TECHNICKÁ UNIVERZITA V LIBERCI
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Organické hybridy - využití fotochromních potisků v módním designu (Biomimetics design)

Bakalářská práce

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Faculty of Textile Engineering

Organic hybrids - Use of photochromic prints in fashion design (Biomimetics design)

Bachelor thesis

Study programme: B3107 – Textil
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3. Design motivu vzoru s inspirací - fauna, biomimetický design.
4. Technologie shibori, sítotisk fotochromními barvami.
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With all my love

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ANNOTATION

This thesis deals with a development of new designs of photochromic colors and their use in fashion design focusing on inspiration by biomimetic design and natural optical structures based on relations between silkscreen printing and shibori dyeing.

The theoretical part briefly describes the principes of photochromism and presents evaluation of color measurement data. The design part describes basis of biomimetic design and it focuses on designing patterns for menswear collection. In conclusion will be provided an evaluation of measurement and sample of final realization of collection.

KEY WORDS:

- Photochromic color
- Photochromism
- Biomimetic design
- Silk-screen printing

ANOTACE

Tato práce je založena na rozvíjení nových vzorů fotochemických barev a jejich použití v módním designu, a to se změřením na hlavní zdroj inspirace, kterým je biomimetický design a optické struktury, které jsou založené na vztahu mezi sieťotlačou-to nevim co je a barvením shibori.

Teoretická část práce stručně popisuje principy fotochromizmu a prezentuje výsledné hodnoty naměřených dat fotochromatických barev. Designová část popisuje základy biomimetického designu a zaměřuje se na návrh vzorů pro pánskou kolekci. Na závěr budou na základě měření vybrány vzorky, které budou následně použity v kolekci.

KLÍČOVÁ SLOVA:

- Fotochromatická barva
- Fotochromizmus
- Biomimetický design
- Sítotisk

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From times immemorial, people have dealt with development and discovering of new mechanisms and systems which facilitate their daily lives. One of the branches focusing on solving design and technological solutions is known as biomimetic design.

Nowadays, with increasing amount of technology and digitization of society and operating systems, designers and scientists are trying to find bases, which are created by nature in simple forms. Nature has solved many engineering problems such as self-healing abilities, hydrophobicity and harnessing solar energy. Many of these solutions help to increase research and innovative technologies in the textile industry since clothing is often used as "second skin" of man and provides protection against external environment as well as skin, skin derivatives and shelters and skin epithelium of living organisms.

One of the most interesting characteristics of living organisms is the ability of mimicry and imitation of the environment protecting them from predators, searching for food or mating. The animals use skin discoloration or change the structure of their surface, which may also lead to a change in the overall appearance and body shape. These changes are caused by the incident light, UV light, muscle contraction or the presence of special cell´s systems. If there are changes in the impact of solar radiation, it is called the ability of photochromism.

The objects of this thesis are adequately designed colours of photochromic pigments which corresponding with selected inspiration focus and their application onto textile substrate by screen printing which will be used in designing process of menswear collection. The work consist of two main parts which included theoretical and practical sections.
The theoretical part deals with mixing and measuring the shades of selected photochromic colors, evaluation of the collected data, thus preparing materials for using the colors in the second part of the work. The practical part uses the results obtained in the theoretical part and their application in fashion design, so it deals with

the design of patterns focusing on the photochromic printing using silk-screen printing and supplemented by shibori dyeing.
Design of prints and clothing is inspired by animal mimicry and optical illusions and uses principles of biomimetic design. The aim is to create collection which is based on technological part and which changes its silhouette and visual appearance.

We must also take into consideration the issue of combining shibori dye and screen printing because it is a different technology from dyeing and printing material with colors. For natural shibori dyeing process is optimal to use 100 % of natural cotton fibers to achieve the ideal characteristics after dyeing material in water based indigo solution. Likewise, for screen-printing is important to use a material with strong natural fibers, usually cotton, because permanent color adhesion to the substrate and thereby achieve the characteristics and conditions of use.

I. THEORETICAL PART
1. PHOTOCHRMOMIC COLOURS

Photochromism is a reversible coloration process when the visible colour change goes from colourless to the coloured reaction as a result of changes in electronic absorption spectra. Those changes are exposed to ultraviolet light (UV), usually from the Sun or a black light. After removal of a radiation, colours return to a state before irradiation in the short time. [1] Changes can be easily detected by the human eye or using simple colorimetric, spectrophotometric or CCD sensor.

„*Basic requirements for ideal organic photochromic compounds are:*

1. <u>Colour development</u>. Upon irradiation with ultraviolet light colour must be developed rapidly and strong on material.

2. <u>Control of return back to colourless state</u>. The fade rate back to the colourless state must be controllable.

3. <u>Wide colour range</u>. The range of the colours must be across the visible spectrum.

4. <u>Long life</u>. The response must be constant though many coloration cycles.

5. <u>Colourless rest state</u>. The colourless rest state must have as little colour as possible.“[1]

Photochromic molecules can belong to the five classes of chemical compounds, such as spiropyrans, spiroindolone benzopyrans, spironaphthoxazines, naphthopyrans, fulgides and diarylethenes.

In the next section each of five classes will be described.

<u>Spiropyrans</u> are on of the oldest and probably most studied class of photochromic molecules. They are closely related to spirooxazines. They consist of a pyran ring, mostly 2H-1-benzopyran, linked via a common spiro group to another heterocyclic ring. After the irradiation of the colourless spiropyran with UV light causes heterolytic cleavage of the carbon – oxygen bond forming the ring- opened coloured species, usually called „merocyanine“. When the UV light is removed, the molecules gradually relax to the ground state and return into its colourless state. This class of photochromes are thermodynamically unstable in one form so i tis necessary to use a rapid scanning spectrophotometer to measure the absorption spectrum. They

revert to the stable form in the dark unless cooled to low temperatures. UV irradiation can affect their lifetime.

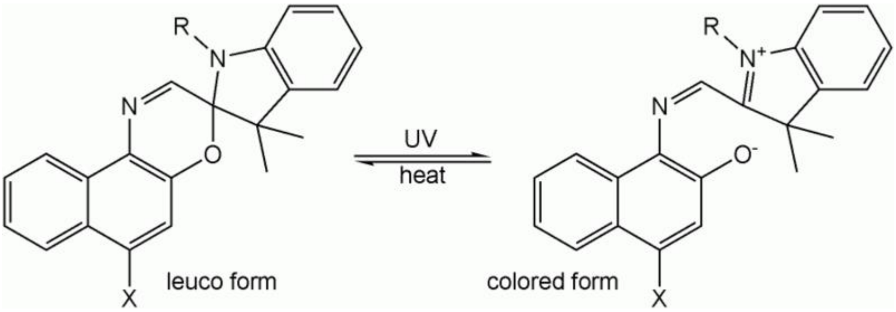


Figure 1 Spiropyran transition from leuco (colourless) form to coloured form (merocyanine)[2]

Naphthopyrans have very similar photochromic mechanism as spiropyrans introduced above. Under the irradiation of UV the C-O bond in the pyran ring is broken to give either the zwitterionic form or, more likely the cir- and trans-quinoidal forms. However, naphthopyrans show little or no useful photochromic behavior and can be discounted from any further discussion.

The family fulgide constitutes an important type of photochromic compounds. Stobbe first discovered the photochromism of some phenyl-substituted bismethylene succinic anhydridesin the solid state and named as fulgides. The fulgides are generally synthesized by the condensation of an arylaldehyde or ketone with substituted methylene succinate. [1]

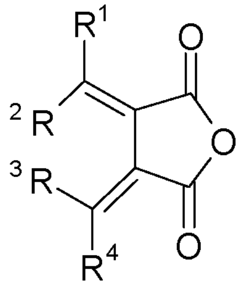


Figure 2 The General form of fulgides[2]

„Thermally assisted reversion of coloured to colourless is not observed, because the interaction between two syn methyl groups prevent the symmetry allowed, disrotatory mode of opening of the electrocyclic ring does not occur.“[1] The structure of fulgide is skillfully constructed as a hexatriene unit that has two different isomers, a Z form and an E form based on the rotation around the C-C double bonds.

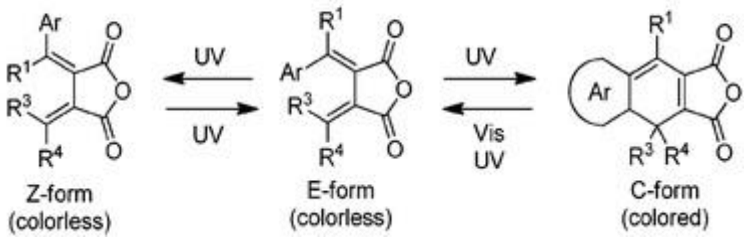


Figure 3 Fulgides photochromic reaction [2]

Isomerization of the yellow Z-fulgide (Fig.3 Z) to the E-fulgide (Fig.3 E) and cyclisation of this to the red coloured photochrome (Fig.3 C), designated as C here but often called the P state, occurs on irradiation with UV light. The coloured species (Fig.3 C) are converted back into the E fulgide by white light but not by the heat.

Diarylethenes are compounds that have aromatic groups bonded to each end of a C-C double bond. „*The simplest example is stilbene and it has been brought into the useful photochromic range by replacing the phenyl rings with thiophenes, and the bridging ethylene group by a maleic anhydride of perfluorocyclopentene group.*" [1]

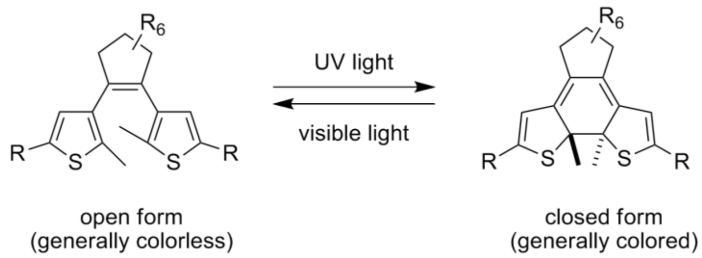


Figure 4 Stilbene molecular switch under the influence of UV light and visible light [2]

„*The thiophene ring can be annulated with a benzene ring or replaced with indoles, furans and thiazole rings. The reversible electrocyclic interconversion between the colorless ring-open state and the colored ring-closed state on irradiation with light occurs at well- separated wavelengths. The thermal conversion is not favored and compounds show very high fatigue resistance.* " [1] Furthermore, some of the diarylethenes have so little shape change upon isomerization that they can converted while remaining in a crystalline form. [3]

1.1 UV RADIATION, INTERACTION OF LIGHTS

Ultraviolet means „beyond violet“, (UV) is a radiation in a part of the electromagnetic spectrum (Fig.no.) with a wavelength from 10 nm to 380 nm (or 30Phz to 750THz).It has a higher frequency than violet light. Those wavelengths are shorter than a wavelength of visible light but longer than X-rays. It is present in sunlight, but also specialised lights such tanning lamps, black lights or produced electric arcs. Though UV light is invisible to a human eye, some animals, for example, bumblebees or polar bears can see them. Scientists have discovered different types of UV light (Fig.no.2), such as UVA, UVB, UVC, near ultraviolet NUV, which is visible for insects, mammals and some birds, far ultraviolet FUV and extreme ultraviolet EUV.Long-wavelength ultraviolet radiation can lead to the chemical reaction, and cause many substances to glow or fluoresce. For human health UV spectrum has beneficial and harmful effects. It is responsible for causing our sunburns. Most of the ultraviolet waves produced by Sun are blocked from entering to the Earth by various gases like Ozone. [4]

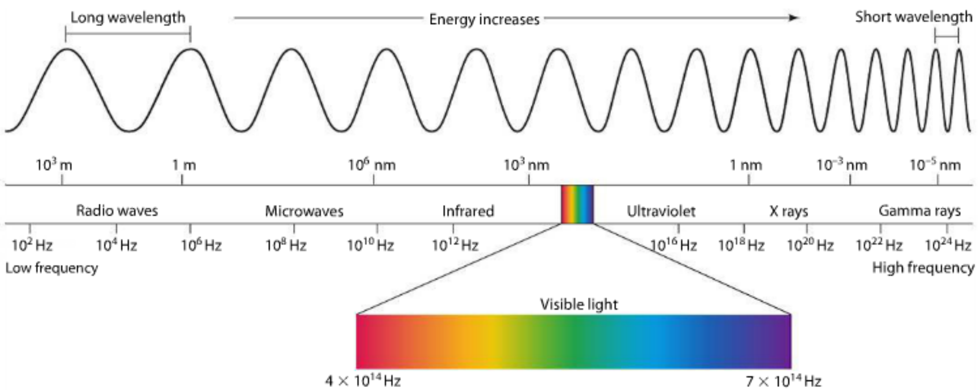


Figure 5 The electromagnetic spectrum [5]

Name	Abbreviation	Wavelength (nm)	Photon energy (eJ,aV)	Notes , alternative names
Ultraviolet A	UVA	315-400	3.10-3.94,0.497-0.631	Long wave, black light, not absorbed by the ozone layer
Ultraviolet B	UVB	280-315	3.94-4.43,0.631-0.710	Medium wave, mostly absorbed by the ozone layer
Ultraviolet C	UVC	100-280	4.43-12.4,0.710-1.987	Short wave, completely absorbed by the ozone layer and atmosphere
Near ultraviolet	NUV	300-400	3.10-4.13,0.497-0.662	Visible to birds,, insects and fish
Middle ultraviolet	MUV	200-300	4.13-6.20,0.662-0.993	
Far ultraviolet	FUV	122-200	6.20-12.4,0.993-1.987	
Hydrogen Lyman-alpha	H Lyman-α	121-122	10.16-10.25,1.628-1.642	Spectral line at 121.6 nm, 10.20 ev Ionizing radiation at shorter wavelengths
Vacuum ultraviolet	VUV	10-200	0-0,0-0	Strongly absorbed by stmospheric oxygen, though 150 – 200 nm wavelengths can propagate through nitrogen
Extreme ultraviolet	EUV	10-121	12.4-124,1.99-19.87	Entirely ionizing radiation by some definitions, completely absorbed by the atmosphere

Table 1 Ultraviolet ranges subdivided into a number of ranges recommended by the ISO standard ISO-21348[6]

Some of the very hot objects such as Sun or hot stars emits UV radiation called solar ultraviolet. At the top of Earth's atmosphere sunlight is composed of 50% infrared light, 40% visible light and 10% ultraviolet light. [4]

A few of the dyes and pigments absorb a part of the UV and change colour, what means, that they need some extra protection, ich the color changing effect is not suitable. The most common source of UV light is sunlight or fluorescent bulbs. UV is also responsible for polymer degradation, such as discoloration, fading, cracking, disintegration etc. Colourless fluorescent dyes which are added as optical brighteners (also known as Fluorescent Brightening Detergents - FBD) emit blue light under the influence of UV. The fluorescent dyes that glow in the primary colours are used in passports, as watermark, in biochemistry and forensics or in some special pepper sprays. [4]

1.2 CIELAB COLOUR SPACE

CIELAB is a colour space specified by the international organisation, the Commission Internationale de L'Eclairage (CIE) early in 20th century. It describes all the colours visible to the human eye and it is based on the concept that colours can be considered as combinations of red and yellow, red and blue, green and yellow, and green and blue. Space is presented only three-dimensional since the L*a*b* model is three-dimensional, what means L for lightness and a and b for the colour- opponent dimensions. L*a*b* model has one the most important attribute, what is colour independence; practically, it takes no account to their nature of creation or the device they are displayed on. Lab colour space includes both, RGB and CMYK gamut. Further, some of the colours inside Lab space fall outside of human vision, what basically means that they can not be reproduced fo physical world; they are completely imaginary.[1][7]

$$\begin{aligned} L^\star &= 116 f(Y/Y_n) - 16 \\ a^\star &= 500\left[f(X/X_n) - f(Y/Y_n)\right] \\ b^\star &= 200\left[f(Y/Y_n) - f(Z/Z_n)\right] \end{aligned}$$

(Eq.1.2.1)[7]

"The color axes are based on the fact that a color can't be both red and green, or both blue and yellow, because these colors oppose each other. On each axis the values run from positive to negative. On the a-a' axis, positive values indicate amounts of red while negative values indicate amounts of green. On the b-b' axis, yellow is positive and blue is negative. For both axes, zero is neutral gray:" [1]

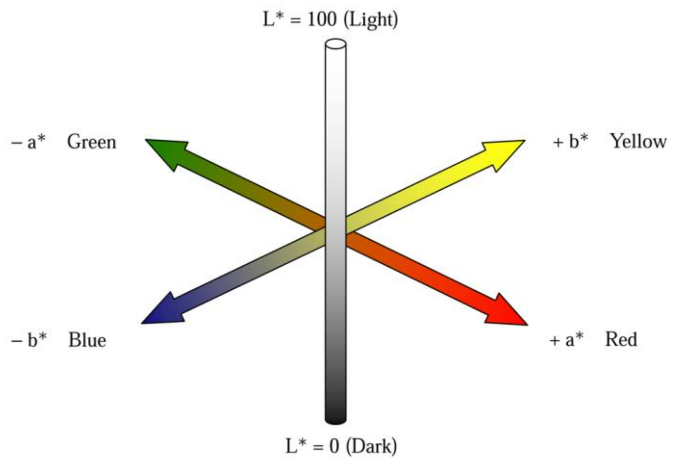


Figure 6 The CIE L*a*b* colour space[8]

The CIELAB space is akin to CIEXYZ space based on Adams model of opponent colour vision using nonlinear transformation. The XYZ tristimulus values is only part of defining the colour. The colour itself is better understood in terms of hue and chroma (to use Munsell's terms). [1]

$$\begin{cases} L^* = 116\left(\dfrac{Y}{Y_0}\right)^{1/3} - 16 & \text{if } Y/Y_0 > (24/116)^3 \\ L^* = 903.3\left(\dfrac{Y}{Y_0}\right) & \text{if } Y/Y_0 \le (24/116)^3 \\ a^* = 500\left[f\left(\dfrac{X}{X_0}\right) - f\left(\dfrac{Y}{Y_0}\right)\right] & \\ b^* = 200\left[f\left(\dfrac{Y}{Y_0}\right) - f\left(\dfrac{Z}{Z_0}\right)\right] & \end{cases}$$

(Eq. 1.1.2) [1]

Considering human perception, two polar parameters chroma C_{ab} (relative saturation) and hue h_{ab} are, used that more closely match the visual experience of colours. For example, colours are described as stronger or weaker. This colour system is called CIELCH.[1]

$$C^*_{ab} = \sqrt{a^{*2} + b^{*2}}, \qquad h^\circ_{ab} = \arctan\left(\frac{b^*}{a^*}\right)$$

(Eq. 1.1.3) [1]

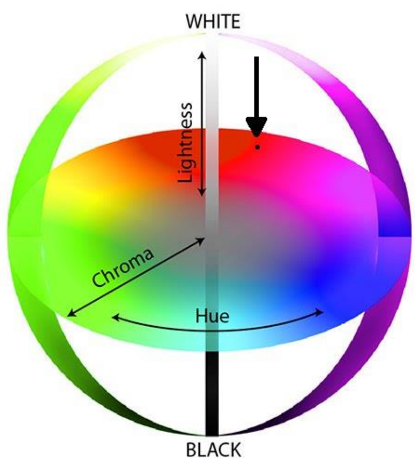


Figure 7 The CIEL*C*h* colour space[9]

2. EXPERIMENTAL

The experimental section contains development of new designs of photochromic printing and testing their technical properties and user properties. Further, searching other options for use.

