KAUNAS UNIVERSITY OF TECHNOLOGY

MECHANICAL ENGINEERING AND DESIGN FACULTY

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RESEARCH OF INK PRINTED LAYER ON A TINPLATE

Master's Degree Final Project

Supervisor:

dr. Vaidas Bivainis

KAUNAS, 2016

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Industrial Engineering and Management (code M5106M21)

Supervisor

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(Title of study programme, code)

"Research of ink printed layer on a tinplate"

DECLARATION OF ACADEMIC INTEGRITY

____ ________________ 20 _____

Kaunas

I confirm that the final project of mine, **Anton Ananjev**, on the subject "Research of ink printed layer on a tinplate" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources; all direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

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Ananjev Anton. Research of Ink Printed Layer on a Tinplate: Master‘s thesis / supervisor dr. Vaidas Bivainis. The Faculty of Mechanical Engineering and Design, Kaunas University of Technology.

Study area and field: Production and Manufacturing Engineering, Technological Sciences

Key words: offset, tinplate, adhesion, colour, shade, surface, ink, print.

Kaunas, 2016. 51 p.

SUMMARY

In this research ink shade is produced, which is selected by the customer. The sample is scanned by special equipment, the desired colour of ink is formulated and mixed. It consists of four different inks. The printing is held on a tinplate. For this surface special offset inks are used, with high resistance properties against heat and chemicals. These printed tinplates are bended and then used for canning of food. Most important thing is that the inks should have high adhesion properties and should not crack.

Tests are held to understand the properties of these inks and how they differ from the technical data given by the manufacturer. Each batch is controlled and tested to be sure that the customer receives mixed ink with desired colour shade. Adhesion and bending tests are held to determine if this inks are suitable for this particular printing technology. If print houses would introduce these quality tests before the job starts, nonconformities would greatly decrease.

Ananjev Anton. Spausdinimo būdu ant skardos padengto dažų sluoksnio tyrimai. Magistro baigiamasis projektas / vadovas dr. Vaidas Bivainis; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas.

Studijų kryptis ir sritis: Gamybos inžinerija, Technologijos mokslai.

Reikšminiai žodžiai: *Ofsetas, skarda, adhezija, spalva, atspalvis, paviršius, dažai, spaudas.*

Kaunas, 2016. 51 p.

SANTRAUKA

Šiame darbe sukuriamas dažų atspalvis, kurį parinko užsakovas. Pavyzdis buvo skenuotas specialiu prietaisu, dažų formulė buvo sukurta, kad išgauti reikalingą atspalvį ir galiausiai dažai buvo sumaišyti. Šis dažų atspalvis susideda iš keturių komponentų. Spausdinimas vykdomas ant skardos. Šiai dangai specialus ofsetiniai dažai (su aukštomis atsparumo savybėmis nuo temperatūros ir cheminių medžiagų) yra naudojami. Ši skarda yra lankstoma ir naudojama, kaip dangtelis maistui uždaryti. Pats svarbiausias dalykas, tai kad dažai turi turėti aukšta atsparumą nuo trinties ir neskilinėti.

Bandymai atliekami, kad suprasti šių dažų savybes ir kaip savybės skiriasi nuo techninių duomenų lapų, kuriuos pateikia gamintojai. Kiekviena dažų partija yra kontroliuojama, kad užsakovas gautu sumaišytus dažus norimo atspalvio. Trinties ir lenkimo bandymai atliekami, kad nustatyti ar šie dažai tinkami šitam spaudos būdui. Spaustuvės įvesdamos šiuos kokybės bandymus prieš atliekant darbus, žymiai sumažintų neatitikmenų tikimybę.

KAUNAS UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Approved:

Head of ____________________ *(Signature, date)*

Production engineering Department

Kazimieras Juzėnas

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MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme INDUSTRIAL ENGINEERING AND MANAGEMENT

The final project of Master studies to gain the master qualification degree, is research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

Research of ink printed layer on a tinplate

Approved by the Dean Order No.V25-11-7, 3 May 2016

2. Aim of the project

To analyse ink printed layer on a tinplate by making bending, adhesion and colour matching tests.

3. Structure of the project

Scientific research: UV Technology, offset printing inks, properties of inks, migration of inks. **Technological part:** Technical data, ink testing equipment, quality control of colour shade, quality tests. **Experimental part:** Ink printing of tinplate; Colour shade test methods of different ink batches; determination of colour shade deviation; adhesion determination by applying pull-off, cross-cut, X-cut tests; cracks evaluation by applying bending tests;

4. Requirements and conditions

In order to determine colour deviation different batches of mixed ink components should be used, when printing inks on a tinplate. Adhesion tests should be made to determine resistance of surface. Bending of a printed tinplate should be made to determine surface damage.

5. This task assignment is an integral part of the final project

6. Project submission deadline: 2016 05 15.

Given to the student

____

Task Assignment received	Anton Ananjev	________________________
	(*Name, Surname of the Student*)	(*Signature, date*)
Supervisor	dr. Vaidas Bivainis	________________________
	(*Position, Name, Surname*)	(*Signature, date*)

Table of Contents

Introduction

Toyo Ink Group is the third largest ink producer in the world. Toyo has in its range all types of printing inks and coatings: water-based, solvent-based, oil-based, and products, which are dried by UV light. The Toyo Ink Group has selected UV curable inks as one of the product groups that is well positioned for the pursuit of eco-friendly products in its endeavour to achieve a breakthrough for significant future growth. [1] While working in this company, the quality was always controlled and was most required aim. However this project work goes more deeply in examining quality of ink.

The aim of this work to analyse ink printed layer on a tinplate by making bending, adhesion and colour matching tests.

The first task is to select one ink shade. Then reproduce, mix and examine every batch of its components to control its colour shade. This ink is printed on a tinplate for cans, which requires the ink to have high adhesion properties. So the third task is to examine adhesion of ink. Fourth task is to bend the printed tinplate and examine the surface.

1. Scientific research

In this chapter the following fields will be analysed: UV technology, offset printing inks, printing and coating technics.

1.1 UV Technology

The chemistry of UV inks and varnishes

The printing industry, particularly in the letterpress and lithographic fields, has required increasingly faster setting inks with rapid drying and the advantages of reduced spray powder, no set-off, and speedier turn around.

The ultimate in "drying" was achieved with a complete change in the chemistry of ink making, from the use of traditional vegetable oils, a wide variety of oxidisable resins and resin solvent blends, to a UV curable technology. The primary chemistry used throughout the UV graphics sector is referred to as free radical type, where products consist of blends of urethane, epoxy and polyester acrylates with photoinitiators which, when activated by exposure to intense UV light, crosslink virtually instantaneously to form a dry, solid ink film.

Alternatively, a small number of UV curable products that employ a cationic mechanism are also used in the industry. These products are epoxy based, and have specific properties and end uses.

The instant "drying" characteristics of UV products have enabled ink makers to formulate inks and varnishes, which, after printing and exposure to UV light, produce tough-dry print at the delivery. Over the years, much development has taken place in improving the resin technology, the suitability of UV inks and varnishes for various end-uses, and their stability and safer handling.

Printing technology over the same period has seen many improvements in mechanical press design, coupled with better plates and offset blankets. These factors, taken together, have raised customer awareness and demand for quality UV printed products.

It is essential, however, that printers and end-users understand where the advantages and disadvantages of UV systems lie, and that there will always be a role for conventional, oxidation drying ink systems in the market place.

The printer and UV curing

UV has become well established in sheetfed litho carton, roll label letterpress and silk screen printing, and is now expanding rapidly into flexo. The process requires the inclusion of ultra-violet lamps at the end of the printing press after the application of ink or varnish, and sometimes between units on a multicolour press (inter-deck drying). [24]

UV inks have a number of advantages: drying on the press is no longer a problem because the inks are very stable to air exposure; there is no colour change on drying since the ink is dry at delivery; and UV varnishes give a protective and high gloss finish.

As a result of these desirable properties, UV inks find particular use in packaging, and clear UV-cured varnishes and lacquers are employed for general over-printing work, on food cartons, cosmetic cartons, book jackets and labels.

Due to the solvent-free nature of the UV chemistry, there is no evaporation and the infinite press stability allows ink formulators to accommodate most printing processes. Similarly, UV varnishes can be applied by offset litho or by dry offset and letterpress, but, due to the high gloss potential, the main volume of UV varnish is applied through in-line or off-line flexolannilox coater devices. [25]

As the UV market has matured, printers have a wider choice of UV drying systems. The lamp power and design are dictated by press configuration, press speed, substrate and temperature control.

Odour and taint

After initial cure, printed work has a distinctive odour, but, provided the lamps are in good condition and adequate exposure to UV light has occurred, the odour will have virtually disappeared within two days.

Taint from UV inks is extremely low, thus the system is ideal for packaging of foodstuffs, particularly those that have a tendency to absorb flavours such as chocolate and pastry products.

Safety aspects

Skin contact

In the early days of UV curing there were instances of skin irritancy and sensitisation. However, these are now virtually non-existent, particularly where ink makers have avoided materials with higher potential for irritancy, and materials with a known potential to sensitise. [26]

Inhalation

Ink fly or misting is a problem that can apply to many inks, and whilst this has been reduced by modifications to rheological properties, on high-speed printing presses action may be needed to minimise the escape of mist into the workplace atmosphere - mist extraction installations have become simple and practical.

Safety handling

Guidelines have been established in the UK for many years and The Confederation of European Paint, Printing Ink and Artists' Colours Associations (CEPE) has adopted these on a European basis and offers the following safe handling advice based on general experience and commercial practice:

- Refer to suppliers' safety data sheets and take appropriate actions. Seek guidance if necessary.
- Maintain good levels of hygiene and, in particular, clean up spillages immediately as

advised in the safety data sheet. Energy curing systems remain wet until exposed to the appropriate radiation, so spillages and accidental contact can spread.

- All personnel involved in handling and cleaning spillages and equipment should have hand and eye protection.
- Should be avoided prolonged skin contact. In the event of accidental contamination, should be washed with soap and water. It is forbidden to use solvents as they will degrease the skin and possibly promote irritation. In case of severe skin damage, medical advice should be sought. In case of accidental skin contact should be avoided concurrent exposure to the sun or other sources of UV light, which may increase the sensitivity of skin.
- When washing hands, use neutral pH and avoid the use of abrasive materials.
- Protective clothing should provide adequate protection and should be changed immediately if significantly contaminated. All industrial contaminated clothing should be laundered before re-use.
- When splashed into the eyes, it should be washed with water, ensuring that contact lenses are removed.
- It is forbidden to eat, drink and smoke in the immediate area where these products are handled. The hands should be washed before breaks.
- In case of prolonged discomfort, refer to the person responsible for health and safety for the company. [27]

Environmental issues

All UV ink systems use non-renewable resources for their raw materials. Similar levels of energy are required to manufacture most types of printing ink.

Vapour emissions are negligible since the volatile organic compound (VOC) content of UV products is minimal. Since these products are stable until exposed to UV radiation, they do not need to be washed-up so frequently. The emissions of VOC's to atmosphere are thus reduced.

Recycled fibre mills can recover fibres from UV printed paper and board by the flotation method.

Power is required to run UV lamps. This is not necessary with conventional (oxidation drying, quickset) inks, except where hot air is employed to assist the drying of water borne coatings applied in-line, or heat set web-offset inks

1.2 Offset printing inks

Properties of offset printing inks

Offset printing inks are produced for offset presses. The inks should withstand reaction with the press fountain solution and dampened offset plate. The water should not be absorbed by the ink roller. The ink should not mix with it and be transferred to the non-printing areas. Either of these emulsification problems will tend to impair the body, colour, or drying qualities of the ink, or cause tinting on the non-printing areas of the plate and printed sheets. [4]

The offset printing inks used on an offset printing press must be able to carry the full-intended colour and covering power to the paper despite the split-film action. Ink must be able to show its full colour and opacity with this film. [28]

Composition of offset inks

Ink is made of three main ingredients: pigment, which is the colouring substance in the ink; vehicle, which is the liquid that is holding the particles; and modifiers, that is controlling the curing of the ink as well as other factors such as fading, scuff resistance and smell.

Adhesion and anti-adhesion

A fluid movement transmitted to the surface, depend on the temporary external forces. Established phenomena associated with forces of water and heat cannot be explained with the aid of the movement approaches. The movement nature of forces for wetting and drying will not be considered.

Ink transfer in waterless offset printing is used in this study as an example, to offer a new understanding of adhesion. Adhesive strength is concentrated in this study, rather than done by the adhesion of the ink surface of the panel work. Based on the formation of a weak boundary layer and the softening of the surface for the non-image area, it can be suggested that the ink will reject the non-image surface. [5]

The solid surface of a viscous fluid with a movement state, a situation which is common in the ink industry. Since the interaction between the liquid and solid state is still examined, wetting movement phenomena often have to quantify under static conditions using classical theory of wetting and adhesion, the work, the work of adhesion, energy of surface and the contact angle has been investigated.

While the movement approaches are successful in solving problems, under static conditions fixing, they offer limited insight and sometimes false declarations for problems under movement conditions. In some cases, wrong explanation, the result of confusion over the use of classical theories for wetting.

In other cases, erroneous statements were the result of lack of processes understanding, for example in the case of transfer of ink study of the lithographic offset printing mechanism.

This study shows an experimental investigation of adhesion and anti-adhesion - viscous liquids transfer to solid surfaces under movement conditions. On the adhesion of the ink on image area, and in particular to non-image area. The most serious problem in waterless offset printing is the inability of the region, without the image plate effectively reproduce the colour.

