, ki so posledica surovinske sestave. Površina, dimenzije, kristaliničnost in oblika prečnega prereza definirajo na/v vlaknu refleksijo in lom svetlobe (absorpcijo in sipanje).

Po surovinski sestavi in glede na možnosti nadaljnjih obdelav delimo vlakna na naravna (celulozna in beljakovinska) ter kemično regenerirana in sintetična vlakna [11]. Oblika in zgradba naravnih vlaken (bombaž, svila in volna) sta danosti narave, zato nanju skoraj ne moremo vplivati, razen z določenimi izbranimi kemičnimi in mehanskimi postopki. Pri kemično regeneriranih vlaknih (viskoza, rajon, beljakovinska regenerirana vlakna) človeški poseg intenzivneje vpliva na lastnosti, s čimer se te lastnosti do določene mere priredijo potrebam uporabe. Najvišja stopnja tehnološke manipulacije so sintetična vlakna (poliestri, poliamidi), katerih kemična sestava, oblika in površina so glede na nadaljnjo uporabo pred izdelavo skrbno načrtovane.

Pri analizi odnosa vlakno-svetloba lahko omenimo nekaj lastnosti, ki močno vplivajo na barvno podobo izdelka [16]:

- površina vlaken,
- orientacija vlaknaste strukture,
- dolžinska masa,
- prečni prerez,
- poobdelava s kalandriranjem ali brezbarvno apreturo,
- matirno sredstvo.

their chemical composition, shape, and surface are carefully planned with regard to their further usage prior to manufacture.

When the fibre-light relationship is analysed, few parameters, which considerably influence the colour of a woven product, have to be mentioned [16]:

- *fibres surface,*
- *fibrous structure orientation,*
- *linear density,*
- *cross section,*
- *after-treatment by calendering or by applying colourless finish,*
- *matting agent.*

Natural fibres

Natural fibres have rather unequal dimensions and rough surface produced by scales at wool, by lumen at cotton, and by longitudinal furrows at stem fibres. The length of fibres varies from 12 to 50 mm with cotton, and from 50 to 400 mm with wool. The cross-section of these fibres also varies lengthwise the fibres, and has irregular shape: furrowed, flattened, kidney-shaped. With the exception of silk, which has rather smooth surface and oval cross-section, the light reflection from natural fibrous structures is therefore diffusive as a result of the light scattering in all directions from uneven texture. Lustre of these fibres is lower and less dependent on the angle of viewing. To achieve the same colour effect as with the fibres with round cross-section, larger quantity of dyestuff is required. Due to more irregularities in the structure (arrangement of crystalline and amorphous regions), the possibility of unequal distribution of a dyestuff throughout fibre and, consequently, of unequal colour effect at viewing is greater [11, 16, 17]. Figure 7 presents the contact of the light with a cotton fibre (a), and a wool fibre (b).

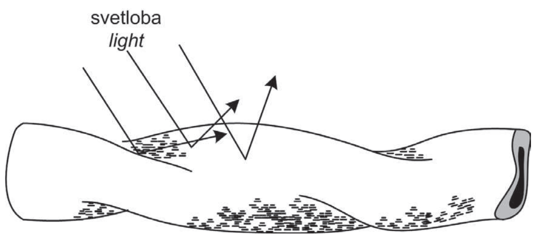
Synthetic fibres

The shape of the cross-section of synthetic fibres, and the size of their diameter are determined during their extrusion through nozzles with adequately shaped openings. At the same time, the fibres properties are adjusted to further use. The length of multifilament fibres is infinite, whereas shorter lengths of synthetic fibres are formed after the spinning process by

Naravna vlakna

Naravna vlakna imajo precej neenakomerne dimenzije in grobo površino, ki jo oblikujejo pri volni luske, pri bombažu lumen, pri stebelnih vlaknih pa vzdolžne brazde. Dolžina vlaken precej varira: od 12 do 50 mm pri bombažu in od 50 do 400 mm pri volni. Podobno je tudi prečni prerez teh vlaken neenakomeren po dolžini vlaken in nepravilnih oblik: nabrazdan, sploščen, ledvičast. Razen pri svili, ki ima precej gladko površino in ovalen prerez, je torej odboj svetlobe od naravnih vlaknastih struktur difuzen, saj se zaradi razgibane teksture in oblike svetloba sipa na vse strani. Lesk teh vlaken je manjši in manj odvisen od zornega kota opazovanja, za doseganje enakega barvnega efekta pa je potrebna večja količina barvila kot pri vlaknih z okroglim prerezom. Zaradi več nepravilnosti v strukturi (razporeditvi kristaliničnih in amorfnih področij) je večja tudi možnost neenakomerne porazdelitve barvila po vlaknu in posledično neenotnega barvnega učinka pri opazovanju [11, 16, 17]. Na sliki 7 je prikazan stik svetlobe z bombažnim (a) in volnenim (b) vlaknom.

a) Cotton



b) Wool

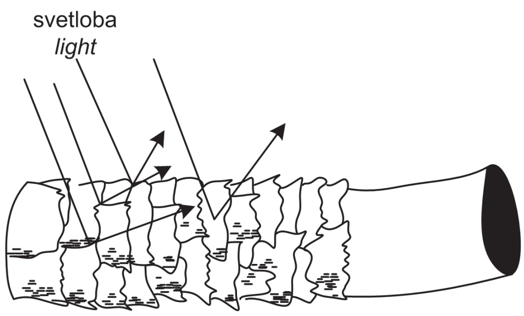


Figure 7: Surface and cross-section of natural fibres with light reflection

Sintetična vlakna

Obliko prečnega prereza in velikost premera določamo pri postopku ekstrudiranja vlaken skozi šobe z odprtinami ustreznih oblik. Pri tem karakteristike vlaken prilagodimo nadaljnji uporabi. Pri multifilamentnih vlaknih je dolžina vlaken neskončna, manjše dolžine sintetičnih vlaken pa oblikujemo šele po predilnem postopku,

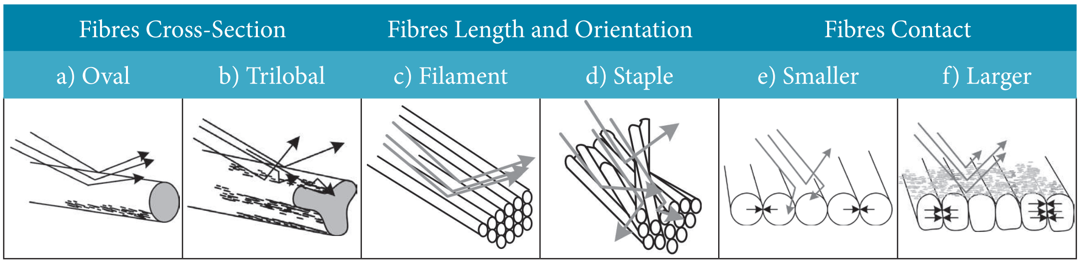


Figure 8: Reflection and scattering on fibres surface

cutting them on a cutting machine to a staple length of optional size [17]. Since it is possible to plan the three mentioned parameters of synthetic fibres, their relationship with light can be pre-determined as well.

Due to pushing of spinning blend through nozzles, the surface of synthetic fibres is perfectly smooth, and the light reflection from such surface would be rather specular and mirror-like, which can be controlled with the shape of nozzles, which determine the dimensions of the fibres cross-section. It is the application, which decides whether the shape of the cross-section of synthetic fibres will be oval, indented, trilobal, multilobal, tubular, convex, triangular, or of any other shape. With all shapes of cross-section different from the regular oval shape, the incident light diffuses at the air-fibre contact under different angles in view of the line of incidence. Similar as with natural fibres, diffusive light reflection influences visually lighter colours, which may also look less saturated. In the case of lustrous fibres, the bundle of light rays that reaches the eye produces visually more intensive colours in dependence of the angle of viewing. This is the result of the mirror effect and specular reflection of light. Light scattering on fibres can be additionally intensified by adding scattering active particles into the spinning solution (e.g. titanium dioxide); the appearance of the product will be less lustrous and more matt.

Beside the shape of cross-section, it is also its size, which is important. Fibres with lower linear density usually have smaller cross-section. Consequently, they absorb less light, but are due to larger specific surface of fibres more scattering active. The comparison of thinner and thicker fibres, which absorbed equal quantity of dyestuff, reveals visual differences between them.

ko se na rezalnem avtomatu vlakna razrežejo na štapelno dolžino poljubne velikosti [17]. Glede na to, da lahko pri sintetičnih vlaknih sami načrtujemo vse tri omenjene lastnosti, lahko določamo tudi odnos med sintetičnimi vlakni in svetlobo.

Zaradi potiskanja predilne zmesi skozi šobe je površina sintetičnih vlaken popolnoma gladka, odboj svetlobe od takšne površine pa bi bil precej usmerjen in zrcalen. Slednje lahko kontroliramo z obliko predilnih šob, ki določajo dimenzije prečnega prereza vlaken. Od namena uporabe je torej odvisno, ali bodo oblikovana sintetična vlakna imela ovalni, nazobčani, trilobalni, multilobalni, cevasti, konveksni trikotni ali kakšen drug prerez. Pri vseh oblikah prereza, ki se razlikujejo od pravilne ovalne oblike, je vpadla svetloba pri srečanju medijev zrak-vlakno razpršena pod različnimi koti glede na vpadnico. Difuzen odboj svetlobe vpliva podobno kot pri naravnih vlaknih na vizualno svetlejše barve, ki so lahko videti tudi manj nasičene. Pri lesketaj očih vlaknih pa snop žarkov svetlobe, ki doseže oko, povzroča vizualno intenzivnejše barve, odvisne od zornega kota opazovanja. To je posledica zrcalnosti in usmerjenosti odbite svetlobe. Dodatna možnost povečanja sipanja svetlobe na vlaknih je dodajanje sipalno aktivnih delcev v predilno maso (kot npr. titanov dioksid), ki povzročajo manj lesketajoč in bolj mat videz končnega izdelka.

Poleg oblike prečnega prereza je pomembna tudi njegova velikost. Vlakna z manjšo dolžinsko maso imajo običajno tudi manjši prečni prerez. Posledično absorbirajo manj svetlobe, vendar so zaradi večje specifične površine ta vlakna sipalno bolj aktivna. Pri primerjavi tanjših in debelejših vlaken, pri katerih je bila absorbirana enaka količina barvila, prihaja do vizualnih razlik. Finejša vlakna so videti namreč svetlejša kot bolj groba, za doseganje enakega vizualnega barvnega efekta pa bi bilo potrebno večje navzemanje barvila [16, 17].

Omenjenim pojavom se pri odnosu svetloba-vlakno v skupini vlaken pridružujeta še učinka orientacije in stika vlaken.

Naključnost orientacije vlaken močno vpliva na vizualno podobo obarvanosti tekstilnih materialov. Učinek orientacije opazimo pri primerjavi štapelnih vlaken z bolj ali manj naključno urejenostjo in filamentnih vlaken, ki so usmerjena v določeno smer večjih linijskih ali ploskovnih tekstilnih tvorb. Barvni videz filamentnih vlaken je pri tem močno odvisen od zornega kota opa-

Finer fibres look lighter than thicker fibres, and to achieve the same visual effect, higher dyestuff up-take would be required [16, 17].

There are two additional phenomena related to the relationship between the light and the fibre – orientation of fibres, and contact of fibres.

Randomness of fibres orientation considerably influences the appearance of colour of textile materials. The role of orientation is noticed when staple fibres with more or less random arrangement, and filament fibres, which are oriented in direction of bigger linear or flat textile formations are compared. Colour appearance of filament fibres highly depends on the angle of viewing because the light reflects from their surface specularly. The opposite is the case with staple fibres, in which, due to random light reflection from staple fibres, the observer's perception of colour is less dependent on the angle of viewing.

By enlarging the contact surface of fibres, "optical contact" of fibres increases, which reduces the scattering power of the coloured fabric surface. Such phenomenon is achieved with after-treatments, such as calendering and application of colourless finishing agents. It can be described by reducing the value of scattering coefficient-S in Kubelka-Munk Equation, the result of which is the increased value of coloration K/S [18, 19].

Light reflection and scattering in dependence of the shape of fibres cross-section, fibres length and orientation, and fibres contact surface are presented in Figure 8.

3.1.2 Type and shape of yarn

Yarn is a linear textile formation consisting of a multitude of fibres. This means that all properties of fibres described above are indirectly transferred to the yarn. Additionally, the constructional parameters of yarn establish new relations between fibres, which define the light-yarn relationship.

The parameters of yarn, which should be considered when the colour of a fabric is designed, are the following [20]:

- *type,*
- *linear density,*
- *yarn twisting, i.e. direction of yarn twists or torques,*
- *diameter,*

zovanja, saj se svetloba usmerjeno odbija od njihove površine. Nasprotno pa je zaradi naključnega odboja svetlobe od štapelnih vlaken opazovalčevo dojemanje barve manj odvisno od smeri opazovanja.

S povečanjem stične površine vlaken se poveča „optični stik" vlaken, kar zmanjša sipalno moč površine obarvane tkanine. Tak pojav dosežemo s poobdelavami, npr. s kalandriranjem in nanosom brezbarvnih apreturnih sredstev. Opišemo pa ga lahko z zmanjšanjem vrednosti koeficienta sipanja S v Kubelka-Munkovi enačbi, s čimer naraste vrednost obarvanosti K/S [18, 19].

Odboj in sipanje svetlobe v odvisnosti od oblike prečnega prereza vlaken, dolžine in orientacije vlaken ter stične površine vlaken sta prikazana na sliki 8.

3.1.2 Vrsta in oblika preje

Preja je linijska tekstilna tvorba, sestavljena iz množice vlaken. Vse lastnosti, ki so bile opisane v poglavju o vlaknih, se torej posredno prenesejo tudi na lastnosti preje. Dodatno pa se zaradi konstrukcijskih parametrov preje oblikujejo nova razmerja med vlakni, ki določajo odnos svetloba-preja.

Lastnosti preje, na katere moramo biti pozorni pri načrtovanju barve tkanine, so [20]:

- vrsta preje,
- dolžinska masa,
- vitje preje ali smer zavojev oz. zasukov,
- premer,
- barvne lastnosti preje,
- kosmatost,
- strukturne značilnosti zaradi predilnega postopka,
- togost in kompaktnost,
- navzemanje vlage in kemičnih sredstev.

Od navedenih lastnosti bomo podrobneje opisali le nekaj najpomembnejših.

Vrsta preje

Vrsto preje določajo tip vlaken, ki jo sestavljajo, njihova urejenost in orientacija. Glede na vrsto ločimo naslednje skupine prej: predivne, filamentne, sukane, efektne in teksturirane. Pri naštetih skupinah je zaradi različne oblike in reliefa različna tudi refleksija vpadle svetlobe. Filamentna preja je sestavljena iz enega ali več filamentov neskončne dolžine. Ker je orientacija vlaken v smeri vzdolžne osi preje, sta smer odboja in intenziteta sipanja svetlobe najbolj odvisna od oblike in vrste vlaken. Pri predivnih in sukanih prejah se vlakna pri predenju in sukanju delno orientirajo v smer vzdolžne osi preje. Orientacija je odvisna od vrste in zaporedja faz pri predenju ter števila in intenzitete zavojev oz. zasukov. Kot primer lahko omenimo bombažni preji, ki sta bili izdelani na prstanskem in rotorskem predilniku. Prstanska preja ima večje število zavojev in boljšo orientacijo vlaken, zato je njen videz bolj sijoč z večjim leskom. Rotorska preja pa ima po dolžini bolj naključ-

- *colour parameters,*
- *hairiness,*
- *structural parameters resulting from spinning process,*
- *rigidity and compactness,*
- *absorption of humidity and chemical agents.*

Only few more important of these properties are going to be described in detail.

Type of yarn

The type of yarn is defined by the type of constituent fibres, their arrangement and orientation. There are the following groups of yarns by type: spinning, filament, twisted, fancy, and textured yarns. Due to different shape and relief of these groups of yarns, the incident light reflection is different. Filament yarn consists of one or more filaments of infinite length. Since fibres are oriented lengthwise the yarn axis, the direction of the light reflection and the intensity of the light scattering mostly depend on the shape and type of fibres. As to spinning and twisted yarns, fibres are partly oriented lengthwise the yarn axis during spinning and twisting. Orientation depends on the type and sequence of spinning phases, and on the intensity of twists or torques. As an example, two cotton yarns produced on ring and rotor spinning machines can be mentioned. Ring spun yarn has higher number of twists and its appearance is therefore glossier with higher lustre. Rotor spun yarn has more random position and direction of fibres by length, which results in more unequal light reflection.

Yarn twist

Yarn twisting is the most important process to achieve the desired breaking strength of yarn. By increasing the number of twists/torques, friction between fibres and thread resistance to tensile stress increase to a certain degree. Optical importance of the yarn twist is exhibited above all in the direction of twists of spinning yarns or torques of ply yarns. Namely, the direction of twists/torques determines the orientation of fibres in yarn and, consequently, the direction of the incident light reflection. In the case of yarn with shorter fibres (staple yarn), lustre increases with the increase of the number of twists as a result of the orientation of fibres in the direc-

no lego in smer vlaken, kar zaradi večjega sipanja povzroča bolj neenakomeren odboj svetlobe.

Vitje preje

Proces vitja preje je primarnega pomena za doseganje želene pretržne trdnosti preje, saj se z večanjem števila zavojev oz. zasukov do določene meje povečujeta trenje med vlakni in upor niti proti natezni sili. Optični pomen vitja preje se kaže predvsem v smeri zavojev predivne oz. zasukov sukane preje. Smer zavojev oz. zasukov določa orientacijo vlaken v preji in s tem smer odboja vpadle svetlobe. Pri preji iz krajših vlaken (štapelna preja) se lesk povečuje z večanjem števila zavojev, ker se vlakna orientirajo v smer vzdolžne osi preje. Pri multifilamentni preji, ki je ob nastanku brez zavojev, pa se z dodajanjem zavojev lesk zmanjšuje, saj se povečuje sipanje svetlobe na površini.