2.1 MIXING NEW SHADES OF PHOTOCHROMIC COLOURS

According to the design part of this thesis, we have to develop new colour designs from already existing photochromic pigments, which will better match with inspiration focus described in following chapters. In experiment was used two different photochromic pigments which were supplied by MATSUI International Company, INC. Mixing this two photochromic pigments in prescribed range will rise to new designs, which will be later evaluated and measured. [1]

2.1.1 RECIPE MATCH PREDICTION

Referring to the theory of colours it is known, that mixing blue and yellow gave us blue-like and green– like colour results, so they can be easily described via CIELab colour system. The expectations are not even photochromic pigments, but we must take into consideration their own properties.

The substance consist of the selected amount of yellow pigment **PHOTOPIA®AQUALITE INK YELLOW AQ** (Y) and amount of blue **PHOTOPIA®AQUALITE INK BLUE AQ** (B) colouring pigment and constant amount of thickener (x). Ranges of A and B pigments concentration in 200g acrylate paste:

1:4	2:3	2,5:2,5	3:2	4:1

The concentrations were selected on the basis of the visual assessment of the strongest colour change and contrast. As already mentioned, five different ranges of pigment were prepared using pigments from MATSUI International Company, INC. These pigments were applied as PTP – photochromic textile print. To achieve ideal results, for printing was used standard printing composition TF (complex paste), which is often used by standard textile pigment printing:

Water	818g
Glycerin	20g
Lukosan S (antifoamer)	2g
Sokrat 4924 (acrylate binder)	70g
Acramin BA (butadiene binder)	70g
Ammonia	5g
Lambicol L 90 S (thickening agent)	15g
Total	1000g

Table 2 Composition of complex paste TF [1]

Those pigments were applied on the cotton textile substrate by the method of screen printing. Pigment concentration was 100g per 1 kg of printing paste. After the printing, all samples were dried for 5 minutes at 80°C and then cured for 5 minutes at a temperature of 130°C.[1]

2.1.2 METHOD OF RANGE ASSESSMENT

Samples were prepared for the purpose of the study of photochromic behaviour on different textile surfaces. Five different samples were screen printed on three different materials as ecru cotton denim, cotton knit and cotton jersey – both with **fluorescent brightening detergents** (FBD) treatment. The use of the optical brightening agent was displayed in their graphs with measured values wherein the curve is not continuous but split at the half. We can see this in the figure below. Further, the different species and structure of textile materials affect the properties of photochromic pigments.

This concentration range was selected to compare differences between samples in the dependence of photochromic reaction on different textile material samples. In conclusion, we selected most contrastive concentration range by visual observation. 1:4 Y/B and 4:1 Y/B accomplish optimal results according to design. [1]

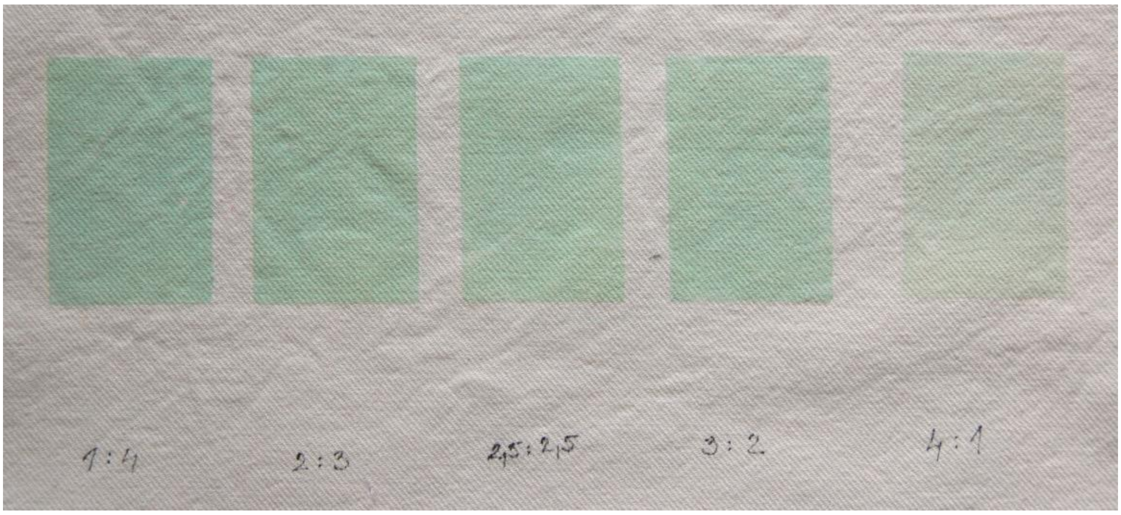
2.2 PREPARATION OF COLOURS AND SAMPLES

As was determined in previous chapters we have to mix and prepare five different concentrations of photochromic colours (see page 19). For the testing is ideal to prepare 200g of substance, because this amount is easily divisible into five parts. Composition of complex paste for PTP was discussed in previous chapters as well as composition of each range.

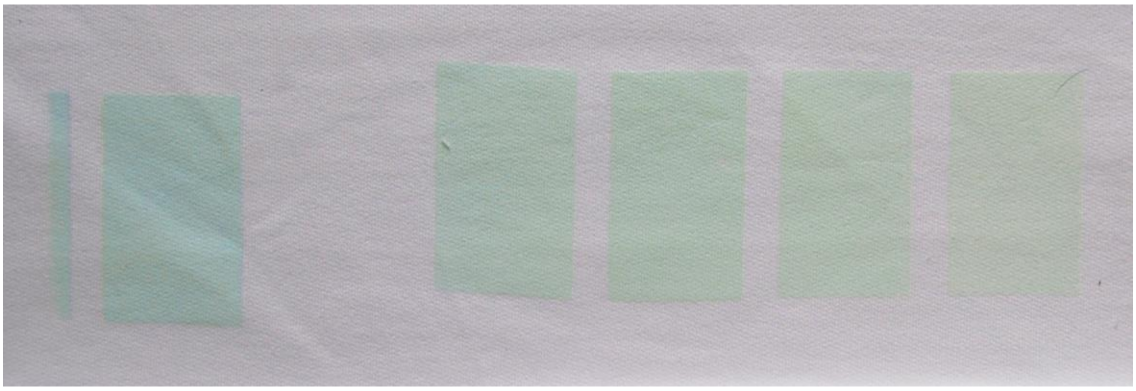
	Range Y/B	Yellow /g	Blue /g
Substance 1	1:4	40	160
Substance 2	2:3	80	120
Substance 3	2,5:2,5	100	100
Substance 4	3:2	120	80
Substance 5	4:1	160	40

Table 3 Composition of photochromic substances in 1 kg of printing paste

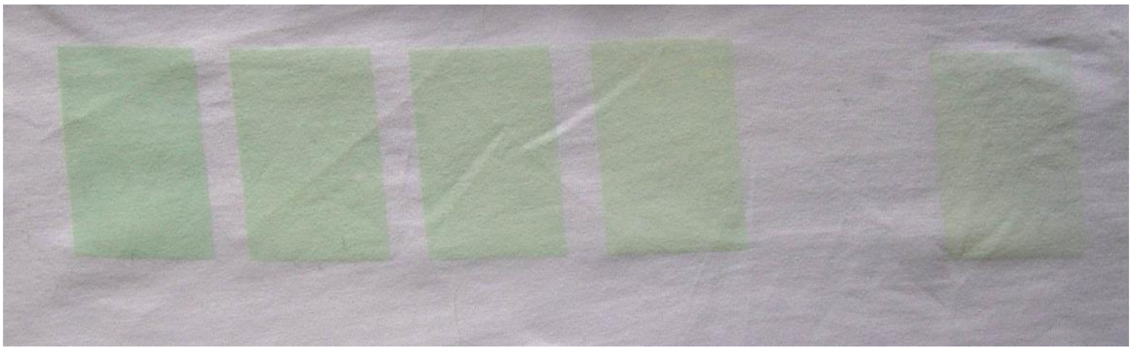
The samples of photochromic pigments were screen printed on textile surfaces, which were washed at 30°C and laundered. After the process of screen printing photochromic pigments have been dried for 5 minutes at 80°C and then cured for 5 minutes in 130°C. The process of multiple drying, in this case drying and curing, helps to achieve ideal conditions of use. Photochromic pigments are not soluble in water. Based on discussion with the supervisor of this thesis a temperature 30°C was selected for washing. Washing has to be provided without bleaching to not damage the print ot photochromic effect. [1]



a)



b)



c)

Figure 8 Photochromic pigment ranges 1:4; 2:3; 2,5:2,5; 3:2; 4:1 screen printed on a) 100% ecru cotton denim b) 100% cotton knit (FBD) and c) 100% cotton Jersey (FBD) textile surface without influence of UV irradiation. Those samples were washed at 60°

Figure 9 Photochromic pigments ranges 1:4 Y/B and 4:1 Y/B applied on 100% ectu cotton denim textile surface without influence of UV irradiation

Figure 10 Photochromic pigments ranges 1:4 Y/B and 4:1 Y/B applied on 100% ectu cotton denim textile surface after UV irradiation in dark room

Figure 11 Photochoromic pigments ranges 1:4 Y/B and 4:1 Y/B applied on 100% ecru cotton denim textile surface after UV irradiation in presence D65

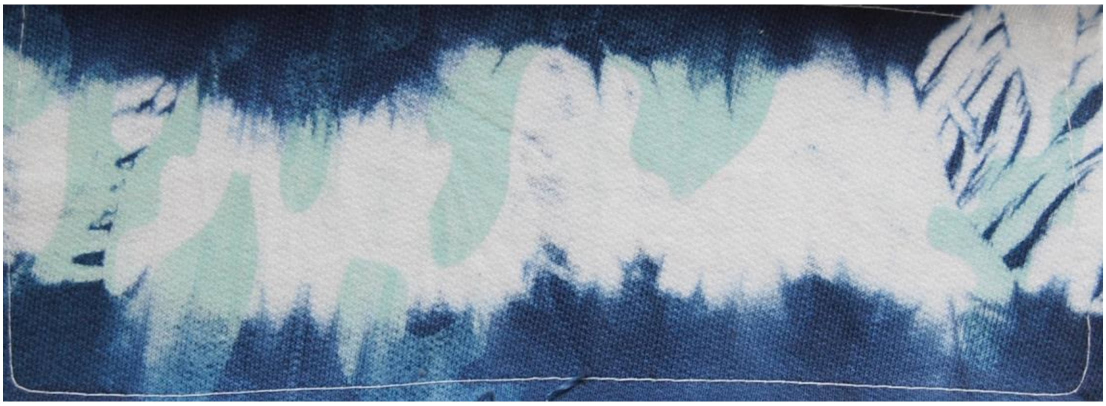


Figure 12 Photochromic pigment range 1:4 Y/B scteen printed on 100% cotton knit and then shibori dyed in IBERIA CLASSIC textile dye in navy colour.

The sample is without influence of UV irradiation

Figure 13 Photochromic pigment range 1:4 Y/B scteen printed on 100% cotton knit and then shibori dyed in IBERIA CLASSIC textile dye in navy colour.

The sample is under influence of UV irradiation

2.3 MEASUREMENT

For the measurement of photochromic pigments was a necessity to use a special measuring system developed at Laboratory of Colour and Appearance Measurement on Faculty of Textile Engineering which will be able to measure photochromic colour printed on textile surface. In this case we used specially modified spectrophotometer Chroma- Sensor CS-5 and it was placed in the dark room to eliminate luminous irradiation from other light sources. [1]

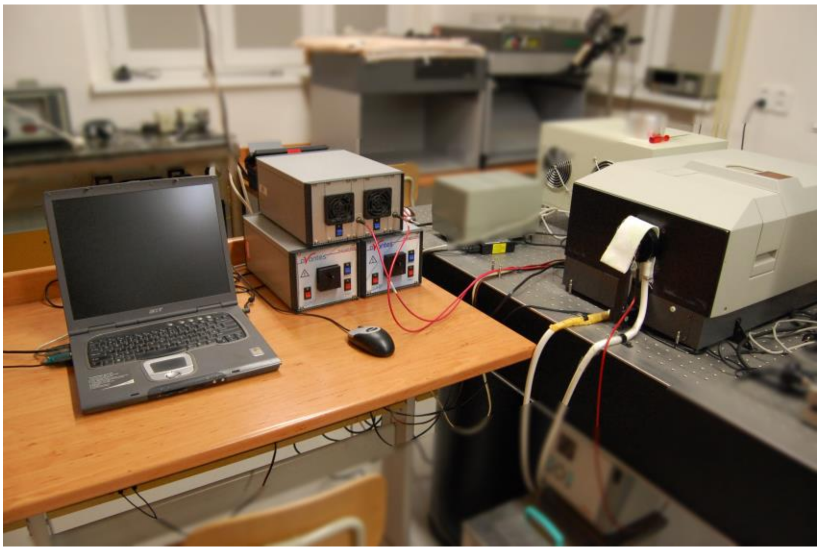


Figure 14 Prototype of measuring system PHOTOCHROM, which was developed at Laboratory of Colour and Appearance Measurement on Faculty of Textile Engineering Technical University in Liberec

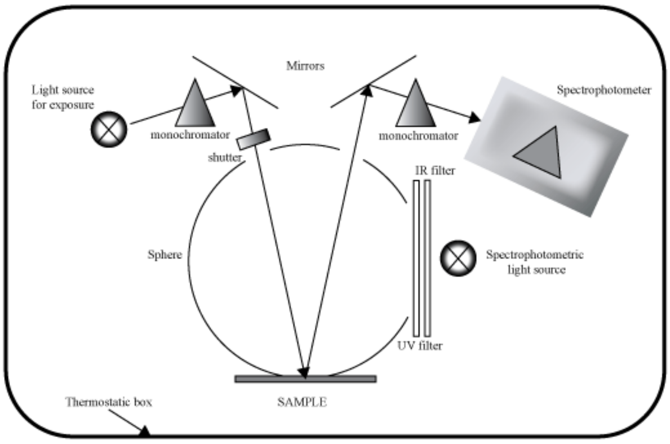


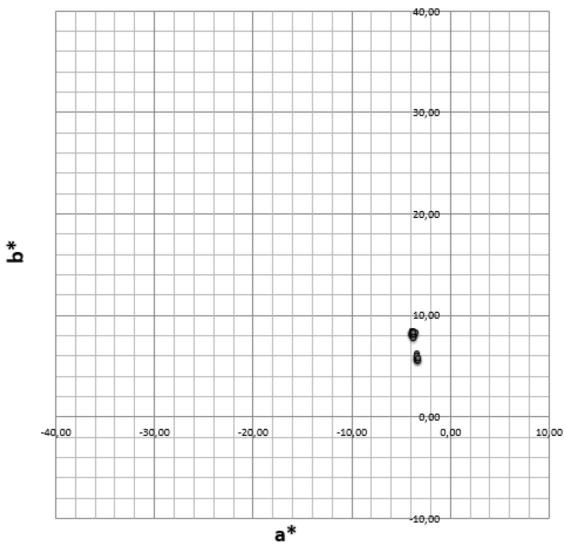
Figure 15 Optical scheme of LCAM PHOTOCHROM measuring system [1]