A movement work of adhesion approach and the theory of the weak boundary layer, and the results of these studies have split because of the lack of direct evidence. There is another method for recording direct splitting forces ink film from the image and non-image areas for the waterless offset - printing plate. This approach provides opportunities for scientific knowledge about the mechanism of the ink that can be achieved. [29]

This study shows that at high movement state, the surface energy of the solid support and viscous liquid (ink) do not play a dominant role in liquid transfer. This study provides new results that show the soft layer presents on the surface of the non-image area after the contact with the ink. This layer is probably responsible for the failure of the area without the ink image.

The method developed in this study allows for the first time to measure the cohesive strength of the soft layer.

Ink transfer mechanism for waterless offset

Offset printing is a planographic printing. The image and non-image areas on offset printing plate are in the same plane and are physically supported by their different surface characteristics - chemicals. The image area is covered with paint, while the non-image area is free of ink.

The difference between the colours of the transfer and adhesion of conventional technologies is that the time of contact with the ink and the plate is very short. Image or parts of the image should be able to accept or reject the ink.

Traditional research approaches are almost always based on the surface energy, wettability, adhesion work and cohesion. [6] By measuring the contact angle of liquids, it can be concluded that the ink of non-image areas was associated with a low ratio of resistance to acid.

The surface energy of waterless offset plates used are the geometric mean model, in which the work of adhesion was observed as of molecular interactions. The dispersion component of the surface energy of the plate must be greater than that of the ink. It showed that the theory on the surface energy cannot explain the inking of non-image areas. [30]

The observations raise serious doubts about the reliability of all theories based for ink transfer of direct comparison to the surface energy between the plate and ink.

2. Technological part

Offset printing (lithography) - currently one of the most popular technology used in the printing industry. In offset press the mold forming print and intermediate elements are in one plane. Printing elements are hydrophobic (water is not accepted), but accept oil. The spacer element is opposite - hydrophilic.

During printing the printing form passes through the irrigation section where not printed place absorbs special water solution. Then the printing cylinder passes through the paint section where printing elements are covered with an even layer of paint. During printing, it is important to adjust the paint and fluid balance. In case of shortage of fluid intermediate elements may be painted, and vice versa, resulting in reduced print quality.

Paint from the printing form to the printing material lay indirectly, they are transferred with intermediate rubberized cylinders. This gives at least a few advantages:

- Press form can withstand a higher number of prints, because the contact with the softer surface results in less wear.

- Rubberized intermediate cylindrical surface compensates micro and macro cracks in the surface of the printed material.

In this chapter the following fields will be analysed:

Technical data of used inks, ink certificates, testing equipment used, quality control and test methods.

2.1 Technical data of TOYO inks for tinplates

Ink A

CHARACTERISTIC

Inks A show very good adhesion on all possible closed substrates with low odour and low migration properties and are suitable for metal decorating.

PROPERTIES

- Good adhesion;
- Good lamination properties of film;
- Good ‘post-curing’ rate;
- Gloss is good, high strength of colour;
- Formulated without benzophenone;
- Formulated without ITX.

APPLICATION AREA

- Letterpress;

- Wet offset.

UV CURING SPEED (number of lamps - 3, each 120 W/cm)

- 300 meters per minute (9000 sheets/hour);

SUITABLE SUBSTRATES

- High gloss paper and board;
- Hard and soft vinyl (corona treated);
- Coated metals;
- Plastic films that are pre-treated (acetate, polyester);
- PP films that are pre-treated.

Preliminary adhesion tests are recommended.

AVAILABLE COLOUR SHADES

- Process colours;
- Mixing system;
- Opaque white;
- Other colours: on request.

REMARKS

- UV overprint varnish is used to improve scuff resistance for surfaces that are not laminated;
- Cleaning: do not wash the press immediately after printing. Ink A will not cure in the press and is therefore ready to use for the next day's printing.

Ink B

CHARACTERISTIC

Ink B - UV inks for offset printing, which are created for a high-speed equipment.

APPLICATION AREA

- PVC, PP, PE plastics (pre-adhesion test is required before commercial use);
- All kinds of paper and board.

STRENGTHS

- Excellent flexibility.

- Excellent adherence.

- Intense colours.

- It is very easy to match the emulsification.

- Ink B comply with ISO 12647-2 and achieve colour reproduction equivalent to conventional SF printing.

PROPERTIES

- UV drying: 96 W/cm, air cooled, 1 metal-halogen lamp.

AVAILABLE COLOUR SHADES

- Process colours;
- Mixing system;
- Opaque white;
- Other colours: on request.

2.3 Offset ink testing equipment used

The equipment for the tests made is described in this chapter.

2.3.1 Testing equipment IGT C1

Fig. 2.3.1.1. Testing equipment IGT C1 [23]

Offset ink testing equipment IGT C1 is very simple, easy to maintain and is widely used in the world. The testing device used by various industries: cosmetics, hardware, electronics, plastics, packaging, paper, printing ink.

It consist of a section for inks, the printing section where the printing disc can be removed. The inking sections has two aluminium drums with a top roller. The printing disc is covered with ink in 30 seconds and is printed on a substrate in 15 seconds.

2.3.2 UV-drying system AKTIPRINT-Mini

Fig. 2.3.2.1. UV-drying system AKTIPRINT-Mini [22]

Remarks on the operational safety:

Any repair work must only be performed by a skilled, authorized electrician. Maintenance work and UV-tube replacement may be performed by a trained operator, who had been made acquainted with such work.

Unauthorized changes with the UV-system or with parts thereof, removal of covers and of machine plates, improper treatment or unsuitable spares and tools when carrying out repair work imply some risk and with this cancel the right for guarantee claims of any kind.

The UV-system must be run only with the voltage and periodicity which are indicated on the machine plate.

The use of solvent containing lacquers and paints is forbidden. All safety instructions, which are given by the manufacturers, must be obeyed. UV-tubes emit ultraviolet rays between 200 and 400 nm. For this reason, the covers must be closed during the operation. It must be granted that they cannot get loose. The function must be sure.

The UV-rays which are required for the drying process are detrimental to eyes and skin.

Metal covers, windows glass of at least 4mm thickness, close textures, and thick clothing absorb these rays sufficiently.

The used UV-tubes form ozone. Ozone irritates the breathing organisms and in concentrations, which exceed the MAK tolerance value of 0,01 ml/m3 is detrimental to human health. The limit of smell begins already with 0,01 ml/m3. Therefore, it must be observed that the ventilation equipment operates well.

UV-lamps contain quite a lot of mercury. Therefore, avoid any glass break. No amends can be made for broken glass.

Worn UV-tubes must be removed according to the local safety regulations.

Description of UV-dryers and their function

The UV-drying system AKTIPRINT-Mini is used for quick hardening of UV-inks on flat stock and moulded parts.

This UV-system is ready for being connected. It deals, here, with a continuous table printer, which is laid out for continuous operation. Power portion, connection fuse, and connection cables to the power source are lodged in the lamp housing. The UV-tube and the reflector are air-cooled, have a controlled automatic post-cooling unit which works by means of a thermostat. The geometry is laid out for optimal lamp focussing and with this makes sure quick hardening of the applied coating.

The conveying system comprises frames with driving and feed-back shafts, an idler with belt rest, PTFE glass fibre conveyor-belt and a belt section unit. The passage can be set from 12 to 50 mm. In the standard execution, the driving motor is equipped with a belt speed selector from 2,5 to 12 meters per minute. The idler allows quick post adjustment and replacement of the conveyor-belt. In this manner, straight travel of the belt is made.

The UV-system must not be started without closed lamp housing, because screening is required to avoid the escape of rays.

Easy operation and easy maintenance are made sure by optimal modular system.

2.3.3 Colour measuring device “X-Rite”

Fig. 2.3.3.1. Colour measuring device “X-Rite”

In order to determine the colour spectral measurements, these measurements are carried out with help of spectrophotometer, otherwise known as spectrodensitometer. Spectrodensitometer can also perform densitometer measurements. In spectrophotometer, light source is directed perpendicular to the research print, from which reflected by 45º dissipated diffraction grating and is directed to the detector line. In most cases it is measured in the range of 400-700 nm. Experimental measurements were carried out with help of spectrodensitometer "X-Rite”. This multifunctional measuring device is used for checking surface colour shade and manage colour system profiles. Spectral measurements, and measurement data is translated and converted to the corresponding optical density values of colour coordinates.

Spectrodensitometer "X-Rite" design consists of two parts - the base and the measuring head. The measuring head has control buttons and display screen showing functions and measurement data.

Spektrodensitometras turns on with a button. The device shuts off automatically if idle for 5 minutes.

With a fully charged battery can perform up to 10 000 measurements.

Measuring head equipment must be placed on the measurement surface and in seconds screen appears. During measurement, it is important that the device is stable in contact with the measurement surface and there is no gap between it. Since the surface on which the object is placed may influence the measurement results. White base is used for measurements of single-sided printouts and measuring the double-sided - black base. [18]

2.3.4 Elcometer F506-20DC

Fig. 2.3.4.1. Elcometer

The Elcometer 506 are lightweight, portable and easy-to-use adhesion testers. They have a digital gauge and are suitable for measuring the pull-off adhesion of coatings up to 50MPa (7250psi) either on-site, or in the laboratory.

Technical characteristics:

Dolly Diameter: 20mm;

Scale Range: 0- 26MPa;

Operating Range: 2 - 25MPa;

Scale Resolution: 0.01 MPa;

Accuracy: ±1 of full scale;

Power Supply: 2 x AA alkaline dry batteries (rechargeable batteries can be used);

Instrument Weight: 1.8kg;

Kit Weight: 4kg;

Instrument Length: 290mm;

Actuator Height: 20mm skirl fitted.

2.3.5 TQC master paint plate SP3000

TQC master paint plate SP3000 is multifunctional steel measuring tool, with help of which adhesion of the surface can be measured.

Fig. 2.3.5.1. Master paint plate

2.3.6 Tesa 4100, 4104, 4120, 4965 tapes

Fig. 2.3.6.1. “Tesa” tapes

Tesa tapes are used for measuring adhesion of the surface.

Technical characteristics of 4 different tapes are seen in Table 2.3.6.2.

Table 2.3.6.2. Technical characteristics of tapes

	Tape 4100	Tape 4104	Tape 4120	Tape 4965
Backing material	PVC film	PVC film	PVC film	PET film
Total thickness	65 µm	65 µm	49 µm	205 µm
Type of adhesive	Natural rubber	Natural rubber	Natural rubber	Tackified acrylic
Adhesion to steel	2.2 N/cm	2.3 N/cm	2 N/cm	11.5 N/cm
Tensile strength	47 N/cm	60 N/cm	43 N/cm	20 N/cm

2.3.7 Microscope Dino-Lite 9093

Fig. 2.3.7.1. Microscope

Dino-Lite is a multifunctional microscope which helps to check the quality of various surfaces and helps the industrial companies to control the quality of the products. [19]

2.4 Quality control of colour shade

2.4.1 Printing quality

Printing quality depends largely on the preparatory work of postpress process, printing process, printing machines support costs of care and the materials used, for example, paper and inks. Final printed output quality depends on the final process and equipment.

The impression of quality can be described by the original colour reproduction, colour register places, shaded and tone reproduction element of precision and so on.

The print quality is often checked visually. Visual quality control of the lighting and viewing condition must meet certain minimum requirements.

Only instrumental measurements allows to objectively assess print quality.

One of the most important quality characteristics of printing is colour reproduction quality.

Quality control methods

In order to produce the best possible quality products are used special control devices for quality control - densitometers. These devices measure ink reflected light intensity - the main printed output quality indicator. It is also used for measuring optical density.

Universal densitometers measure the optical density, which pass by and are mirrored in the light, it can at the same time measure the optical density values on the film and on the printout. Densitometer with built-in magnifier allows to measure the raster point size.

Print quality control of the printing process uses a densitometer (measuring the optical density of the reflection method), it is necessary for press control. Paint supply printing machine is adjustable for each colour separately, so that each colour has to be achieved by the corresponding optical density values. The elements point deformation degree of measuring, the relative press contrasting elements, paint coverage among the other control fields, grey balance control fields and others. All these factors must meet the standards set by their tolerance. Maximum approach to a standard value is determined by the high quality of its products.

Densitometer control parameters

By controlling the paint supply after the preparatory work, the beginning of the print edition is measured in 100% colour density optical element. Those plots describe optical density of the dye layer thickness, which is on the printout. Using different reflection densitometers, be aware of measurement system characteristics. It depends on a zone of light filter. These filters have different bandwidth zones. Optical density value provided is absolute or measured according to paper. All measurements are usually performed by evaluating optical paper thickness.

In densitometry polarizing filter role is very important. The light is reflected differently from what was printed on a wet surface and from the surface of the paint that has dried up. Dried print optical density is always less than the moistured one. Polarized filters allows you to enter adjustments according to the reflective properties of the surface. This simplifies and speeds up the work, comparison of press results can be made.

Deformation point of raster point

It is very important to control the circulation time of printing raster element in changing size compared to original size in the printing form.

Mechanical deformation depends on the pressure, damping conditions, offset rubber harmonization, paper surface properties.

Densitometer measures and automatically calculates the relative raster element of the area and its increase.