Po vrsti vitja delimo preje na:

- preje brez vitja ali z minimalnim številom zavojev (multifilamentna),
- preje z Z-smerjo vitja in
- preje s S-smerjo vitja.

Na sliki 9 so predstavljene preje brez, z Z in S smerjo vitja. Smer zavojev oz. zasukov vpliva na smer odboja svetlobe, kar se intenzivneje izraža v kombinaciji z orientacijo niti v tkanini in smerjo vezav, zato bomo to lastnost podrobneje obravnavali v poglavju o lastnostih tkanin.

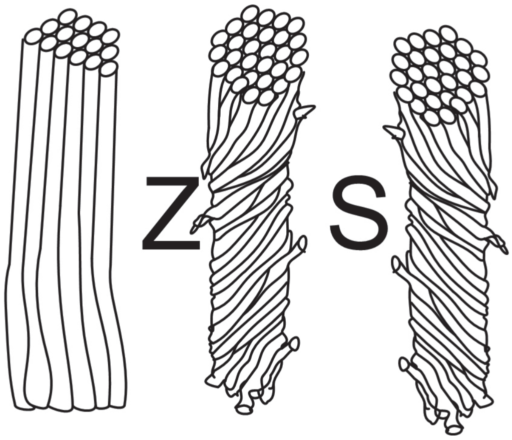


Figure 9: Yarn without twist, yarn with twist in Z direction, and yarn with twist in S direction

Namen izdelave efektnih in teksturiranih prej je lahko funkcionalen ali povsem estetski. V obeh primerih pa se oblikuje preja, ki po dimenzijah odstopa od klasičnih prej in ima zaradi tega tudi specifičen odnos s svetlobo. Z dodajanjem strukturnih ali barvnih efektov se na določenih mestih preje spremeni razmerje med reflektirano, absorbirano in sipano svetlobo, tako da obarvanost preje variira po njeni dolžini.

tion of the yarn longitudinal axis. In the case of multifilament yarn, which has no twists at its formation, lustre is reduced with the addition of twists as a result of the increased light scattering on the surface.

By the type of twist, yarns are divided into:

- *yarns without twist or with a minimum number of twists (multifilament yarn),*
- *yarns with Z twist, and*
- *yarns with S twist.*

Figure 9 presents the yarn without twist, with Z twist and with S twist. The direction of twists/torques influences the direction of the incident light reflection, which is much more accentuated in the combination with the orientation of threads in a fabric, and with the direction of weaves, and will be discussed in detail in the chapter dealing with the properties of fabrics.

The purpose of producing fancy and textured yarns can be functional, or exclusively aesthetic. In either case, a yarn is produced which differs from standard yarns in dimensions, and which establishes quite specific relationship with light. By adding structural or colour effects, the relationship between the reflected, absorbed and scattered light changes in certain parts of the yarn which results in variations of colour by its length.

Linear density and diameter of fibres

Linear density and diameter of fibres are two interdependent parameters of yarn. With increasing linear density, the mean diameter of yarn and, consequently, the surface of its cross-section respectively is normally increasing as well. However, the compactness of yarn should also be taken into account as it might happen that voluminous yarn with very large mean diameter has low value of linear density.

The two most important dimensions of yarn (diameter-d and length-l) are presented in Figure 10. Equation 7 serves for calculating linear density of yarn-Tt (tex) where m_p is the mass of yarn in grams (g), and l_p its length in metres (m). Equation (8) presents the relationship between linear density-Tt and theoretical diameter of yarn-d_t. In this Equation, linear density is expressed in tex, ρ_{vl} is specific density of fibres (g/cm^3), and i is the factor of filling, which is determined tabularly by using experimentally determined fac-

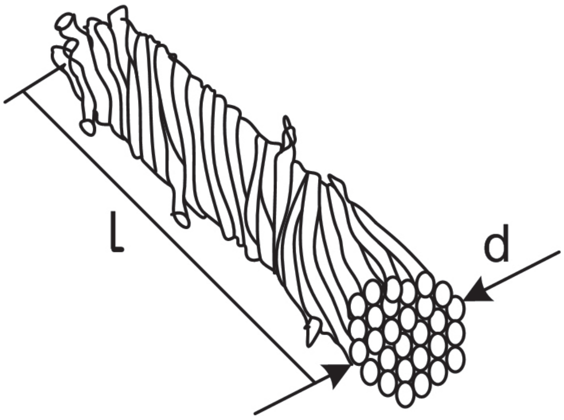


Figure 10: Diameter and length of yarn

Dolžinska masa in premer preje

Dolžinska masa in premer vlaken sta soodvisni lastnosti preje. Z večjo dolžinsko maso se praviloma povečuje tudi povprečni premer preje oz. površina njenega prečnega prereza. Upoštevati pa je treba tudi kompaktnost preje, saj se lahko tudi za nizko vrednostjo dolžinske mase skriva voluminozna preja z zelo velikim povprečnim premerom.

Enačba (7) predstavlja izračun dolžinske mase preje Tt (tex), kjer je m_p masa preje v gramih (g), l_p pa njena dolžina v metrih (m). Z enačbo (8) je podano razmerje med dolžinsko maso Tt in teoretičnim premerom preje d_t. V tej enačbi se dolžinska masa podaja v texih, ρ_{vl} je specifična gostota vlaken (g/cm^3) in i je faktor izpolnjenosti, ki se tabelarično določa s pomočjo eksperimentalno določenih faktorjev. Faktor izpolnjenosti predstavlja razmerje med prostornino vlaken v volumenski enoti in volumensko enoto niti [21].

$$Tt = \frac{m_p \cdot 10^3}{l_p} \quad (7)$$

$$d_t = 3{,}57 \cdot 10^{-2} \sqrt{\frac{Tt}{\rho_{vl} \cdot i}} \quad (8)$$

Podobno kot pri vlaknih bi lahko tudi pri preji definirali odnos med velikostjo njenega premera in odbojem svetlobe, vendar bomo tu izpostavili drugačen vpliv premera preje na dojemanje barve tkanine. Debelina preje direktno vpliva na velikost posamezne barvne površine na tkanini, saj se pri prepletanju nit dvigne na površino tkanine in odvisno od svojih dimenzij bolj ali manj prispeva k skupnemu barvnemu učinku. Vizualna in numerična barvna analiza tkanine v obojestranski vezavi platno z enakim številom zelo tankih osnovnih in zelo debelih votkovnih niti v raportu vezave bi namreč pokazala, da na skupni barvni efekt vplivajo predvsem votkovne niti.

tors. The factor of filling represents the ratio of the fibres volume in a unit volume to the thread unit volume [21].

Although the relationship between the diameter and the light reflection in yarn could be defined similarly as in fibres, a quite different influence of the diameter of yarn on fabric colour sensation will be presented. The yarn count has direct influence on the size of individual coloured surface on fabric. Namely, during interlacing a thread rises on the fabric surface, and in dependence of its dimensions, it contributes more or less to the overall colour effect. Visual and numerical colour analysis of a fabric in double plain weave with the same number of very thin warp threads and very thick weft threads in the weave repeat would show that weft threads have predominant influence on overall colour effect.

Fineness of warp and weft threads in a fabric is not always constant; namely, it is possible to use different thread counts in one and the same fabric. By varying the fineness and, consequently, the yarn count, and the diameter of yarn, colour effects of weaves and thread surfaces in dependence of thread fineness are more or less visible, the result of which is the increased dynamics in the fabric.

Figure 11 presents fabrics in four-end Panama weave with the same fineness of warp and weft threads (a) with two times higher linear density of weft threads (b), and with varying fineness of warp and weft threads (c).

Yarn compressibility

The cross-section of yarn discloses the fibrous structure with interspaces filled with air. That is why yarn is compressible and flexible formation. During interlacing in the fabric, yarn can be bended and compressed, and can change its shape and diameter. Its diameter is the smallest in the spots in which yarn passes from the fabric face to back side because it forces its way between the threads of the other thread system. On top and bottom surfaces, the pressure and friction between fibres decrease, and the yarn passes into the state of balance by increasing its diameter. In such state, it influences the appearance of the fabric with its colour and texture. Higher is the number of air spaces between fibres in the yarn bigger can be the changes in di-

Finost osnovnih in votkovnih niti v tkanini ni vedno konstantna, saj je možna tudi uporaba različnih titrov niti znotraj ene tkanine. Z variiranjem finosti oz. posledično titra in premera preje so barvni efekti vezav in površin niti v odvisnosti od finosti niti bolj ali manj vidni, s čimer se poveča dinamika v tkanini.

Na sliki 11 so prikazane tkanine v vezavi štirivezni panama pri enaki finosti osnove in votka (a), pri dvakrat večji dolžinski masi votkovnih niti (b) ter z variiranjem finosti osnovnih in votkovnih niti (c).

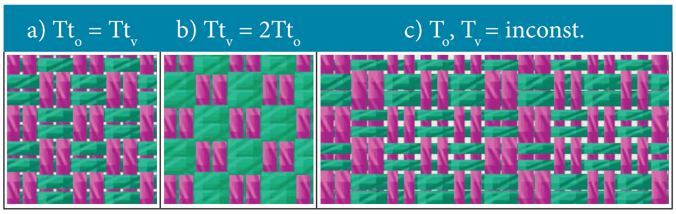


Figure 11: Influence of thread fineness on colour effect of fabric (Pictures were made by using CAD program by Arahne [22].)

Stisljivost preje

V prečnem prerezu vsake preje si lahko ogledamo vlaknato strukturo, katere vmesne prostore napolnjuje zrak. Zato je preja stisljiva in fleksibilna tvorba. Pri prepletanju v tkanini se lahko preja upogiba in stiska ter spreminja svojo obliko in premer. Na mestih prehoda z lične strani tkanine na hrbtno in obratno se njen premer najbolj zmanjša, saj se preriva med nitmi drugega sistema. Na zgornji in spodnji površini pa nato pritisk in trenje med vlakni popustita in preja preide v ravnotežno lego s povečanjem svojega premera. V tem stanju vpliva na videz tkanine s svojo barvo in teksturo. Več ko je zračnih prostorov med vlakni v preji, večje so lahko spremembe dimenzij in posledično večji je lahko vpliv preje na skupni barvni učinek tkanine. Poleg tega je treba upoštevati tudi soodvisnost oblike preje in konstrukcijskih parametrov tkanine, ki direktno vplivajo na vrednosti premera niti. Omeni-

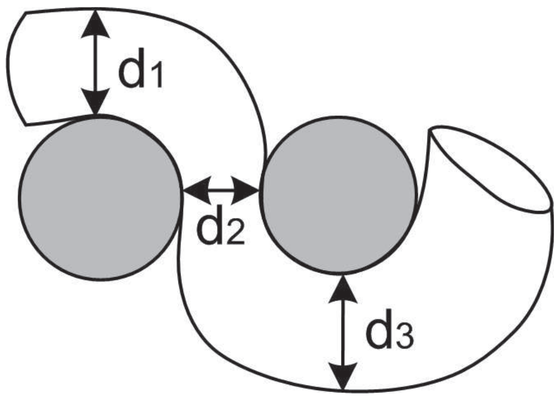


Figure 12: Compressibility of yarn at its passage between two threads

mensions and, consequently, the influence of the yarn on total colour effect of a fabric. Besides, interdependence of the shape of the yarn and the constructional parameters of a fabric, which directly influence the values of the diameter of threads, should be taken into account. Only two most important parameters are going to be mentioned: threads spacing and weave. Higher number of threads per unit length produces more contact points and higher friction between threads. This induces higher compression of yarn. In the same way, yarn can be more compressed in weaves with higher length of thread floating due to less frequent interlacing, which enables larger contact of threads at lateral sides.

At defining the diameter of yarn, it is necessary to take into account compressibility of the yarn, and the thickness of the yarn should be analysed in such a state as is required for investigations. Precise analyses of yarn are possible by using microscopic methods and picture analysis as will be described in the chapter dealing with the degree of coverage.

The change of the diameter at the yarn passage between two threads of the other thread system is presented in Figure 12 where d_1 is the thickness prior to the passage between two threads on face side, d_2 is the reduction of the diameter of yarn, and d_3 the diameter of thread on back side of a fabric. Compressibility of yarn can occur due to air expelling from the spaces between fibres.

3.2 Constructional parameters of fabric

Dependence between individual elements in a fabric is transferred from linear structures, i.e. fibres and yarns, to flat structure, i.e. fabric. Namely, there is a significant interdependence of the properties of a fabric and the properties of the yarn and fibres it is made of.

Among the most important parameters of a fabric, which also influence its colour appearance, are:

- *warp and weft thread spacing,*
- *weave (simultaneous influence of yarn orientation and weave),*
- *types of pores,*
- *coverage factor, and fabric compactness,*
- *warping and weaving pattern,*
- *finishing processes.*

mo le dve najpomembnejši lastnosti: gostoto niti in vezavo. Večje število niti na dolžinsko enoto povzroča več stičnih površin in večje trenje med nitmi. To povzroča večji stisk preje. Podobno se lahko preja bolj stisne pri vezavah z večjo dolžino flotiranja niti, saj je zaradi manj pogostega prevezovanja možen večji stik niti na bočnih straneh.

Pri določanju premera preje je torej treba upoštevati stisljivost preje in analizirati debelino preje v takšnem stanju, kakršno potrebujemo za svoje raziskave. Natančne analize premera preje so možne z mikroskopskimi metodami in slikovno analizo, kot bo opisano v poglavju o stopnji pokritosti.

Sprememba premera pri prehodu preje med dvema nitma drugega nitnega sistema je prikazana na sliki 12. Debelina d_1 je pred prehodom med nitma na lični strani, d_2 je zmanjšanje premera preje in d_3 je premer niti na hrbtni strani tkanine. Stisljivost preje je možna zaradi izpodrivanja zraka iz vmesnih prostorov med vlakni.

3.2 Konstrukcijski parametri tkanine

Odvisnost med posameznimi elementi v tkanini se od linijskih struktur (vlaken in preje) prenese tudi na ploskovno strukturo – tkanino. Obstaja namreč velika soodvisnost med lastnostmi tkanine ter lastnostmi preje in vlaken.

Med najpomembnejše lastnosti tkanine, ki vplivajo tudi na njen barvni videz, štejemo:

- gostoto osnovnih in votkovnih niti,
- vezavo (sočasen vpliv orientacije preje in vezave),
- vrste por,
- faktor pokritosti in kompaktnost tkanine,
- vzorec snovanja in tkanja,
- apreturne postopke.

Omenimo lahko še nekaj lastnosti, ki na barvne vrednosti tkanin ne vplivajo neposredno, ampak posredno preko drugih lastnosti: skrčenje in stkanje, površinska masa in napetost niti.

3.2.1 Gostota osnovnih in votkovnih niti

Gostota osnovnih in votkovnih niti je določena s številom niti na dolžinsko enoto. Ta lastnost je primarnega pomena za mehansko-fizikalne lastnosti tkanin, pri čemer so pomembne same vrednosti gostote osnovnih in votkovnih niti ter razmerje med njimi. Gostota niti definira v sodelovanju z vezavo sekundarno tudi velikost učinka določenih niti na površini. Pri večji gostoti niti je namreč večja tudi intenzivnost reliefnega in/ali barvnega efekta teh niti.

Vrednost gostote niti je v veliki meri odvisna tako od dolžinske mase niti kot od vezave. Večja ko je dolžinska masa niti, več prostora pokrijejo niti v tkanini, posledično pa je število takih niti na dolžinsko enoto manjše. Obratno velja za niti manjše dolžinske mase in manjšega premera. Opis razmerja vezava-gostota je nekoliko kompleksnejši. Na splošno pa lahko odnos definiramo s trditvijo, da ima večje število prepletanj osnovnih in votkovnih niti

Few properties will be mentioned, which do not influence the colour values of fabrics directly but only indirectly through other parameters: shrinkage and run-in, mass per unit area, and threads tension.

3.2.1 Warp and weft thread spacing

The warp and weft thread spacing is determined by the number of threads per unit length. This parameter is of primary importance for mechanical and physical properties of fabrics; the values of the warp and weft thread spacing are as important as their ratio. The thread spacing coupled with the weave also defines the intensity of the effect of certain threads on the surface. Higher is the thread spacing higher is the intensity of a relief and/or colour effect of these threads.

The value of the thread spacing highly depends on linear density of threads, and weave. Higher is the linear density larger is the space they cover in the fabric and, consequently, lower is the number of threads per unit length. Just the opposite applies to the threads with lower linear density and smaller diameter. The description of the relationship of the weave and the thread spacing is slightly complex. In general, it can be stated that higher number of warp and weft threads interlacing points in a fabric result in lower thread spacing. This phenomenon can be explained on the basis of the contact surfaces of fibres and the friction between them. In a warp and weft thread interlacing point, the position of threads changes from face to back side of the fabric, and vice-versa. Threads pass through the spaces between the threads of the other thread system and contact them on a large surface. Due to roughness and fibrous structure of yarn, intense frictional force generates in contact points that prevents slippage and motion of threads. Balance is established between the frictional force and the tension in threads. Since the threads assembly enforces the balanced position, each trial to increase the number of threads per unit length is unsuccessful. In plain weave, it is therefore possible to achieve the lowest values of the thread spacing due to frequent changes of the warp and weft threads position. In the weaves with slightly larger repeat, however, it is possible to practically achieve higher number of

v tkanini za posledico manjšo gostoto niti. Pojav lahko pojasnimo s stičnimi površinami vlaken in trenjem med njimi. Pri prepletanju osnove in votka se menja položaj niti z lične na hrbtno stran tkanine in obratno. Niti pri tem prehajajo skozi prostore med nitmi drugega nitnega sistema in se z njimi stikajo na veliki površini. Na stičnih točkah se zaradi hrapavosti in vlaknate strukture preje pojavi velika sila trenja, ki preprečuje zdrs in premik niti. Med silo trenja in napetostjo v nitih se vzpostavi ravnotežje. Poskus prekomernega večanja števila niti na dolžinsko enoto zato ni uspešen, ker skupina niti izsili svojo ravnotežno lego. Pri vezavi platno lahko tako dosežemo najmanjše vrednosti gostote niti zaradi pogoste menjave lege osnovnih in votkovnih niti. Pri vezavah z nekoliko večjo velikostjo raporta pa lahko praktično dosežemo večje število niti na dolžinsko enoto, saj se menjava lege niti z lične na hrbtno stran ali obratno zgodi redkeje (kepri in atlasi manjših sosledij). Pri največjih velikostih sosledja je zaradi daljšega flotiranja niti prisoten še pojav prekrivanja zaporednih niti, kar omogoča še dodatno povečanje gostote niti (vezavi panama in atlas večjih sosledij).