Measured value	Averange
Temperature of black panel thermometer	53,6°C
Temperature external thermometer	22,3°C
Relative humidity	45,1%

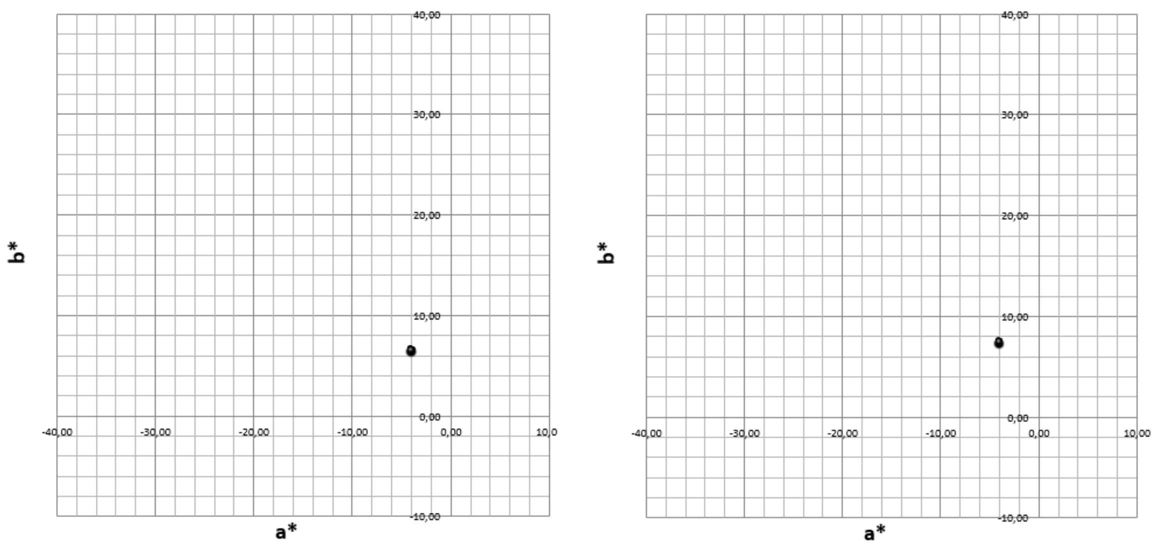
Table 4 Climatic conditions

2.3.1 PROGRESS

As discussed, each of fifteen different photochromic samples was measured with the special spectrophotometer. On the tables under we can see differences between concentration range of photochromic colours and materials in CIEL*a*b* colour space.

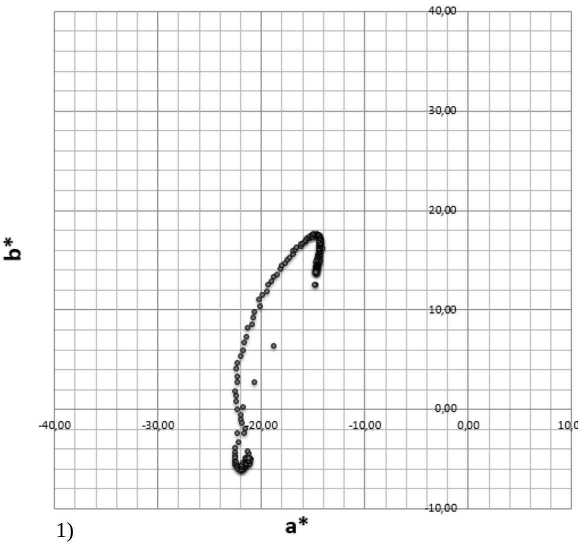


Tab. 5 100% Ecru cotton denim textile material without photochromic colour in L*a*b* colour space

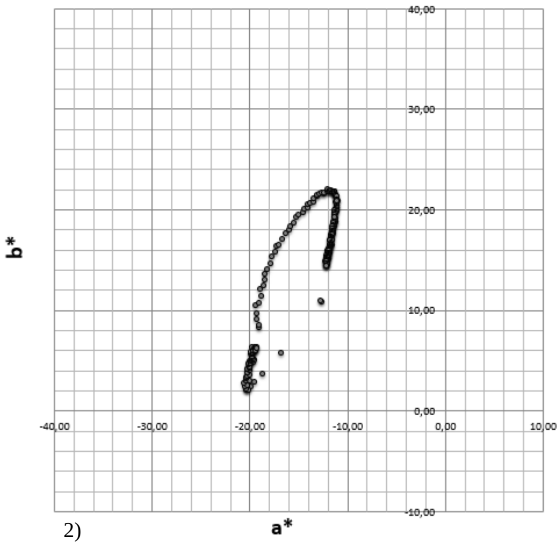


1) 2)

Table 5 Textile materials with FBD without photochromic colour 100% cotton 1) jersey and 2) knit in L*a*b* colour space



1)



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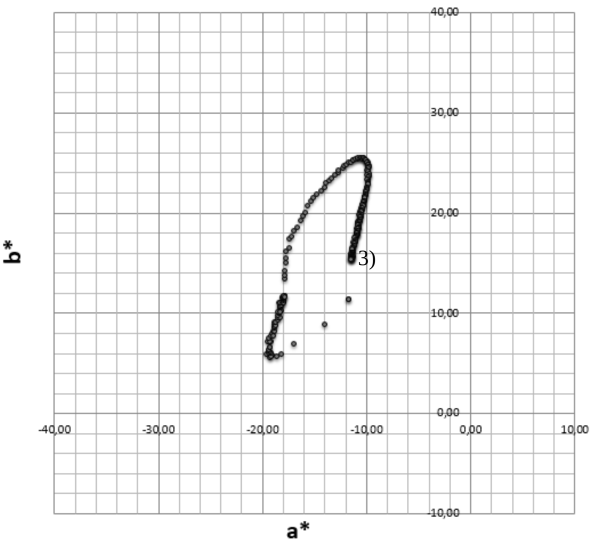

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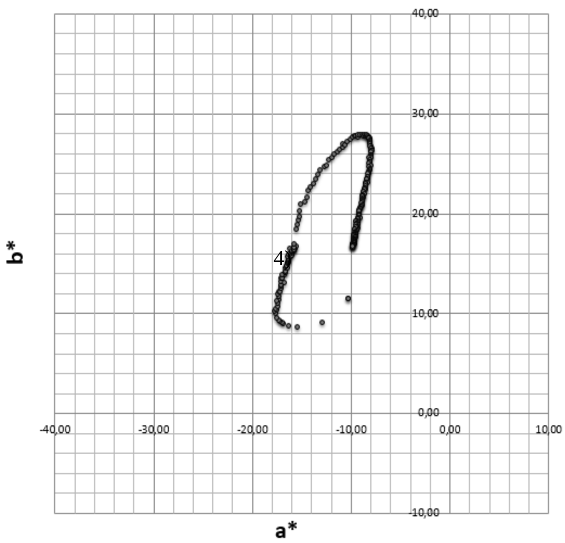

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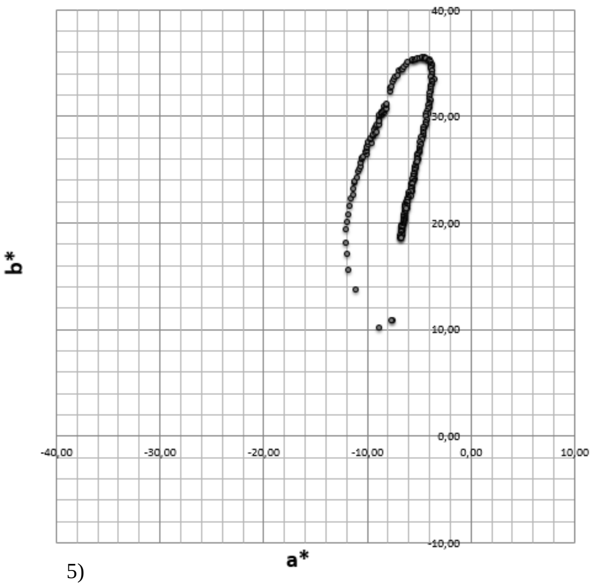
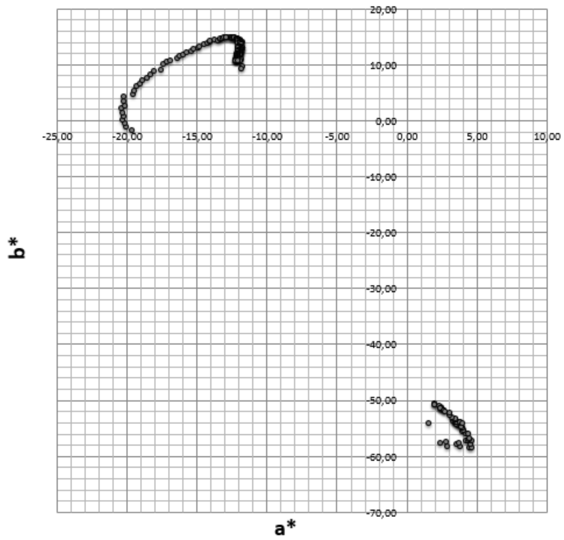
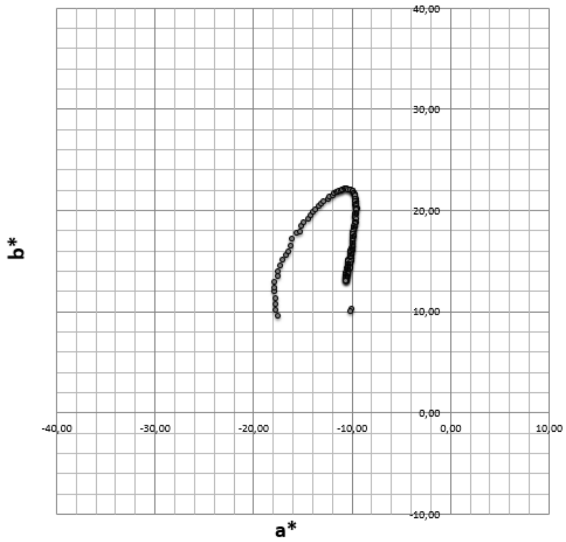


5)

Table 6 100% ecru cotton denim textile with 5 different concentration of A and B photochromic pigment in L*a*b* colour system 1) 1:4 2) 2:3 3) 2,5:2,5 4) 3:2 5) 4:1



1)



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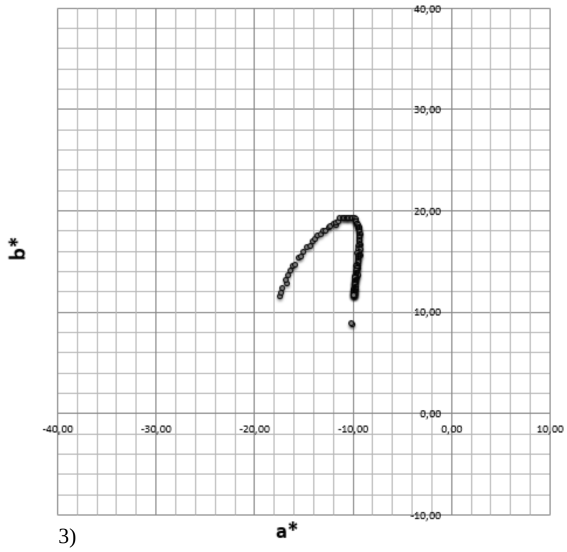

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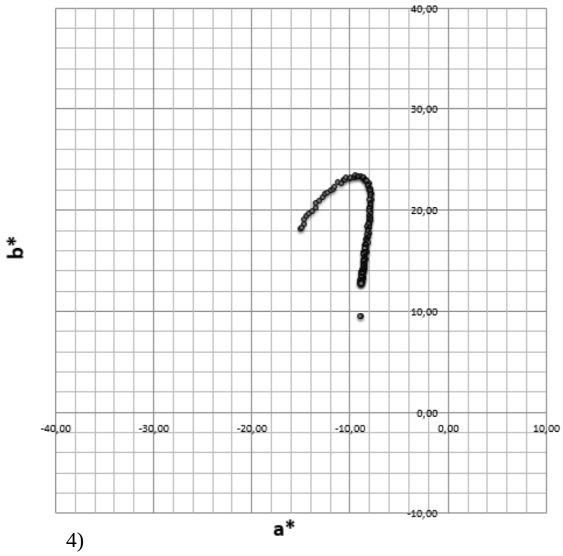

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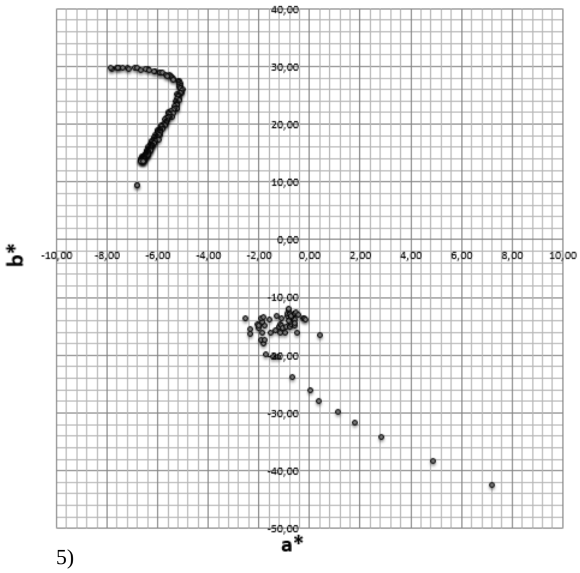
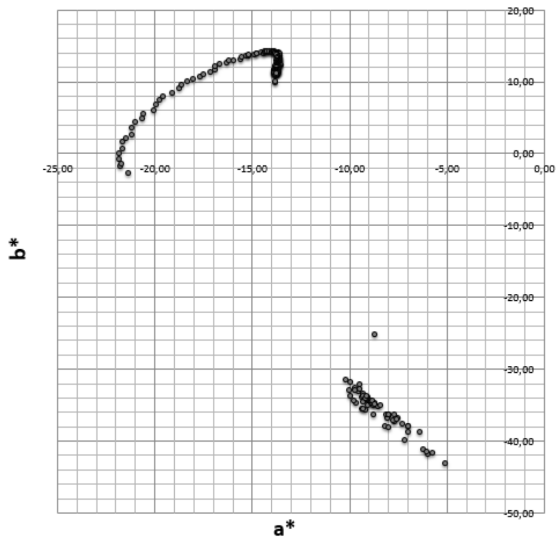
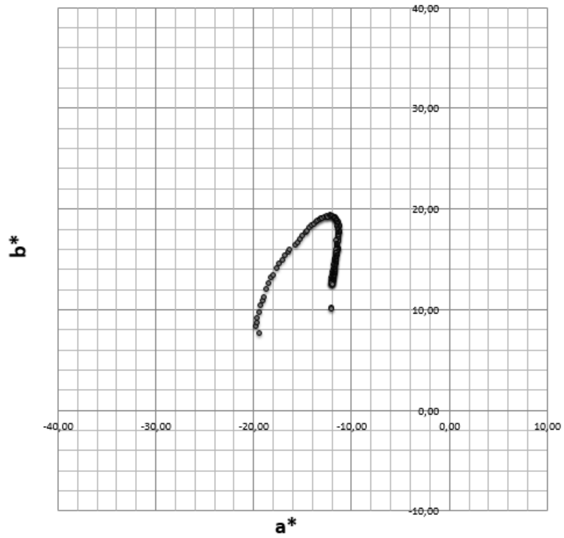


5)

Table 7 100% cotton jersey textile (including FBD) with 5 different concentration of A andB photochromic pigment in CIEL*a*b* colour system 1) 1:4 2) 2:3 3) 2,5:2,5 4) 3:2 5) 4:1



1)



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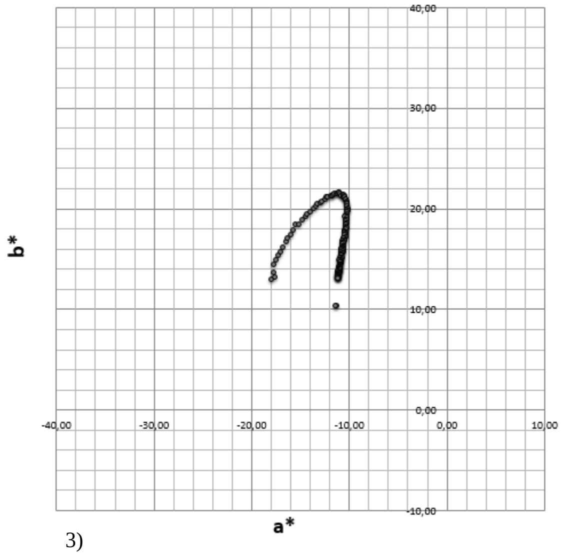