Resolution in the press

Resolution is the ability to transmit the smallest picture element. Resolution is determined by printing special test-objects with varying sizes of black and white elements. It should be noted, that the smallest elements recorded, depend on the element's shape, which is made, developed and used in various death. Resolution is determined visually, searching for least isolated parts. This method is not very accurate in certain subjectivity and does not provide information about higher pixel quality. [31]

Paint coating with each other

When printing colour output on a printing machine, the second and the other inks, printed on already covered ink on the first surface of the layer, thickness is less than it would be on a clean sheet of paper. In this case, ink adhesion on the impression depends on many factors: first printed ink drying degree, viscosity and so on.

If the elements on which are printed two colours, creating binary colours - red, green and blue visually look unnatural. It means that inks are improperly adjusted, and it will be difficult to extract, for example, the body's natural colour.

Colour balance

Cyan, magenta and yellow colour balance is easily checked by the control scale. In the ideal colour balance, printed on top of each other will appear neutral grey. The resulting grey scale shade (reddish, bluish or yellowish) shows mixed raster point increase or uneven coat of paint thickness. When checking grey zone with densitometer, optical densities of all three light filters must be approximately equal.

Deviation of colour tones

Ideal colour - cyan, magenta and yellow (C, M, Y) has a characteristic to absorb full spectrum of one of the areas in the form, passing another. Cyan absorbs red, magenta - green, yellow - blue zone. Densitometer can determine the quality of printing ink according to their spectral characteristics. Major differences between various triad ink spectral characteristics can be a cause of mismatched triad ink printouts. [32]

2.4.2 Colour analyses

L*a*b colour coordinates

Most of the information about the surface would reflect the characteristics of the light provided by the colour characteristics of L * a * b * space. Each colour is described in three sizes: L * - bright, this parameter value determines the total reflective coefficient, which can range from 0 (black paper) of up to 100%, a * - is the coordinate axis of "green-red", which states that positive coordinate value of paper shade tends to redness and negative - to green. b * - is the coordinate axis of "cyan – yellow”, positive coordinates value means that the paper shade tends to yellowness, and negative – to bluish. If a * and b* are equal to 0, then the paper is ideal gray, with no shade. These sizes are calculated from the spectrum, which reflect through the XYZ coordinates using the colorimetric functions, selecting the light source and viewing angle (which is usually the day room light source D50 and a viewing angle of 2º). [33]

Colour of ink

Scanner or digital camera transfers the image information into digital form, all the digital image colour should look exactly the same as the original. If the colours are specially modified monitor production colours must be identical to the on-screen colours. The data about the colours should be displayed on the digital colour printing system so that it would be easy to modify on any print production process.

The colour is the most important feature of them. Since the ink depends mainly on the colour reproduction in CMYK printing, or six colours, including single colours (PANTONE® system). Colour - is a visual sensation, allowing qualitatively distinguish between various spectral composition of the radiation. A person sees only a small part of the spectrum of electromagnetic radiation with a wavelength between 400 and 700 nm.

The colour of object depends on the spectral composition of the reflected light and the intensity. If the light is reflected evenly across the visible spectrum, this object is uncoloured (achromatic) - white, grey or black, if unevenly – coloured.

The same reflection spectrum of objects is always the same colour, but different reflectance spectrum is not necessarily a different colour. For example, colour can be obtained by summing the very different spectrum of light. This is typical not only white, but also in all other colours. Although colour is a sensation, but in order to manage the colour reproduction processes, it is needed to paint and print colours to measure and express them in numbers. Moreover, these figures should allow quantitative assessment of the colour, for example, batch differences.

High-quality colour can be described in words, such as blue, pastel blue and so on. Such definitions are visually, but not quantifiable. Colours are used to measure the characteristics of human colour vision. Human eye senses the colour with cones. There are three types. One are sensitive to spectrum of blue, the second - green, the third - red. When all three cones respond in the same way, a person, depending on the intensity, sees white or grey colour. Without colour shade, there is still one more colour describing size - saturation.

RGB colorimetric system is very convenient, because it uses a real radiation and available in the laboratory. RGB system’s primary colours are red, green and blue.

However, it has drawbacks. It cannot reproduce very saturated colours and it is needed to use negative colour coordinates. Therefore, the RGB system has been upgraded and was designed XYZ colorimetric system. It is based on a realistic, virtual colour, marked with mathematical symbols. They are close to the RGB colours, but is richer. XYZ colour is associated with the RGB colours mathematically.

RGB and XYZ colorimetric colour space is calculated in three-dimension and represented in xyz plane. XYZ system provides the ability to display colour in plane, but does not have information about the colour brightness.

Ellipses size, the axle ratio and direction depends on the starting point position of the chart. This does not indicate that equal distance between two points XY is equal to difference of colour graph and the difference of colour coordinates XYZ system are unlikely to be used to express colour difference because of the colour differences based on the point position. It comes out that the XYZ space and XY graph is not in one colour contrast space. It should be deformed so that all threshold ellipses turn into circles of equal size. This can be done using affinity geometry techniques. Although it is impossible to solve this task perfectly, CIE colorimetric adopted two approximately equal-contrast colour schemes - CIE L * a * b * and CIE L * u * v *.

CIE L * a * b * colorimetric system suitable for colour reproduction with a differential method (printing, colour photography) and CIE L * u * v * - compound (TV). In CIE L * a * b * system XYZ coordinates are changed to other L * a * b * coordinates, which are calculated from the XYZ coordinates.

2.5 Quality control and test methods for adhesion and surface cracking

Adhesion is the grip between two different solids, solid and liquid or immiscible liquid surfaces by particle interaction of bodies. In order to fulfil its function properly, the ink must be sufficiently bonded to the surface.

Control is done by several methods. After any test is done and deviations are found, it is important to figure out the cause of the problem.

There are two main problems:

a) Poor adhesion;

b) Poor cohesion.

Adhesion is always important for the quality of work, so control needs to be carried out in the beginning of printing works.

Adhesion tests:

- Pull-off test
- Cross-cut test
- X-cut test

2.5.1 Pull-off test

This test method covers the laboratory determination of organic coating adhesion to metal substrates by mounting and removing an aluminium stud from the surface of the coating and measuring the force required to break the coating/substrate bond with a tensile tester.

This test method requires that the aluminium stud be adhered directly to the surface of a coated, cured panel.

This test method is used to compare the adhesion of coatings to various metal substrates, thus allowing for a quantitative comparison of various coating/substrate combinations.

An aluminium stud is bonded directly to a coated cured panel. The adhesive is allowed to cure for 2 h at room temperature. The specimen is then subjected to test on a tensile tester equipped with an upper coupling adapter, and a restraining device.

Pull-off test is the most accurate adhesion test, the result are gained in a numeric expression.

Test quality depends on the preparation and materials used. The following test should be made:

- Surface degreasing
- Surface roughing with grinding paper P60, P80;
- Degreasing of the surface once again;
- The glue is applied and the sample is glued to the surface;
- If needed, coated surface around the sample is removed (cut) with a special tool from the complete set;
- The sample is pulled off from the surface.

The sample is pulled with a force not larger than 0.1MPa per second (it is necessary to monitor the data of the testing device). The testing device is rotated and the force is applied till the sample is pulled off. When the sample is pulled off, data is recorded and the surface is examined.

There are three types of results:

a. Adhesion – ink layer is pulled off from the surface or other ink layer (of multi-layer was applied).

b. Cohesion – part of ink layer was pulled off from the same layer.

c. The sample was pulled off from glue, but the ink layer was not damaged.

2.5.2 Cross-cut test

Special tools are used to make different direction cuts on a plane at an angle of 90°.

Table. 2.5.2.1. Technical characteristics of tapes

Surface thickness of ink	Distance between cuts
0-60 µm	1 mm
61-120 µm	2 mm
121-250 µm	3 mm

The thickness of offset printed ink layer are considerably small about 1-3 µm (depends on the quantity of layers). That means 1mm distance between cuts are used, see Table 1. For other industries can be used bigger distances between cuts, which depend on the surface thickness.

When the surface is cut, tape is applied to that place. Within 90 seconds, the tape should be took off at angle closer to 180° and for not more than one second. And the class is selected in accordance to Fig. 2.5.2.2.

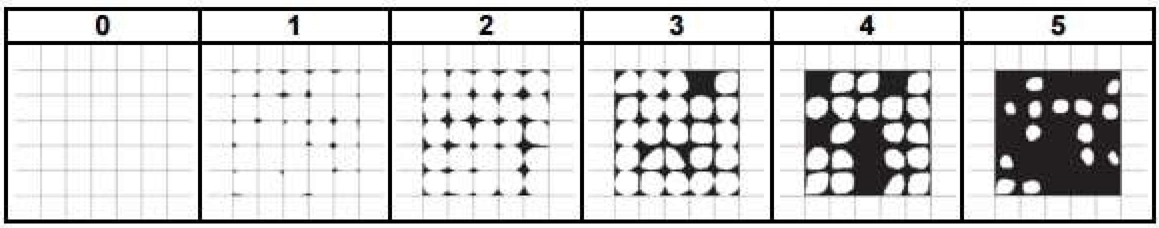

Fig. 2.5.2.2. Classes of visual measurement for cross-cut test Figure.[20]

Class 0: No squares are detached, smooth edges.

Class 1: 5% of the surface is affected, small flakes are detached.

Class 2: Area of affected surface is from 5% to 15%.

Class 3: Area of affected surface is from 15% to 35%.

Class 4: Area of affected surface is from 35% to 65%.

Class 5: Are of affected surface do not fall under above percentage. [20]

2.5.3 X-cut test

A simple way to test the adhesion of the surface using knife and tape.

On painted surface two cuts of 40 mm length are made, the smaller the angle between the bound must be between 30° and 45°. Adhesive tape is pulled off with an angle of 180°. After that the class is selected in accordance to Fig. 2.5.3.1.

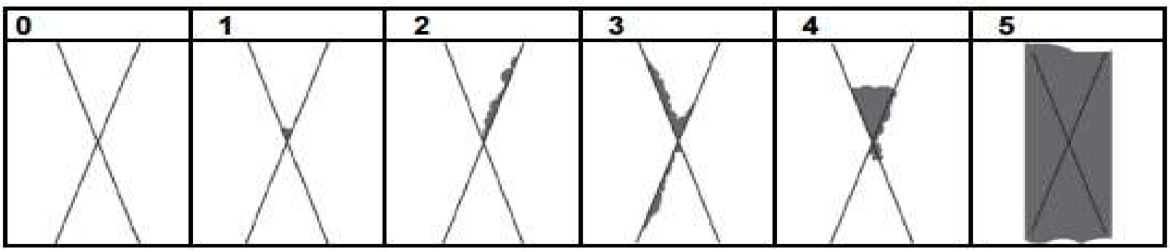

Fig. 2.5.3.1. Classes of visual measurement for cross-cut test. [20]

Level 0: No peeling or removal of coating.

Level 1: Trace peeling or removal along cuts or at their intersection.

Level 2: Jagged removal along cuts, extending up to 1.5 mm out on either side.

Level 3: Jagged removal along most of the length of the cuts, extending up to 3.0 mm out on either side.

Level 4: Removal from most of the area of the X-cut under the tape.

Level 5: Removal of coating beyond the area of the X-cut

3. Experimental part

3.1 Colour shade test methods of single and double layer

The research work with metal surface and mechanical properties change in offset printing inks began after samples were prepared for ongoing experiments. The tests were carried out on the same surface. Initially, all of the surfaces were cut at the appropriate size needed for each measurement. The inks used for the research were from different batches, to determine the quality of inks in the long-run.

In the beginning a sample from the customer was scanned with help of spectrodensitometer “X-rite”. Then the surface was scanned and the information was uploaded to the input program. It was needed to choose the components (inks), which were needed to mix the same ink shade. After that the program determined the formula, and after numerous tests and fixes in the formula the desired shade of ink was chosen.

During experiment the following types of inks were used:

Cyan, Violet, Black and White.

These inks’ quality was always controlled to be certain that the customer receives the same colour during mixing. Each batch of inks were tested separately. In the ink mixing machine “Mix-Graf” with help of precise weighing machine “Sartorius” were mixed the above four inks in accordance to the fixed formula. The inks were printed on a print testing machine “IGT C1”, which performs 3,3 mm wide and 220 mm long prints, and then the samples were archived. All the samples were covered with 2 different layers of mixed ink. These samples with different batch numbers were designated by letters to separate them from each other.

Fig. 3.1.1. Samples of printed inks.

After finishing printing all the samples, optical properties of ink shade were examined. Surface colour and optical properties were investigated with spectrodensitometer "X-Rite" and online program, which includes all the factories produced inks, to make changes to the colour shade, if needed.

3.1.1. Single layer

Wave length of ink, printed with one layer.

The wave length of ink printed tinplate was investigated. Below we can see the obtained data.