Gostota niti se med procesom tkanja in po njem precej spreminja. Za oceno vpliva gostote na končni videz zato upoštevamo meritve na relaksirani tkanini po procesu tkanja. Enačbi (9) in (10) podajata določanje gostote osnovnih in votkovnih niti – g_o, g_v – na določeno dolžinsko enoto tkanine (cm) [21,23]:

$$g_o = \textit{number of wrap threads/length unit} \qquad (9)$$

$$g_v = \textit{number of weft threads/length unit} \qquad (10)$$

V primeru tkanin, v katerih imajo osnovne in votkovne niti enako dolžinsko maso in gostoto, govorimo o kvadratični tkani konstrukciji. Tu imata oba nitna sistema podoben vpliv na mehanskofizikalne lastnosti tkanine. Za oceno razmerja njunih efektov na površini pa moramo upoštevati še vezavo.

V industriji se velikokrat uporabljajo tudi posebne tehnike, s katerimi spreminjamo gostoto osnove ali votka znotraj ene tkanine. To dosežemo z uporabo različnega vdeva osnovnih niti v greben in z uporabo regulatorja. Tako se osnovne in votkovne niti ponekod zgostijo, drugod pa razredčijo, kar še dodatno poudari ali zakrije določen barvni in vezavni efekt.

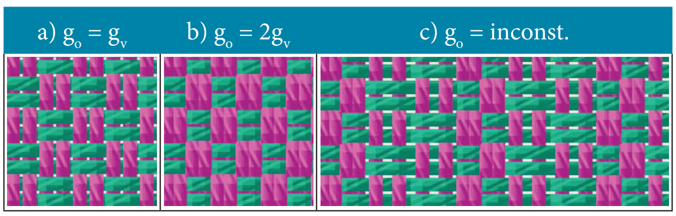


Figure 13: Influence of thread spacing on colour effect of fabric (Picture was made by using CAD program by Arahne [22].)

threads per unit length as the change of threads from face to back side or vice-versa occurs less frequently (twills and satins of smaller repeats). In the largest repeats, another phenomenon, i.e. overlapping of sequential threads, occurs due to longer flotation, which enables additional increase of the thread spacing (panama and satin weave of larger repeats).

Thread spacing is changing considerably during the weaving process and after it. To estimate the influence of thread spacing on final appearance, the measurements carried out on a relaxed fabric after the weaving process have to be taken into account. Equations 9 and 10 present the determination of the warp and weft threads spacing – g_o, g_v *of the fabric (cm) [21, 23]:*

Fabrics made of warp and weft threads with the same linear density and the same thread spacing have square woven construction. In such construction, both thread systems have similar influence on mechanical and physical properties of the fabric. However, to estimate the ratio of their effects on the surface, the weave should be taken into account as well.

Special techniques for changing the warp and weft thread spacing inside one and the same fabric are frequently used in industry. This is possible by using different types of warp threads reeding and by using regulator. In this way, warp and weft threads become denser in some points, and thinner in other points so that certain colour or weave effects are additionally exposed or concealed.

Figure 13 brings the comparison of woven structures in four-end Panama weave with low (a) and high (b) warp thread spacing, and constant weft thread spacing, and with woven structure with inconstant warp thread spacing (c).

3.2.2 Weave

Weave indicates the way of warp and weft threads interlacing which influences the relief and colour structure of a fabric by the following parameters [20, 24]:

- *size of the weave repeat,*
- *number and ratio of warp to weft interlacing points,*
- *distribution of individual warp and weft interlacing points and their assemblies (relief, non-oriented, oriented weaves),*

Na sliki 13 je podana primerjava tkanih struktur v vezavi štirivezni panama z majhno (a) in veliko (b) gostoto osnovnih niti ter konstantno gostoto votkovnih niti in tkane strukture z nekonstantno gostoto osnovnih niti (c).

3.2.2 Vezava

Vezava označuje način prepletanja osnovnih in votkovnih niti, kar vpliva na reliefno in barvno strukturo tkanine z naslednjimi lastnostmi [20, 24]:

- z velikostjo sosledja vezave,
- s številom in razmerjem osnovnih in votkovnih veznih točk,
- z razporeditvijo posameznih osnovnih in votkovnih veznih točk in njihovih skupin (relief, neusmerjene, usmerjene vezave),
- z dolžino flotiranja in posebnimi teksturnimi efekti,
- z velikostjo in razporeditvijo barvnih površin (z upoštevanjem vzorca snovanja in tkanja).

Velikost sosledja vezave

Velikost sosledja vezave določa najmanjše zaporedje skupine osnovnih in votkovnih veznih točk. Najmanjša velikost tega ponavljajočega strukturnega vzorca je lahko 2 × 2 (platno), največja pa lahko sega do velikosti, ki je enaka številu vseh osnovnih niti na tkalskem stroju.

Število in razmerje osnovnih in votkovnih veznih točk

Z razmerjem med številom osnovnih in številom votkovnih veznih točk določamo vpliv niti obeh sistemov na celotni barvni učinek.

Glede na razmerje delimo vezave v tri skupine:

- obojestranske vezave,
- vezave v osnovnem efektu,
- vezave v votkovnem efektu.

Obojestranske vezave imajo v raportu enako število osnovnih in votkovnih veznih točk. Vpliv reliefnega in barvnega učinka osnove in votka na skupni videz tkanine je tako enak. Primer takšnih vezav so: platno, panama, rips in obojestranski ojačeni kepri različnih velikosti.

Enostranske imenujemo vezave, pri katerih na površini prevladuje efekt enega nitnega sistema. Vezave v osnovnem efektu imajo zaradi večjega števila osnovnih veznih točk na površini poudarjeno barvo in teksturo osnovnih niti. Podobno pa lahko označimo vezave v votkovnem efektu s poudarjenim votkom. Enostranske vezave so osnovni in votkovni kepri in atlasi ter druge kompleksnejše vezave.

Razporeditev osnovnih in votkovnih veznih točk in njihovih skupin

Razporeditev osnovnih in votkovnih veznih točk vpliva na velikost, obliko, zaporedje in usmerjenost reliefno in barvno različnih površin v sosledju vezave. Reliefne in barvne karakteristike dobi pri tem vezava preko lastnosti osnovnih in votkovnih niti. Na sli-

- *length of floating, and special texturing effects,*
- *size and arrangement of colour surfaces (by considering the warping and weaving patterns).*

Size of weave repeat

The size of the weave repeat determines the smallest sequence of interlacing points of a set of warp and weft threads. The smallest size of such recurring structural pattern is 2 × 2 (plain weave); the highest size is the size equalling the number of all warp threads on a weaving machine.

Number and ratio of warp to weft interlacing points

The ratio of the warp to weft interlacing points defines the influence of the threads of each system on overall colour effect.

On the basis of this ratio, weaves are divided into three groups:

- *reversible weaves,*
- *weaves in warp effect,*
- *weaves in weft effect.*

Reversible weaves have the same number of warp and weft interlacing points in a repeat. This means that the influence of the warp and weft relief and colour effect on overall appearance of the fabric is the same. Examples of such weaves are: plain weave, Panama weave, repp, and double-sided reinforced twills of various sizes.

One-sided weaves are the weaves in which the effect of one tread system predominates on the surface. In weaves in warp effect, the colour and texture of warp threads is exposed on surface due to higher number of warp interlacing points. Likewise, weaves in weft effect have the colour and texture of weft threads exposed on surface. The examples are warp and weft twills and satins, and other more complex weaves.

Distribution of warp and weft interlacing points and their assemblies

Distribution of warp and weft interlacing points influences the size, shape, sequence and orientation of the surfaces differing in relief and colour in a weave repeat. Warp and weft threads impart relief and colour characteristics to the weave. Figure 14 presents the groups of weaves with variously distributed interlacing points,

ki 14 so predstavljene skupine vezav z različno urejenostjo veznih točk, kar posledično vpliva na barvne površine različnih velikosti, oblik, zaporedij in usmerjenosti. Osnovne in votkovne niti imajo na sliki enako dolžinsko maso in gostoto. Posamezne lastnosti, ki jo povzroča razporejenost osnovnih in votkovnih, niti ne moremo obravnavati osamljeno, saj dobi pravi pomen šele pri sočasnem vplivu vseh parametrov.

Različno velikost barvnih površin dosežemo z grupacijo ali združevanjem veznih točk. Majhne velikosti površin so prisotne v primeru osamljenih veznih točk, saj med veznimi točkami enega tipa ni večjih stičnih površin. Primer je vezava platno, v kateri se vezne točke istega tipa stikajo le na ogliščih. Z združevanjem veznih točk se površina določene niti in s tem njenega barvnega in reliefnega učinka na tkanini povečuje (primer panama). Dojemaje skupnega barvnega učinka tkanin z optičnim mešanjem svetlobe, odbite od barvnih površin različnih velikosti, je odvisno od razdalje, s katere opazujemo. Pri vezavi platno se odbita svetloba zli-

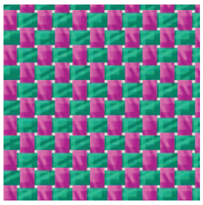
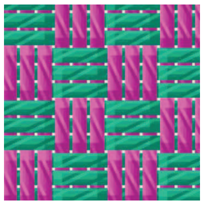
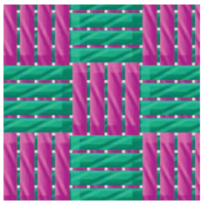
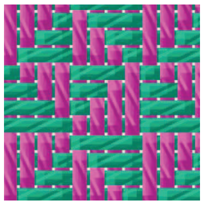
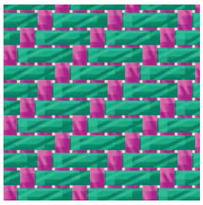
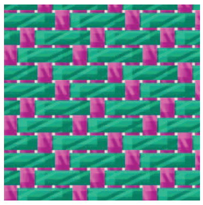
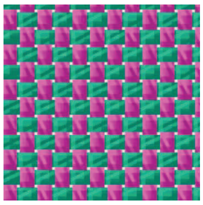
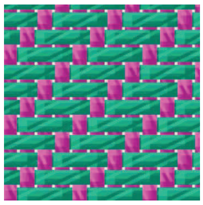
Parameter	Weaves	
Size		
Shape		
Sequence		
Orientation		

Figure 14: Distribution of interlacing points in a weave repeat (Picture was made by using CAD program by Arahne [22].)

which consequently influences the size, shape, sequence and orientation of colour surfaces. The presented weaves have warp and weft threads of the same linear density, and the same thread spacing. Any parameter resulting from the arrangement of warp and weft threads cannot be dealt with isolated from other parameters. Each parameter obtains its real significance only in combination with all parameters.

Different size of colour surfaces is obtained by assembling or agglomerating the interlacing points. Smaller sizes of surfaces appear in the case of isolated interlacing points as there are no larger contact surfaces between the one type interlacing points. Such example is plain weave in which the one type interlacing points contact only on corners. By agglomerating the interlacing points, the surface of a particular thread, and consequently, its colour and relief effect on the fabric are increasing (e.g. Panama weave). The overall visual colour effect of fabrics produced by optical mixing of the light reflected from colour surfaces of different size depends on the distance of viewing. In plain weave, the reflected light merges into a uniform effect already at small distance of viewing whereas in Panama weave a longer distance from the observed surface is required.

With different shapes of relief and colour surfaces in a weave repeat, different patterns on weave are produced. In dependence of the agglomeration of the warp and weft interlacing points, these patterns can be more/less geometrical, regular/irregular, larger/smaller etc. The shape of the surfaces influences optical perception of what is going on in the weave, as the eye is able to perceive faster and easier the uniform, regular and larger shapes. The third and the fourth parameter of a weave are sequence and orientation. The weaves in which the colour surfaces of interlacing points are arranged in such a manner that beams, ribs or any other type of oriented elements are present on the fabric surface are called oriented weaves. Likewise in yarns, orientation can be in S or Z direction, and its angles of inclination can be different. From optical viewpoint, these weaves are considered special because the perception of their colour depends on the angle of observation. Namely, the incident light reflects spec-

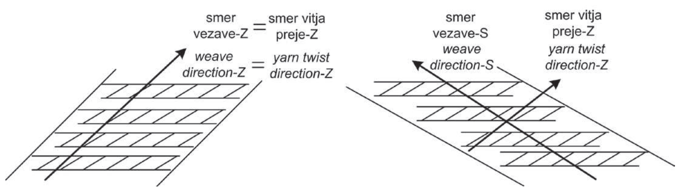


Figure 15: Same direction and opposite direction effect of yarn twist and weave

je v enoten učinek že pri majhni razdalji opazovanja, medtem ko je pri vezavi panama potreben večji odmik človekovega očesa od opazovane površine.

Z različnimi oblikami reliefnih in barvnih površin v sosledju ustvarjamo vzorce na vezavi. Ti vzorci so lahko v odvisnosti od združevanja osnovnih in votkovnih veznih točk bolj/manj geometrijski, pravilni/nepravilni, večji/manjši in podobno. Oblika površin vpliva na optično dojemanje dogajanja v vezavi, saj človeško oko hitreje in lažje zazna enakomerne, pravilne in večje oblike.

Tretja in četrta lastnost vezave sta zaporedje in usmerjenost vezave. Če so barvne površine veznih točk organizirane tako, da so na površini tkanine prisotni žarki, rebra ali katere koli druge oblike usmerjenih elementov, govorimo o usmerjenih vezavah. Podobno kot pri prejah je lahko usmerjenost Z ali S, njeni naklonski koti pa so lahko različni. Z optičnega vidika so te vezave posebne, saj je dojemanje njihove barve odvisno od zornega kota opazovanja. Vpadla svetloba se namreč usmerjeno odbija odvisno od usmerjenosti niti v vezavi, kar glede na kot opazovanja zaznamo kot različen lesk tkanine. Primera sta vezavi keper in atlas. Pri neusmerjenih vezavah, kot sta platno in panama, je zaradi zrnčaste teksture odboj svetlobe razpršen in neodvisen od smeri opazovanja.

Izrazitost usmerjenosti vezave je odvisna tudi od smeri vitja preje. V primeru istosmerne orientacije preje in vezave se niti vlezejo druga v drugo ter tako zmanjšajo izrazitost učinka smeri na tkanini. Nasprotno pa se niti med seboj odbijajo, če sta smeri vitja preje in vezave različni. Učinek žarkov in reber pri tem očitno izstopi. Na sliki 15 sta shematsko prikazana primera istosmerne in nasprotnosmerne kombinacije preje in vezave [7, 23, 24].

Dolžina flotiranja in posebni teksturni efekti

Izraz flotiranje niti izhaja iz angleške glagolske besede „to float", ki pomeni plavati, lebdeti, biti dvignjen. V tekstilni praksi se uporablja za opis stanja, v katerem osnovne ali votkovne niti prehajajo čez več veznih točk nasprotnega nitnega sistema. Od dolžine flotiranja niti so odvisni določeni konstrukcijski parametri tkanine, nekatere mehansko-fizikalne lastnosti ter optično-barvni pojavi na tkani površini.

Kot prvo lahko omenimo gostoto niti, ki je tesno povezana z dolžino flotirajočih niti. Pogostejše ko je prevezovanje, težje je doseči visoke vrednosti gostot niti zaradi velikega trenja. V primeru pla-

ularly depending on the threads orientation in the weave, which is perceived in dependence of the angle of viewing as different lustre of the fabric. The examples are twill and satin weave. In non-oriented weaves, such as plain weave and Panama weave, the light reflection is diffusive due to the granular texture, and independent of the direction of viewing.

The prominence of the weave orientation depends also on the yarn twist direction. In the case of the yarn and weave orientation in the same direction, threads fit closely and reduce the prominence of the effect of orientation in the fabric. On the contrary, threads repulse one another in the case of the yarn twist and weave orientation in different directions. The effect of beams and ribs becomes noticeably prominent. Figure 15 schematically presents the examples of the yarn and weave being oriented in the same direction, and of the yarn and weave being directed in opposite directions [7, 23, 24].

Length of floating and special texturing effects

The term "floating" is derived from the English verb "to float" which means swim, float, be raised. In textile field, it is used to describe the state in which warp or weft threads traverse more than one interlacing points of the other thread system. Certain constructional parameters of the fabric, some mechanical and physical properties, as well as optical and colour effects on the woven surface depend on the length of thread floating.

First, it is the thread spacing, which is closely connected with the length of floating threads. More frequent is the floating, more difficult is to achieve high values of densities due to intense friction. In plain weave in which warp and weft interlacing points interchange on the surface, it is possible to manufacture the fabrics with low thread spacing. In eight-end satin with floating over seven interlacing points, extremely high values of thread spacing can be achieved. The dependence of mechanical and physical properties on the length of floating threads is the following: lower is the floating, higher is the compactness of the fabric and better are its mechanical and physical properties. However, it is necessary to consider also

tna, kjer se izmenjujeta osnovna in votkovna vezna točka na površini, je možno dejansko stkati tkanine z majhno gostoto niti. Pri osemveznem atlasu s flotiranjem čez sedem veznih točk pa lahko dosežemo ekstremno velike vrednosti gostote. Odvisnost mehansko-fizikalnih lastnosti od dolžine lebdečih niti se izraža takole: manjše ko je flotiranje, večja je kompaktnost tkanine in boljše so mehansko-fizikalne lastnosti. Seveda pa te dvojice ne moremo obravnavati osamljeno, ampak je treba pri tem upoštevati še sočasni vpliv drugih konstrukcijskih parametrov.