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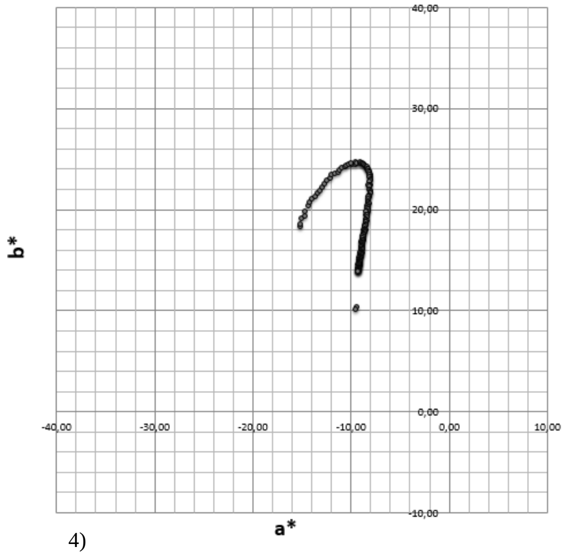

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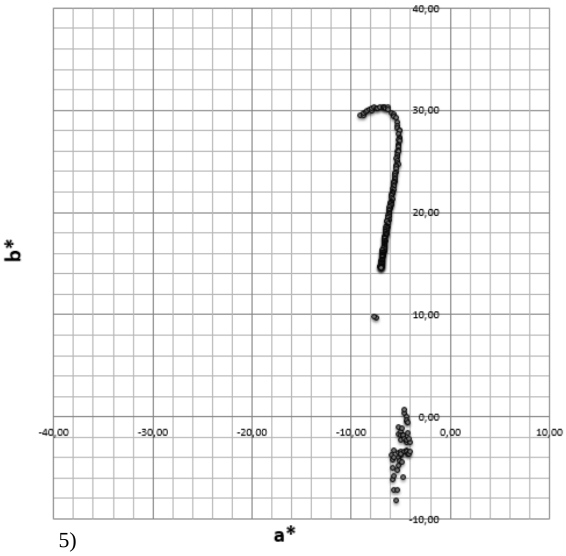


5)

Table 8 100% cotton knit textile (including FBD) with 5 different concentration of A and B photochromic pigment in CIEL*a*b* colour system 1) 1:4 2) 2:3 3) 2,5:2,5 4) 3:2 5) 4:1

In conclusion, we can now discuss differences between concentrations of photochromic pigments, where one of two elements is reflected more than the other one. Via this measurements we developed that concentrations with higher amount of blue photochromic pigment is more reversible, what means that it has shorter time to return to the colourless state. Concentrations with the higher amount of the yellow photochromic pigment are more stable in coloured state. The reversible time of this concentrations is circa 50 seconds. Further, the coloration of photochromic colour in coloured state depends on the current local temperature. It is already known, that with higher temperature coloration of photochromic pigment is reduced. The result is a creation of new designs of photochromic colour. Concentration 1:4 Y/B (Tab. 2.) is displayed more into blue values in CIEL*a*b* colour space and with rising amount of yellow photochromic element in other concentrations we can see less blue and more yellow coloration in visual reflection as well as in CIEL*a*b* colour space. On the samples there were no used optical brightening agents (100% ecru rotton denim textile) the curve in CIEL*a*b* colour space is continuous. On the other hand, other two materials (100% cotton Jersey and knit textile), where optical brightening agents were used before measuring, displayed curve split on two parts and it is creating a loop- like curve.

3. OPTIONS OF USING IN TEXTILE TECHNOLOGY

3.1 ADVANTAGES

Reversible photochromic prints are found in an apllications such as toys, cosmetics, clothing, fashion industry and industrial apllications. In textile technology and clothing design they are mostly used as a design elements as well as photochromic sensors warn against high solar radiation. When it comes to design and technology, very huge benefits of PTP are conditions of use, because as was already mentioned upon, the photochromic prints are not soluble in the water, so they are suitable to use in designer's collection as well as in industrial made clothing product.

3.2 DISADVANTAGES

Photochromic pigments used in this experiment from the MATSIU International Company, INC were developed to be used on natural fibres, such as cotton, wool, silk etc. what means that they are not stable and does not have same conditions on the syntetic textiles.

II. PRACTICAL PART

4. INSPIRATION

Nature is source of unlimited inspiration for human being and creative process. All the times scientists, discoverers and artists were studying both parts of living nature , fauna and flora, and researching for new possibilities and inovations, which can be applied and used by human. Nowdays with an increasing impact on the environment people are trying to use sources which are already created by the nature instead of generating new. Some sources are saying, that human cannot create anything new (mechanism, structure, design etc.) what was not created before, but only discover new way how to reproduce and use already existing thing. Finding a fresh solution to this problem means, first of all, looking for what has been already out there that could be helpful in solving this problem. This is the main idea of biomimetic design.

For this collection I took the main inspiration form the deep sea animals, which are able to turning skin colour and shape of body, known as cephalopod species. The most interesting kings of camouflage are deep sea cuttlefish and mimic octopus (***Thaumoctopus mimicus)***. They are able to turning colour and shape of their body in really short time and use various numbers of patterns and colours ways, which is why I decide to combine Japanese dying technique *shibori* and *photochromic* pigments to achieve the desired results. The main shapes and patterns used in collection are circles and orbits. Both of used techniques as well as colouring skin system of cephalopod are extensively explained in the following sections.

4.1. FAUNA

Animals and other organisms living on the Earth are significant source of inspiration to large discover of science, technology and arts. Every day we are discovering new species of animals and studying their life, structure and body shape, features and capabilities. Thanks to these discoveries and studies about the living around us, we can many of them to apply and use them to simplify our life. For example, Leonardo Da Vinci examine in depth anatomy of human body and body of animals, such as birds, that figure out a way to get a man to the clouds. He discovered flying instrument for a man, which was constructed and shaped similarly as bones and muscles of bird's wing. Nowadays we can find many similarities between animals and designed machines, such as aerodynamic shape of cars, air planes and also shape of some buildings and architectural objects.

For textile and surface designers is very challenging to develop artificial photonic structures design and the desired optical features. They can easily find an inspiration in fauna or flora by researching their body surface. Nature are found to develop photonic structures millions of years before our initial attempts. Photonic structures are revealed in butterflies, beetles and sea animals and even plants in recent surveys. The exhibited optical features are regarded to have particular biological functions such as signal communications, conspecific recognition, and camouflage, which are optimized under selection pressure. Fauna gives us many sources such as cutaneous epithelium and its derivatives of animal's bodies, for example birds, reptiles and cephalopods etc., that we can design and produce material or surface with ideal shape, finishing and properties for their use. Due to this we know display technology of Morpho butterfly, colour turning mechanism – coloration of longhorn beetles and tropic neon fish tetra. [10]

5. BIOMIMETIC DESIGN

The term biomimetic design „ *represents the studies and imitation of nature's methods, mechanisms and processes. Nature's capabilities are far superior in many areas to human capabilities, and adapting many of it is features and characteristics can significantly improve our technology"*. [11] Nature creatures are able to execute quite well while having an identity that tell the difference between one member from another in the similar species and that makes conflacted to man-made designs that are in need of exact duplication. It means that man-made commercial products and devices are needed to be duplicated as closely as possible assuring their quality and performance. If we will be successful in creating biomimetic structures consist of numerous quantity cells, we may be able to discover and design devices, systems and mechanisms that are directly related to science fiction.[11]

5.1. HISTORY

The term biomimetic design was coined by Otto Herbert Schmittby but earlier before him Leonardo da Vinci was keen observer of the anatomy of flying birds and different animals and made numbers of sketches and studies on his observations.
Otto H. Schmitt, American polymath and biophysicist, developed the Schmitt trigger during his doctoral research in 1950s by studying nerves in squid. He focused his work on mimic natural systems and in 1957 he had preceived to the standard view of biophysics and come with biomimetics.[12]

The term biomimetic, has few common meanings with term bionic which was coined by Jack Steele earlier before biomimetic. Later in 1892 the term biomimicry appeared. It was popularized by the Janine Benyus, American science writer and lecturer ,in 1997 when she published the book „Biomimicry, Innovation Inspired by Nature and she gave us new impulsion for the so-called biologically inspired approach. She defined it as the *„new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems".*[10] She claimed that nature is a model, measure and mentor of sustainability which is an objective of biomimetic design. [13]

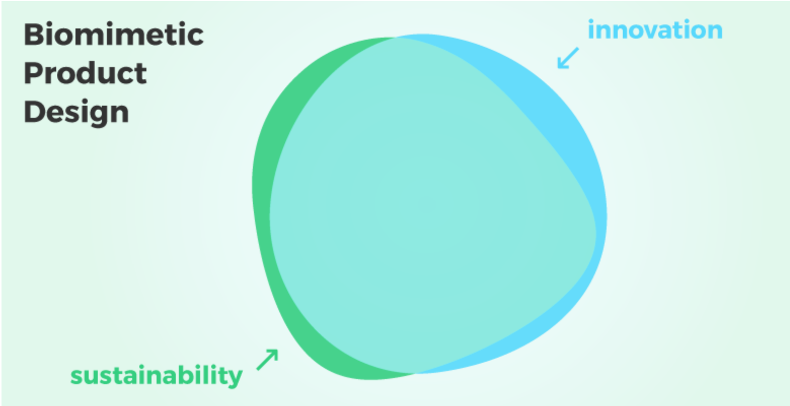


Figure 16 Relationship between inovation and sustainability[14]

5.2. BIOLOGY AS A MODEL

The various conditions of biology that humans used to generate man-made technologies show the colossal progress that has been made. Nowadays we can define many various selections so-called biologically inspired, for example mechanisms and structures, materials, tools and machines, biosensor, defense and atack mechanisms, and for future space exploration applications biomimetics for planetary application. This features can be inspired by two capabilities, one of them is the ability to operate with multiple mobility opinions including flying, swimming, running, climbing, digging, crawling and another part including more practical biologically inspired capabilities, for example controlled camouflage, photochromic changes of skin color, materialls with self-healing.

In the following part there are selected examples from biologically inspired developments, which are most interesting, including the selection which can be shared and used in textile technology and fashion design. [11]

- George de Mestral´s Velcro – it is a hook and loop fasten invited by Swiss electrical engineer George de Mestral in 1948, and it was patented in 1955. The word Velcro came crom the combination of the two French words velour (velvet) and crochet (hook). Mestral observed that the seeds of burdock plants got caught in his dog´s fur, being easily removed with a light force, what inspired him to analyze the surface of the seeds and he discover tiny hooks. Hook-and-loop fasteners consist of two components: typically, two lineal fabric strips (or, alternatively, round "dots" or squares) which are attached (e.g., sewn, adhered, etc.) to the opposing surfaces to be fastened. Velcro makes a distinctive "ripping" sound. [11][15]

- Display technology – Wings of the large Morpho butterfly consist of microstructures such as ridges, cross-ribs, ridge – lamellae and micro ribs that create coloring effect through structural coloration, and they are responsible for coloration. The structural color has been simply explained as the interference due the layers of cuticle and air using an imitation of multilayer interference.This photonic structures of Morpho can be simply replicated with using the metal oxides and alkoxides which means biomorphic mineralization. [11] [16]

- Self- cleaning surfaces – or known as “lotus effect” and “superhydrofobicity”. This ability was invited by German researches, Barthlott and Neinhuis, while they were studying plants surfaces as the mechanism that allowed lotus plants stayed clean. It was also found on the wings on certain insects or on feathers of birds. The principal of self-cleaning effect is based on high surface tension, minimize surface of water droplets by trying to achieve a spherical shape and special double layer of superimposed hydrophobic waxes. Some nanotechnologists have developed coatings, paints, fabrics, textiles and other surfaces that can stay dry and clean themselves.

- Spider web/ fibres- It was a Janine Benyus who first refered to spides that create web silk as strong as Kevlar fibers used for example in bulletproof vests. The webs are made of silk which is produced by spider from their spinneret glands located at the tip of their abdomen. The produced web has the ability to resist external conditions such as rain, wind and sunlight and it is barely visible. Humans were using the spider webs to help to heal and reduce bleeding for artificial tendons. In the textile industry engineers are inspired and enthralled by the elasticity, strength of fibers and also from weaving of webs.

- Camouflage – There are several types of animals which have capability to change their body color. The chameleon and octopus are known like greatest supporter of camouflage in nature. Camouflage in not solely used for concealment, but it has also great importance geting closer to prey by gaining the moment of surprise before charging ahead and captureing it. In some animals camouflage provides deterrence, especialy for sneakes and insects which are harmless. This capability were also used by all armies maked them minimally visible by matching the background color where the personnel operate. [11]

- Body armor – Some creatures, including turtles, snails and another soft-body marine creatures, were grown several forms of shells on their back, or surounded their body. It makes them protected against predator and also serve as shelter. They may be also equipped by hooks, pins, stinge, barbs and spears. This idea of body protection was used by humans tousands of years ago by using armor, hand-carried shields. Likewise, we can discuss about the clothing as a protection from the outdoor enviroment, with use numerous layers of fabrics, special padding into outerwear clothing or bulletproof vests. [11] [17]

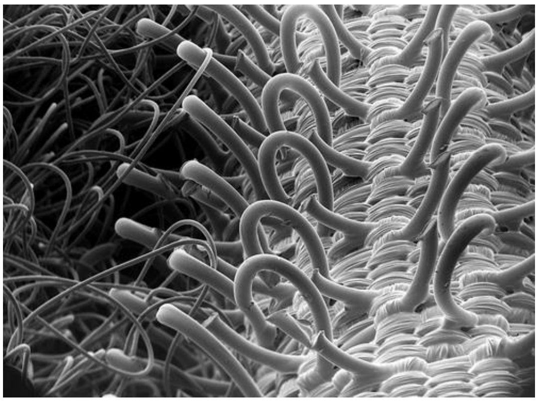


Figure 17 Microstructure of Velcro fasten (photo by Bob Anderhalt)

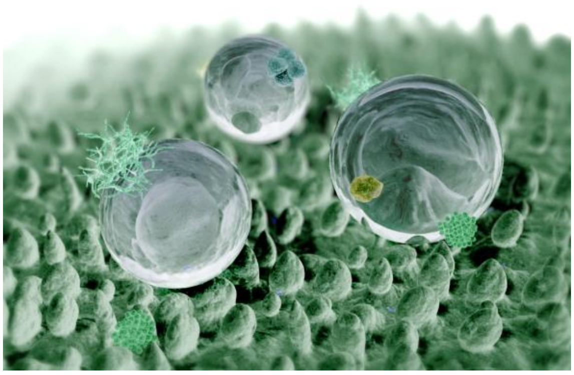


Figure 18 Model of self- cleaning ability [19]

Figure 19 Demostration of octopus camouflage [20]

5.1.2. BIOMIMETICS IN FASHION DESIGN

As we learned in the previous part, biological capabilites were inspired many of engineers to create sturctures, models and tools, which are applicable in textile industry and fashion design. Some of them can be used as technological facility inside of creating construction of clothing, self-cleaning ability, hydrofobility, use of slepcial natural fibres to achieve better propertis for following production. Another are used as the textile application what means ease of use, for example George de Mestral´s Velcro, special weave, luminous materials and security elements.

Fashion designer were always inspired by natural structures, objects and progress. Nature creates many elements which are ready to use in fashion. Nowdays high-fashion designers are using ready-made natural products inside their garments as application or they get inspiration for printing design, development of new fabric´s structures using different types of weaving, knitting or destruction. But inside of the technical part of biomimetics we can also see many technologies applied on wearable fashion or solider´s uniforms. This clothing can be inspired by the camouflage ot they can use special protective tools and elements. With rapid evolution, the society has changed the conditions imposed on the dressing, wear properties and maintenance of clothing. Sportwear and activewear garments are able to self –cleaning and super hydrofobility, they are more elastic by using special microfibres. Construction of clothing are more sophisticated by using thermal keeping textiles, air and sweat permeable layers. Specific outerwear are equipped with special sensors that respond to the skin temperature and heart rate and monitor body temperature, external temperature to prevent too hot or cold. It is also used so-called photochromic printing, responsive to the intensity of incident solar and UV radiation.[23]

Figure 20 Dress by Donna Sgro from Morphotex [21]

Figure 21 Suzzane Lee – Biocouture, growing textiles [22]

6. CEPHALOPODS

6.1 CHARACTERISTICS

Cephalopods are members of the molluscan group Cephalopoda, which stands for the Greek plural „ head-feet". These sea animals are characterized by a set of tencales or arms and a bilateral body system. The arms or tencales are modifications of the primitive foot. The class includes two, only distantly related, extant subclasses : Coleoidea, the class of squids, octopuses and cuttlefish and Nautiloidea represented by Nautilus and Allonautilus. The biggest difference between these two classes lies in their shell: in the Coleoidea group, the shell is absent or has been internalized whereas in the Nautiloidea group, the shell remains. They are also called inkfish because of their ability to squir ink. Given their soft-body structure, they occupy the majority of ocean depths and do not get easily fossilized.