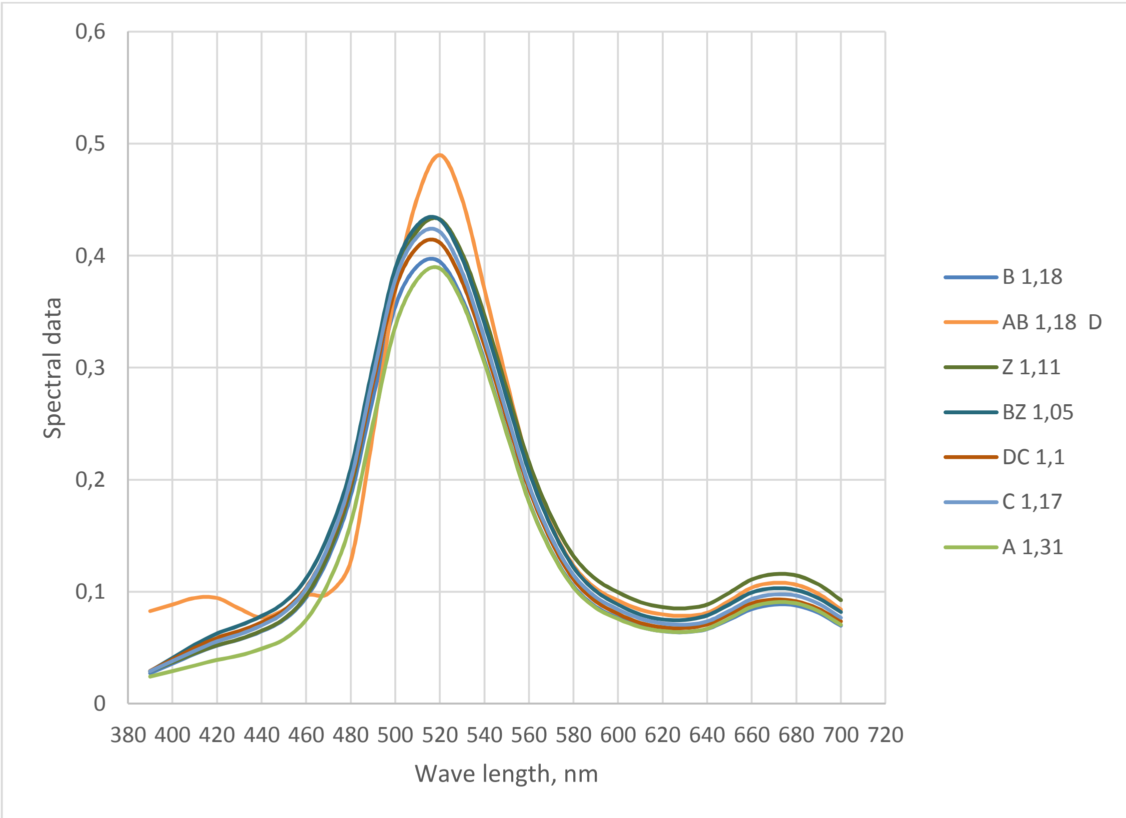

Fig. 3.1.1.1 Wave length of single coated layers

As it seen from the provided graph, the wave length begins from 400 nm and ends at 700 nm. This range is described as visible light, which is seen by human eye.

Ink printed layer "C" is accepted to be the desired shade of ink.

It is seen that spectral data of ink printed layer "AB" greatly differs from the standard point. It is also seen that in range of 515-520 nm the graphs begin to decrease and this is described as a critical point. Below we can see spectral data of wavelength in range of 520 nm and difference between Layer "C", which is a standard and other layers.

Table 3.1.1.2. Table of difference between layer "C" and other layers.

Layer name	Spectral data	Difference
Layer "C" (standard)	0.4211	0.000
Layer "DC"	0.4116	0.010
Layer "BZ"	0.4320	-0.011
Layer "Z"	0.4325	-0.011
Layer "AB"	0.4898	-0.069
Layer "B"	0.3945	0.027
Layer "A"	0.3886	0.033

It is seen that the difference more than 0.02 have layers "AB" (it was also greatly seen from the graph), "B" and "A". Layers "DC", "BZ" and "Z" differ very slightly.

L*a*b parameters of ink, printed with one layer.

In order to compare the difference of ink shade from L*a*b parameters, it is needed to calculate ΔE. The following formula for calculation was used.

$$\Delta E = \sqrt{L^2 + a^2 + b^2} \quad (3.1.1.3)$$

From the parameters gathered, the graph was made.

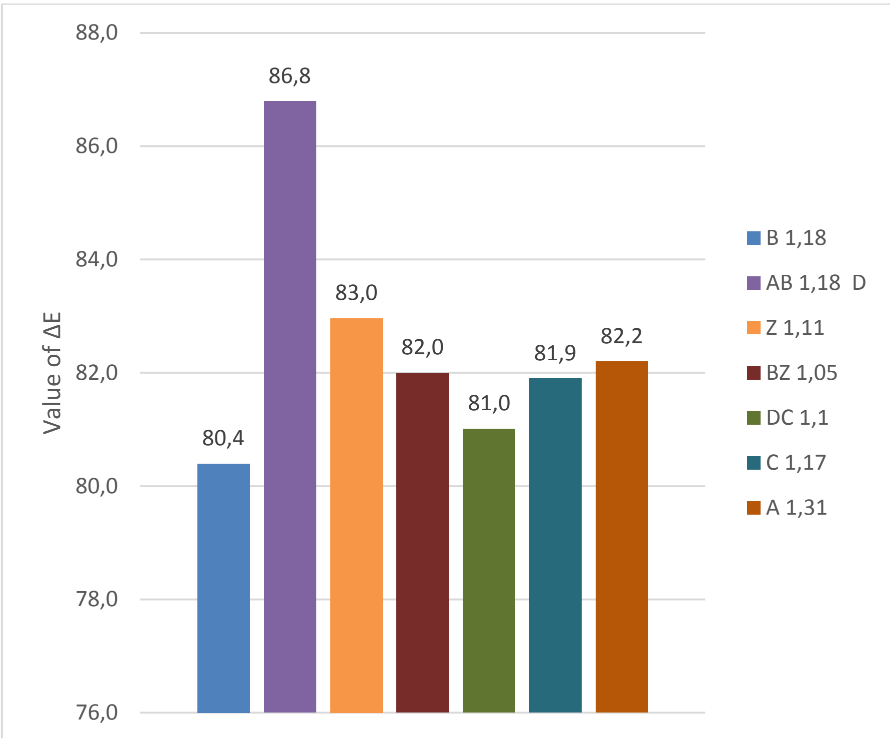

Fig. 3.1.1.3. ΔE parameters of single layer surfaces

It is seen that layer "AB" greatly differs from majority. The wave length of this layer, which was described before, had also the biggest difference.

All the data was written to table below and the difference between layer “C” and other layers was calculated.

Table 3.1.1.4. ΔE difference

Layer name	Value of ΔE	Difference
Layer “C” (standard)	81.9	0.0
Layer “DC”	81.0	0.9
Layer “BZ”	82.0	-0.1
Layer “Z”	83.0	-1.1
Layer “AB”	86.8	-4.9
Layer “B”	80.4	1.5
Layer “A”	82.2	-0.3

The difference of ΔE, which is necessary for the customer is no more than 1. It can be minus or plus. It is seen that layers “Z”, “AB” and “B” do not fall into this range and are not accepted for use. Layers “DC”, “BZ” and “A” differ slightly (fall into the desired range), this means that the colour shade is accepted.

3.1.2 Double layer

Wave length of ink, printed with two layers.

The wave length of ink printed tinplate was investigated. Below we can see the obtained graph.

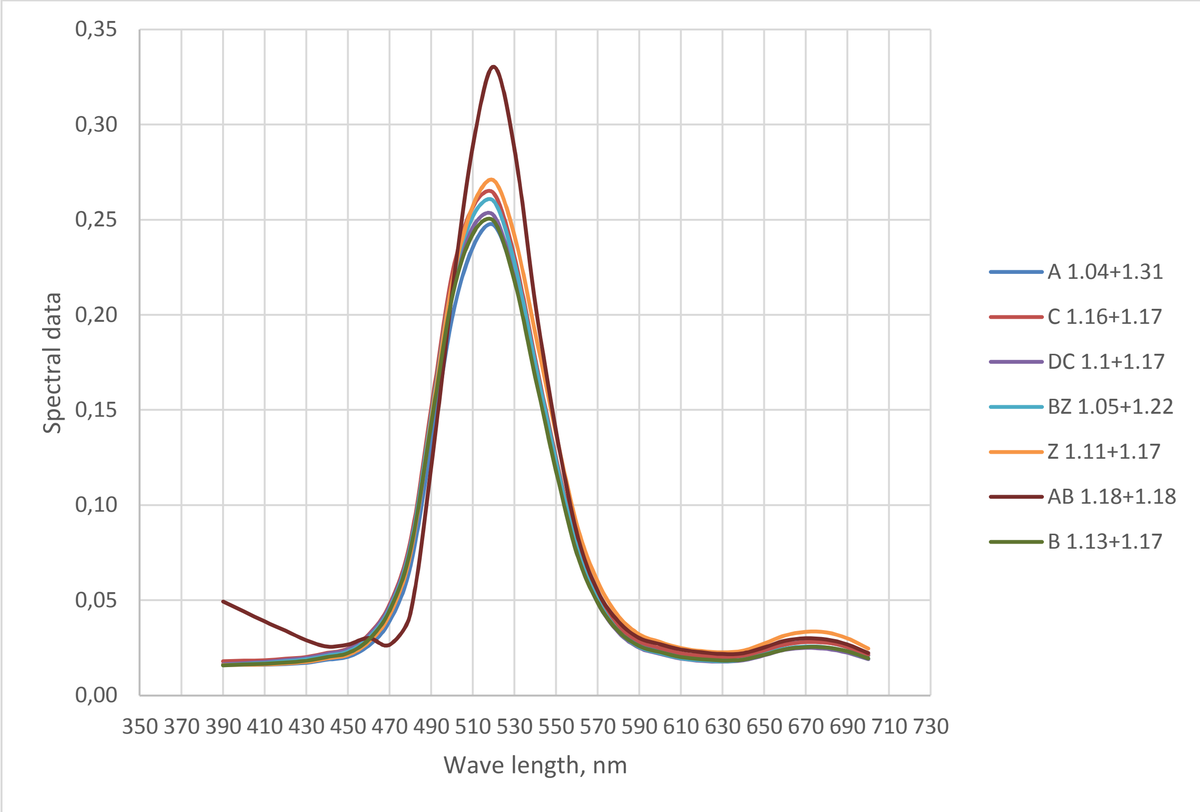

Fig. 3.1.2.1 Wave length of double coated layers

It is seen that layer “AB” has the biggest difference from layer “C”, which is the standard. It is seen that in range of 520nm of wave length the graph begins to decrease. The spectral data was examined at this point and the difference between layer “C” and other layers was written into the table below.

Table 3.1.2.2. Table of difference between layer “C” and other layers.

Layer name	**Spectral data**	**Difference**
Layer “C” (standard)	0.2640	0
Layer “DC”	0.2523	0.012
Layer “BZ”	0.2598	0.004
Layer “Z”	0.2707	-0.007
Layer “AB”	0.33037	-0.066
Layer “B”	0.24933	0.015
Layer “A”	0.24723	0.017

It is seen that layer “AB” differs significantly, however other layers have much less difference if compare with the previous investigation of one layer. It can be concluded that with bigger layer, the ink changes colour, the shade becomes darker and the wave length becomes more similar to layer “C”.

L*a*b parameters of ink, printed with two layers.

In order to compare L*a*b parameters for two layers of ink, which is printed on a tinplate, the formula is used:

$$\Delta E = \sqrt{L^2 + a^2 + b^2} \quad (3.1.2.3)$$

We obtain the following graph.

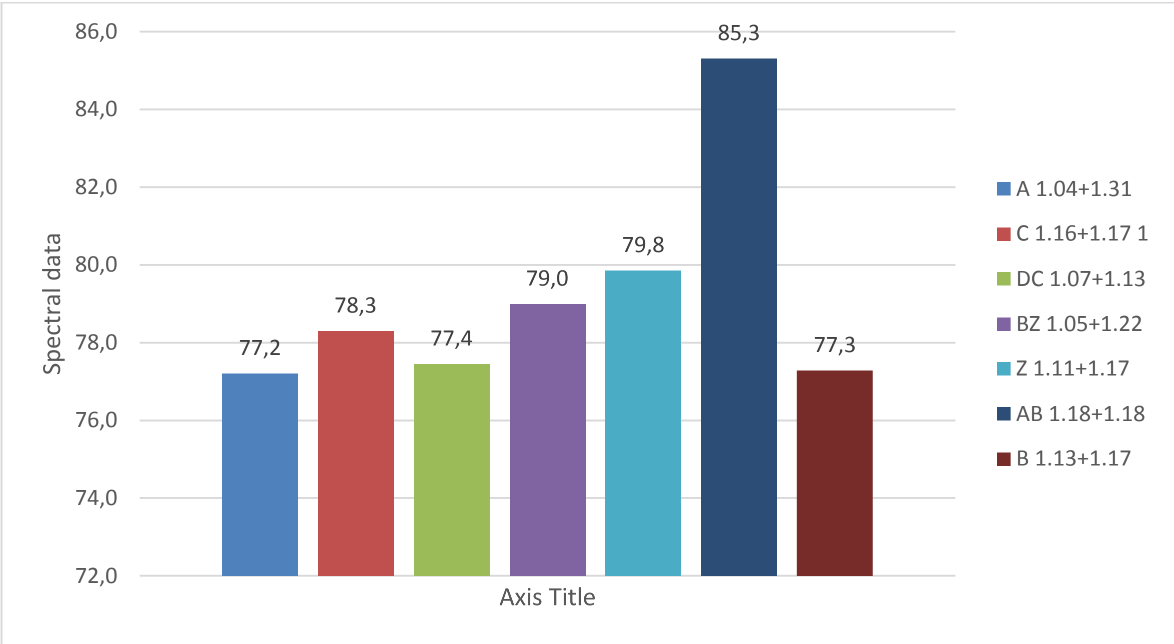

Fig. 3.1.2.3. ΔE parameters of double layer surfaces

Layer "AB" has the most significant difference from layer "C". The data is written to the table below and the difference is calculated.