Z barvno-optičnega vidika vpliva dolžina flotiranja niti na površino barvnega oz. reliefnega učinka. Daljše ko je prehajanje določene niti na lični ali hrbtni strani tkanine, večja je izpostavljenost učinka te niti. Svetlobni pojavi se na takšnih konstrukcijah razlikujejo od tistih na vezavah s pogostejšim prevezovanjem. Kot primer lahko omenimo vezavi platno in večvezni atlas. Za vezavo platno je značilen majhen lesk, saj se osnovne in votkovne vezne točke najpogosteje izmenjujejo in prevezovanje osnovnih in votkovnih niti je veliko. Svetloba se od zrnčaste površine tkanine odbija difuzno – v vse smeri. Z vezavo atlas pa dosežemo večji lesk, saj se zaradi specifične razporeditve točk na površini in večjega flotiranja osnovnih ali votkovnih niti svetloba usmerjeno odbija od paralelno urejenih niti. Videz platna je tako neodvisen od zornega kota opazovanja, medtem ko vizualno obarvanost atlasa zaznamo kot različno – odvisno od smeri opazovanja (slika 16). Prav ta lastnost vezave atlas se v praksi izrablja na izdelkih, za katere želimo svilnat lesketajoč videz [18].

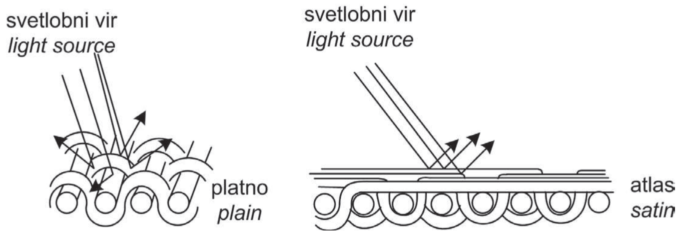


Figure 16: Reflection on fabric in plain weave – diffusive, and on fabric in satin weave – specular

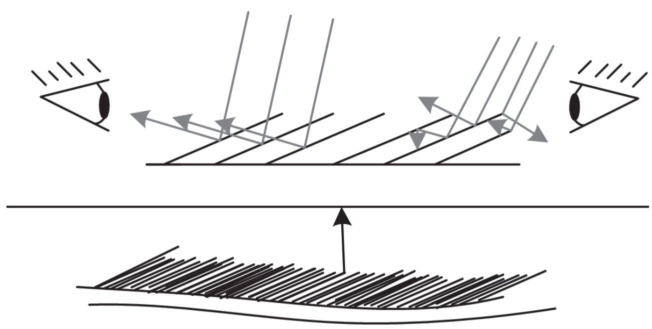


Figure 17: Fabric in velvet weave

the concurrent influence of other constructional parameters.

From the colour and optical viewpoint, the length of thread floating influences the colour and relief effect area. Longer is the floating of a thread on the face or back side of the fabric, more exposed is the effect of such thread. Light effects on these constructions differ from those occurring on the weaves with more frequent floating. The examples are plain and satin weave. Plain weave is characterized by low lustre due to most frequent interchanging of warp and weft interlacing points and, consequently, high floating of warp and weft threads. From granular surface of the fabric, the light reflects diffusively, i.e. in all directions. With satin weave, more lustre is produced; namely, due to specific distribution of interlacing points on the surface, and higher floating of warp and weft threads, the light reflects specularly from parallelly oriented threads in a defined direction. The appearance of the fabric in plain weave is therefore independent of the angle of viewing whereas the colour of satin weave differs in dependence of the angle of viewing (Figure16). This feature of satin weave is used in practice to manufacture the products with silky glossy look [18].

Special texturing effects are achieved by using special fancy yarns, and with special weaves, such as velvet, plush, cord, terry cloth, etc. Fancy yarns differ from standard ones by having one parameter extremely pronounced (lustre, hairiness, colour), or by having one parameter, which distinctly changes lengthwise the thread (thickness, colour), or by having special effects, which appear here and there lengthwise the thread.

One of special weaves is velvet, which belongs to pile fabrics. The pile is oriented in a certain direction of the fabric and influences the colour sensation. Figure 17 presents velvet weave with a defined pile arrangement. If the fabric is observed in the direction of pile, it looks glossy and with more saturated colour than if it is observed in the opposite direction when the light diffuses on pile ends and on the spaces between them [18].

The mentioned weave effects usually represent the problem for objective determination of colour values of the fabrics in these weaves, and because of that it is necessary to consider the specific characteristics of each product individually.

Posebne teksturne efekte dosežemo lahko z uporabo posebnih efektnih prej in s specialnimi vezavami, kot so žamet, pliš, kord, frotir in podobno. Efektne preje se od običajnih razlikujejo po tem, da imajo zelo izrazito eno lastnost (lesk, kosmatost, barva), lahko se jim določena lastnost izrazito spreminja po dolžini (spreminjanje debeline, barve) ali pa se po dolžini mestoma pojavljajo posebni efekti.

Med specialnimi vezavami lahko natančneje pogledamo površinsko strukturo žameta, ki je lasasta vezava. Lasje tkanine so orientirani v določeno smer tkanine, od katere je odvisno tudi naše dojemanje obarvanosti. Na sliki 17 je prikazana vezava žamet z določeno urejenostjo las. Pri opazovanju v smeri las je videti tkanina lesketajoča in barva je bolj nasičena, kot če tkanino opazujemo v nasprotni smeri, kjer se svetloba sipa na konceh las in v prostorih med njimi [18].

Omenjeni vezavni efekti običajno predstavljajo težavo za objektivno določanje barvnih vrednosti tkanin v teh vezavah, zato je treba specifičnosti vsakega izdelka upoštevati posebej.

3.2.3 Presevanje v tkanini in vrste por

S konstrukcijskimi parametri tkanine, kot so finost, gostota niti in vezava, ne določamo le velikosti in urejenosti barvnih površin skupine niti na tkanini, temveč tudi velikost in razporeditev prostorov med nitmi. Votli prostori med nitmi ali pore so prav tako kot niti pomemben element tkanine, saj prispevajo k zračni in vodni prepustnosti, kompaktnosti, toplotnoizolacijskim lastnostim ter prosojnosti. Z barvnega vidika je pomembna predvsem zadnja lastnost – prosojnost, saj skozi odprtine med nitmi na površinski barvni učinek vpliva barva podlage oz. ozadja tkanine. Učinek ozadja je sicer resda odvisen od konstrukcijskih parametrov tkanine in bi ga pri kompaktnejših tkaninah le na podlagi vizualne presoje lahko tudi izključili. Spektrofotometrično določanje barve klasičnih tkanin z različnimi podlagami pa dokazuje nezanemarljiv vpliv barve podlage na skupni barvni efekt, zato je treba presevanje upoštevati kot enakovreden element tkanine, njegovo barvo pa kot soustvarjalko skupnega barvnega učinka [25]. V določenih primerih najdemo z raziskavo presevanja celo razlago za nekatere nepričakovane rezultate pri barvni analizi tkanin.

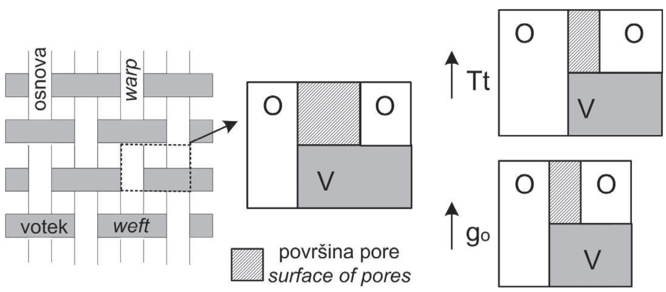


Figure 18: Change of the size of pores

3.2.3 Foundation reflectance and types of pores

It is not only the size and arrangement of the colour areas of a thread assembly on a fabric surface, which is determined by the constructional parameters of a fabric, such as thread fineness, thread spacing, and weave, but also the size and arrangement of the spaces between threads. Voids between threads, i.e. pores are an important element of a fabric just like threads as they contribute to air and water permeability, compactness, heat insulation, and translucence of a fabric. As far as colour is concerned, translucence is particularly important. Namely, the colour of the fabric foundation/background reflects through the pores between threads and influences the colour of the fabric. It is true that the effect of background depends on the constructional parameters of the fabric and could be in more compact fabrics ignored on the basis of visual estimation only. However, spectrophotometric measurements of the colour of conventional fabrics with different foundations prove that the influence of the colour of foundation on overall colour effect cannot be neglected, and this is why the foundation reflectance should be considered as an equivalent parameter of a fabric, and its colour a co-creator of overall colour effect [25]. In particular cases, the investigation of the foundation reflectance even provides explanations of some unexpected results obtained at colour analysis of fabrics.

In the structure of fabrics with different constructional parameters there are spaces between threads, which can differ in:

- *size,*
- *shape,*
- *volume,*
- *(two additional parameters are the number and distribution of pores which are more characteristic for the pores of nonwovens; in wovens, pores always appear between two pairs of warp and weft threads).*

It should be mentioned that the analysis of pores could include also the pores between fibres in the yarn, but nevertheless, this phenomenon will not be discussed.

The size of pores mostly depends on the combination of two parameters of the fabric: its diameter and thread spacing. They are in inverse

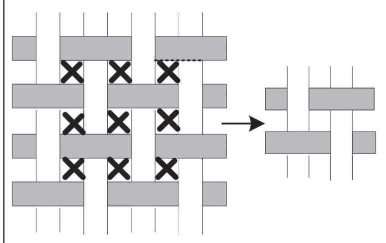
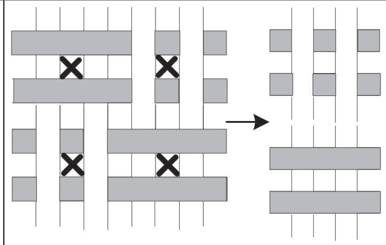
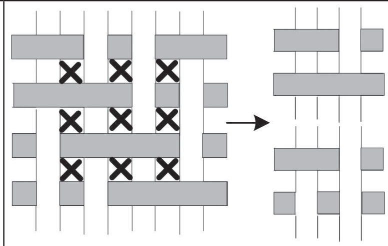
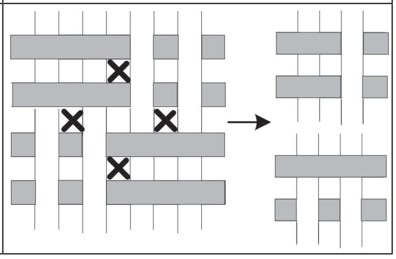
Type of Pores	Scheme
Type 1 (plain weave)	
Type 2 (Panama weave)	
Type 3 (twill weave)	
Type 4 (Panama weave)	

Figure 19: Four types of pores in fabrics

Tkanine z različnimi konstrukcijskimi parametri imajo v svoji strukturi prostore med nitmi, ki se lahko razlikujejo po:

- velikosti,
- obliki,
- volumnu,
- (dodatni lastnosti sta še število in porazdelitev por, ki sta bolj značilni za pore netkanih izdelkov, saj se v tkaninah pore pojavljajo vedno med dvema paroma osnovnih in votkovnih niti).

Omenimo, da bi lahko analiza por vključevala tudi pore med vlakni v preji in pore v vlaknu, vendar bomo te pojave izpustili iz obravnave.

Na velikost por sočasno vpliva predvsem kombinacija dveh lastnosti tkanine: premera in gostote niti. Razmerje je obratno sorazmerno, saj načeloma velja, da je velikost por manjša pri večji dolžinski *relation, i.e. the size of pores decreases with increasing linear density and thread spacing, and with other unchanged parameters. The change of the size of the space between threads on the scheme of an interlacing point at increased linear density (Tt↑) and thread spacing (g_o↑) is presented in Figure 18.*

The type of weave determines the intensity of the contact of either the adjacent threads of the same thread system, or of the threads of two different thread systems. In this way, the surface of the space between threads is also defined, as well as its shape and influence on the appearance of the fabric. In spite of a large number of various weaves, there are only four types of pores in general, as is presented in Figure 19 [7, 26, 27].

Type 1 pores are formed between warp and weft threads in plain weave. Here, the position of the threads of both systems, which surround the pore, changes. Due to friction, any higher contact between parallel threads is not possible, and higher values of thread spacing are not possible as well.

Type 2 pores are present between the pairs of warp and weft threads when both warp threads lie over weft threads, and vice-versa. Since there are no thread passages in this structure, tight closeness of adjacent threads is possible, and consequently high values of thread spacing. The example of the weave in which such type of pores appear is Panama weave.

Type 3 pores are formed by a pair of warp or weft threads respectively, one of them passing over the two threads of the other thread system, and the other changing at this time its spatial position from the face side to the back side, or vice-versa. Such thread composition enables higher closeness of parallel threads than it is possible in plain weave.

The last possible position of adjacent threads is Type 4. It consists of two warp or weft threads each travelling on the opposite side of the fabric without changing its spatial position. The example of such weave is Panama in which one warp or weft thread passes under the two threads of the other thread system, and the other warp or weft thread over the two threads of the other thread system. Likewise in type 2 pores, threads can closely approach each other because there

masi oz. gostoti niti in drugih nespremenjenih lastnostih. Sprememba velikosti prostora med nitmi na shemi vezne točke pri povečanju dolžinske mase (Tt↑) in gostote niti (g_o↑) je prikazana na sliki 18.

Vrsta vezave odloča o možnosti intenzitete stika sosednjih niti istega sistema ali stika niti dveh različnih nitnih sistemov. S tem so definirani tudi površina prostora med nitmi, njena oblika in vpliv na videz tkanine. Kljub velikemu številu različnih vezav razlikujemo na splošno le štiri tipe por, kot je prikazano na sliki 19 [7, 26, 27].

Pore tipa 1 se oblikujejo med nitmi osnove in votka v vezavi platno. Tu se menja lega obeh osnovnih in votkovnih niti, ki obkrožajo poro. Zaradi trenja ni možen večji stik med vzporednimi nitmi in onemogočene so večje vrednosti gostote.

Pore tipa 2 so prisotne med dvojico osnovnih in votkovnih niti, ko obe osnovni niti ležita nad votkovnima ali obratno. Ker v tej strukturi ni prehodov niti, je možna popolna bližina sosednjih niti, vrednosti gostot pa so zato lahko velike. Primer vezave, kjer se pojavlja takšna vrsta pore, je panama.

Pore tipa 3 oblikuje dvojica osnovnih oz. votkovnih niti, od katerih gre ena nad obema nitma drugega sistema, druga pa med tem zamenja prostorsko lego z lične na hrbtno stran ali obratno. Takšna kompozicija niti omogoča večjo bližino vzporednih niti kot v vezavi platno.

Zadnjo možno postavitev sosednjih niti lahko potemtakem imenujemo tip 4. Tvorita ga dve osnovni oz. votkovni niti, ki potujeta na nasprotni strani tkanine in pri tem ne menjata prostorske lege. Primer vezave je panama, kjer gre ena osnovna oz. votkovna nit nad oz. pod dvema nitma drugega nitnega sistema, njena soseda pa ravno obratno. Podobno kot pri tipu por 2 se lahko niti precej približajo druga drugi, saj je izključeno trenje zaradi prostorskega prehoda niti [7].

Tretja pomembna lastnost por je njihov volumen. Vpadla svetloba namreč pri stiku s tkanino ne ostaja le na njeni površini, temveč prehaja tudi v tretjo dimenzijo tkanine, globino. Prehajanje svetlobe v notranje prostore tkanine zmanjšuje refleksijske pojave na površini, ki neposredno vplivajo na barvo objekta. Tudi v primeru, ko se svetloba zaradi notranje refleksije v plasteh tkanine vrača v opazovalčevo oko, so njene optične lastnosti nekoliko spremenjene. Ker so niti deformabilne, stisljive in imajo različne oblike prečnega prereza, se med nitmi ustvarjajo prostori najrazličnejših oblik. Pri tem imajo svojo nalogo tudi konstrukcijski parametri, ki vplivajo na stisnjenost niti, stanje volumna med nitmi pa

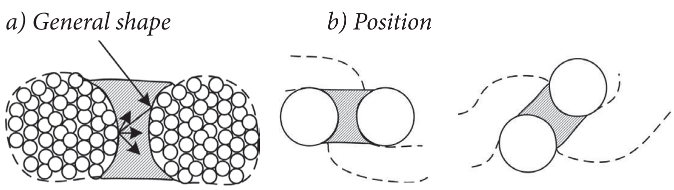


Figure 20: Shape of volume and its position in fabric

is no friction resulting from the threads spatial passage [7].

The third important parameter of pores is their volume. At contact with a fabric, the incident light does not remain only on the fabric surface but passes into its third dimension – the depth. Passage of the light into the inside spaces of the fabric reduces reflection effects on the surface and directly influences the colour of the object. Even if the light returns due to inside reflection in the fabric layers into the observer's eye, its optical properties are slightly changed. Since threads are deformable, compressible and have different shapes of their cross-sections, spaces of various shapes are created between them. There are also constructional parameters, which have influence on compression of threads so that the state of the pore volume between threads becomes quite unpredictable. Although it is difficult to generalize and describe the volume with a uniform scheme, the approximation can be made. One of the most general shapes of the pore volume, and two positions will be mentioned.

By investigating the cross-section of a fabric it can be found that the shape of the spaces between threads depends on the shape of the threads cross-sections, which in a particular moment depends on the stress and forces in the fabric. If the shape of the thread cross-section is considered to be round as is shown in Figure 20a, the pore is the widest at leaving the fabric whereas it is narrowed between threads. Another parameter is the position of volume, which changes with the position of threads. Figure 20b presents the state when two adjacent threads are parallel in a woven construction, and the position of pore is vertical. At higher stresses in a fabric (higher thread spacing, more thread systems), two adjacent threads spatially displace to be slightly one under the other, the result of which is the inclined position of pore.