My main focus is on the Coleoidea class, more precisely the octopus, squid and cuttlefish subclasses. They can change colour faster than a chameleon. *„They can also change texture and body shape, and, and if those camouflage techniques don't work, they can still "disappear" in a cloud of ink, which they use as a smoke-screen or decoy."* [24]

6.1.1 STRUCTURE OF THE BODY

As was mentioned in the previous section, Cephalopods are a marine molluscan with bilateral body system. The body contains a head with or without a shell and foot, which can be modified as arms or tentacles. They have a large brain, well-developed senses and they are the most intellignet of the invertebrate class. *„Cephalopods are social creatures; when isolated from their own kind, they will sometimes shoal with fish."*[27] Some molluscans are covered with an external hard shell and many of them are not very mobile. The shell of cuttlefish is internal and is called cuttlebone, which is sold in many pet shops as a supplement of calcium for birds. Squids also have a reduced internal shell called pen. Octopuses lack a shell altogether. The Cephalopod's eye is probably the most sophisticated eye of all invertebrates. The size of the eye is relatively large for their body size. Nevertheless, the eye is not highly developed, and thus their resolution is rather poor, being useful only to detect light and to communicate with one another. Given their surprisingly poor vision, the ability of changing color seems to come from cells. The only color vision has been developed in the sparkling enope squid *Watasenia scintillans* by using three different molecules. The sense of hearing has been found only in the squids by using their statocysts.

The body of cephalopods is characteristic of a head and arms or tentacles, which is another distinguishing characteristic of theirs. The fact is that all of them have arms but only some of them have tentacles. "*Octopuses, cuttlefish, and squid have eight non-retractable arms, but only cuttlefish and squid have tentacles (two each)."* [28] Along the underside arms, they may have some outgrowths like suckers, palps or occasionally hooks. Tentacles are usually longer than arms and are paired with two and contractile. Moreover, they often have a tip finished with a blade - shaped or flattened. Cuttlefish and squids use tentacles to strike quickly at prey. Modifications of primary feet are also used for moving across the ocean and feeding. [28]

6.1.2 CHANGING COLOR SYSTEM

Cephalopods have an incredible ability of changing color, shape and pattern of their body very quickly which they can use in a startling array of fashions. Most of them possess chromatophores pigment – filled bags that expand and contract to reveal or conceal small dots of color – this is how the color and pattern is created. These cells can be so densely concentrated that there may be found 200 of them in the size of a pencil eraser. The coloring system serves either for signaling (both within the species and for warning) and can also be manipulated to aid camouflage, courtship rituals, or accompany color changes. The phenomenon of coloration is more strongly represented in near-shore species than species living in the open ocean. Researchers show that the coloring system and patterns were more complex in the Devonian era.[25]

"We call this electric skin, because as soon as the information gets to the brain – the information is taken out of the brain goes to the skin and says do this. It is really quick." Says Roger "The top layers are the pigmented cells that give you most of the

patterning. They are layered – they have a yellow, a red and a brown. One little pigment cell is this little ball of color all tightly bounded as we do not see it. And as his muscles attached to it and the muscles can pull a pigment sack out into a little disc of color. And then when the muscles let go it just point goes right back in and you do not see anything. And so it is very simple mechanism. Next there is a layer of iridescent reflecting cells. They produce blue, green along with red and pink. At the white base the color fish palette is complete. "

Roger Hanlon, Marine Biological Laboratory

The ability of providing camouflage with a background is a special ability of some cephalopods bioluminescence. *"Bioluminescence may also be used to entice prey, and some species use colorful displays to impress mates, startle predators, or even communicate with one another."*[25] *"It is not certain whether bioluminescence is actually of epithelial origin or if it is a bacterial production."*[29]

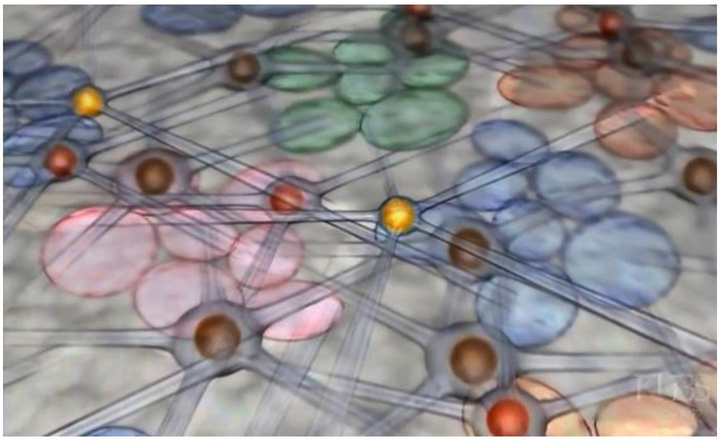


Figure 22 Illustration of cuttlefish skin with different layers of cells. Three upper layers with yellow, blue and brown cells and the basis layer with different colored cells

Figure 23 Glowing cuttlefish. Cuttlefish can change colour, pattern and shape of the body depending on current surroundings or mood.
In the dark deep seawater it may reflect as glowing – bioluminescence

7. MATERIAL SAMPLES

100% Ecru- cotton denim	100% cotton denim	100% cotton
100% cotton knit	100% bamboo jersey	100% cotton jersey
100% cotton rib	PTP 100% ecru-cotton denim	PTP 100% cotton knit
PTP 100% cotton jersey	100% cotton mesh	100% polyester

7.1. APLICATION OF COLOURS ON MATERIALS

For this collection, I have decided to use two different technologies of textile coloring, such as screen printing and shibori dying. To obtain the best results, natural fibres like cotton, wool or viscose need to be used. For this study, I opted for 100 % ecru cotton denim fabric and 100 % knitted fabrics, one of them is non-brushed knit and single jersey.

7.1.1 TECHNOLOGY OF SCREEN PRINTING

Silk- screen printing , also known as screen printing or serigraphy, is an old form of stencil, which first appeard in a recognizable form in China (Song Dynasty). The technique quickly spread across others countries in Asia, for example Japan. Later in the 18th century, it was introduced to the Western Europe. Screen printing was rapidly picked up by artists from all over the world and it became very popular during the pop art era, best known from Andy Warhol’s canvas pictures. Over the time, the technology got improved from the basic frame with cardboard stencils to factory-made screen printing machines. *„Graphic screenprinting is widely used today to create mass or large batch produced graphics, such as posters or display stands. Full color prints can be created by printing in CMYK (cyan, magenta, yellow and black ('key')).”*[30]

A screen is made of a frame with stretched piece of mesh over. A stencil is formed by blocking off parts of the screen in the negative image of the design to be printed; that is, the open spaces are where the ink will appear on the substrate. The stencil with the designed pattern needs to be printed on transparent paper with a full-black color. As already touched upon, a full-black color needs to be printed in the CMYK colors, so that it has four different layers of color. The frame is coated with a special pallet tape. For each color, we need a separate frame is needed.

When the frame is prepared, the printing part can start. The screen is placed on the top of the textile material. The ink (photochromic pigment) is placed on the top of the screen. The flood bar is used to push the ink through the holes in the mesh. We have to be careful about the amount of the ink placed on the screen. If less amount of the ink pattern is used, it will not come fully printed and the allover results will be insufficient. On the other hand, if the operator uses a lot of ink, the results will represent a relief on the surface of the material formed out of the dry color. For the best results, a squeegee and the right amount of ink (this ability is necessary to train) needs to be used. As the squeegee moves toward the rear of the screen, the tension of the mesh pulls the mesh away from the substrate (called snap-off) leaving the ink upon the substrate surface. Textile items printed with multi-colored designs often use a wet on wet technique, or colors dried while on the press, while graphic items are allowed to dry between colors that are then printed with another screen and often in a different color after the product is re-aligned on the press.[30]

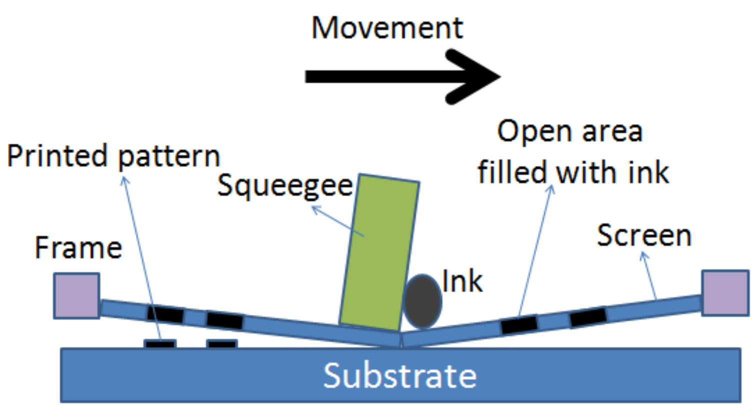


Figure 24 Explanation of the screen printing process[31]

7.1.2. TECHNOLOGY OF SHIBORI DYING

Shibori is an old Japanese tie-dying technique which dates back to the 8th century. It is the best known and oldiest indigo dying technique. The results of dying are based on folding, bounding and knotting fabric to create different shapes and patterns. Traditional fibers used in Japan were silk, hemp and later cotton. The main dye was indigo and later madder and purple root became widespread.

Until the 20th century textile art of shibori had been improving and nowadays there is an infinite number of ways to stitch, bind, twist, fold or knot and each results in a totally different design. The ideology behind this technique is to work with harmony and find a balance between the used pattern and type of cloth. Likewise, the desired pattern depends not only on the technique of shibori used but also on the characteristics of the material and the range of indigo substance. Nowadays textile artists combine different techniques, color variations, dye substance and sometimes dye cloth with different results all over again. [32]

There is 6 best known traditional shibori types: *kanoko* shibori, *arashi* shibori, *nui* shibori, *kumo* shibori, *miura* shibori and *itajime* shibori. *Kanoko* shibori is based on binding a certain part of cloth with a thread. Achieved the final pattern depends on how long the cloth has been dipped in the substance and how tight the thread knot is. The result represents patterns of random circles and of different sizes. The result of *Arashi* shibori (diagonal pole wrapping) is a ful-length pattern. The cloth is wrapped around the pole in a diagonal direction and ~~next~~ (then) scrunched on the pole. The achieved patterns suggest instantiate rain driven by a strong wind. The effects of *nui* shibori are determined by random or systematic stitches running across the cloth and then pulled tight and secured by knotting. In the 14th century this method was combined with brush painting, embroidery and stylized motives from nature. *Kumo* shibori is based on the wood-block prints of the Edo period (1603 – 1868) when lower class people where forbiden to wear silk. . The specific ~~is~~ spider-like design is the product of pleating and bounding. Kumo shibori can be tied by hands or using specific tools (kikai gumo). Over the time, artists developed many simple tools which hook a point of the cloth. This results in a cone shape while the thread is wound around mechanically. The technique that involves binding and looping is known as *miura* shibori. The sections are plucked with hooked needle and then the thread is looped around each section twice. However, it is not knotted so it is very easy to unbind. This results in a water- like design – a look that is very unique. It is the easiest technique of the shibori techniques. *Itajime* shibori is the shape-resistant technique where the cloth is folded and sandwiched between two pieces. Originally, the fabric is systematically sandwiched between two wood-shaped pieces, which are pulled together with string. Differing tensions of folding give different designs. [32][33]

As already mentioned, kanoko shibori method was selected to be used in this collection because of the most appropriate dying results. The cloth was dyed in a blue color substance, which was prepared form the coloring powder with the exact range of water and color pigment. Before dying, the cloth has to be damped with water, however only moderately to achieve better results and the color contrast between the new color layer and the underlying cloth. This process is followed by the process of creating pattern. The basic approach is to draw up selections of cloth and bind each of them with a thread, for instance. The final pattern depends on how tight it is, how many times it is bound, how much it is plucked, the size of the thread used and, last but not least, the manner in which the cloth is drawn up. After this preparation, the cloth is finally ready to be dyed. The designed cloth is drowned in a dying substance for a specific period. The recommended time is 30 minutes. After dying, we have to wash the cloth with warm clean water in order to elute the excess color pigments. Washing is provided until the cloth is fully colored and water clean.

In my experiments, use three different coloring powders from different producers – DUHA Námořnická modř 20 (Novaks.sk), IBERIA CLASSIC námořnická modř (Grupo ac Marca Barcelona) and TexBA Námornícká modrá (Druchema). I tested each of the products with the same conditions. I dissolved 0,021kg of coloring powder with 0,5l boiling water and than I added 2l of warm water and brought to boil. When the boiling coloring substance was prepared, I dipped the pieces of the cloth for 10 minutes. The manual also says to use 5 soup spoons of salt, but I decided not to use it because I am using natural cotton fibers and the substance with the salt can be destructive for the fibers and bond. After dying and washing with the warm clean water, I obtained interesting results. Cloring powder DUHA came out very uniformly all over the cloth but the final colour was a bit lighter than I expected. On the other hand, IBERIA CLASSIC coloring powder gave me the best deep blue results – the shade is most comparable with natural indigo dye results. TexBA coloring powder has some pink-like or purple-like shades and the uniformity of the color all over the cloth was not perfect.

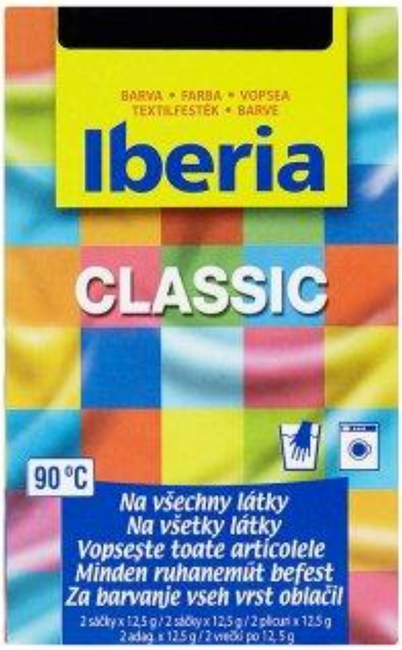


Figure 25 Iberia Classic coloring powder packing case

After the experiments with coloring powders, different temperatures of coloring substance and coloring time, I decided to use product from Spanish brand Grupo ac Marca Barcelona IBERIA CLASSIC.

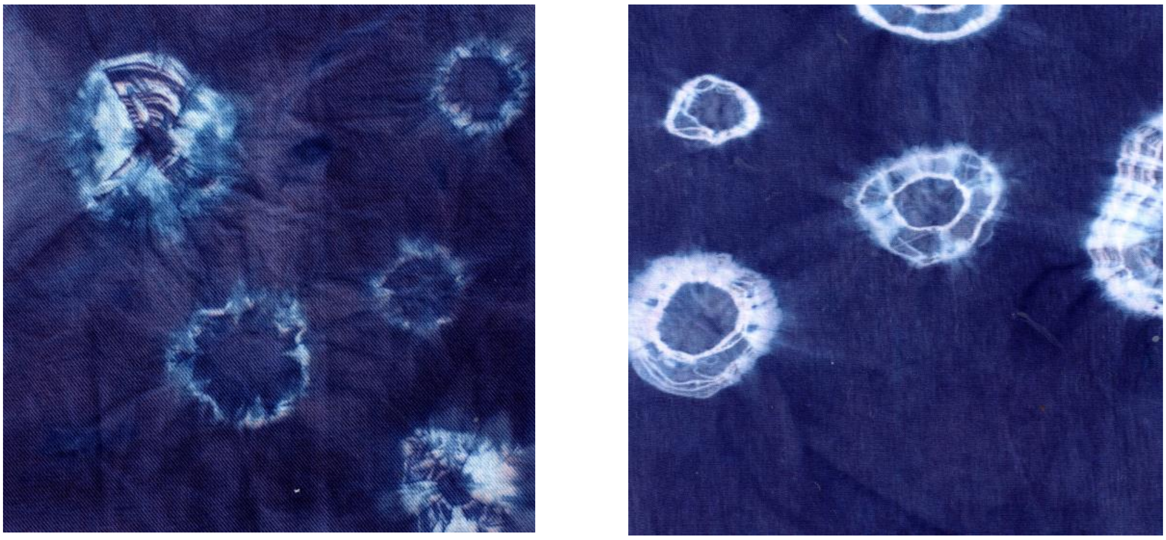


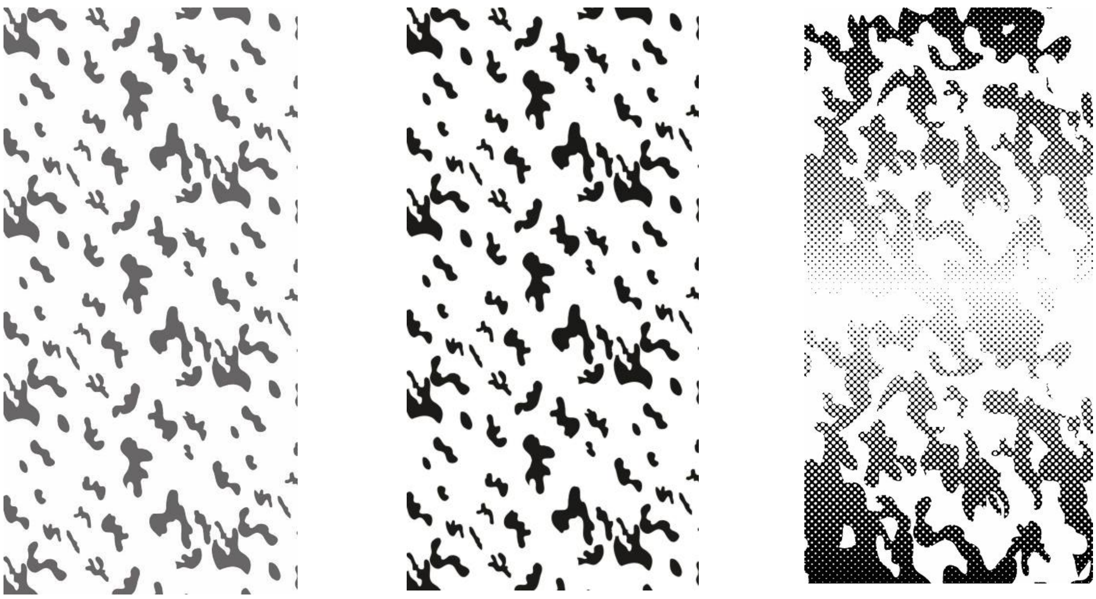
Figure 26 Examples of shibori dying technique *kanoko* on denim (1) and jersey fabric (2)

8. DESIGN PATTERNS

8.1 INSPIRATION

As an inspiration for the printing design, I choose the skin of cuttlefish and other similar cephalopods. As we learned in the previous chapters, cuttlefish skin is made of many different layers of cells with various colour tones. This skin layers and nervous system are collaborating together to create an accurate pattern. Each layer of cells is expanding the size of cells differently, which means that they are growing in the size or they are shrinking, what makes diverse variations of colours and patterns. The main meaning of these colour changes is to form the camouflage effect. Therefore they can protect themselves against predators or human, alarm the prey, or it has a huge meaning in the process of reproduction. Because the camouflage pattern is my favourite one, I was searching how to innovate design of this pattern by using different technologies and moreover make them cohesive at the same time.