Table 3.1.2.4. ΔE difference

Layer name	Value of ΔE	Difference
Layer "C" (standard)	78.3	0.0
Layer "DC"	77.4	0.9
Layer "BZ"	79.0	-0.7
Layer "Z"	79.8	-1.5
Layer "AB"	85.3	-7.0
Layer "B"	77.3	1.0
Layer "A"	77.2	1.1

As described before, ink shade difference of ΔE, acceptable by the customer cannot be more than 1. From the table we see that layers "Z", "AB", "B" and "A" do not meet the requirements. Layers "DC" and "BZ" fall into the given range and are accepted by the customer. However it is seen that layers "A" and "B" are out of range very slightly.

3.2 Pull-off experiment of ink, printed with one and two layers.

In this experiment the pull-off experiment will be held, were it will be seen how the layers of printed ink react on applied forces. To pull off the layer “Elcometer F506-20DC” and glue will be required.

The surface of the dolly and the coating is prepared by roughening the abrasive pad in the place where the dolly will be applied. Then both surfaces were degreased and cleaned using a suitable solvent and dried. Then a thin, even layer of glue was applied to the prepared surface of the dolly. The dolly was pressed firmly onto the prepared test surface and pressure to squeeze out access between surfaces was applied.

Fig. 3.2.1. Glued dollies

After the adhesive is cured, the crank handle was turned anti-clockwise to fully unwind. The adjustment screw was also turned anti-clockwise and fully unwound. This turning is used to release the pressure. The pressure gauge was zeroed by holding the reset button, the measurement units (MPa) and dolly size (20 mm) were selected.

Fig. 3.2.2. Zeroed pressure gauge

The quick connect coupling was pulled up and the actuator was placed over the dolly. The coupling was released to grip the dolly.

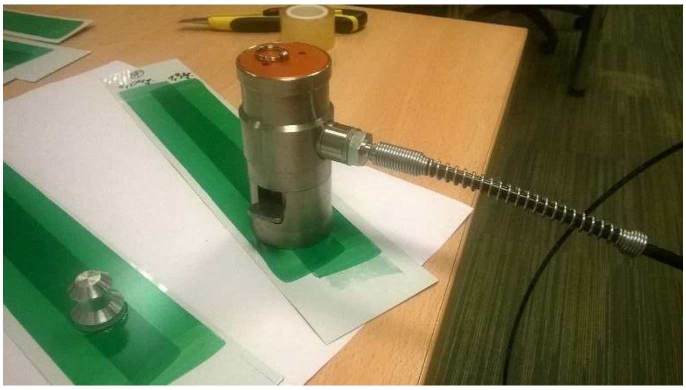

Fig. 3.2.3. The actuator placed over the dolly

The adjustment screw was turned to apply pressure. And it was continued to turn until the dolly is removed from the surface. Then the pressure indicated on the display was recorded, the crank was unwound and the test was repeated.

The minimum force of the two layer surface was obtained, which was 0.21 MPa.

Fig. 3.2.4. Minimum force applied on two layer surface

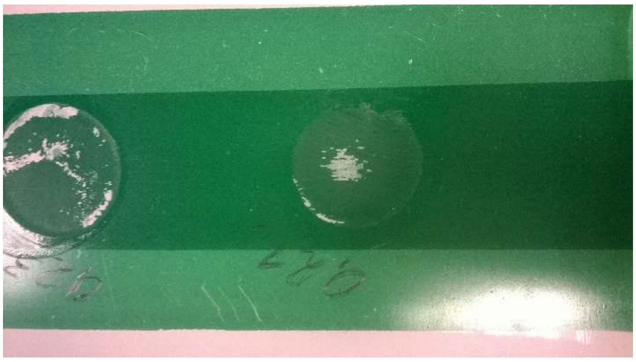

Fig. 3.2.5. Surface after applied force

It is seen that the surface was slightly damaged by applying 0.21 MPa force.

The maximum force of the two layer surface was obtained, which was 0.36 MPa.

Fig. 3.2.6. Maximum force applied on a two layer surface

The coating around the dolly was cut using the dolly cutter.

Fig. 3.2.7. Dolly cutter

The minimum force of the two layer surface cut with dolly cutter was obtained at 0.21 MPa.

The maximum force of the two layer surface cut with dolly cutter was obtained at 0.4 MPa.

The compared results between the ordinary surface and the cut one were approximately the same. And it is concluded that there is no sense to use dolly cutter on such a thin surface. The cutter can play a bigger role when the surface thickness is larger.

The minimum force of the one layer surface was obtained at 0.24 MPa.

The maximum force of the one layer surface was obtained at 0.62 MPa.

It is seen from the results that one layer surface is stronger and the adhesion of the surface depends on the thickness. With help of a microscope “Dino-Lite 9093” the surface is examined more deeply.

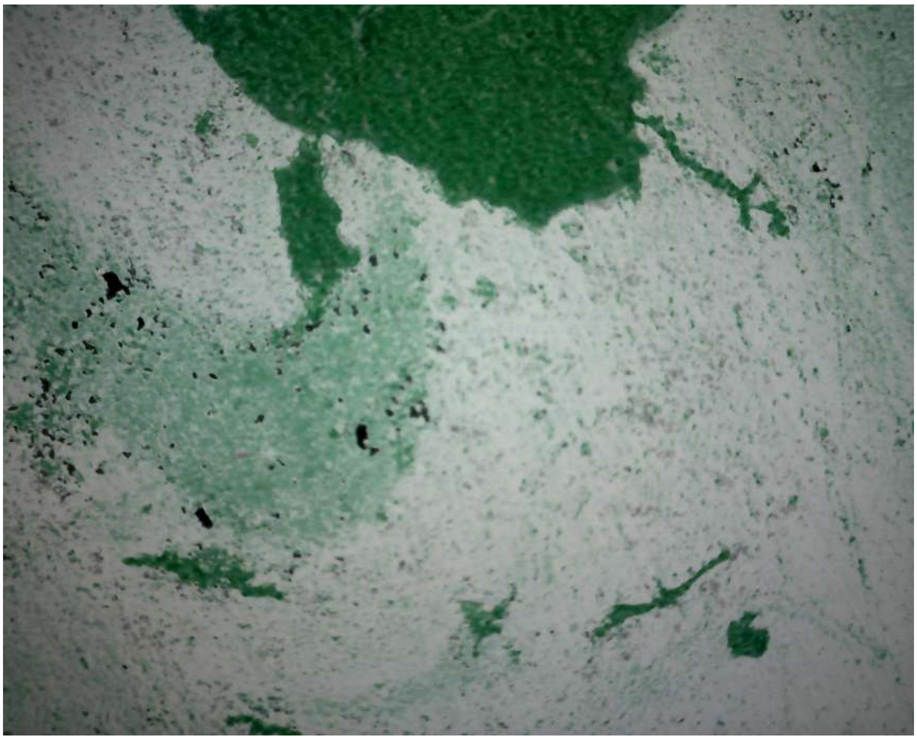

Fig. 3.2.8. Surface of one layer after 0.24 MPa force was applied.

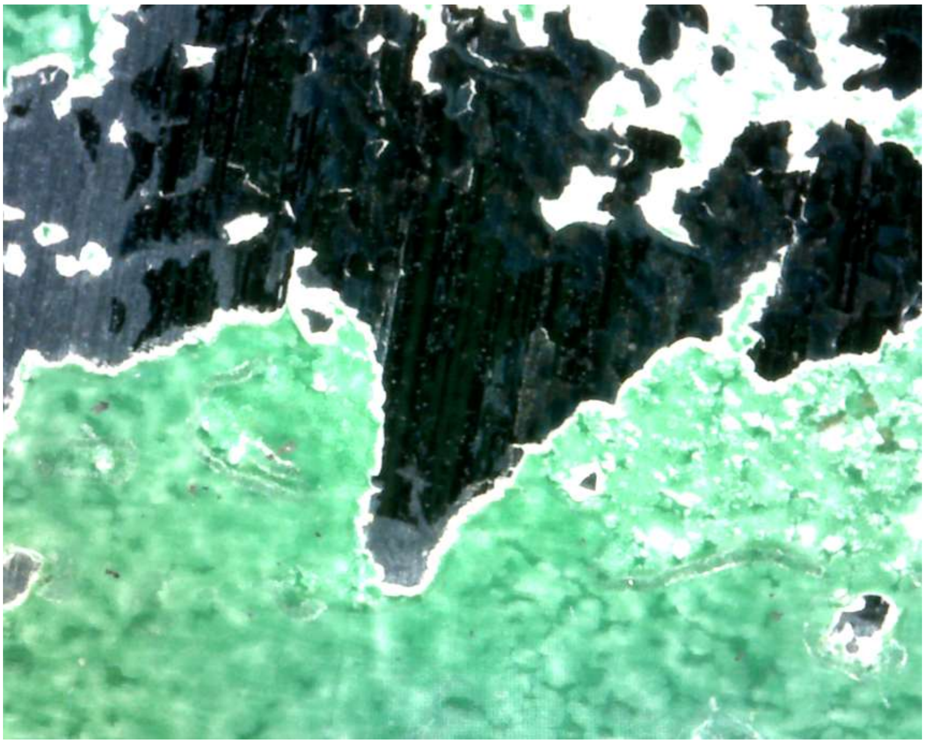

Fig. 3.2.9. Surface of one layer after 0.62 MPa force was applied.

In Fig. 3.2.8. it is seen the surface of one layer after 0.24 MPa force was applied. White colour is seen, which is the coating of metal.

In Fig. 3.2.9. it is seen the surface of one layer after 0.62 MPa force was applied. Black colour is seen, which means that the printed ink and metal coating was pulled off. The ink adhesion properties are so strong, that the coating of metal was also damaged.

3.3 Cross-cut test.

For the next test "TQC master paint plate SP3000", special knife and four different "Tesa" tapes were used.

With help of master plate the surface was cut horizontally and vertically. After what the adhesion was tested.

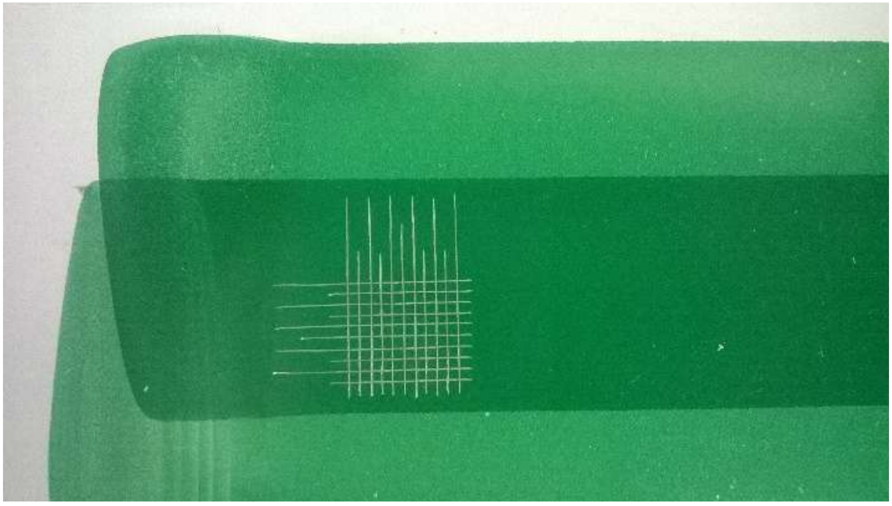

Fig. 3.3.1. The surface is cut horizontally and vertically

After applied tapes, the result is viewed through a microscope, as visually there was no damage.

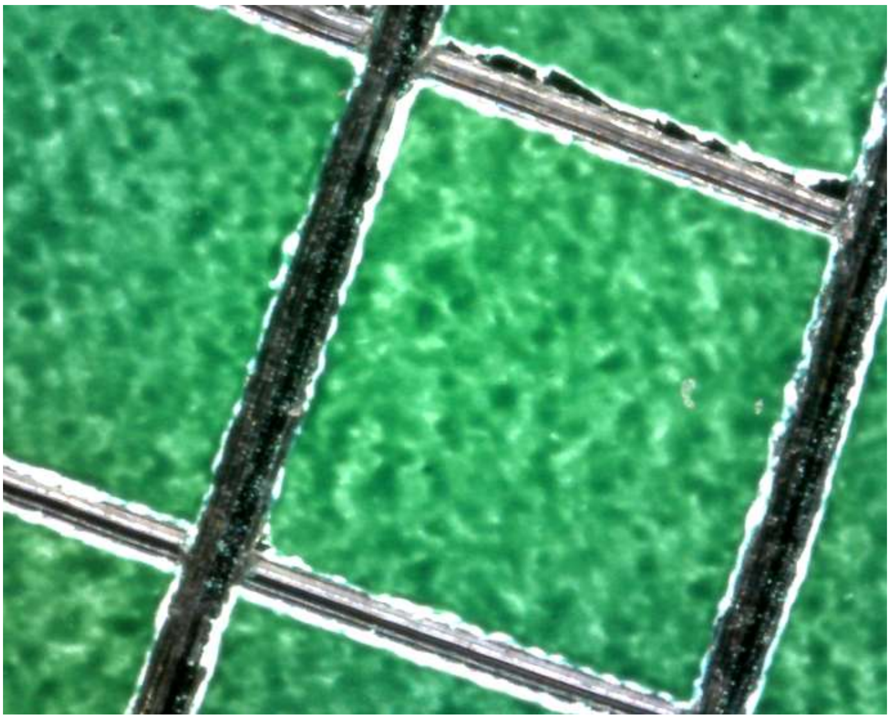

Fig. 3.3.2. Microscope result of cross-cut test

From the result, which is seen through the microscope, it can be concluded that the surface has perfect adhesion properties. In accordance with paragraph 3.2, figure 3.2.1, class 0 is determined, as there are no damage seen.