The mentioned parameter of pores influences the path of the light penetrating into the dept of a fabric and, consequently, its scattering and inside reflection effects. When the light rays pass through the space between threads, they hit against the thread wall and reflect several times under different angles. Reflection of the light,

postane tako precej nepredvidljivo. Čeprav ga s težavo posplošimo in opišemo z enotno shemo, si lahko pomagamo s približkom. Omenili bomo le eno, najbolj splošno obliko volumna pore in dve postavitvi volumna.

Pri prečnem prerezu tkanine lahko ugotovimo, da je oblika prostora med nitmi odvisna od oblike prečnega prereza niti, ta pa je v določenem trenutku odvisna od napetosti in sil v tkanini. Če posplošimo prečni prerez preje na okroglo obliko, kot prikazuje slika 20a, lahko rečemo, da je pora najširša pri izstopu iz tkanine, med nitmi pa se zoži. Druga lastnost je postavitev volumna, ki se spreminja z lego niti. Na sliki 20b je kot prvo prikazano stanje, ko dve sosednji niti ležita vzporedno v tkani konstrukciji, postavitev pore je pri tem vertikalna. Pri večjih napetostih v tkanini (večja gostota, več sistemov niti) se sosednji niti nekoliko prostorsko zamakneta druga pod drugo, s čimer postane postavitev pore poševna.

Omenjene lastnosti por vplivajo na pot svetlobe pri prodiranju v globino tkanine in s tem na sipanje svetlobe in notranje refleksijske pojave. Ko svetlobni žarki prehajajo skozi prostor med nitmi, udarjajo ob stene niti in se tam večkrat odbijajo pod različnimi koti. Refleksija svetlobe, ki je ujeta v prostor, poteka torej nekoliko drugače kot odboj na prosti površini. Ko temu dodamo še poševno lego prostora, je stanje še kompleksnejše.

3.2.4 Stopnja pokritosti

Pokritost oz. stopnja polnosti tkanine je definirana kot površina, ki je v tkanini pokrita z nitmi osnove in votka. Posredno podaja tudi podatek o prosojnosti in kompaktnosti tkanine. Shema za izračunavanje faktorja pokritosti je prikazana na sliki 21 [28, 29].

Stopnja pokritosti tkanine je odvisna od konstrukcijskih parametrov niti (premera in gostote niti). Posredno pa nanjo vpliva tudi vezava, ki glede na vrsto določa mejne vrednosti gostot.

Na sliki 21 je sicer predstavljen le shematski prikaz tkanine v vezavi platno, vendar lahko iz nje vseeno sklepamo na veliko soodvisnost stopnje pokritosti določenega nitnega sistema in njegovega vpliva na skupni barvni učinek tkanine. S pomočjo površin osnovnih, votkovnih niti, njihovih konstrukcijskih parametrov ter prostorov med nitmi lahko stopnjo polnosti posameznih elementov izračunamo po enačbah (11) in (12). Na sliki je označena votkovna vezna točka, podobno pa bi izračuni veljali tudi za osnovno vezno točko.

Polnost osnove se lahko v posamezni vezni točki izračuna po enačbi:

$$P_o = \frac{p_{AHFD}}{p_{ABCD}} = \frac{\overline{AH}}{\overline{AB}} = \frac{d_O}{\frac{1}{g_O}} = d_O \cdot g_O \tag{11}$$

Polnost votka je izračunana po enačbi:

$$P_v = \frac{p_{ABIE}}{p_{ABCD}} = \frac{\overline{BI}}{\overline{BC}} = \frac{d_v}{\frac{1}{g_v}} = d_v \cdot g_v \tag{12}$$

which is caught in the space, is therefore different than reflection on an open surface. The inclined position of the space makes the situation still more complex.

3.2.4 Cover factor

Cover factor, i.e. the degree of fabric fullness is defined as the area of a fabric, which is covered by warp and weft threads. Indirectly, it gives the information about transparency and compactness of a fabric. The cover factor calculation scheme is presented in Figure 21 [28, 29].

The degree of cover of a fabric depends directly on the thread constructional parameters (diameter and thread spacing), and indirectly on the weave, which defines, in dependence of the type, the boundary values of thread spacing.

Although it is only a fabric in plain weave, which is schematically presented in Figure 21, it can be assumed that there is a great interdependence of the degree of cover of a particular thread system and its influence on overall colour effect of a fabric. On the basis of the area of warp and weft threads, their constructional parameters, and the spaces between threads, the degree of fullness of individual elements can be calculated by using Equations 11 and 12. In Figure 21, a weft interlacing point is indicated; likewise, the calculations would apply for a warp interlacing point.

Warp fullness in an individual interlacing point can be calculated by using the equation 11.

Weft fullness is calculated by using the equation 12.

The degree of fullness of a fabric is determined by using Equations 13 and 14. The part of thread cover with area AHGE is deducted from the area of warp and weft threads. P_o, P_v and P_{tk} are the degrees of fullness of warp and weft threads, and of fabric, d_o and d_v are the diameters of warp and weft threads (cm), and g_o and g_v are the densities of warp and weft thread spacing (threads/cm).

The above equations evidence that theoretical calculations of fabric fullness do not take into account the weave, although the frequency and distribution of interlacing points define the intensity of the threads contact. Thus, for example, with five-end satin weave higher fullness of warp and weft can be expected as threads can

Stopnja polnosti tkanine se določa po enačbah (13) in (14), kjer se od površin osnovne in votkovne niti odšteje del prekrivanja niti s površino AHGE. P_o, P_v in P_{tk} so stopnje polnosti osnovnih in votkovnih niti ter tkanine, d_o in d_v sta premera osnovnih in votkovnih niti (cm), g_o in g_v pa sta gostoti osnovnih in votkovnih niti (niti/cm).

$$P_{tk} = \frac{p_{AHFD} + p_{ABIE} - p_{AHGE}}{p_{ABCD}} = \frac{d_o \cdot \frac{1}{g_v} + d_v \cdot \frac{1}{g_o} - d_o \cdot d_v}{\frac{1}{g_o} \cdot \frac{1}{g_v}} \qquad (13)$$

$$P_{tk} = d_o \cdot g_o + d_v \cdot g_v - d_o \cdot g_o \cdot d_v \cdot g_v = P_o + P_v - P_o \cdot P_v \qquad (14)$$

Iz predstavljenih enačb vidimo, da teoretični izračun polnosti tkanine ne upošteva vezave. Od pogostosti in razporeditve prevezovalnih točk je namreč odvisna intenziteta stika niti. Tako lahko na primer pri vezavi petvezni atlas pričakujemo večjo polnost osnove in votka, saj se lahko niti precej približajo druga drugi in se pri večjih gostotah celo prekrijejo. Zaradi prostorske lege niti se pore med nitmi postavijo v poševno lego, kar onemogoča direkten vpliv podlage na površino tkanine. Pri vezavi platno pa do takšnih zamikov niti pride redkeje, lega por je tako navpična, kar dopušča pri vertikalnem opazovanju direkten vpogled v prostore med nitmi. Obenem pa je treba poudariti, da je od stopnje polnosti odvisna tudi velikost vpliva barve podlage na površino tkanine. Pri običajnih tkaninah obsega polnost tkanine vrednosti od 80 do 90 %. Pri legi takšnih tkanin na določeni podlagi sicer zaradi prepletenosti vlaken med nitmi vizualno ni opaziti vpliva presevanja, pri pogledu proti svetlobi pa se zaradi prehoda svetlobnih žarkov skozi pore razkrije prosojnost tkanine. Pri manjših vrednostih polnosti se učinek podlage pod tkanino lahka zazna že vizualno.

Poleg teoretičnih – računskih metod lahko stopnjo pokritosti tkanine in s tem učinek posameznega nitnega sistema določamo tudi mikroskopsko s pomočjo slikovne analize. Pri tem postopku zajamemo slikovne podatke tkanine, ki jih v digitalni obliki pod določeno povečavo obdelujemo z orodji programov za slikovno analizo. Prednost te metode so natančni numerični podatki o velikosti

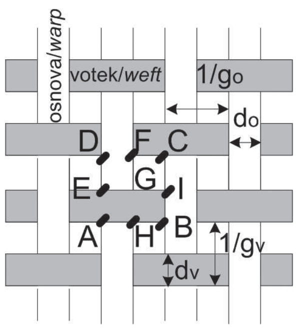


Figure 21: Cover factor calculation scheme

approach considerably, and can even cover each other at higher thread spacing. Due to spatial position of threads, pores between threads take the inclined position preventing thus direct influence of foundation on the fabric surface. Such thread displacements are rare in plain weave, the position of pores is vertical, which admits a direct insight into the spaces between threads at vertical observation. It is necessary to point out that the extent of the foundation colour influence on the fabric surface also depends on the degree of fullness. The fullness of usual fabrics is 80 to 90%. When such fabrics lie on a particular foundation, no influence of the foundation reflectance can be seen due to thread interlacing but when such fabrics are looked towards the light, transparency of the fabric is disclosed due to the light rays passing through pores. At lower values of fullness, the effect of the underlying foundation can be already visually perceived.

Besides theoretical methods by calculating, the degree of fabric fullness and, consequently, the effect of an individual thread system can be determined microscopically by using the image analysis. This process is based on acquiring image data of a fabric and their processing in digital form at particular magnification by using programming tools for image analysis. The advantage of this method are precise numerical data about the size of the areas of warp and weft threads on the fabric surface, about particularities at threads interlacing and weave arrangement, as well as about the extent and influence of reflectance (pores) on overall colour effect. However, this method is very time-consuming and because of that theoretical calculations of fabric fullness are mostly used in practice. The results of some researches prove that theoretical calculations are appropriate despite certain simplifications. In simpler weaves, the results are highly comparable with the results obtained by the more precise method of image analysis [10].

3.3 Colour design parameters of fabric

At colour designing of fabrics, design parameters of fabrics, such as warping and weaving patterns and compositional effects are utilized. A fabric is a flat textile formation consisting of one lengthwise and one crosswise tread system

površin osnovnih in votkovnih niti na površini tkanine, o posebnostih pri prepletanju niti in urejenosti vezave ter o velikosti in vplivu presevanja (por) na skupni barvni učinek. Slabost slikovne analize tkanine je zamudnost postopka, zato v praksi največkrat uporabljamo kar teoretični način izračunavanja pokritosti tkanine. Glede na ugotovitve nekaterih raziskav so teoretični izračuni kljub določenim poenostavitvam primerni, saj so rezultati pri enostavnejših vezavah zelo primerljivi s tistimi, ki so dobljeni z natančnejšo metodo slikovne analize [10].

3.3 Barvno-oblikovni parametri tkanine

Pri barvnem oblikovanju tkanin izkoriščamo oblikovne parametre tkanine, kot so vzorec snovanja in tkanja ter kompozicijski učinki. Tkanina je ploskovna tekstilna tvorba, sestavljena iz vzdolžnega in prečnega sistema niti (osnovne in votkovne niti). Kot osnovni gradniki so tako osnovne in votkovne niti glavni povzročitelji barve tkanine. Vzorec snovanja in tkanja pa opredeljuje število in zaporedje barvno ali konstrukcijsko različnih niti osnove in votka. V primeru, ko ta podatek podaja le barvno različne niti, je efekt vzorca snovanja in tkanja izključno estetskega pomena, medtem ko v primeru konstrukcijsko različnih niti (dolžinska masa, pretržna trdnost, elastičnost) lahko posegamo tudi v mehanske lastnosti tkanine.

Glede na barvne vrednosti prej, ki se pojavljajo v vzorcu snovanja in tkanja, ter kompozicijske efekte delimo tkanine na tri skupine [30]:

- enobarvne tkanine z enako barvo osnovnih in votkovnih niti,
- tkanine z različnima barvama osnovnih in votkovnih niti,
- večbarvne tkanine.

V naslednjih poglavjih bodo opisani le nekateri osnovni oblikovni parametri, ki vplivajo na enostavne barvne in teksturne učinke eno- in večbarvnih tkanin. Analiza zahtevnejših oblikovnih elementov, kot so barvni učinki večosnovnih in večvotkovnih tkanin ter žakarski vzorci, bi upravičeno našla mesto v posebnem članku s to osrednjo tematiko.

3.3.1 Enobarvne tkanine

Tkanine z enako barvo osnovnih in votkovnih niti so enobarvni izdelki. Vzorčne efekte dosegamo s pomočjo sprememb konstrukcijskih parametrov tkanine: dolžinsko maso, gostoto in vezavo. Pri tem se igramo z zakoni optike in svetlobnimi pojavi. Odboj svetlobe v različne smeri in različna intenziteta sipanja na ploskvah omogočata dojemanje teksture in volumna tkanine. Sklepali bi, da je barva enobarvne tkanine kar enaka barvi preje. Vendar že zelo enostaven vizualni poskus, pri katerem navitek niti določene barve prislonimo k tkanemu izdelku iz teh niti, dokaže, da je naše dojemanje barve na teh dveh vzorcih različno. Ta barvna razlika pa ni samo subjektivno zaznavanje, temveč jo lahko tudi numerično ovrednotimo, saj med barvo niti in barvo tkanine, stkane iz teh niti, obstajajo sicer majhne, a nezanemarljive spektralne razli-

(warp and weft threads). As basic constructional elements, warp and weft threads are major inducers of the colour of a fabric. The warping and weaving patterns determine the number and sequence of warp and weft threads that differ in colour and construction. In the case of threads of different colour, the effect of the warping and weaving patterns is exclusively of aesthetic importance whereas in the case of constructionally different threads (linear density, breaking strength, elasticity), also the mechanical properties of a fabric can be modified. Considering the colour values of yarns, which appear in the warping and weaving pattern, and the compositional effects, fabrics are classified into three groups [30]:

- *single-colour fabrics with warp and weft threads of the same colour,*
- *fabrics with warp and weft threads of different colour,*
- *multicolour fabrics.*

Only few of the basic design parameters, which have influence on simple colour and texturing effects of single-colour and multicolour fabrics, will be described in the following chapters. The analysis of more complex design elements, such as colour effects of multi-warp and multi-weft fabrics, and Jacquard patters would deserve to be dealt with in an extra paper.

3.3.1 Single-colour fabrics

Fabrics with warp and weft threads of the same colour are considered single-colour products. Pattern effects are obtained by changing the constructional parameters of a fabric: linear density, thread spacing, and weave. The laws of optics are applied, and light effects are utilized. Reflection of the light in different directions, and different intensities of scattering on surface planes enable perception of texture and volume of a fabric. It might be concluded that the colour of a single-colour fabric is identical to the colour of the yarn. However, a simple visual test by putting the yarn package close to the woven product made of this yarn proves that our sensation of colour on these two samples differs. This colour difference is not only subjective sensation but can be numerically evaluated as there are slight but not negligible spectral differences between the

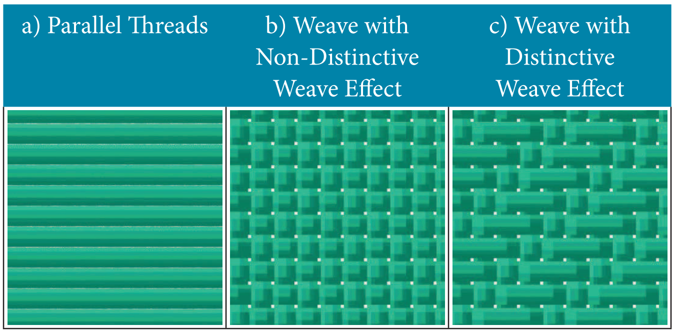


Figure 22: Parallel single-colour threads (a), and single-colour fabrics without (b) and with weave effect (c) (The picture was made by using CAD program by Arahne [22].)

ke [10]. Na sliki 22 so predstavljene vzporedne niti določene barve (a) ter enobarvna tkanina z neusmerjenim (b) in z usmerjenim (c) vezavnim efektom. Na tkaninah z efektom vezave lahko opazimo spreminjanje odboja svetlobe v odvisnosti od vrste vezave.

3.3.2 Večbarvne tkanine

Pojav barve postane kompleksnejši v primeru dvo- in večbarvnih tkanin iz različno obarvanih osnovnih in voktovnih niti. V tem primeru je barvni dražljaj, ki izzove nadaljnje reakcije v očesu in možganih, sestavljen iz svetlobe, odbite od površin niti obeh barv. Tekstilni material je pri tem pretvornik svetlobe, saj se le del vpadle svetlobe odbija od njega, in ne oddajnik, za katerega veljajo pravila aditivnega mešanja. Za razlago nastanka optičnega mešanja barve na dvobarvnih tkaninah si lahko pomagamo s principi aditivnega mešanja, obenem pa je pri tem treba upoštevati specifiko nastanka skupnega barvnega dražljaja na večbarvni površini [7, 10].

Napovedovanje barve ploske večbarvne tkanine

Barvna metrika je kot metoda za določanje barvnih vrednosti preje in enobarvnih tkanin popolnoma uveljavljena. Nasprotno pa ta metoda ni standardizirana za določanje barvnega (teksturnega) učinka različnih vezav in tkanin, izdelanih iz raznobarvnih niti (pestrih tkanin). Ne glede na to, da je v praksi običajno končni videz večbarvnih tkanin prepuščen vizualni oceni, se za načrtovanje barv nekaterih skupin večbarvnih tkanih izdelkov uporablja barvno napovedovanje. Tu lahko predstavimo program slovenskega porekla – ArahWeave [22], v katerem se napovedovanje uporablja pri avtomatskem barvnem senčenju. Pri tem gre za pretvorbo barve z digitalne slike (fotografije z originalnim številom barv) v skupni barvni učinek večslojne vezave z izbranimi barvami v osnovi in votku.

Barvna metrika je torej neutemeljeno zapostavljena pri objektivnem ocenjevanju barve pestrih tkanin, saj se lahko ob poznavanju barvnih vrednosti osnovnih in votkovnih niti ter konstruk-

colour of threads and the fabric woven from these threads [10]. Figure 22 presents parallel threads of certain colour (a), a single-colour fabric with non-oriented weave effect (b), and a single-colour fabric with oriented weave effect (c). On fabrics with weave effects, the changes of the light reflection, in dependence of the type of weave can be noticed.