So I started to work with an original camouflage design and transform it, by using cut-outs and blank section into the not fully filled pattern. Over this layer, I placed a layer of gradient dots grid which made overall design more dynamic and ever-changing. The figures below this section shows simulation of each layer separately and also all together.



Layer no.1 **Layer no.2** **Layer no.3**

Figure 27 Stencils for screen printing separately.

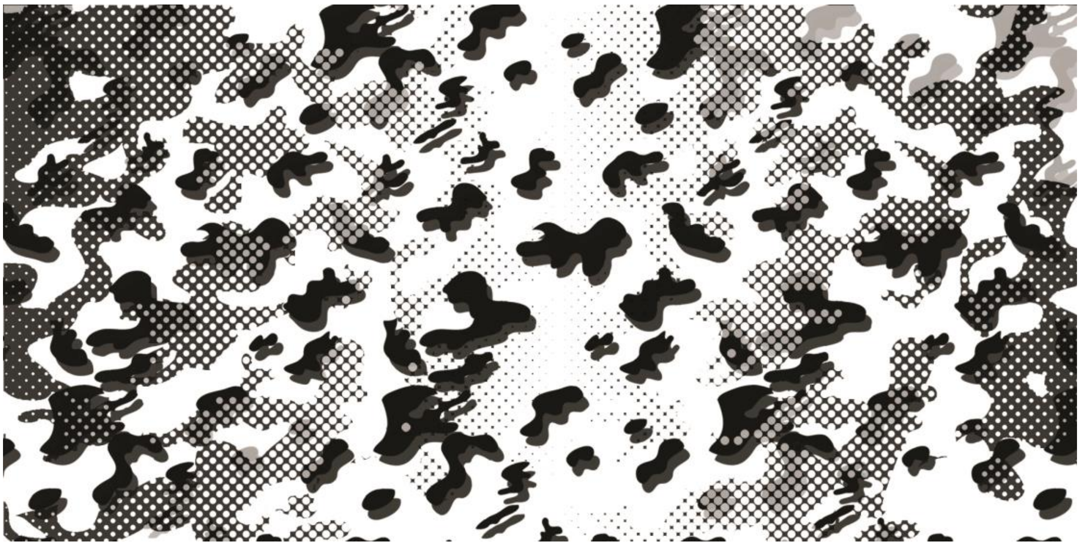
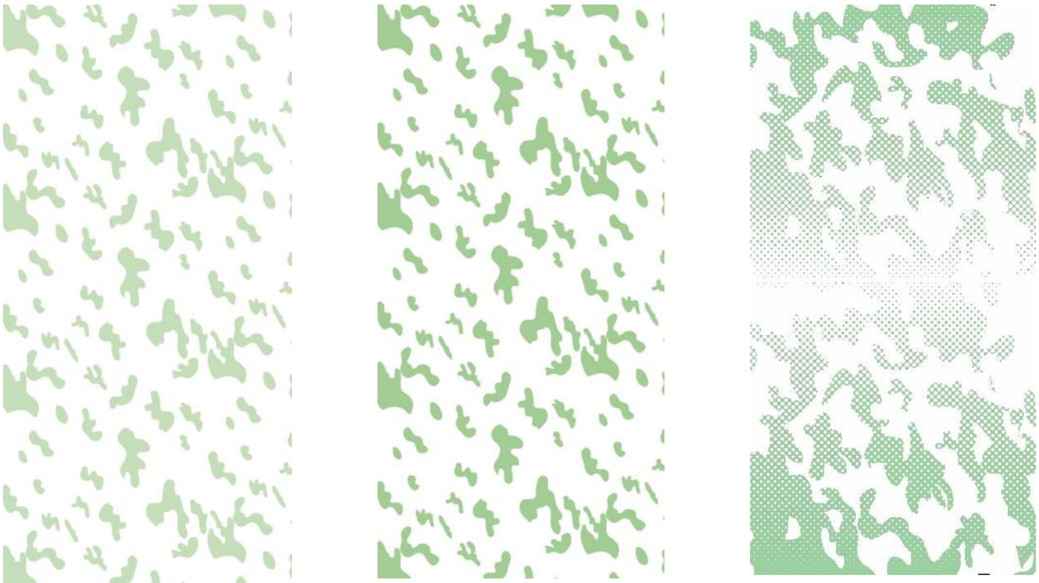


Figure 28 Final pattern simulation for screen printing

8.2 SELECTION FOR PHOTOCHROMIC COLOURS

To demonstrate this cephalopod's capability, I decided to work with a photochromic colouring pigments. They are developed and designed to change the colour when it comes

to the meeting with the UV radiation, which includes UV radiation contained in the sun's rays or pure UV light inside lightboxes. I worked with two colours of photochromatic pigments, blue and yellow, and mixing them in five different ranges. The most contrastive ranges, which mean ranges A and D (range A means 1:4 yellow/blue and range D means 4:1 yellow/blue) has the most preferred colouring results, so by this, they were chosen for designed pattern. For the human vision colours without touching of UV radiation are mostly in very light green tones as Pistachio green, seacrest or reed tints. After the contact with UV radiation, the range A will turn into Tempo teal shades and the range D will turn into olive-like shades.



Layer no.1 range D layer no.2 range A Layer no.3 range A

Figure 29 Stencils for screen printing with relevant ranges A and D (colour simulation in exact green tones)

The figures above this section illustrate simulations of ranges A and D with a relevant pattern stencil. The camouflage pattern is designed in three different layers, named as layer no.1, layer no.2 and layer no.3. They are placed at each other in order no.1, no.2, no.3. If we want we can print them in the different order or we can skip one layer and create some other pattern. Also, we can exchange the colours.

Working with screen printing technology and three layers prolonged printing process, but after drying and fixation, I discover a new surprising phenomenon. The small places where the colours are layered at each other have different colouring effect as the rest of the print. So coloration of the print is even more interesting and dynamic.

9. CREATING COLLECTION

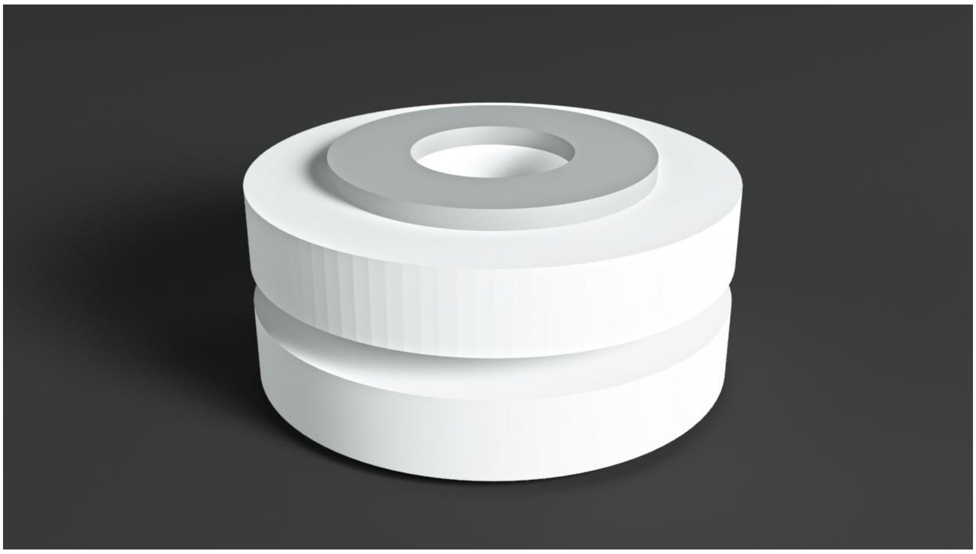
9.1 JEWELLERY DESIGN

The collection is complemented by a collection of jewellery pendants, which include four designs, each of which has the same basic shape but different detailing on the top. My decision to bring this idea to live was because it makes models more cohesive and hybridised. The pendants are inspired by the huge eye of cuttlefish, which is considered as a visual centrepiece of a head of cephalopod. Cephalopods have this giant and intelligent eye to detect mostly movement around them self, since they cannot discern colours correctly. As we can see on the next pages, where the technical drawings are, two of them (both 120 mm average) are designed simpler, to show the baseline for other two designs. Basic shape for pendants is simply the same shape as metallic rivets used on cloths as functional detailing. Another two of them (both 140 mm average) are more specific and special for the collection, because they carry the fond symbols, such as HYBRID and name with logo of the collection ORGANIC HYBRID. The pendants are made by 3D printer PRUSA I3 from ABS Ivory filament produced by PRUSA Company. Printing process starting with three base layers which are fully filled with filament and rest of the layers are made with a honeycomb structure to make pendants lighter. Final three layers are again fully filled. Printing process is conducted on a glass surface, from which we can easily remove the printed object. [24]

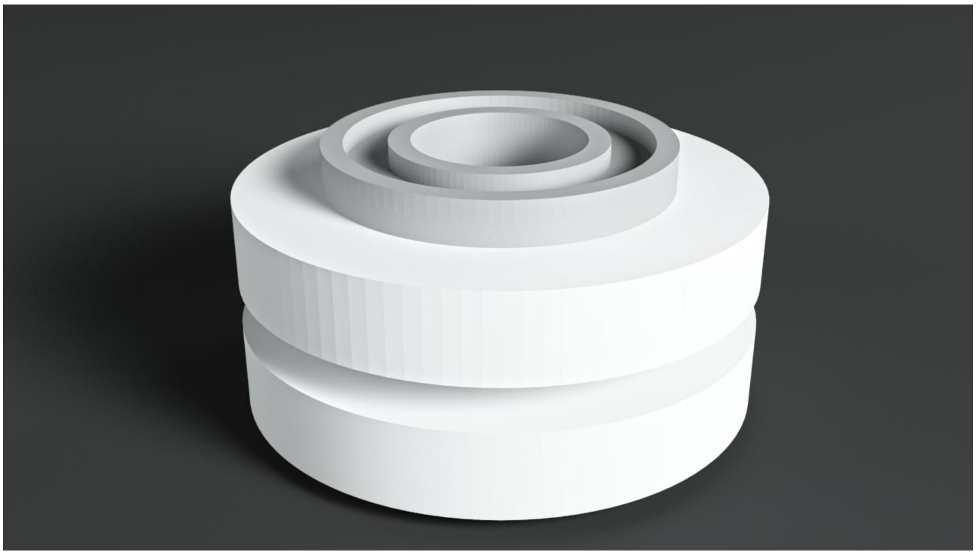
I also innovative 3D printing technology for printing on textile. I used ecru cotton denim fabric as a surface for printing. Results are surprising because it looks like a new type of futuristic embroidery especially on denim fabric. The thickness of the filament is 15 mm, what is a very good size for terms of use. We can wash this print at washing machine at 40 °C because ABS filament is resilient, but using dryer has a destructive reaction. Further, we can find some imperfections located at the corners of the letters, which has sharp edges.

I applied this prints on denim textile on the back of the bomber jacket and on the back pockets of the pants.

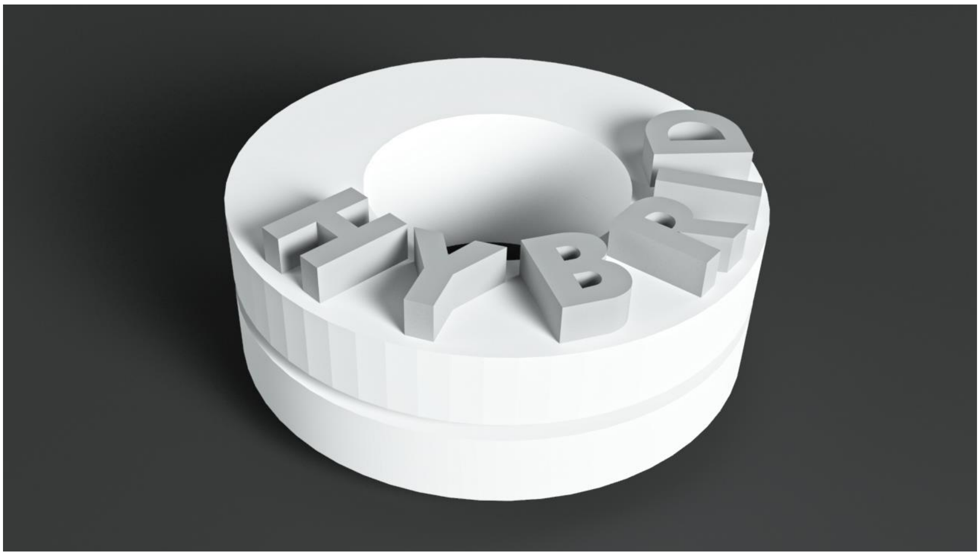
Figure 30 Detail of the cuttlefish eye and skin cells with different colour tones which was used as an inspiration to design jewellery collection.[32]



Model 1



Model 2



Model 3

Model 4

Figure 31 3D rendering of jewellery pendants

9.2 TECHNICAL DOCUMENTATION

TERMS OF USE

WASHING - photochromic prints	Soft cycle - maximum at 30°C or wet chemical washing
WASHING – shibori dye	Handwash or wet chemical washing
BLEACHING	DO NOT BLEACH!
DRYING	DO NOT USE TUMBLER! Drying in suspension.
IRONING	The maximum temperature of soleplate 150°

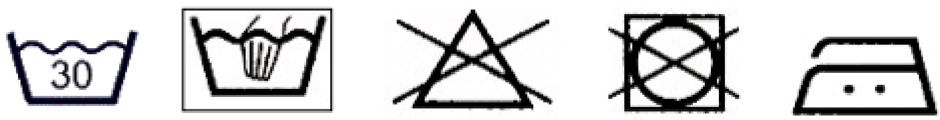


Table 9 Terms of use

MODEL 1

Men's fitted tank top with deep cut armholes with the narrower front part on the chest than is back part. The edges on the both sides of armholes and also neckline are lined with stretch jersey stripe fixed with an overlock stitch. The hemline is once folded and stitched

The men's oversize hoodie with removable bottom part. The hoodie has a hood made of 7 pieces stitched into the collar. The construction of the hoodie is similar like the other jackets. The front parts which are identical has placket pockets on the sides stitched all around on the top. On the back there is attached piece which has curved shape and it can be tighten on the bottom sides with ribbon. Sleeves are horizontally cut in halves in the middle where the elbows are. The edges of the hole are once folded and double stitched and stitched together 2 cm from each side, so they hole is not from side to side. The sleeves are ended with stretch rib tunnel. The hoodie has a zipper on the middle of the front side. The hemline is ended with stretch rib tunnel. The removable part is zipped to the top part with two zippers which are hidden under the rib tunnel. The lower part has two pocket at the front stitched on the top and two pockets on the back stitched on the top. The pockets on the back has rivets, two each of them. At the front it has a zipper for closing as well as at the back as a detail. The hemline is ended with stretch rib tunnel. The hoodie has a lining except sleeves.

The men's jogging pants with zippers in the middle of the front sides. The jogging pants has a pockets on each hips side and waist is lined with waistband made of folded knit tunnel with elastic inside. It has two rivets and elastic inside of the tunnel which is tighten with cord lock stopper toggles with two holes. The zippers are stitched along the whole front part of the leg in the muddle except 10 centimeters from the waistband. The front part has an extra cut part on the knee from the outside as well as from the inside. The fitting of the pants is lower crotch because of the extra parts added inside of the legs. On the back part is pocket stitched on the top of the pants with two rivets. Both sides are identical as well as front parts. The back part is cut behind the knee which is giving more fitted shape. In between ankles on the both parts, front and back, there is extra curved shape stitched. The hemline is ended with stretch rib tunnel. Under the hips pockets there are four rivets with elastic going thru them to the back pocket and back. The elastic is fixed with cord lock stopper toggles with two holes.