3.4 X-cut test.

With the same equipment another cross-cut test was done. The surface was cut in accordance to Figure. 5 and four “Tesa” tapes were applied.

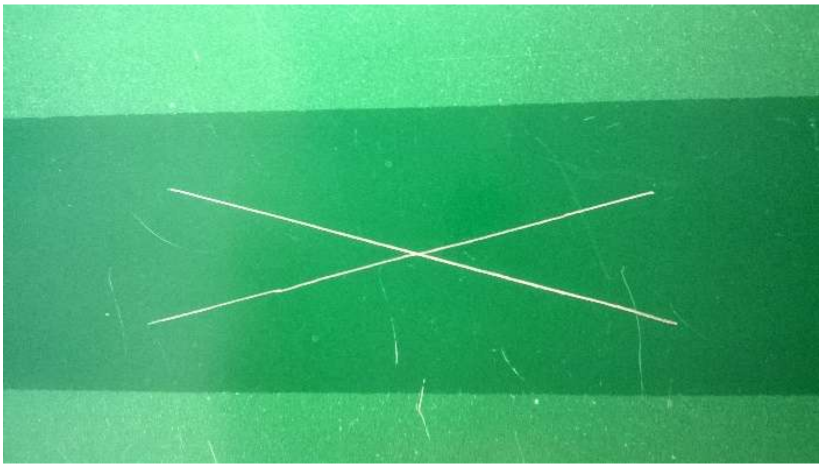

Fig. 3.4.1. X-cut test

Visually there was no damage seen and the result was viewed through the microscope.

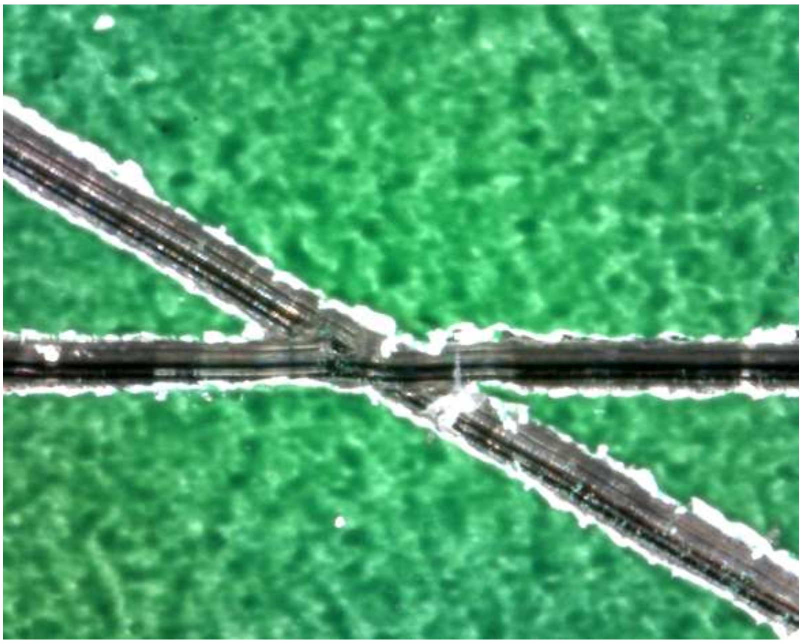

Fig. 3.4.2. Microscope result of X-cut test

From the result in Fig. 3.4.2, it can be concluded that there is also no damage done to the surface and the adhesion properties of provided ink are perfect. Level 0 is selected for this surface (best result).

3.5 Bending test.

The printed tinplate was bended by almost 180 degrees and examined with help of a microscope.

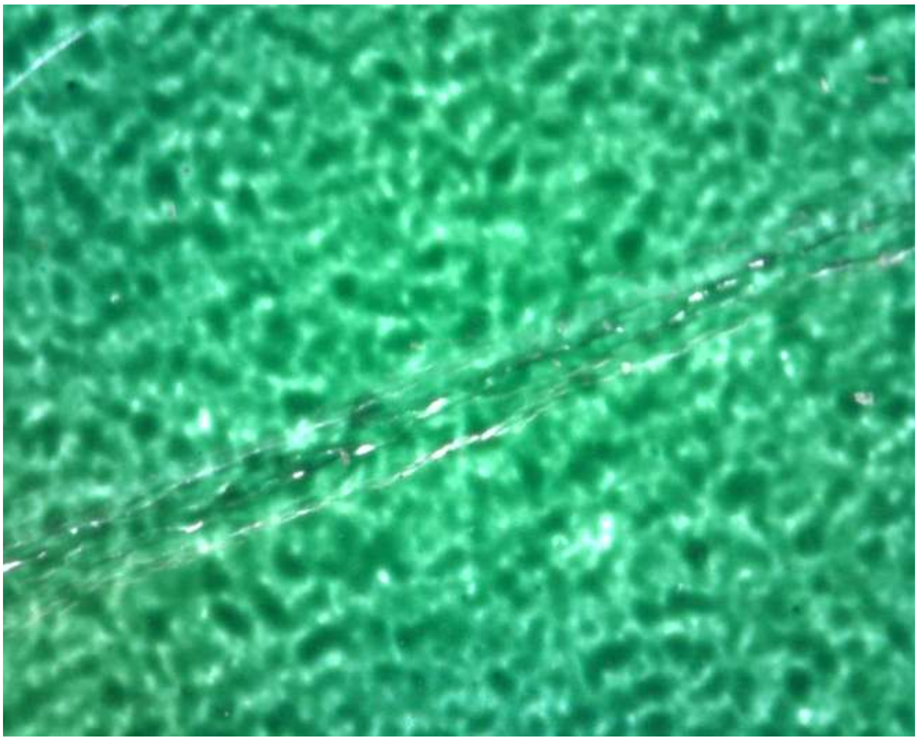

Fig. 3.5.1. Tinplate bended by 180 degrees.

Another printed tinplate was bended by 90 degrees and examined with help of a microscope.

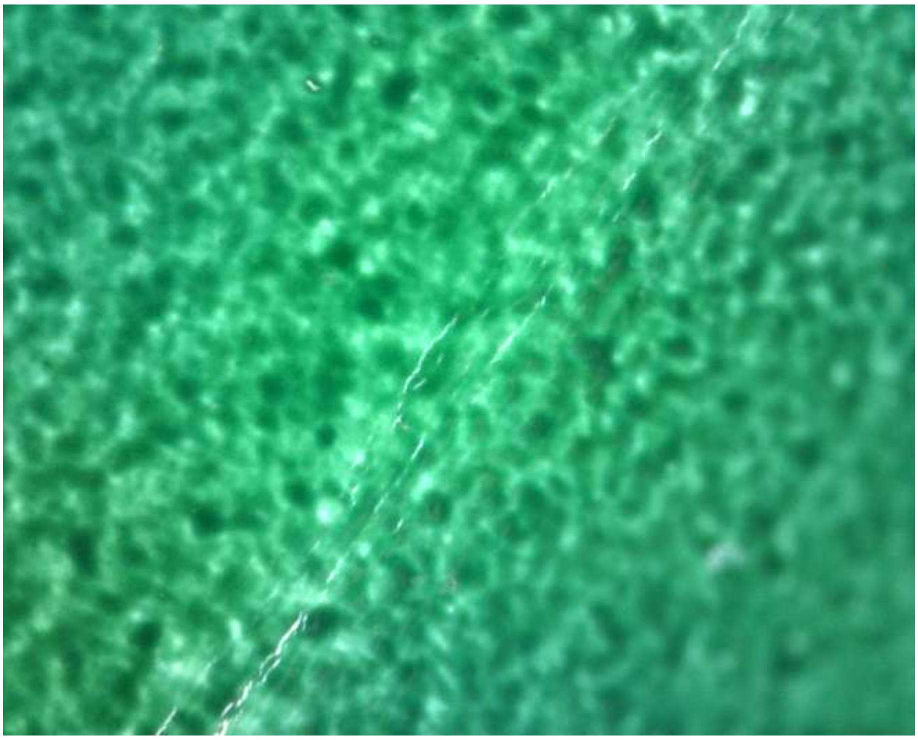

Fig. 3.5.2. Tinplate bended by 90 degrees.

From Figure. 3.5.1. and Figure. 3.5.2. it is seen that both ink layers were cracked after bending by 90 and 180 degrees. The inks are not elastic enough to be bended in accordance with sharp angle. That is why the angles of the caps for cans have no sharp angles and are bended more roundly.

4. Economic analysis

4.1 Business philosophy

Company’s values:

- Long-standing;
- Production traditions of eco-friendly UV inks;
- Reasonable product prices;
- Qualified staff;
- High-quality products;
- Large attention to customers.

4.2 Quality control of the company

The company focuses on the quality of products, since it is one of the most important product characteristics that influence company's reputation. The inks are produced in the factory, the tests are made, then packed and shipped to the subsidiaries to sell them to customers. In the subsidiaries most problematic inks are checked for colour shade deviation and adhesion properties.

The company also achieved quality management system in accordance with EN ISO: 9001: 2008.

4.3 Exports analysis

Export is considered one of the strategic directions of the development of Lithuanian industry as the domestic market is not large. However through exports can be sustained economic growth, this form of promotion of international business remains one of the most important factors in the development of Lithuanian industry. International companies have an advantage in planning, implementing and managing its operations globally. Where possible, companies simply do not pay attention to the traditional market boundaries and enable a foreign market opportunities, gain advantage over their competitors.

4.4 Analyses of ink manufacturing companies

Table 4.4.1. Turnover of companies in 2014. [21]

Position	Company name	Turnover in 2014
1	DIC/Sun Chemical	$3.55B
2	Flint Group	$2.90B
3	Toyo Ink	$1.44B
4	Sakata INX	$1.34B
5	Siegwerk Group	$1.33B
6	Huber Group	$1.08B
7	T&K Toka	$500M
8	Tokyo Printing Ink	$478M
9	SICPA	$400M
10	Fujifilm North America	$375M

As it is seen from the table 4.4.1, Toyo Ink was on the third place according to turnover in 2014. The 1.44 Billion dollars was achieved by expanding its' business around the world. Arets Graphics N.V was bought in 2013, a leading UV ink manufacturer to develop UV inks and varnishes for food packaging. With its eco-friendly products and Toyo Ink experience in handling large business this group have all the chances to grow and expand their business even more.

Recommendation.

In order to achieve high quality standard, respect and loyalty from the customers, it is necessary to implement this kind of tests in print houses before the beginning of each job. Otherwise, print houses will not gain stable growth. There will be a risk of losing a client, whose respect is very tough to return. The doors can be closed for your co-operation with a client for ten years and more, it greatly depends on the politics established by the specific client. It is very useful to be one step forward and forecast the problems, before they occur.

Conclusions.

1. Obtained results of two layers are compared with spectral parameters of one layer. As can be seen layers “Z”, “AB” and “B” in both experiments were out of acceptable range, but layer “A” has a slight difference in two layer experiment only, which cannot be omitted during the quality procedure. Layers “DC” and BZ passed the test.

2. In pull-off test were found minimum and maximum applied force from the result of which it is concluded that the layer was pulled from the surface, i.e. adhesion. However from the surface were maximum force was applied it is seen slight cohesion (the damage of particles in the same surface). It is concluded that the layer is too thin to see very clear damage caused by cohesion.

The compared results between the ordinary surface and the cut one were approximately the same. And it is concluded that there is no sense to use dolly cutter on such a thin surface. The cutter can play a bigger role when the surface thickness is larger.

3. From cross-cut and x-cut tests it is concluded that the surface adhesion properties are perfect. For both tests the damage made to the surface is assigned to class 0 (no damage). Compared with technical data sheets of inks, the surface adhesion properties are confirmed and this inks are suitable for offset printing on tinplates.

4. The inks are not elastic enough to be bended in accordance with sharp angle. That is why the angles of the caps for cans have no sharp angles and are bended more roundly.

5. Toyo Ink was on the third place according to turnover in 2014. The 1.44 Billion dollars was achieved by expanding its’ business around the world. Arets Graphics N.V was bought in 2013, a leading UV ink manufacturer to develop UV inks and varnishes for food packaging. With its eco-friendly products and Toyo Ink experience in handling large business this group have all the chances to grow and expand their business even more.