3.3.2 Multicolour fabrics

The phenomenon of colour becomes more complex in the case of bicolour and multicolour fabrics made from differently coloured warp and weft threads. In such case, the colour stimulus that induces further reactions in the eye and brains consists of the light reflected from the surface of threads of both colours. Textile material is the light converter as only a portion of the incident light reflects from it, and not the light transmitter for which the rules of additive mixing apply. The occurrence of optical colour mixing on bicolour fabrics can be explained with the principles of additive mixing by considering at the same time the specificity of occurrence of a common colour stimulus on a multicolour surface [7, 10].

Predicting of colour of multicolour flat fabric

Colorimetry as a method for determining the colour values of yarn and single-colour fabrics has been well established. However, it has not been standardized for determining the colour (texturing) effect of various weaves and fabrics made of differently coloured threads (multicolour fabrics). Regardless of the fact that in practice, final appearance of multicolour fabrics is left to visual estimation, colour predicting is used for designing colours of some groups of multicolour woven products. The program of Slovenian origin – ArahWeave [22] uses colour predicting in automatic colour shading. It transforms the colour in digital image (a photos with the original number of colours) into an overall colour effect of multilayer weave with the selected colours in the warp and weft.

Colorimetry is therefore unreasonably disregarded at objective estimation of the colour of multicolour fabrics as it can within certain tolerance limits predict colour values of a finished

cijskih parametrov preje v določenih mejah tolerance napove barvne vrednosti končnega izdelka. Uspešnost napovedi je pri tem odvisna od uporabljenega barvnega sistema oz. prostora (spekter, RGB, CIEXYZ, CIE L*u*v*, CIE L*a*b*) ter predvsem od barvne kombinacije niti v kompoziciji. V vsakem primeru se barvne razlike med teoretično izračunanimi in merjenimi barvnimi vrednostmi večbarvne tkanine izbrane barvne kombinacije in konstrukcije gibljejo okoli določene vrednosti barvne razlike (ΔE_{XYZ}, ΔE_{00}, ΔE_{ab}) [10].

Za primer lahko predstavimo dvobarvno tkanino z osnovnimi nitmi določene barve o, votkovnimi nitmi barve v in barvo podlage p. Iz konstrukcijskih parametrov (finosti niti, gostote in vezave) so izračunani deleži osnovnih in votkovnih niti ter podlage v tkanini [10], spektrofotometrično pa so izmerjene barvne vrednosti oz. koordinate (refleksija, RGB, XYZ, L*a*b* itd.) vhodnih barvnih komponent. Barvno vrednost oz. koordinato bomo na splošno poimenovali BV.

Vhodni podatki za teoretični izračun barve večbarvne tkanine so torej:

- o = osnova,
- v = votek,
- p = podlaga,
- BV_o (refleksija$_o$ (λ), R_o, G_o, B_o, X_o, Y_o, Z_o) = barvna vrednost barvne komponente o,
- BV_v (refleksija$_v$ (λ), R_v, G_v, B_v, X_v, Y_v, Z_v) = barvna vrednost barvne komponente v,
- BV_p (refleksija$_p$ (λ), R_p, G_p, B_p, X_p, Y_p, Z_p) = barvna vrednost barvne komponente p,
- u_o = delež osnovnih niti barve o v barvnem raportu,
- u_v = delež votkovnih niti barve v v barvnem raportu,
- u_p = delež podlage barve p v barvnem raportu.

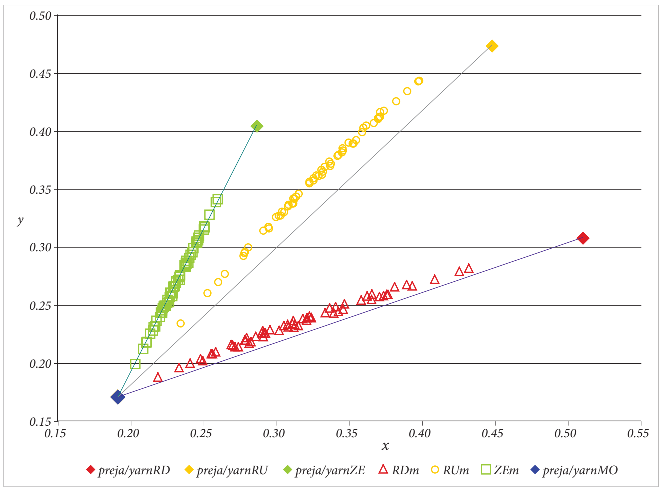


Figure 23: Example of bicolour fabrics position between warp and weft threads positions in CIE xy diagram

*product if the colour values of warp and weft threads and constructional parameters of yarn are known. How successful such prediction is depends on the used colour system or space (spectre, RGB, CIEXYZ, CIE L*u*v*, CIE L*a*b*), and particularly on the colour combination of threads in the composition. In any case, deviations of the theoretically calculated values from the measured colour values of a multicolour fabric in a selected colour combination and construction, range around certain value of colour deviation (ΔE_{XYZ}, ΔE_{00}, ΔE_{ab}) [10].*

*As an example, a bicolour fabric with warp threads colour o, weft threads colour v, and the foundation colour p will be presented. On the basis of constructional parameters (thread fineness, thread spacing and weave) the portions of warp and weft threads, and that of the foundation in a fabric are calculated [10], and the colour values (coordinates) (reflection, RGB, XYZ, L*a*b* etc.) of input colour components spectrophotometrically measured. Colour value (the coordinate) will be generally called BV.*

Therefore, the input data for theoretical calculation of the colour of multicolour fabric are the following:

- *o = warp,*
- *v = weft,*
- *p = foundation,*
- BV_o *(reflection*$_o$ *(λ),* R_o, G_o, B_o, X_o, Y_o, Z_o*) = colour value of colour component o,*
- BV_v *(reflection*$_v$ *(λ),* R_v, G_v, B_v, X_v, Y_v, Z_v*)= colour value of colour component v,*
- BV_p *(reflection*$_p$ *(λ),* R_p, G_p, B_p, X_p, Y_p, Z_p*) = colour values of colour component p,*
- U_o *= portion of the warp threads colour in colour repeat,*
- U_v *= portion of the weft threads colour in colour repeat,*
- U_p *= portion of the foundation p colour in colour repeat.*

The colour value of the fabric BV_{tk} *is therefore defined by Equation 15 [10].*

In general, Equation 15 can be extended to the number n of different colour components i in the fabric, and the colour values of the fabric BV_{tk} *can be expressed as Equation 16 [10].*

In Equation 15:

- BV_i *= colour values of i component of fabric,*

Barvna vrednost tkanine BV_{tk} je potem določena z [10]:

$$BV_{tk} = (BV_o \cdot u_o) + (BV_v \cdot u_v) + (BV_p \cdot u_p) \qquad (15)$$

Na splošno lahko enačbo (15) razširimo na število n različnih barvnih komponent i v tkanini in napišemo barvne vrednosti tkanine BV_{tk} kot [10]:

$$BV_{tk} = \sum_{i=1}^{n} (BV_i \cdot u_i) \qquad (16)$$

V enačbi (16) so:
– BV_i = barvne vrednosti i-te komponente tkanine,
– u_i = delež komponente i v barvnem raportu,
– n = število barvnih komponent v barvnem raportu tkanine.

Večbarvne tkanine lahko prikažemo tudi grafično v določenem barvnem prostoru oz. sistemu.

Kot primer lahko predstavimo rezultate raziskave [10], v kateri so bile merjene barvne vrednosti niti osnove in votka ter barvne vrednosti dvobarvnih tkanin. Lege dvobarvnih tkanin so prikazane v barvnem diagramu CIE xy. V osnovi je bila konstantna barva – modra, v votku pa so bile barve različne: rdeča, rumena in zelena. S spreminjanem konstrukcijskih parametrov so se spreminjali deleži barve osnove in votka in s tem tudi lega merjenih barv dvobarvnih mešanic v barvnem diagramu. Na sliki 23 predstavljajo lego treh skupin dvobarvnih tkanin točke RDm, RUm, ZEm, lege prej osnove in votka pa so označene s prejaMO, prejaRD, prejaRU in prejaZE. Če bi bile niti osnove in votka idealne primarne barve točno določenih valovnih dolžin (kot so to rdeča, zelena in modra svetloba pri aditivnem principu mešanja [13]), bi dvobarvne mešanice ležale na ravni daljici, ki povezuje obe izhodiščni barvi. Drugačni rezultati, ki se kažejo kot bolj ali manj nelinearno gibanje leg dvobarvnih mešanic med dvema barvnima izvoroma, so seveda posledica kompleksnosti optičnega mešanja svetlobe, odbite od površin niti različnih barv.

Tkanine z gladkim vzorcem snovanja in tkanja

Barva tkanin z gladkim vzorcem snovanja in tkanja in različnima barvama osnovnih in votkovnih niti nastaja z optičnim mešanjem odbite svetlobe dveh različnih spektralnih lastnosti. Delež svetlobe, ki se absorbira na površini osnovnih in votkovnih niti, je različen zaradi različne kemijske sestave barvil v nitih. Posledično pa sta različni tudi refleksijski krivulji odbitih žarkov. Ker oboji žarki dosežejo naše oko, dojemamo njihovo vsoto, ki deluje vizualno kot mešanica barv osnovnih in votkovnih niti. Zlitje dražljajev iz raznobarvnih niti bo izrazitejše v primeru manjše dolžinske mase in večje gostote niti ter pri večji pogostosti prepletanja in enakomernosti flotiranja niti [7, 31].

Na sliki 24 sta prikazani tkanini v vezavi platno z različnima barvama v osnovi in votku ter različnimi vrednostmi finosti in gostote niti. V primeru manjše gostote in večje dolžinske mase niti

- *U_i = portion of component i in colour repeat,*
- *n = number of colour components in the fabric colour repeat.*

Multicolour fabrics can also be presented graphically in a colour space or system.

As an example, we are going to present the results of the research [10] in which the colour values of warp and weft threads, and the colour values of bicolour fabrics were measured. The positions of bicolour fabrics are presented in CIE xy colour diagram. The colour of warp threads was constant, i.e. blue, whereas the colours of weft threads were different, i.e. red, yellow and green. By changing constructional parameters, the portions of the colour of warp and weft and, consequently, also the position of the measured colours of bicolour mixtures in a colour diagram changed. In Figure 23, the position of three groups of bicolour fabrics is presented by points RDm, RUm, ZEm, and the positions of warp and weft yarns are marked preja/yarnMO, preja/yarnRD, preja/yarnRU, and preja/yarnZE. If warp and weft threads had ideal colour of exactly defined wavelengths (such as red, green and blue light at additive principle of mixing [13]), bicolour mixtures would lie on a straight line that connects both original colours. Other results, which show more or less non-linear motion of the positions of bicolour mixtures between two colour origins, are the result of the complexity of optical mixing of the light reflected from the surface of differently coloured threads.

Fabrics with flat warping and weaving pattern

The colour of fabrics with flat warping and weaving pattern, and with differently coloured warp and weft threads is produced by optical mixing of the reflected light with two different spectral properties. The portion of the light, which is absorbed on the surface of warp and weft threads, is different due to different chemical composition of dyestuffs in threads. Consequently, the two reflection curves of the reflected rays are different as well. Since both rays reach the eye, the perceived colour is in fact their sum, which looks as a mixture of the colours of warp and weft threads. Merging of colour stimuli from multicolour threads will be more pronounced when line-

(a) vidimo pri enaki povečavi slabše zlitje barvnega efekta kot pri tkanini z večjo gostoto in manjšo dolžinsko maso niti (b).

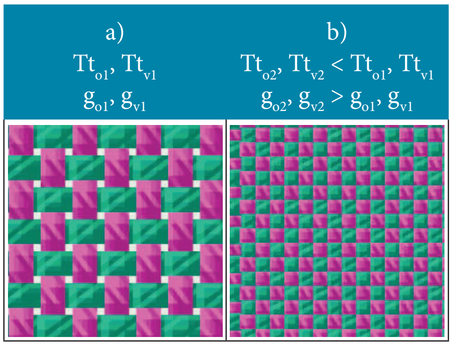


Figure 24: Magnification of two fabrics with different colours of warp and weft threads with warp and weft thread spacing 20 threads/cm (30 tex) and 40 threads/cm (20 tex). (Picture was made by using CAD program by Arahne [22].)

Tkanine z zahtevnejšim vzorcem snovanja in tkanja

Pri dvo- ali večbarvnih tkaninah se v vzdolžni in prečni smeri tkanine pojavljajo površine različnih barv, kar lahko dosežemo na več načinov.

- Z vzorcem snovanja in tkanja pri določeni konstrukciji tkanine, ko se po osnovi in votku pojavlja več različnih barv. Običajno nastajajo vzdolžni, prečni ali karo efekti različnih barv.
- S spremembo konstrukcije tkanine (najpogosteje vezave), ko se izmenjujeta osnovni in votkovni efekt na tkanini. Na tkanini dobimo barvno različna polja.
- Vzorčimo lahko tudi s kombinacijo zgornjih dveh načinov. Vzorec snovanja in tkanja prilagodimo konstrukciji tkanine tako, da na površini tkanine po nekem vzorcu dosežemo skupine veznih točk enakih barv (pike, črte, figurativni vzorci).
- Pri večplastnih tkaninah (tkanine z več sistemi osnove in votka) vzorčimo s pomočjo raznobarvnih niti osnove in votka ter

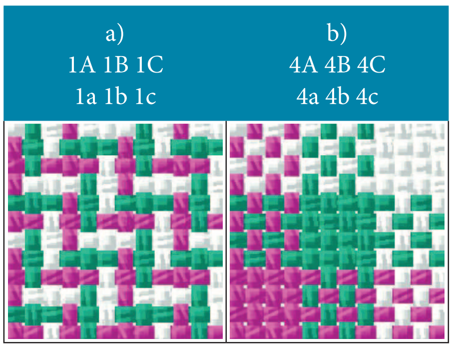


Figure 25: Multicolour fabrics with different thread sequence in warping and weaving pattern (Picture was made by using CAD program by Arahne [22].)

ar density of thread is lower and thread spacing higher, and when interlacing is more frequent and thread floating uniform [7, 31].

In Figure 24, two fabrics in plain weave with different colours of warp and weft threads and different values of thread fineness and thread spacing are presented. The same magnification of both fabrics reveals less effective mixing of the colour effect in the fabric with lower thread spacing and higher linear density (a) than in the fabric with higher thread spacing and lower linear density (b).

Fabrics with more complex warping and weaving pattern

In the case of bicolour and multicolour fabrics, the areas of different colours appear in lengthwise and crosswise directions, which can be achieved in several ways:

- *by using a warping and weaving pattern in a certain fabric construction in which several different colours appear in warp and weft; in that case, longitudinal, transversal and check effects of different colours are usually produced;*
- *by changing the fabric construction (most frequently the weave) with warp and weft effects are alternating on the fabric; in that case, differently coloured areas are produced on the fabric;*
- *by combining the two above mentioned ways; on that case, the warping and weaving patterns are adjusted to the fabric construction so that groups of interlacing points of the same colour are formed to produce a certain pattern (dots, stripes, figurative patterns);*
- *by using differently coloured warp and weft threads and multi-layer structure (fabrics with more warp and weft threads systems); in that case, the colours and their sequence are adjusted to the layers and their weaves so that different colour and structural effects are produced on several levels of the fabric.*

With bicolour and multicolour fabrics too, the principle of optical mixing of colours on the surface is utilized. It should be pointed that the sequence of threads in the warping and weaving pattern is of vital importance for the effectiveness of optical mixing of colours. If optically sin-

s strukturo. Barve in njihovo zaporedje prilagajamo plastem in njihovim vezavam, tako da na različnih nivojih tkanine dobimo različne barvne in strukturne efekte.

Tudi pri dvo- ali večbarvnih tkaninah izkoriščamo princip optičnega mešanja barv na površini. Tu je treba upoštevati, da je za učinkovitost optičnega mešanja bistveno zaporedje niti v vzorcu snovanja in tkanja. Če želimo doseči optično enobarvno tkanino, naj bo barvno sosledje 1 : 1 : 1 ali 2 : 2 : 2, saj so le tako barvne površine dovolj majhne za učinkovito optično mešanje. V nasprotnem primeru se na tkanini pojavljajo zaporedja večjih raznobarvnih površin, kar oko ne dojame kot enotno barvo pri normalni (bralni) razdalji opazovanja.

Na sliki 25 sta predstavljeni tkanini v vezavi platno s tremi barvami v vzorcu snovanja in tkanja pri zaporedju 1A 1B 1C, 1a 1b 1c (a) in 4A 4B 4C, 4a 4b 4c (b). V prvem primeru se barvni učinek lažje zlije v enotnega, medtem ko v drugem primeru dojemamo večji vzorčast efekt.

Barvno sosledje

V poglavju o vezavah smo definirali sosledje vezave kot najmanjši ponavljajoči se element v tkanini, ki opisuje način prevezovanja osnovnih in votkovnih niti. Ko temu elementu dodamo še določeno zaporedje barv niti, se velikost najmanjše enote na tkanini spremeni, saj postane odvisna od kompozicije in barve niti. Nov najmanjši element lahko imenujemo barvno sosledje. V barvnem sosledju se med kompozicijo vezave in zaporedjem niti ustvarijo določena razmerja, s pomočjo katerih določamo površine posameznih barvnih komponent in njihove deleže. Posamezne vezne točke ali njihove skupine so druga poleg druge in od njihove barvne vrednosti je odvisno dojemanje skupnega barvnega učinka [31].