Figure 32 Sketch model 1

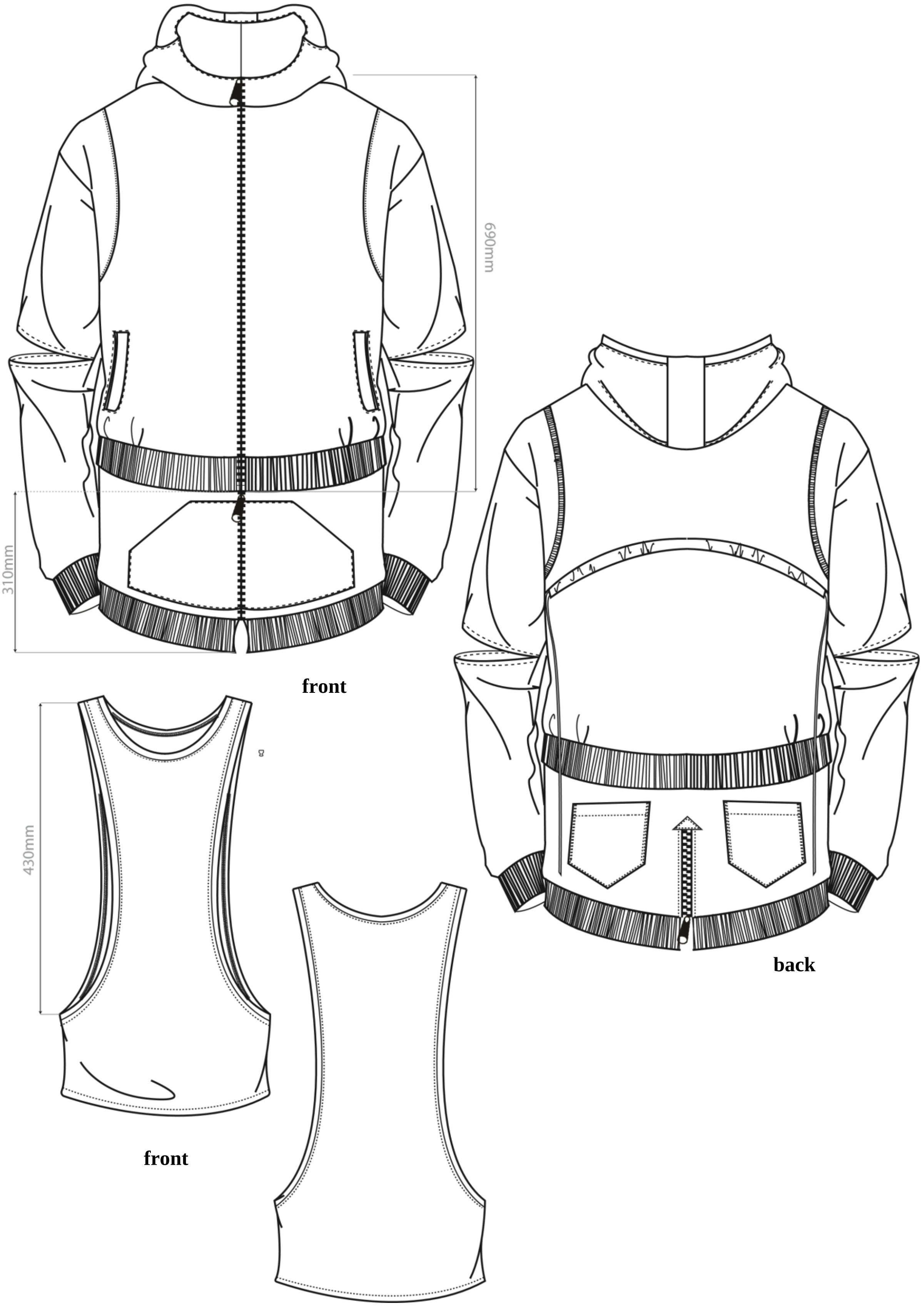


Figure 33 Technical documentation model 1

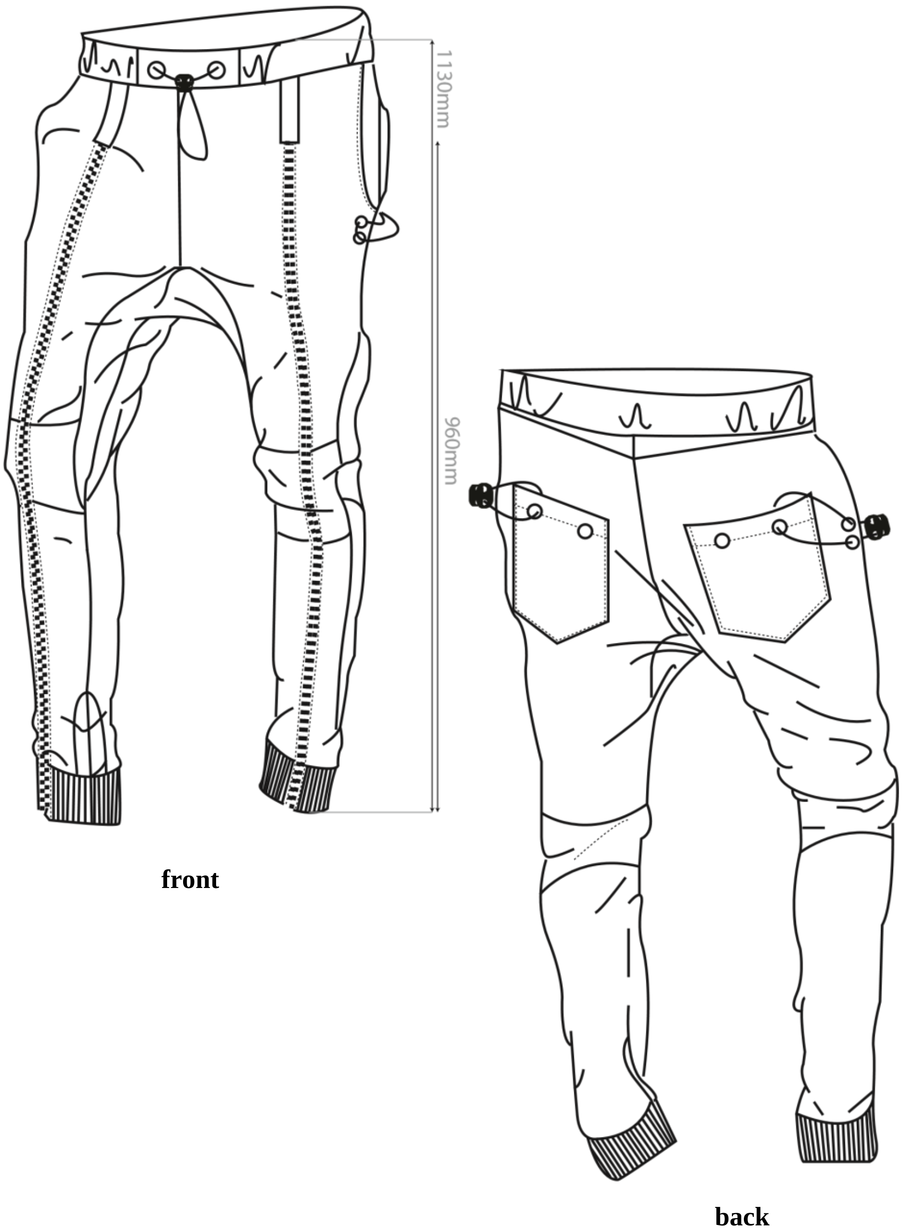


Figure 34 Technical documentation model 1

Figure 35 Model 1 (front)

Figure 36 Model 1 (back)

MODEL 2

Men’s loose T-shirt with long sleeves and drape detail on the front part. The T-shirt is all over stitched with overlock except the cut on the front part, which is just stitched from the inside. The neckline is lined with jersey stripe from the same material, hemline and bottom line on the both sleeves are once folded and stitched.

The men’s lower crotch pants. The pants have a loose fit and hips pockets and the construction is similar to the pants on the model 5. . Both of the legs are identical at the front as well as at the back. The front leg is cut in the middle horizontally and vertically. The outside part of the front leg is more structured, it has stitched details on the top. The leg is cut on halved on the knee where is extra piece of knit fabric stitched and ten covered with top part of the leg. The waistband is lined with the tunnel with elastic inside with two rivets at the front and ribbon inside the tunnel. On the back of the leg is pocket with two rivets stitched on the top of with OH 3d printed logo on the right side – this is not identical. The lower crotch fit is created with extra parts in between legs, each leg has one part. The back part is cut behind the knee which is giving more fitted shape. In between the ankles there is extra curved shape stitched. The hemline is lined with knit tunnel with elastic inside.

Figure 37 Sketch model 2

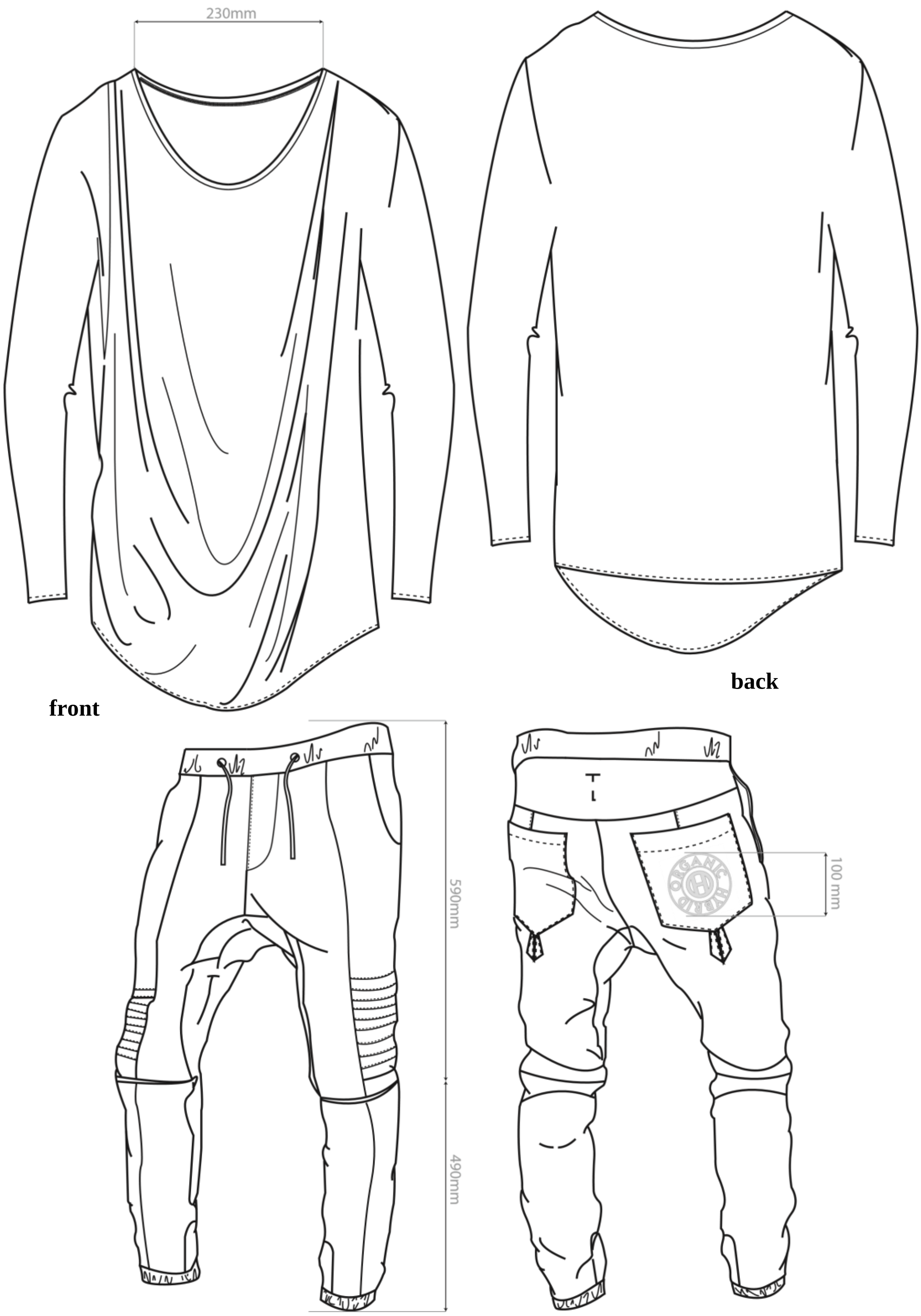


Figure 38 Technical documentation model 2

Figure 39 Model 2 (front)

Figure 40 Model 2 (back)

MODEL 3

Men's loose cut long sleeve shirt closing with ledge on the front middle. The collar is from classic shirt, sleeves are long with opposite folds and simple cuffs. On the right front side is the pocket with two rivets stitched on the top of the shirt. The hemline of the shirt is twice folded and stitched. On the back are two opposite folds and logo OH stitched on the top of the material from the same fabric. The edges of the logo are frayed. On the bottom of the shirt is attached extra part of the shirt, which is stitched inside of the hemline. Between this two parts is tunnel with ribbon to make shirt tighten. The extra part is also closing with ledge on the front middle, but it is not connected to the top of the shirt, because the extra part is stitched only on three quarters of the hemline, what means that 10 cm from the ledge is loose. On the back of this part are two pockets stitched on the top from the dame material, with two rivets each. The hemline of the attached part is twice folded and stitched. The shirt and cuffs are closing with studs.

The men's short bomber jacket with hood and closing with zipper which is stitched all over the hood. The hood is made of six pieces. The hood is stitched into the collar. The sleeves are long and have pockets on the first fifth from the top of the arm. The pocket with flap is stitched on the top of the sleeve and it has small stripe hook right under the pocket in the middle. The sleeves have opposite flop and then cuff with small belt closing with studs. Under the cuff is stretch rib tunnel. The both front parts which are identical has side placket pockets covered with the flops and closing with the studs. The bottom of the jacket is tighten with the elastic stitched inside of the lining on the three quarters. The jacket has a lining inside made of printed knit and two harness stitched into the neckline and hemline.

The men's jogging pants with zippers in the middle of the front sides. The jogging pants has a pockets on each hips side and waist is lined with waistband made of folded knit tunnel with elastic inside. It has two rivets and ribbon inside of the tunnel. The zippers are stitched along the whole front part of the leg in the muddle except 10 centimeters from the waistband. The front part has an extra cut part on the knee from the outside. The fitting of the pants is lower crotch because of the extra parts added inside of the legs. On the back part is pocket stitched on the top of the pants with two rivets. Both sides are identical as well as front parts. Behind the knee is triangle reduction from the inside and outside. In between ankles on the both parts, front and back, there is extra curved shape stitched. The hemline is ended with stretch rib tunnel. Under the hips pockets there are four rivets with elastic going thru them to the back pocket and back. The elastic is fixed with cord lock stopper toggles with two holes.