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APPENDICES

Spectrophotometer colour data

Colour Name		CIE Lab	
B 1,18 1	52,87	-56,46	22,05
B 1,18 2	53,34	-55,73	21,92
B 1,18 3	52,87	-56,53	22,32
B 1,06 1	54,82	-54,36	21,1
B 1,06 2	54,66	-54,38	20,99
B 1,06 3	54,04	-55,06	21,29
B 1,06+1.18 1	39,25	-62,28	23,54
B 1,06+1.18 2	39,49	-61,11	22,95
B 1,06+1.18 3	39,3	-61,85	23,4
B 1.17 1	53,08	-56,89	22,74
B 1.17 2	39,06	-61,07	23,02
B 1.17 3	39,14	-62,21	23,66
B 1.13 1	53,43	-55,72	22,05
B 1.13 2	53,97	-54,96	21,65
B 1.13 3	53,45	-55,95	22,12
B 1.13+1.17 1	38,83	-62,99	23,95
B 1.13+1.17 2	39,3	-61,47	23,2
B 1.13+1.17 3	39,45	-62,35	23,72
AB 1.18 K 1	56,62	-59,44	28,06
AB 1.18 K 2	56,38	-59,4	27,91
AB 1.18 K 3	55,92	-59,55	27,92
AB 1.18 D 1	56,51	-60	28,44
AB 1.18 D 2	56,77	-59,35	28,09
AB 1.18 D 3	57,29	-58,49	27,59
AB 1.18+1.18 1	42,55	-67,43	29,39
AB 1.18+1.18 2	42,58	-67,47	29,44
AB 1.18+1.18 3	42,91	-68,08	30,05
AB 1.3 1	54,01	-63,17	29,2
AB 1.3 2	54,71	-61,92	28,38
AB 1.3 3	54,29	-62,99	29,1
AB 1.24 1	55,11	-60,63	28,18
AB 1.24 2	55,82	-59,42	27,59
AB 1.24 3	56,03	-59,68	27,86
AB 1.3+1.24 1	41,48	-66,72	28,41
AB 1.3+1.24 2	41,57	-66,61	28,32
AB 1.3+1.24 3	41,68	-67,59	28,86
Z 1.11 1	56,62	-54,58	26,23
Z 1.11 2	56,09	-55,09	26,46
Z 1.11 3	55,85	-55,33	26,75
Z 1.17 1	55,31	-55,6	26,7
Z 1.17 2	55,22	-55,81	26,92
Z 1.17 3	55,75	-55,08	26,76
Z +1.11+1.17 1	40,86	-62,92	27,47
Z +1.11+1.17 2	41,41	-62,41	27,42
Z +1.11+1.17 3	41,69	-62,39	27,41
BZ 1.05 1	55,43	-56,52	22,06
BZ 1.05 2	56,13	-55,49	21,61
BZ 1.05 3	55,4	-56,32	21,92

BZ 1.22 1	54,55	-57,1	22,52
BZ 1.22 2	54,21	-56,53	22,01
BZ 1.22 3	54,19	-56,77	22,29
BZ 1.05+1.22 1	39,72	-64,35	24,36
BZ 1.05+1.22 2	40,17	-63,28	23,75
BZ 1.05+1.22 3	39,7	-63,82	24,02
DC 1.1 1	54,04	-56,78	21,7
DC 1.1 2	54,57	-55,89	21,33
DC 1.1 3	53,8	-56,26	21,39
DC 1.17 1	53,58	-56,34	21,45
DC 1.17 2	53,44	-56,2	21,3
DC 1.17 3	53,43	-56,57	21,5
DC 1.1+1.17 1	39,2	-62,49	22,7
DC 1.1+1.17 2	39,35	-62,39	22,63
DC 1.1+1.17 3	39,49	-63,37	23,15
DC 1.13 1	53,61	-56,87	21,72
DC 1.13 2	54,32	-55,79	21,17
DC 1.13 3	52,62	-57,03	21,7
DC 1.07 1	54,67	-54,31	20,58
DC 1.07 2	55,05	-54,96	20,9
DC 1.07 3	54,94	-55,39	21,08
DC 1.07+1.13 1	38,7	-63,12	22,98
DC 1.07+1.13 2	39,37	-62,71	22,82
DC 1.07+1.13 3	38,88	-62,83	22,82
C 1.16 1	55,25	-56,47	22,6
C 1.16 2	55,02	-56,54	22,54
C 1.16 3	54,11	-57,05	22,71
C 1.17 1	54,79	-57,1	22,74
C 1.17 2	54,81	-56,57	22,51
C 1.17 3	54,45	-56,29	22,34
C 1.16+1.17 1	40,44	-62,75	23,93
C 1.16+1.17 2	40,02	-62,41	23,63
C 1.16+1.17 3	40,47	-63,14	23,88
A 1.04 1	56,11	-54,24	25,79
A 1.04 2	55,81	-54,26	25,69
A 1.04 3	55,42	-54,99	26,1
A 1.31 1	52,45	-57,4	26,84
A 1.31 2	53,36	-56,37	26,45
A 1.31 3	52	-57,86	27,01
A 1.04+1.31 1	39,02	-61,75	25,86
A 1.04+1.31 2	39,51	-60,76	25,44
A 1.04+1.31 3	39,26	-61,48	25,64

	Wave length, nm									
Colour Name	390	400	410	420	430	440	450	460	470	480
B 1,18 1	0,0271	0,0355	0,0439	0,0514	0,0568	0,064	0,0743	0,0939	0,1298	0,1845
B 1,18 2	0,0281	0,0372	0,0463	0,0542	0,0597	0,0669	0,0774	0,0973	0,1336	0,1886
B 1,18 3	0,0267	0,0349	0,0431	0,0505	0,0559	0,0631	0,0733	0,0928	0,1288	0,1837
B 1,06 1	0,0303	0,0411	0,0519	0,0614	0,0681	0,0765	0,0885	0,1102	0,1495	0,2072
B 1,06 2	0,0302	0,0411	0,052	0,0614	0,0679	0,0762	0,088	0,1096	0,1487	0,2061
B 1,06 3	0,0296	0,0394	0,0492	0,0578	0,064	0,072	0,0833	0,1044	0,1424	0,1989
B 1,06+1.18 1	0,0158	0,0161	0,0164	0,0171	0,018	0,0201	0,0224	0,0298	0,0455	0,0773
B 1,06+1.18 2	0,0172	0,0177	0,0182	0,0191	0,02	0,022	0,0244	0,0318	0,0477	0,0795
B 1,06+1.18 3	0,0163	0,0165	0,0167	0,0175	0,0184	0,0206	0,0229	0,0303	0,0461	0,0778
B 1.17 1	0,0259	0,0342	0,0425	0,0499	0,0554	0,0627	0,0729	0,0924	0,1284	0,1835
B 1.17 2	0,0171	0,0175	0,0179	0,0187	0,0196	0,0215	0,0235	0,0305	0,0452	0,0759
B 1.17 3	0,0156	0,016	0,0164	0,0172	0,0181	0,0201	0,0223	0,0293	0,0442	0,0754
B 1.13 1	0,0279	0,037	0,0461	0,0541	0,0599	0,0673	0,0776	0,0972	0,1334	0,1885
B 1.13 2	0,0291	0,0391	0,0491	0,0578	0,0638	0,0715	0,0822	0,1022	0,139	0,1945
B 1.13 3	0,0274	0,0365	0,0456	0,0537	0,0595	0,0669	0,0774	0,0972	0,1334	0,1885
B 1.13+1.17 1	0,0144	0,0148	0,0152	0,0159	0,0167	0,0186	0,0206	0,0276	0,0426	0,0738
B 1.13+1.17 2	0,0168	0,0172	0,0176	0,0184	0,0194	0,0214	0,0235	0,0306	0,046	0,0776
B 1.13+1.17 3	0,0163	0,0166	0,0169	0,0176	0,0185	0,0205	0,0226	0,0298	0,0454	0,0775
AB 1.18 K 1	0,0816	0,0876	0,0936	0,0935	0,084	0,076	0,0823	0,0951	0,0967	0,1251
AB 1.18 K 2	0,0818	0,0874	0,093	0,0927	0,0833	0,0755	0,0817	0,0944	0,0958	0,1239
AB 1.18 K 3	0,0808	0,0859	0,091	0,0904	0,0811	0,0733	0,0794	0,0917	0,0928	0,1203
AB 1.18 D 1	0,0809	0,0862	0,0915	0,0911	0,0817	0,0739	0,0802	0,093	0,0946	0,1231
AB 1.18 D 2	0,0825	0,0882	0,0939	0,0938	0,0843	0,0764	0,0831	0,0962	0,0976	0,126
AB 1.18 D 3	0,0848	0,0914	0,098	0,0984	0,0889	0,0809	0,0877	0,1011	0,1033	0,1323
AB 1.18+1.18 1	0,049	0,044	0,039	0,0343	0,0292	0,0258	0,0268	0,0303	0,0267	0,0429
AB 1.18+1.18 2	0,0496	0,0443	0,039	0,0341	0,0291	0,0259	0,0269	0,0302	0,0266	0,0428
AB 1.18+1.18 3	0,0493	0,0439	0,0385	0,0336	0,0285	0,0253	0,0264	0,0299	0,0265	0,0432
AB 1.3 1	0,0751	0,0758	0,0765	0,074	0,0655	0,0594	0,0653	0,0769	0,0773	0,1043
AB 1.3 2	0,0775	0,0798	0,0821	0,0803	0,0718	0,0654	0,0715	0,0832	0,0841	0,1115
AB 1.3 3	0,0756	0,0768	0,078	0,0756	0,0671	0,061	0,067	0,0786	0,079	0,1061
AB 1.24 1	0,08	0,0827	0,0854	0,0837	0,0747	0,0678	0,0743	0,0866	0,0877	0,115
AB 1.24 2	0,0824	0,0865	0,0906	0,0896	0,0805	0,0734	0,08	0,0927	0,0943	0,1221
AB 1.24 3	0,0828	0,0867	0,0906	0,0895	0,0804	0,0733	0,08	0,0928	0,0945	0,1228
AB 1.3+1.24 1	0,0493	0,0436	0,0379	0,0329	0,0282	0,0253	0,0262	0,0293	0,0257	0,0411
AB 1.3+1.24 2	0,05	0,0443	0,0386	0,0335	0,0287	0,0256	0,0265	0,0296	0,0261	0,0417
AB 1.3+1.24 3	0,0487	0,0431	0,0375	0,0325	0,0276	0,0246	0,0255	0,0288	0,0253	0,0413
Z 1.11 1	0,0296	0,0381	0,0466	0,0544	0,0602	0,0681	0,079	0,1	0,1383	0,1975
Z 1.11 2	0,0287	0,0366	0,0445	0,0518	0,0573	0,0648	0,0753	0,0957	0,1333	0,1917
Z 1.11 3	0,0289	0,0363	0,0437	0,0505	0,0556	0,0628	0,073	0,0931	0,1301	0,1881
Z 1.17 1	0,0281	0,035	0,0419	0,0484	0,0535	0,0607	0,0705	0,0901	0,1264	0,1835
Z 1.17 2	0,0264	0,0335	0,0406	0,0472	0,0522	0,0592	0,0692	0,0888	0,1252	0,1824
Z 1.17 3	0,0276	0,0351	0,0426	0,0496	0,0549	0,0623	0,0726	0,0927	0,1297	0,1874
Z +1.11+1.17 1	0,0151	0,0153	0,0155	0,0161	0,0168	0,0185	0,0202	0,0267	0,0404	0,0714
Z +1.11+1.17 2	0,0166	0,0166	0,0166	0,0171	0,0179	0,0197	0,0215	0,0283	0,0427	0,0746
Z +1.11+1.17 3	0,0163	0,0165	0,0167	0,0173	0,0182	0,0201	0,0222	0,0293	0,044	0,0762
BZ 1.05 1	0,0281	0,0397	0,0513	0,0611	0,068	0,0765	0,088	0,1094	0,1481	0,2066
BZ 1.05 2	0,0307	0,043	0,0553	0,0659	0,0732	0,082	0,0942	0,1163	0,1557	0,2146
BZ 1.05 3	0,029	0,0403	0,0516	0,0614	0,0682	0,0767	0,0884	0,1099	0,1487	0,2072