Vzemimo za primer vezavo platno. Sosledje vezave ima velikost 2 × 2 vezni točki. Z upoštevanjem vzorca snovanja in tkanja lahko definiramo barvno sosledje, ki ima pri enobarvni osnovi in votku ali pri barvnem zaporedju 1A 1B in 1a 1b enako velikost 2 × 2, razmerje med barvami pa različno od razmerja veznih točk. Pri npr. modri enobarvni osnovi in rdečem enobarvnem votku ter

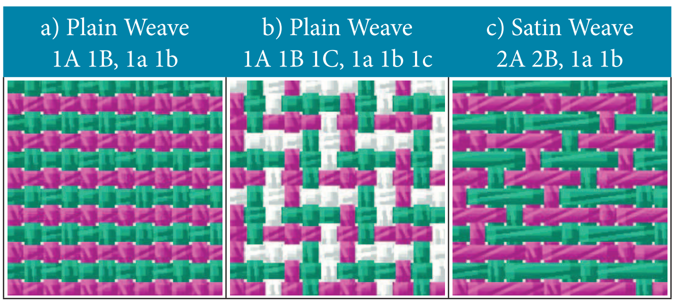


Figure 26: Colour repeats of plain weave and five-end satin weave with different warping and weaving patterns (Picture was made by using CAD program by Arahne [22].)

gle-colour fabric is required, the colour repeat to be 1 : 1 : 1 or 2 : 2 : 2 as only in that case the colour areas are small enough to be effectively optically mixed. Otherwise, the sequences of larger differently coloured areas appear on the fabric and at normal (reading) distance of observation, the eye is not able to view them as a uniform colour.

Figure 25 presents two fabrics in plain weave with three colours in the warping and weaving pattern in the sequence 1A 1B 1C, 1a 1b 1c (a) and 4A 4B 4C, 4a 4b 4c (b). In the first case, the colour effect easily merges into a uniform effect whereas in the latter case, a larger patterned effect is produced.

Colour repeat

In the chapter dealing with weaves, the weave repeat was defined as the smallest recurring element in a fabric which identifies the way of warp and weft threads interlacing. When a certain sequence of thread colours is added to this element, the size of the smallest unit on a fabric changes as it becomes dependent on the composition and the colour of threads. The new smallest element can be called colour repeat. In colour repeat, certain relationships are created between the weave composition and the sequence of threads by which the areas of individual colour components and their portions are determined. Individual interlacing points or the groups of interlacing points are positioned one beside the other, and the sensation of the overall colour effect depends on their colour values [31].

Plain weave, for example, has the weave repeat 2 × 2 interlacing points. By considering the warping and weaving pattern, colour repeat can be defined; with single-colour warp and weft, or at colour sequence 1A 1B and 1a 1b it has the same size 2 × 2 but different colour relation and different relationship between interlacing points. If, for example, warp threads are blue and weft threads are red, and the construction is square, only two colours will be present in the colour repeat. The portion of red and blue colour in the colour repeat will be the same just as is the same the ratio of warp to weft interlacing points in the weave repeat. In the case of bicolour warping and weaving pattern with sequence 1A 1B (e.g. blue, green) and 1a 1b (e.g. red, or-

kvadratični konstrukciji sta v raportu prisotni le dve barvi. Delež rdeče in modre barve v sosledju je enak, tako kot je enako razmerje med osnovnimi in votkovnimi veznimi točkami v sosledju vezave. Pri dvobarvnem vzorcu snovanja in tkanja z zaporedjem 1A 1B (npr. modra, zelena) in 1a 1b (npr. rdeča, oranžna) se na velikosti sosledja 2 × 2 pojavijo štiri barve, modra in zelena osnovna vezna točka ter rdeča in oranžna votkovna točka, vsaka s četrtino pokritosti površine. Sosledje vezave in barvno zaporedje imata enako velikost; sledi, da ima takšno velikost tudi barvno sosledje.

Ko dodamo v vzorec snovanja in tkanja še tretjo barvo, dobimo primer, ko se velikost raporta vezave in števila ponavljajočih se niti v vzdolžni in prečni smeri ne ujemata. Zaporedje niti po osnovi in votku je 1 : 1 : 1. Velikost barvnega sosledja je na takšni tkanini določena z osnovno in votkovno nitjo, in sicer je meja tam, kjer se začneta hkrati ponavljati tako vezava kot barvno zaporedje. V primeru vezave platno in treh barv po osnovi in votku se začne celoten sistem ponavljati na sedmi osnovni in votkovni niti, ko se na popolnoma enak način začne ponavljati zaporedje veznih točk in barvnih površin. Podobno je tudi pri vezavah večjih raportov. Barvno sosledje petveznega atlasa bi imelo pri vzorcu snovanja 2A 2B (= 4 niti) in tkanja 1a 1b (= 2 niti) velikost 20 po osnovi (5 × 4) in 10 po votku (5 × 2).

Na sliki 26 so prikazana barvna sosledja vezave platno z vzorci snovanja in tkanja 1 : 1 (a) ter 1 : 1 : 1 (b) in vezave petvezni atlas z vzorcem snovanja 2 : 2 in tkanja 1 : 1 (c).

Razumevanje velikosti barvnega sosledja je pomembno za določanje vpliva posameznih barvnih komponent (niti osnove in votka ter osnovne in votkovne vezne točke) na skupni barvni učinek tkanine. Treba je upoštevati posebej osnovne in votkovne niti določene barve ter različne tipe veznih točk v kompoziciji. Tako dobimo pregled čez vse možne barvne površine, ki nastanejo med prepletanjem niti.

3.3.3. Odnos med barvami v večbarvni tkanini

Razmerje med barvami niti in veznimi točkami na tkanini ni le fizično in optično, temveč ga lahko opišemo tudi na osnovi različnih odnosov med barvami. Dva pomensko nasprotujoča si odnosa, ki vladata med dvema barvama, sta kontrast in harmonija. V umetniškem smislu sta bila definirana predvsem za primarne in druge barve subtraktivnega mešanja barv, vendar ju lahko s pridom uporabimo tudi pri optičnem mešanju na tkanini [32, 33, 34].

Barvni kontrast

Poznamo več vrst kontrastov barve.

- Kontrast barve k barvi lahko opišemo z najmanj tremi zelo nasičenimi barvami, ki so v barvnem diagramu najbolj oddaljene. Primer so tri primarne barve rdeča, zelena in modra.
- Svetlo-temni kontrast je prisoten med akromatskimi barvami različnih svetlosti (črno-belo), med spektralno različnima bar-

ange), four colours will appear in the weave repeat 2 × 2, i.e. blue and green warp interlacing point, and red and orange weft interlacing point, each covering one fourth of the surface. The weave repeat and the colour sequence have the same size; hence, it follows that the size of the colour repeat will be the same too.

When a third colour is added into the warping and weaving pattern, the size of the weave repeat and the number of recurring threads in lengthwise and crosswise directions do not match. The sequence of threads by warp and weft is 1 : 1 : 1. On such fabric, the size of the colour repeat is determined by warp and weft threads where both the weave and the colour sequence begin to repeat concurrently. In the case of plain weave and three colours by warp and weft, the entire system begins to repeat on the seventh warp and weft thread when the sequence of interlacing points and colour areas begins to repeat in completely identical way. The like applies also for the weaves with larger repeats. The colour repeat of five-end satin weave would have the size 20 by warp (5 × 4) and 10 by weft (5 × 2) at the warping pattern 2A 2B (= 4 threads) and weaving pattern 1a 1b (= 2 threads).

Figure 26 presents the colour repeats of plain weave with warping and weaving patterns 1 : 1 (a) and 1 : 1 : 1 (b), and of five-end satin with warping pattern 2 : 2 and weaving pattern 1 : 1 (c).

The size of colour repeat should be understood as it is important for determining the influence of individual colour components (warp and weft threads, and warp and weft interlacing points) on overall colour effect of a fabric. It is necessary to consider separately warp and weft threads of a particular colour, and various types of interlacing points in composition. In this way, all pos-

vama z različno vrednostjo svetlosti (modro-rumeno) ter med različnima vrednostma svetlosti določene barve (svetlo in temno modro).

- Hladno-topli kontrast se pojavi med hladnimi barvami z nizko stopnjo refleksije pri nižjih valovnih dolžinah (modra, zelena, vijolična) in barvami z višjo stopnjo refleksije ter maksimumom pri višjih valovnih dolžinah (rumena, oranžna, rdeča).
- Komplementarni kontrast tvorijo barve, ki ležijo na nasprotnih straneh središčne bele točke. Pri aditivnem mešanju dveh komplementarnih barv se barvna dražljaja seštejeta v nepestro barvo. V barvnem prostoru CIE L*a*b* bi lahko podobno rekli, da sta to barvi, ki ležita na nasprotnih straneh koordinatnega izhodišča (rdeča-zelena in rumena-modra).
- Dve barvi lahko definiramo kot kakovostno kontrastni, če se razlikujeta po nasičenosti ali kromi. V barvnem diagramu xy bi to bila dvojica barv, od katerih ena leži na spektralni črti, druga pa je umaknjena proti notranjosti diagrama.
- Kontrast količin se pojavi med raznobarvnimi površinami različnih velikosti. Pri tem dve enako veliki ploskvi različnih barv ne delujeta enako veliko, saj na dojemanje vpliva delež svetlobe, odbite od površine (refleksija). Zaporedje intenzivnosti dojemanja kromatskih barv pri enakih površinah barvnih ploskev bi tako bilo: rumena → oranžna → rdeča → vijolična → modra → zelena.
- Sledita še sočasni in zaporedni kontrast, ko človeško oko opazovani barvi priredi komplementarno barvo ali v primeru zaporednega kontrasta dražljaj določenih valovnih dolžin po nekem času izzove nasprotno barvo.

Na sliki 27 so s pomočjo tkanin v vezavah tri- in štirivezni panama prikazane različne vrste kontrastov barv niti. Od barvne kombinacije in barvnih vrednosti posameznih barv je odvisno, kako intenzivno dojemamo tkano površino. Dražljaji svetlobe, odbite od svetlih, toplih in bolj nasičenih barv, so namreč za oko izrazitejši kot dražljaji temnih, hladnih in manj nasičenih barv. V primeru kombinacije niti, katerih barve so v svetlo-temnem, hladno-toplem, kakovostno kontrastnem ali komplementarnem razmerju, se večji delež svetlobe odbije od svetlih, toplih in bolj nasičenih barv. Te površine zato dojemamo intenzivneje. Močnejši dražljaji povzročajo tudi prostorsko razlikovanje med raznobarv-

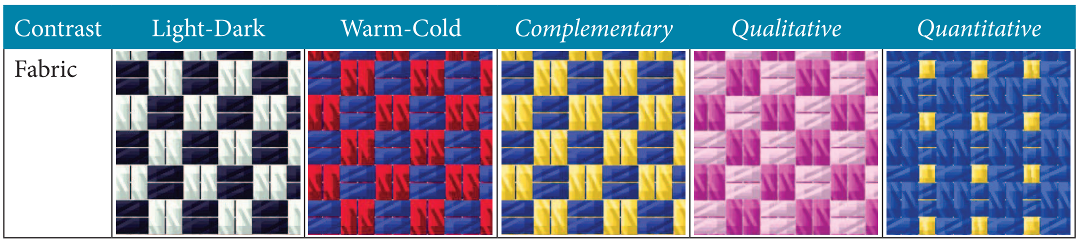


Figure 27: Fabrics with combination of threads being in contrast relationship (Picture was made by using CAD program by Arahne [22].)

sible colour areas, which can be produced during the interlacing of threads, can be viewed.

3.3.3 Relationship between colours in multicolour fabric

The relationship between the threads colours and interlacing points in a fabric is not only physical and optical but may be also described in terms of different relations between colours. Two conflicting relationships, which exist between two colours, are contrast and harmony. In the field of art, both terms were defined above all for primary and other colours of subtractive colour mixing, however, they can be also advantageously used at optical mixing on fabrics [32, 33, 34].

Colour contrast

Several types of colour contrasts are known:

- *Colour-to-colour contrast can be described with at least three highly saturated colours that are most distant in the colour diagram, for example, three primary colours: red, green and blue.*
- *Light-dark contrast exists between achromatic colours of different lightness (black-white), between two spectrally different colours with different value of lightness (blue-yellow), and between two different values of the lightness of a particular colour (light and dark blue).*
- *Cold-warm contrast exists between cold colours with low degree of reflection at lower wavelengths (blue, green, violet) and those with higher degree of reflection and with higher wavelengths (yellow, orange, red).*
- *Complementary contrast is produced by the colours, which lie at the opposite sides of the central white point. At additive mixing of two complementary colours, two colour stimuli merge into a non-multicolour colour. In CIE L*a*b* colour space, these are two colours which lie at the opposite sides of the coordinate starting-point (red-green and yellow-blue).*
- *Qualitative contrast can be defined as a contrast, which is produced by two qualitatively different colours, i.e. two colours differing in saturation, i.e. chroma. In the colour diagram xy, it would be a pair of colours, one of*

nimi površinami, saj toplejše in svetlejše barve učinkujejo bližje kot hladnejše in temnejše. V določenih primerih imajo te barve maksimum reflektirane svetlobe tudi pri višjih valovnih dolžinah vidnega spektra.

Poseben pojav je kontrast količin, ko kvaliteta barve vpliva na kvantitativno doživljanje barve. Velikost barvnih površin v tkanini je definirana s konstrukcijskimi parametri. Večje grupacije veznih točk določene barve ali večja gostota niti načeloma izzovejo močnejši dražljaj v človekovem očesu. Zanimivo pa je, da zaradi različnih refleksijskih pojavov na barvah količinski odnosi med barvami niso enakomerni. Vzemimo za primer neko obojestransko vezavo, ki ima identične konstrukcijske lastnosti različno obarvanih osnovnih in votkovnih niti. Recimo, da so osnovne niti modre, votkovne pa rumene. Površinski deleži obeh barv so pri teh pogojih popolnoma enaki, kljub temu pa rumena barva izzove intenzivnejše dražljaje v našem očesu. Če bi želeli doseči skladnost rumene in modre barve, bi morali količino rumene zmanjšati z zmanjšanjem števila rumenih veznih točk (osnovni efekt vezave) ali zmanjšanjem gostote teh niti [33].

Harmonija barv

Opisali bomo le dve vrsti harmonij barve.

- Harmonija sorodnih barv opisuje tri različne vrste odnosov. Po barvnem tonu so si harmonično sorodne barve tiste, ki ležijo na majhni razdalji v barvnem diagramu. Po svetlosti harmonične so barve, ki imajo podobne vrednosti svetlosti, kromatsko sorodne pa so tiste, katerih vrednosti nasičenosti so precej blizu.
- V barvni teoriji se tudi nekatere oblike kontrastov označuje kot harmonične s t. i. pojavom harmonije kontrastnih barv. Harmonično deluje tudi kombinacija barv, katerih skupni barvni učinek je siva, nevtralna barva.

Pri oblikovanju tkanine iz niti harmoničnih barv pride do optičnega zlitja barv tudi pri nekoliko večjih površinah. Zaradi sorodnosti barv namreč človekovo oko težje loči barvi in se zato prilagodi, da ju zlije v enoten barvni dražljaj. Pojav je prisoten predvsem pri barvah podobne svetlosti in barvnega tona. Naspro-

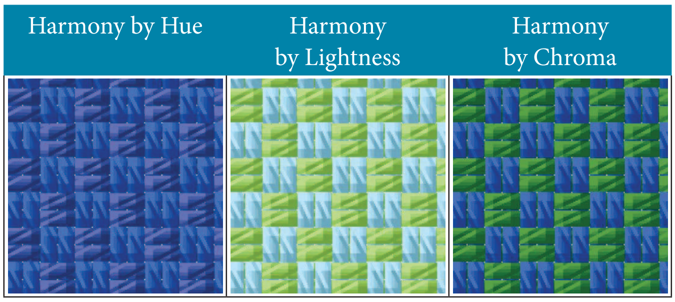


Figure 28: Merging effect of colours being harmonic by hue and lightness (Picture was made by using CAD program by Arahne [22].)

which lying on a spectral line, and the other being removed towards the inside part of the diagram.

- *Quantitative contrast occurs between the areas, which differ in colour and size. Two areas of the same size but of a different colour do not look equally large, namely, the portion of the light reflected from the surface (reflection) influences the sensation of colour. The sequence of the visual intensity of the chromatic colours with the same size of colour area would be: yellow → orange → red → violet → blue → green.*
- *Simultaneous and successive contrasts: the first contrast occurs when the eye adjusts a complementary colour to the observed one, and the latter one occurs when the stimulus of particular wavelengths induces the contrast colour after some time.*

In Figure 27, several types of thread colour contrasts are presented on the fabrics in three- and four-end Panama weaves. How intensive the colour sensation of a woven surface is depends on the colour combination and colour values of individual colours. The stimuli of the light reflected from light, warm and more saturated colours are visually more pronounced than those of dark, cold and less saturated colours. In the case of a combination of threads in light-dark, cold-warm, qualitative or complementary contrast, a bigger portion of the light reflects from light, warm and more saturated colours. The colour sensation of these surfaces is therefore more intensive. Stronger stimuli also lead to spatial differentiation of differently coloured areas; warmer and lighter colours seem to be nearer than colder and darker colours. In some cases, these colours have the reflected light peak also at higher wavelengths of visual spectrum.

Quite a special phenomenon is quantitative contrast in which the quality of colour influences the quantitative colour sensation. The size of the colour areas in a fabric is defined by constructional parameters. Larger assemblies of interlacing points of a particular colour, or higher thread spacing induce stronger stimulus in the eye. However, it is interesting that due to different reflection effects on colours, qualitative relationships between colours are not uniform. Let us take, for example, a reversible weave with

tno pa morajo biti dvo- ali večbarvne površine kontrastnih barv precej majhne, da jih oko lahko zazna kot enotne [7, 31]. Efekt zlitja svetlobno, tonsko in glede na nasičenost harmoničnih barv je prikazan na sliki 28.

4 Apreturni postopki

Namen tega kratkega poglavja je le na splošno omeniti, kakšne posledice imajo lahko različni apreturni postopki za barvo tkanine, v opis posameznih postopkov in njihove mehanizme pa se ne bomo poglabljali.

Namen apreturnih postopkov je stabilizacija tkane strukture, izboljšava mehanskih, fizikalnih in kemijskih lastnosti tkanine ter dodajanje novih barvnih, teksturnih in drugih efektov. Ne glede na vrsto posega imajo ti postopki običajno velik vpliv na odnos tkanina-svetloba. Apreturni postopek je lahko namenjen le enemu nitnemu sistemu, to pomeni, da spremenimo lastnosti samo osnovnih ali votkovnih niti. Efekt obdelanega nitnega sistema se lahko pri tem močno poudari in popolnoma prekrije strukturne in barvne lastnosti drugega, neobdelanega nitnega sistema.