Figure 41 Sketch model 3

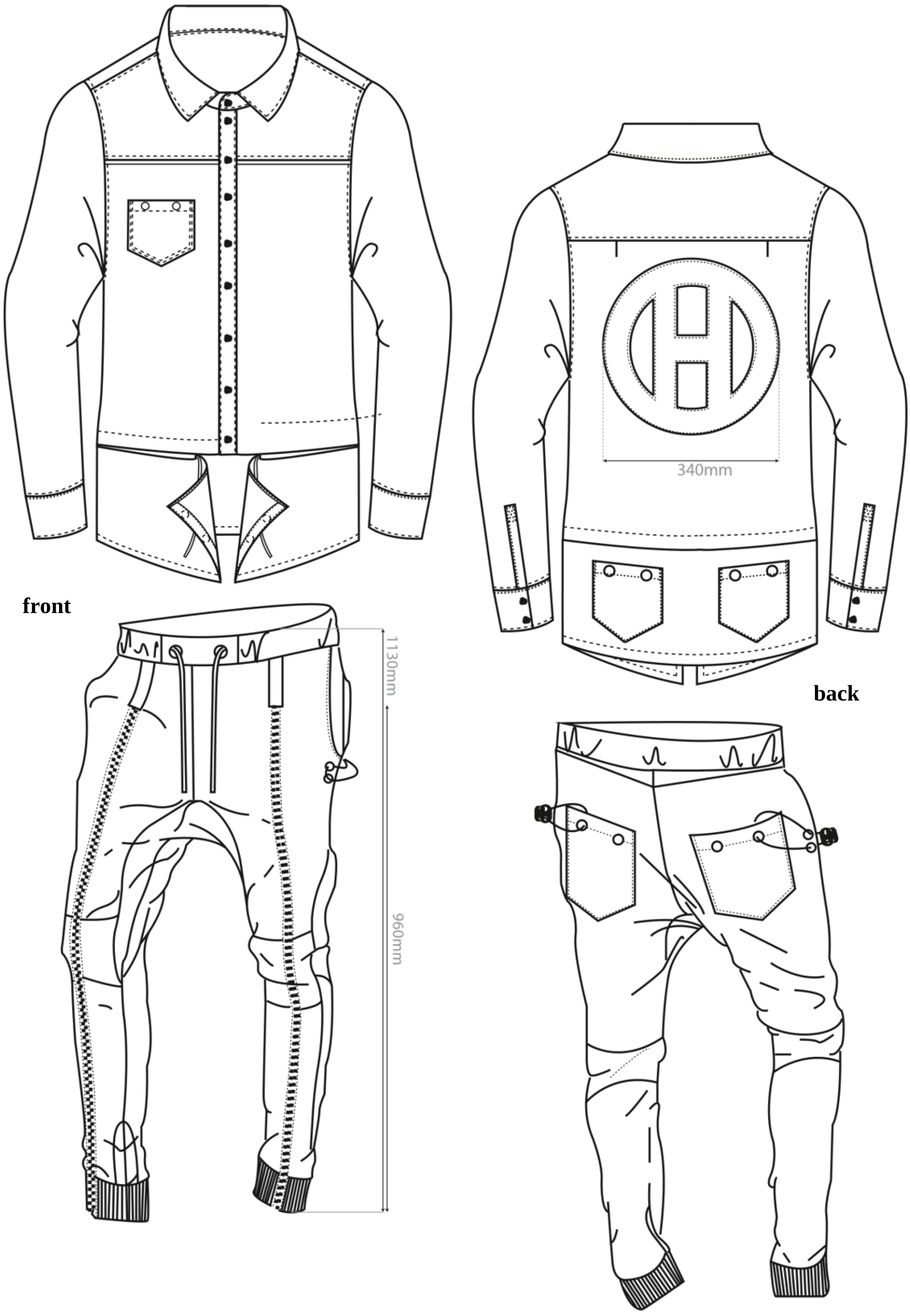


Figure 42 Technical documentation model 3

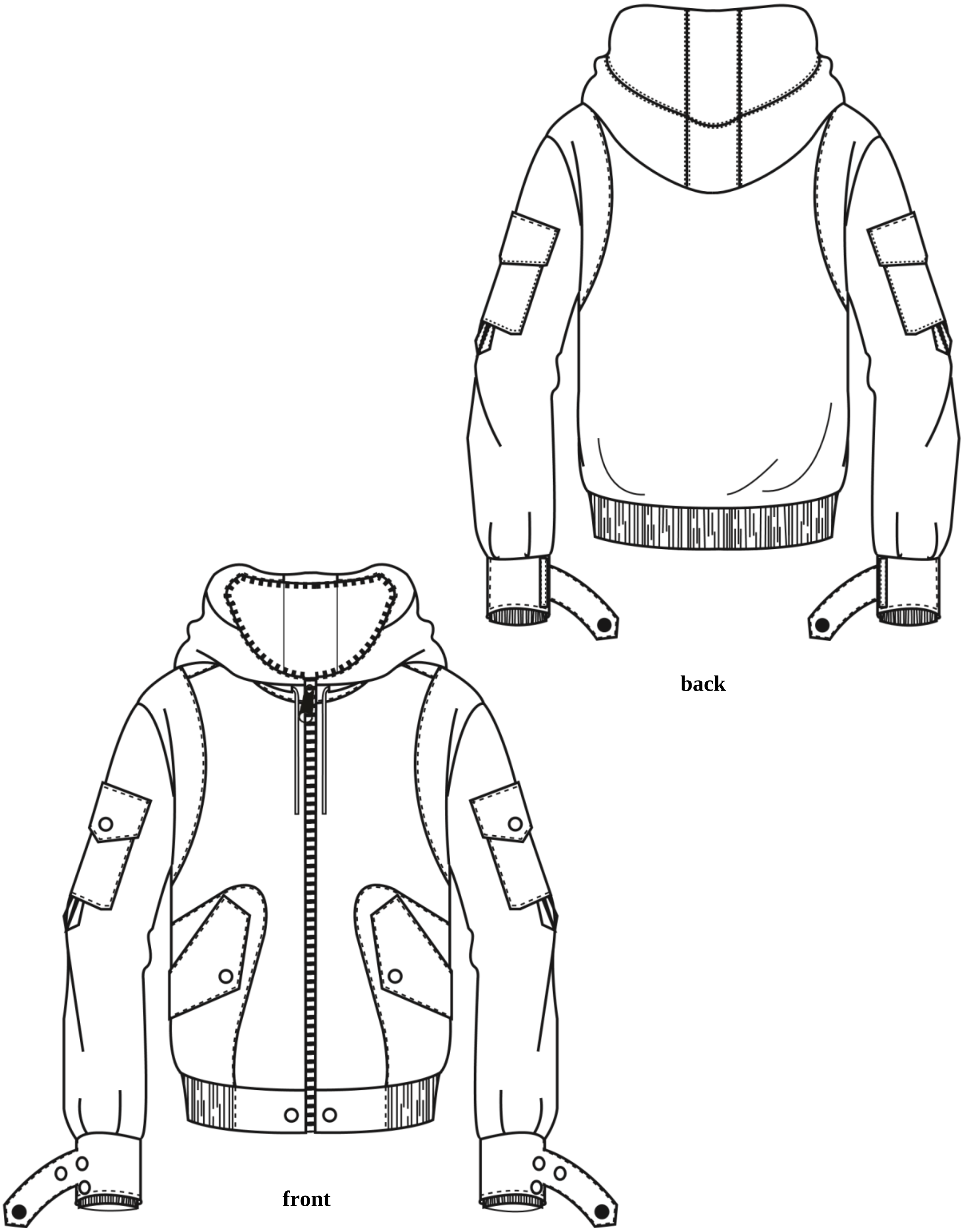


Figure 43 Technical documentation mode

Figure 44 Model 3 (front)

Figure 45 Model 3 (back)

MODEL 4

Men's fitted tank top with medium deep cut armholes. The edges on the both sides of armholes and neckline are lined with the stretch rib stripes fixed with overlock and stitch. The hemline is lined with wider rib stripes front and back separately and fixed with the overlock and stitch.

Men's T-shirt with long sleeves. Sleeves are horizontally cut in halves in the middle where the elbows are. The edges of the hole are once folded and double stitched and after stitched together in 2 cm from each side, so the hole is not from side to side. On the front part is stitched logo OH from the extra printed jersey on the top of the surface. The logo is only stitched and edges are cut. The neckline is lined with stretch jersey stripe from the same material. The hemline and bottom edges of the sleeves are folded and stitched.

Men's leggings with cut along front part of the both legs. The waist is lined with waistband made of folded jersey tunnel with elastic inside and fixed with the overlock. The bottoms of the both legs are ended with stretch jersey tunnel fixed with overlock. Side-stitches and crotch-stitches are fixed once more with stitch.

The men's knit shorts with tighten hemline. The shorts are identical at the front as well as at the back parts. The hips pockets are lined with jersey fabric. Each part of the leg has stitched extra piece inside of the leg what makes the lower crotch fit. The hemline is overlocked, once folded and stitched. The tunnel has two rivets at the side stitch and two rivets are up to them at the side stitch. Inside of the tunnel is elastic which goes to the up rivets tighten with cord lock stopper toggles with two holes. The waist is lined with the stretch tunnel with elastic and ribbon inside and two rivets at the front. The back part has pocket stitched on the top of it with two rivets on the sides. Under the pocket in the middle is small stripe tab.

Figure 46 Sketch model 4

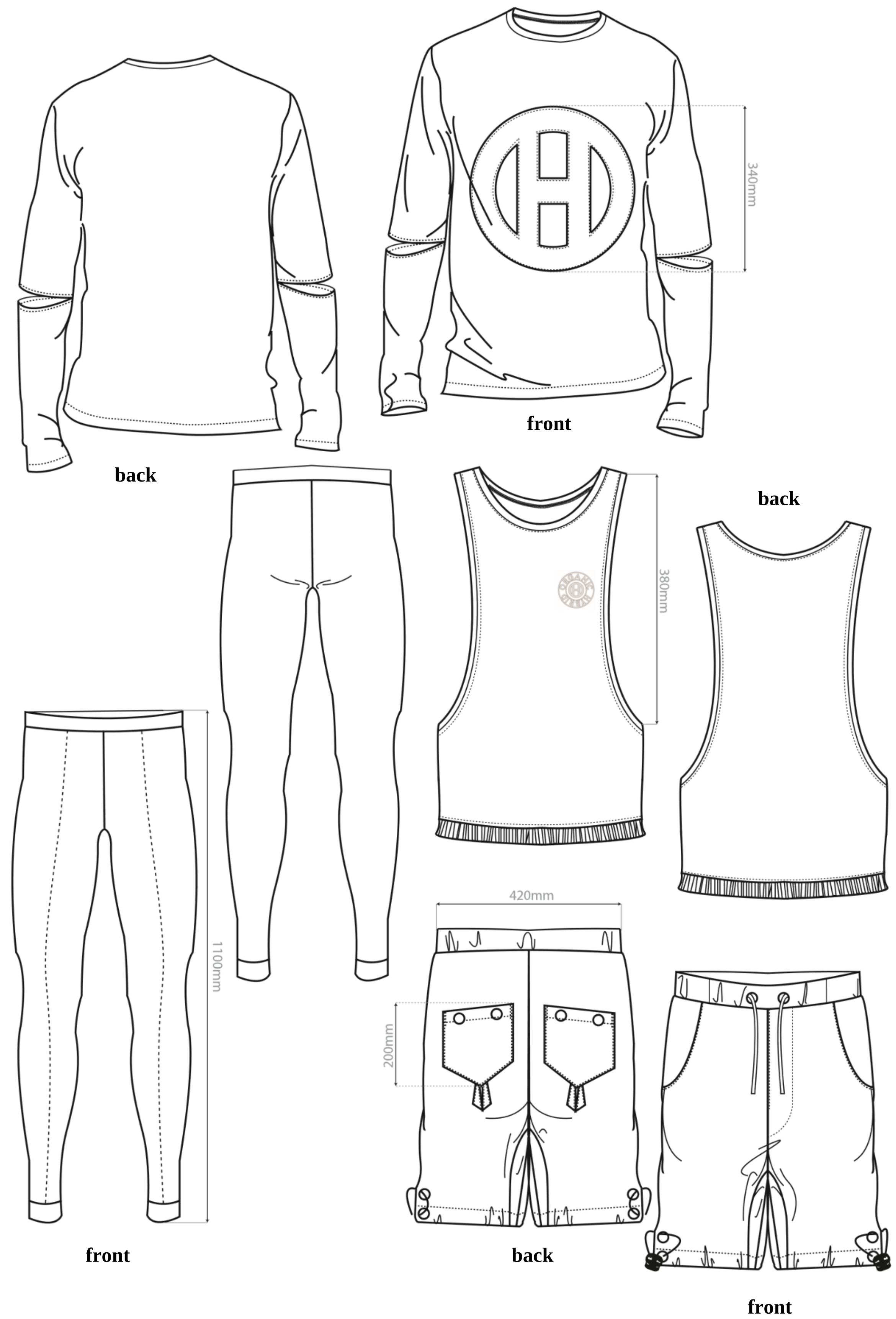


Figure 47 Technical documentation model 4

Figure 48 Model 4 (front)

Figure 49 Model 4 (back)

MODEL 5

Men's parka jacket with the hood and closing with the zipper at the front part. The hood has zipper in the middle vertically and each side of the hood is stitched from two parts. The hood is stitched into the collar. The sleeves are long and have pockets on the first fifth from the arm. The pocket with flap is stitched on the top of the sleeve and it has small stripe hook right under the pocket in the middle. The sleeves have opposite flop and then cuff with small belt closing with studs. Under the cuff is stretch rib tunnel. On the front parts which are identical, there is a flap on the chest closing with stud. The placket pockets covered with flops are on the sides and they are lined with curved shape stitched on the top of the basic surface. The hemline of the parka is longer at the back and shorter at the front and it has tunnel with two rivets in the middle of the back part and two rivets on the front part next to the zipper. Inside of the tunnel is elastic fixed with cord lock stopper toggles with two holes. In the middle of the back is stitched 3D printed application. The jacket has a printed jersey lining with two harness inside.

Men's loose tank top with deep cut armholes with narrower front part on the chest then back part. The edges on the both sides of armholes and neckline are lined with jersey stripe from the same material fixed with overlock. The hemline is just cut– it is not fixed with stitch or overlock.

The men's lower crotch pants with holes on the both knees. The pants have a loose fit and hips pockets. Both of the legs are identical at the front as well as at the back. The front leg is cut in the middle horizontally and vertically. The outside part of the front leg is more structured, it has stitched details on the top as well as bottom part. The leg is cut on halved on the knee. The edges of the hole are double folded and double stitched separately and then together 5 centimetres from each outside edge. On the both horizontal sides of the hole are two rivets. On the top of the vertical cut, under the waistband is stripe with stud. The waistband is lined with the tunnel with elastic inside closing with two studs on the front. Around the waist are 5 belt tabs. On the back of the leg is pocket with two rivets stitched on the top of with OH 3d printed logo on the right side – this is not identical. Under the pocket is a tab from the stripe of the denim fabric. The lower crotch fit is created with extra parts in between legs, each leg has one part. In between the ankles there is extra curved shape stitched. The hemline of the leg is double folded and stitched.

Figure 50 Sketch model 5

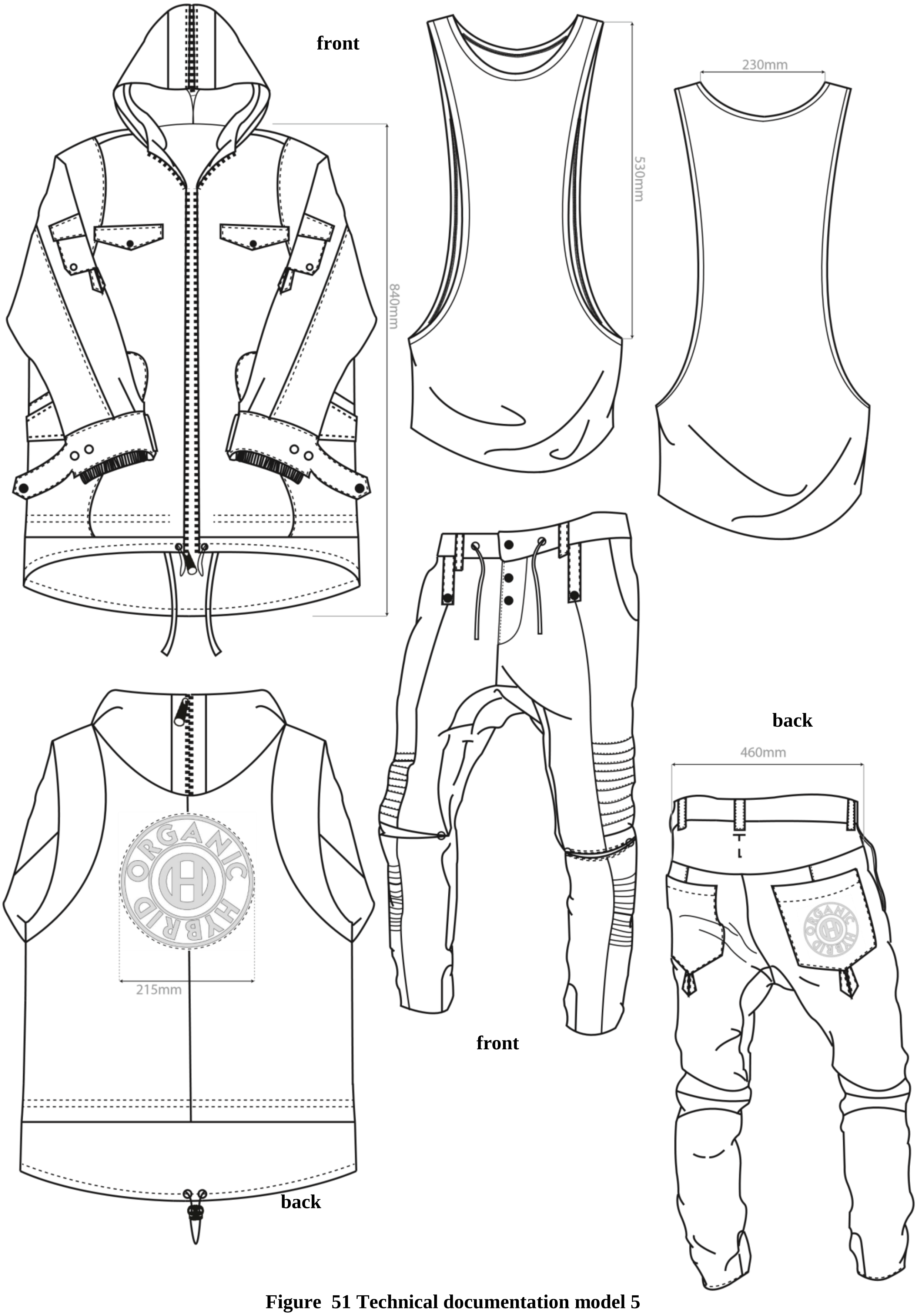


Figure 51 Technical documentation model 5

Figure 52 Model 5 (front)

Figure 53 Model 5 (back)

10. CONCLUSION

At the conclusion of this thesis, I would like to present my own opinion to the results, that has been achieved. The theoretical part based on mixing new designs of photochromic pigments was very successful and innovative for me as a designer and has a very good impact to the practical part of this thesis. The designed photochromic colours have appropriate conditions for their use in designed menswear collection and also follow the conditions of use. Further, the measured data show us some surprising findings according to used textile surface and range of photochromic pigment. The designed menswear collection , which includes 5 models carries the essence of hybridism and living creatures in the depth of the ocean. Due to combining photochromic pigments and Japanese shibori dyeing technique I captured the moment of the main secret of their lives – skin coloration and change of body shape. To be honest, working on this thesis brought to me a fresh point of view to the connection between design and textile technology.

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