Pri kemijskih posegih spreminjamo barvo celotnega izdelka ali na določenih mestih dodajamo barvne in druge apreturne nanose. Sprememba barve tako prinese razliko v absorpcijsko-refleksijskih lastnostih in spremenjeno razmerje med absorbirano ter odbito svetlobo, kar se na tkanini opazi kot nov barvni ton površine ali nekoliko spremenjena svetlost in nasičenost.

Mehanski posegi imajo podobne posledice, le da se po njihovem delovanju spremeni predvsem način odboja vpadle svetlobe ter razmerje med odbito in sipano svetlobo na površini. Pri tem torej ne gre toliko za spremembo barvnega tona kot za odmik v svetlosti barve. Apreturni postopki, ki imajo za posledico večji lesk tkanine, povzročajo videz tkanine, ki je odvisen od zornega kota opazovanja. Mestoma se nam sicer zdi površina svetlejša, ker odbiti žarki usmerjeno dosežejo oko, na splošno pa je vizualno bolj intenzivna. Nasprotno pa je pri posegih, ki mršijo površino, zaradi česar se poveča naključnost smeri odboja vpadle svetlobe. Videz takšne tkanine je neodvisen od zornega kota opazovanja in je zaradi difuznosti odbitih žarkov na splošno vizualno svetlejši.

5 Zaključek

Barva tkanine ni predvidljiv, ampak dinamičen fenomen, ki je odvisen od več lastnosti, pojavov in dejavnikov ter njihove soodvisnosti. Optični pojavi na tekstiliji definirajo spekter, dojemanje barve pa je nato odvisno tudi od svetlobe okolice in lastnosti opazovalca. Primarna lastnost, ki v največji meri določa barvo *identical constructional parameters of differently coloured warp and weft threads. Suppose that warp threads are blue, and weft threads are yellow. The portions of the two colours on the fabric surface are quite the same but nevertheless yellow colour induces stronger stimuli in the eye. In order to harmonize these two colours, the quantity of yellow colour should be reduced by reducing the number of yellow interlacing points (warp effect of weave), or by decreasing the yellow threads spacing.*

Harmony of colours

Only two types of harmony are going to be described.

- *Harmony of relative colours describes three different types of relationship. Harmonic by hue are the colours, which lie at short distance in the colour diagram. Harmonic by lightness are the colours, which have similar values of lightness, and harmonic by chroma are the colours, which have similar values of saturation.*
- *In colour theory, some types of contrasts are also referred to as harmonic, i.e. harmony of contrast colours. The combination of colours producing the overall colour effect in grey, neutral colour also looks harmonically.*

At designing a fabric made of harmonically coloured threads, the colours optically merge also at larger areas. Since the colours are similar, the eye has problems to distinguish them so that it adapts by merging them into one uniform colour impulse. This phenomenon occurs mostly with the colours of similar lightness and hue. Just the contrary is the case with bicolour or multicolour areas of contrast colours, which should be rather small to be perceived as uniform by the eye [7, 31]. The merging effect of the harmonic colours by lightness, hue and chroma is presented in Figure 28.

4 Finishing processes

The only aim of this short chapter is to mention the possible effects of various finishing processes on the fabric colour, and not to explain these processes and their mechanisms.

The purpose of finishing processes is to stabilize a woven structure, to improve mechani-

tkanine, je gotovo barva vlaken in niti osnove in votka. S skrbnim izborom barve preje lahko predvidimo in definiramo barvni ton izdelka. Pri kombiniranju niti različnih barv nastaja nov skupni barvni ton kot posledica optičnega mešanja različnih spektralnih svetlob.

Prava dinamika pojavnosti barve na tkanini pa se izkaže, ko izhodiščnim barvam vlaken in preje dodamo še konstrukcijske parametre preje in tkanine. Te lastnosti se običajno obravnavajo v zvezi s fizikalno-mehanskimi lastnostmi, v članku pa je predstavljeno, kako lahko določena konstrukcijska lastnost preje in tkanine vpliva tudi na refleksijo svetlobe in posledično na dojemanje barve izdelka. Pred izdelavo morajo biti skrbno načrtovane konstrukcijske spremenljivke preje in tkanine ter predvidena njihova soodvisnost. Majhne barvne spremembe so možne že s spremembo surovinske sestave vlaken ter vrste in oblike preje (dolžinska masa, vitje, stisljivost, kosmatenost, druge strukturne značilnosti). Pri tem se spreminja predvsem jakost učinka določene lastnosti in usmerjenost odbite svetlobe (optični pojavi na preji), kar vpliva na učinek svetlosti in nasičenosti barve tkanine. Večje barvne spremembe so možne s spreminjanjem konstrukcijskih in oblikovnih parametrov tkanine (gostota niti, vezava, vpliv presevanja, vzorec snovanja in tkanja), s katerimi lahko intenzivneje posežemo v skupni barvni ton tkanine ter izrazitejše teksturne in optične učinke na površini. Pojav presevanja in barve površin, ki bodo tkane izdelke obkrožale, se morajo upoštevati pri barvni analizi, saj tako z numerično-analitičnega (presevanje) kot tudi subjektivnega vidika opazovalca (okoliške barve) močno vplivajo na dojemanje skupnega barvnega učinka.

Barvno oblikovanje vključuje popoln načrt celostne barvne podobe tkanega izdelka, saj izkoriščamo vzorec snovanja in tkanja ter kompozicijske učinke. Velikost barvnih ploskev, njihova razporeditev, usmerjenost, vzorec, flotiranje niti in tekstura so osnovni oblikovni parametri, ki jim moramo prišteti še poznavanje odnosa med površino in barvo ter odnos in razmerje med barvami, da dobimo končno vsoto skupnega barvnega učinka in našega dojemanja slednjega. Predhodna vizualizacija izdelka je možna s pomočjo CAD-sistemov, ki so nepogrešljiv element sodobnega konstrukcijskega in barvnega načrtovanja tkanin. Za opis vloge teh sistemov pri oblikovanju tkanin bi potrebovali posebno obsežno poglavje, zato razen barvnih simulacij, ki so bile izdelane s CAD-sistemom Arahne [22], ta tema ni vključena v članek. Zavedati pa se je treba, da so ti sistemi v sodobni tekstilni praksi zelo učinkovit nadomestek večmetrskih dolžin vzorčnih tkanin za eksperimentiranje z določenimi kompozicijskimi in barvnimi učinki. Vseeno pa je zadržanost uporabnikov glede verodostojnosti simulacij tkanih izdelkov utemeljena, saj, kot je bilo opisano v tem članku, kompleksnost pojava barve na tkaninah presega zmožnosti tudi že tako dodelane sodobne računalniške tehnologije.

cal, physical and chemical properties of a fabric, and to add new colour, texturing and other effects. Regardless of the type of such processes, they usually have a great influence on the fabric-light relationship. The finishing process can be designed for one thread system only in order to change the parameters of one thread system only. The effect of the finished thread system can be strongly exposed and can completely conceal structural and colour parameters of the other unfinished thread system.

With chemical treatments, either the colour of the entire product can be changed, or colour and other finishes can be added at particular areas. The colour change results in changed absorption capacity and reflectivity properties, and in the changed relation between the absorbed and the reflected light, which can be noticed as a new hue of the fabric surface or as a slightly changed lightness and saturation.

Mechanical treatments have similar effects, only that these effects are noticed mostly in the type of the incident light reflection and in the ratio of the reflected to the scattered light on the fabric surface. In fact, it is the deviation in the colour lightness rather than the change of the hue. Finishing processes, which impart higher lustre to a fabric, give to a fabric the appearance, which is dependent of the angle of viewing. The surface seems lighter here and there as the reflected rays reach the eye specularly, but in general, it is visually more intensive. On the contrary, the treatments, which ruffle the surface, increase the randomness of the direction of the incident light reflection. The appearance of such fabric is independent of the angle of viewing and is in general visually lighter due to diffusion of the reflected rays.

5 Conclusion

The colour of a fabric is not a predictable but a dynamic phenomenon that depends on several parameters, effects and factors, and their interdependence. Optical effects on a textile material define the colour spectrum, but the colour sensation is then dependent also on the ambient light and the observer's characteristics. The most important parameter, which mainly defines the colour of a fabric, is the colour of warp

6 Literaturni viri

1. OJSTERŠEK, V., LAVKO B., REJAVC, P. Računalniško podprta tehnologija barvnih kompozicij tkanin. *Tekstilec*, 1998, Vol. 41, No. 11–12, p. 381–385.
2. ŽIBERNA - ŠUJICA, M., DOBNIK - DUBOVSKI, P. Barva in vzorčenje tkanin. *Tekstilec*, 1994, Vol. 37, No. 11–12, p. 352–357.
3. DIMITROVSKI, K., KERT, M. Unikatne večbarvne žakarske tkanine. V: 33. simpozij o novostih v tekstilstvu. Ljubljana: Naravoslovnotehniška fakulteta, Oddelek za tekstilstvo, 2000, p. 131–136.
4. DIMITROVSKI, K. Multicolour shadowing on Arahne CAD system. V: 23. ročník medzinárodná konferencia Quo vadis textrinum. Tatranská Lomnica, Slovensko, Žilina: New Management Conferences, 2000, p. 94–97.
5. MARTIN, C. T*he surface texture book: more than 800 colour and texture samples for every surface, furnishing and finish*, London: Thames & Hudson, 2005.
6. JAKŠIĆ, D. *Projektiranje in konstrukcija tekstilij*: II del. Ljubljana: Univerza Edvarda Kardelja v Ljubljani, VDO FNT, VTOZD Tekstilna tehnologija, 1988, p. 490–598.
7. KOČEVAR, T. N. Vpliv parametrov konstrukcije in kompozicije tkanin na optično mešanje barv na njeni površini – Doktorska disertacija. Ljubljana: Univerza v Ljubljani, Naravoslovnotehniška fakulteta, Oddelek za tekstilstvo, 2000.
8. KOČEVAR, T. N. Colorimetric analysis and visual valuation of colours on two-coloured fabrics. *Tekstil*, 2006, Vol. 55, No. 3, p. 127–134.
9. GABRIJELČIČ, H., DIMITROVSKI, K. Influence of yarn count and warp and weft thread density on colour values of woven surface. *Fibres & Textiles in Eastern Europe*, 2004, Vol. 12, No. 1(45), p. 32–39.
10. GABRIJELČIČ, H. Razvoj metode za določanje barvnih vrednosti tkanin – Doktorska disertacija. Ljubljana: Univerza v Ljubljani, Naravoslovnotehniška fakulteta, Oddelek za tekstilstvo, 2006.
11. CHRISTIE, R. M., MATHER, R. R., WARDMAN, R. H. *The chemistry of colour application*. Oxford: Blackwell Science, 2000.
12. TILLEY, R. *Colour and optical properties of materials*: an exploration of the relationship between light, the optical properties of materials and colour. Chichester: J. Wiley & Sons, 2000.
13. MC DONALD, R. *Colour Physic for Industry*. (2nd ed.). Bradford, England: Society of Dyers and Colourists, 1997.
14. FIELD, G. G. *Color and Its Reproduction*. (2nd ed.). Pitsburg: GAFTPress, 1999, p. 1–113.
15. GREEN, P., MACDONALD, L. *Colour engineering*: achieving device independent colour. Chichester: Wiley, 2002.

and weft threads. By carefully selecting the colour of yarn, the colour hue of the product can be predicted and defined. With combination of threads of different colours, a new overall colour hue is produced as a result of optical mixing of different spectral lights.

A real dynamics of a colour appearance on a fabric is exhibited when constructional parameters of yarn and fabric are added to the original colours of fibres and yarn. These parameters are usually discussed in connection with physical and mechanical properties; in the paper, it is presented how a particular constructional parameter of yarn and fabric influences the light reflection and, consequently, the sensation of the product colour. Prior to manufacture, the constructional parameters of yarn and fabric should be carefully planned and their interdependence predicted. Smaller colour changes are already possible by changing the material composition of fibres, and the type and shape of yarn (linear density, twist, compressibility, hairiness, other structural parameters). In this way, the intensity of a particular parameter effect and the direction of the reflected light (optical effects on yarn) are changed, which influence the lightness effect and the saturation of the fabric. Higher colour changes are possible by changing the constructional and design parameters of the fabric (thread spacing, weave, foundation reflectance, warping and weaving pattern) by which changes are more intensively introduced into overall colour hue of the fabric, and into texturing and optical effects on the surface. Foundation reflectance and the colour of areas which will surround the woven products should be taken into account at the colour analysis as they have a strong influence on the overall colour effect sensation from both the mathematically-numerical viewpoint (reflectance) and the observer's subjective viewpoint (surrounding colours).

Colour designing includes a complete project of the overall colour image of a woven product as both the warping and weaving pattern, and compositional effects are utilized. The size of colour areas, their arrangement, orientation, pattern, thread floating and texture are the basic design parameters; the relationship between surface and colour, and the relationship and ratio between colours should be added to these param-

16. ETTERS J. N. Influence Of Fabric Surface Effect On Color Depth And Hue Of Garment-Dyed Textile. *American Dyestuff Reporter*, 1997, Vol. 86, No. 5, p. 15–18.
17. INGAMELLS, W. *Colour for textiles*: a user's handbook. Bradford: The society of dyers and Colorists, 1993.
18. MORTON, T. H. Apparent Color Yield in Dyed Textiles. *Journal of the Society of Dyers and Colorists*. 1976, Vol. 92, No. 4, p. 149–157.
19. JAREŠ, T. Colour differences between conventional and microfiber fabrics dyed with disperse dyes. V: 30. mednarodni simpozij o novostih v tekstilstvu. Ljubljana: Naravoslovnotehniška fakulteta, Oddelek za tekstilstvo, 1996, p. 254–256.
20. ADANUR, S. *Handbook of weaving*. Lancaster, Basel: Sultzer, A technical Publishing book Company, Technomic, 2001.
21. DUBROVSKI – DOBNIK, P. *Računalniško konstruiranje listnih tkanin*. Navodila za vaje. Maribor: Univerza v Mariboru, Fakulteta za strojništvo, Oddelek za tekstilstvo, Laboratorij za tekstilno tehnologijo in konstrukcijo tkanin, 2004.
22. Dobby and jacquard CAD/CAM system Arahne, d. o. o. Dostopno na svetovnem spletu: http://www.arahne.si [citirano 25. 12. 2006].
23. ŽIBERNA – ŠUJICA, M., GAČNIK, A. *Kompozicija in uporabnost tkanin* (I. del). Maribor: Univerza v Mariboru, Visoka tehnična šola, VTO strojništvo, 1979.
24. GROSICKI, Z. J. *Watson's Advanced textile design*: compound woven structures (4th ed). London, Boston: Newnes-Butterworths, 1977.
25. DIMITROVSKI, K., GABRIJELČIČ, H. Influence of foundation reflectance on colour values of woven fabrics. V: 25. medzinárodná konferencia Quo vadis textrinum. Štrbské Pleso – Vysoké Tatry: New Management Conferences: Česká odborná skupina tkalcovská, 2004, p. 15–24.
26. DIMITROVSKI, K. Metode za določanje poroznosti v tekstilijah. *Tekstilec*, 1995, Vol. 38, No. 5/95, p. 121–126.
27. Poročilo sejma Techtextil'99. Frankfurt: Allgemeiner Vliesstoff-Report, Techtextil, Index'99.
28. NEWTON, A. The Comparison of Woven Fabrics by Reference to Their Tightness. *Journal of Textile Institute*, 1995, Vol. 86, No. 2, p. 232–239.
29. SEYAM, A., EL-SHIEKH, A. Mechanic of Woven Fabric, Part IV: Critical Review of Fabric Degree of Tightness and Its Application. *Textile Research Journal*, 1994, Vol. 64, No. 11, p. 653–662.
30. DIMITROVSKI, K. Barvno oblikovanje pestrih tkanin. V: *Interdisciplinarnost barve* (2. del). Uredila: Jeler, S., Kumar, M. Maribor: Društvo koloristov Slovenije, 2001–2004, p. 455–475.
31. KOČEVAR, T. N. Optično mešanje barv na površini tkanine. V: *Interdisciplinarnost barve* (2. del). Uredila: Jeler, S., Kumar, M. Maribor: Društvo koloristov Slovenije, 2001–2004, p. 195–210.

eters to get the final sum of overall colour effect and our sensation of such colour effect. Preliminary visualization of the product is enabled by CAD systems, which have become an indispensable element of modern fabric construction and colour projecting. Since an extra comprehensive chapter would be required to describe the role of these systems in fabric designing, this subject has not been included into this paper, with the exception of the colour simulations made by using CAD system by Arahne [22]. The fact is and we should be aware of this fact that in today's textile practice, these systems are an efficient alternative to several metres long specimens of fabrics on which several compositional and colour effects are experimented. Nevertheless, the reserve and precaution of users related to the reliability of simulations of woven products is understandable and well grounded. Namely, as was described in the paper, the complexity of the colour phenomenon on fabrics has already surpassed the capabilities of even the most advanced computer technology.

32. ZUPIN, Ž. Ugotavljanje zakonitosti barvnih harmonij v CIE-barvnem sistemu, Seminarska naloga. Ljubljana: Univerza v Ljubljani, Naravoslovnotehniška fakulteta, Oddelek za tekstilstvo, 2005.
33. ŠUŠTARŠIČ, N., BUTINA, M., ZORNIK, K., DE GLERIA, B., SKUBIN, I. *Likovna teorija*, učbenik za umetniške gimnazije. Ljubljana: Debora, 2004, p. 148–179.
34. ITTEN, J. *Umetnost barve*. Jesenice: študijska izdaja, 1999.
35. ZOLLINGER, H. Color – *A multidisciplinary approach*. Zürich: Verlag Helvetica Chimica Acta, Weinheim: Wiley-VCH, 1999.