BZ 1.22 1	0,0276	0,0377	0,0478	0,0566	0,0627	0,0706	0,0813	0,1018	0,139	0,1962
BZ 1.22 2	0,0296	0,0393	0,049	0,0575	0,0635	0,0712	0,0818	0,1018	0,1385	0,1946
BZ 1.22 3	0,0283	0,0379	0,0475	0,0559	0,0621	0,07	0,0806	0,1007	0,1374	0,1936
BZ 1.05+1.22 1	0,0151	0,0156	0,0161	0,0169	0,0179	0,0199	0,022	0,0292	0,0444	0,0765
BZ 1.05+1.22 2	0,017	0,0175	0,018	0,019	0,0201	0,0222	0,0245	0,0319	0,0475	0,0799
BZ 1.05+1.22 3	0,0157	0,0163	0,0169	0,0177	0,0187	0,0206	0,0227	0,0298	0,045	0,077
DC 1.1 1	0,0289	0,0388	0,0487	0,0574	0,0635	0,0712	0,0818	0,1019	0,1387	0,1951
DC 1.1 2	0,0305	0,0412	0,0519	0,0611	0,0674	0,0753	0,0863	0,107	0,1444	0,201
DC 1.1 3	0,0286	0,0389	0,0492	0,0581	0,0641	0,0716	0,082	0,1017	0,1381	0,1937
DC 1.17 1	0,0292	0,0387	0,0482	0,0566	0,0626	0,0702	0,0805	0,1002	0,1365	0,1919
DC 1.17 2	0,0299	0,0393	0,0487	0,0569	0,0626	0,07	0,0805	0,1001	0,136	0,1909
DC 1.17 3	0,0287	0,0381	0,0475	0,0556	0,0615	0,069	0,0794	0,0992	0,1354	0,1908
DC 1.1+1.17 1	0,0166	0,0172	0,0178	0,0188	0,0198	0,0219	0,0242	0,0315	0,0466	0,0779
DC 1.1+1.17 2	0,0169	0,0175	0,0181	0,0191	0,0202	0,0224	0,0247	0,032	0,0473	0,0788
DC 1.1+1.17 3	0,0156	0,0162	0,0168	0,0179	0,0191	0,0213	0,0236	0,0311	0,0471	0,0795
DC 1.13 1	0,0274	0,037	0,0466	0,0549	0,061	0,0686	0,0791	0,0992	0,1363	0,1927
DC 1.13 2	0,0317	0,0416	0,0515	0,0603	0,0665	0,0744	0,0852	0,1058	0,1437	0,2008
DC 1.13 3	0,0267	0,0355	0,0443	0,0521	0,0576	0,0648	0,0745	0,0935	0,1286	0,1826
DC 1.07 1	0,0313	0,0435	0,0557	0,0657	0,0723	0,08	0,0906	0,1107	0,1478	0,2037
DC 1.07 2	0,0326	0,0437	0,0548	0,0644	0,071	0,0793	0,0907	0,112	0,1508	0,2084
DC 1.07 3	0,0306	0,0418	0,053	0,0626	0,0693	0,0777	0,0892	0,1106	0,1496	0,2074
DC 1.07+1.13 1	0,0152	0,0158	0,0164	0,0173	0,0183	0,0203	0,0222	0,029	0,0441	0,0753
DC 1.07+1.13 2	0,0165	0,0171	0,0177	0,0186	0,0196	0,0218	0,0242	0,0317	0,0472	0,0791
DC 1.07+1.13 3	0,016	0,0164	0,0168	0,0177	0,0187	0,0208	0,023	0,0302	0,0454	0,0766
C 1.16 1	0,0291	0,0391	0,0491	0,058	0,0645	0,0728	0,0841	0,1054	0,1448	0,2044
C 1.16 2	0,0296	0,0392	0,0488	0,0575	0,0638	0,0719	0,0832	0,1045	0,1432	0,2019
C 1.16 3	0,0279	0,0368	0,0457	0,0536	0,0594	0,0671	0,0776	0,0979	0,1355	0,193
C 1.17 1	0,0279	0,0372	0,0465	0,055	0,0613	0,0695	0,0808	0,1021	0,1412	0,2003
C 1.17 2	0,0298	0,0388	0,0478	0,0561	0,0623	0,0706	0,082	0,1035	0,1424	0,2012
C 1.17 3	0,0295	0,0387	0,0479	0,0561	0,0621	0,07	0,0812	0,102	0,1401	0,1976
C 1.16+1.17 1	0,0171	0,0177	0,0183	0,0192	0,0202	0,0223	0,0246	0,0321	0,0483	0,0815
C 1.16+1.17 2	0,0186	0,0187	0,0188	0,0195	0,0203	0,0223	0,0244	0,0317	0,0467	0,0788
C 1.16+1.17 3	0,018	0,0182	0,0184	0,0191	0,02	0,0222	0,0246	0,0323	0,0486	0,0821
A 1.04 1	0,028	0,0367	0,0454	0,0533	0,059	0,0668	0,0777	0,0987	0,1377	0,1968
A 1.04 2	0,0289	0,037	0,0451	0,0526	0,0582	0,0659	0,0768	0,0976	0,1358	0,1938
A 1.04 3	0,0271	0,0348	0,0425	0,0496	0,055	0,0625	0,0728	0,0931	0,1313	0,1896
A 1.31 1	0,0244	0,0291	0,0338	0,0385	0,0424	0,0484	0,0566	0,0738	0,1066	0,1595
A 1.31 2	0,0255	0,0311	0,0367	0,0422	0,0466	0,0531	0,062	0,0801	0,1145	0,1688
A 1.31 3	0,023	0,0276	0,0322	0,0367	0,0403	0,046	0,0541	0,0711	0,1031	0,1551
A 1.04+1.31 1	0,0156	0,0156	0,0156	0,0159	0,0166	0,018	0,0193	0,0249	0,0374	0,066
A 1.04+1.31 2	0,0169	0,0168	0,0167	0,0172	0,0179	0,0196	0,0213	0,0274	0,0404	0,0693
A 1.04+1.31 3	0,0157	0,0158	0,0159	0,0163	0,0169	0,0185	0,0202	0,0263	0,0391	0,0679

	Wave length, nm										
Colour Name	490	500	510	520	530	540	550	560	570	580	590
B 1,18 1	0,2716	0,3536	0,3897	0,3933	0,3602	0,3049	0,2411	0,1791	0,1348	0,1036	0,0854
B 1,18 2	0,2756	0,3575	0,3937	0,3973	0,3647	0,3099	0,2462	0,1841	0,1394	0,1077	0,0894
B 1,18 3	0,2708	0,3528	0,3892	0,393	0,3601	0,305	0,2414	0,1796	0,1351	0,1037	0,0855
B 1,06 1	0,2946	0,3757	0,4105	0,4129	0,3804	0,3261	0,2622	0,1994	0,153	0,1195	0,0999
B 1,06 2	0,2934	0,3745	0,4094	0,4119	0,3788	0,3239	0,2598	0,1971	0,1511	0,118	0,0988
B 1,06 3	0,2859	0,367	0,4022	0,4051	0,3721	0,3172	0,2533	0,1908	0,1454	0,1129	0,0941
B 1,06+1.18 1	0,1435	0,2098	0,2428	0,2491	0,2181	0,1681	0,1187	0,0752	0,049	0,0338	0,0259
B 1,06+1.18 2	0,1452	0,2109	0,2437	0,2498	0,219	0,1694	0,1201	0,0766	0,0505	0,0354	0,0275
B 1,06+1.18 3	0,1435	0,2093	0,2424	0,2489	0,2181	0,1683	0,119	0,0756	0,0495	0,0343	0,0265
B 1.17 1	0,2716	0,3548	0,3922	0,3967	0,3639	0,3084	0,2441	0,1815	0,1366	0,1049	0,0864
B 1.17 2	0,1409	0,2062	0,2395	0,2462	0,2154	0,1656	0,1168	0,074	0,0486	0,0341	0,0266
B 1.17 3	0,1412	0,2076	0,2416	0,2488	0,2177	0,1673	0,1177	0,0742	0,0483	0,0335	0,0258
B 1.13 1	0,2757	0,3578	0,3943	0,3984	0,3659	0,3111	0,2473	0,185	0,1404	0,1087	0,0902
B 1.13 2	0,2819	0,364	0,4001	0,4037	0,3714	0,317	0,2529	0,1903	0,1452	0,1132	0,0945
B 1.13 3	0,2761	0,3587	0,3956	0,3998	0,367	0,3116	0,2474	0,1849	0,1401	0,1084	0,0899
B 1.13+1.17 1	0,1398	0,2061	0,2398	0,2465	0,2153	0,1648	0,1155	0,0723	0,0467	0,032	0,0244
B 1.13+1.17 2	0,1433	0,2092	0,2427	0,2493	0,218	0,1676	0,1184	0,0754	0,0496	0,0346	0,0269
B 1.13+1.17 3	0,1441	0,211	0,2452	0,2522	0,2207	0,1696	0,1197	0,076	0,0497	0,0344	0,0264
AB 1.18 K 1	0,2386	0,3659	0,4488	0,4867	0,4476	0,3677	0,2856	0,2095	0,1571	0,1215	0,1013
AB 1.18 K 2	0,2368	0,3634	0,4455	0,4829	0,4438	0,3643	0,2826	0,2071	0,1551	0,1198	0,0999
AB 1.18 K 3	0,2319	0,3573	0,4392	0,4767	0,4373	0,3577	0,2768	0,2023	0,151	0,1164	0,0969
AB 1.18 D 1	0,2372	0,3653	0,4489	0,4872	0,4474	0,3667	0,2843	0,2081	0,1555	0,1198	0,0996
AB 1.18 D 2	0,2401	0,368	0,451	0,4888	0,4494	0,3694	0,2873	0,2112	0,1585	0,1227	0,1024
AB 1.18 D 3	0,2468	0,3747	0,4566	0,4933	0,4544	0,3753	0,2936	0,2174	0,1642	0,1277	0,107
AB 1.18+1.18 1	0,1191	0,2098	0,2869	0,3285	0,2855	0,2045	0,1377	0,0844	0,0543	0,0384	0,03
AB 1.18+1.18 2	0,1193	0,2102	0,2875	0,3292	0,2861	0,2048	0,1379	0,0844	0,0543	0,0385	0,0301
AB 1.18+1.18 3	0,1208	0,213	0,2911	0,3334	0,2906	0,2093	0,1414	0,0868	0,0557	0,0392	0,0304
AB 1.3 1	0,2152	0,3402	0,4233	0,4614	0,4195	0,3366	0,2543	0,1799	0,1302	0,0977	0,0796
AB 1.3 2	0,2232	0,3487	0,431	0,4683	0,4265	0,3439	0,2617	0,187	0,1368	0,1037	0,0853
AB 1.3 3	0,2179	0,3439	0,4274	0,4656	0,4233	0,3398	0,257	0,1821	0,1322	0,0996	0,0814
AB 1.24 1	0,2258	0,3501	0,4308	0,4673	0,4277	0,3483	0,2677	0,1935	0,143	0,1091	0,0901
AB 1.24 2	0,2337	0,3583	0,4378	0,4732	0,4344	0,3563	0,276	0,2015	0,1504	0,1159	0,0963
AB 1.24 3	0,2355	0,3613	0,4414	0,4769	0,4381	0,3597	0,2788	0,2036	0,1519	0,1169	0,097
AB 1.3+1.24 1	0,1143	0,2014	0,2752	0,3146	0,2719	0,1926	0,1285	0,0779	0,0498	0,0354	0,0278
AB 1.3+1.24 2	0,1151	0,2023	0,2762	0,3156	0,2727	0,1933	0,1289	0,0783	0,0502	0,0357	0,0282
AB 1.3+1.24 3	0,1156	0,204	0,2787	0,3186	0,2754	0,1952	0,13	0,0786	0,05	0,0352	0,0275
Z 1.11 1	0,2927	0,3838	0,4279	0,4376	0,4071	0,3518	0,2857	0,2201	0,1713	0,1357	0,1148
Z 1.11 2	0,2868	0,3778	0,4218	0,4314	0,4009	0,3457	0,2799	0,2146	0,1662	0,131	0,1104
Z 1.11 3	0,283	0,3741	0,4184	0,4284	0,3982	0,3431	0,2774	0,2123	0,1641	0,1291	0,1087
Z 1.17 1	0,2774	0,3677	0,4118	0,4219	0,3916	0,3364	0,2711	0,2064	0,1589	0,1245	0,1045
Z 1.17 2	0,2762	0,3665	0,4106	0,4206	0,3905	0,3356	0,2705	0,2059	0,1583	0,1239	0,1039
Z 1.17 3	0,2814	0,3716	0,4155	0,4254	0,3957	0,3413	0,2764	0,212	0,164	0,1291	0,1087
Z +1.11+1.17 1	0,1405	0,2119	0,2531	0,2667	0,2377	0,1865	0,134	0,0867	0,0573	0,0396	0,0304
Z +1.11+1.17 2	0,1445	0,2166	0,2579	0,2714	0,2424	0,1911	0,1382	0,0903	0,0603	0,0421	0,0325
Z +1.11+1.17 3	0,1468	0,2196	0,2608	0,274	0,2451	0,1938	0,1405	0,0921	0,0617	0,0431	0,0333
BZ 1.05 1	0,299	0,3861	0,4254	0,4302	0,3958	0,3375	0,2706	0,2049	0,1557	0,1197	0,0986
BZ 1.05 2	0,3069	0,3936	0,4325	0,4371	0,403	0,3453	0,2785	0,2125	0,1628	0,1262	0,1047
BZ 1.05 3	0,2992	0,3857	0,4243	0,4288	0,3945	0,3368	0,2702	0,2048	0,1557	0,1198	0,0987

BZ 1.22 1	0,2876	0,3742	0,4139	0,4194	0,3851	0,3269	0,2607	0,1961	0,1479	0,1129	0,0926
BZ 1.22 2	0,2847	0,37	0,4087	0,4136	0,3792	0,3216	0,2563	0,1927	0,1455	0,1113	0,0915
BZ 1.22 3	0,2837	0,369	0,4079	0,4131	0,3791	0,3218	0,2567	0,1932	0,1457	0,1111	0,0912
BZ 1.05+1.22 1	0,1452	0,2147	0,2509	0,259	0,2267	0,1739	0,1224	0,0772	0,0494	0,0329	0,0246
BZ 1.05+1.22 2	0,1488	0,2184	0,2544	0,2624	0,2298	0,1769	0,1252	0,0797	0,0517	0,0351	0,0267
BZ 1.05+1.22 3	0,1453	0,2143	0,2501	0,258	0,2257	0,1732	0,122	0,0771	0,0495	0,0332	0,025
DC 1.1 1	0,2852	0,3702	0,4079	0,4117	0,3769	0,3192	0,2541	0,1909	0,1439	0,1099	0,0901
DC 1.1 2	0,2908	0,3752	0,4126	0,4164	0,382	0,3248	0,2598	0,1964	0,1491	0,1147	0,0946
DC 1.1 3	0,2823	0,3658	0,4029	0,4067	0,3725	0,3156	0,2513	0,1889	0,1426	0,1091	0,0897
DC 1.17 1	0,2802	0,3634	0,4002	0,4039	0,3695	0,3128	0,2488	0,1867	0,1408	0,1076	0,0883
DC 1.17 2	0,2788	0,3617	0,3983	0,4017	0,3674	0,3108	0,247	0,1853	0,1396	0,1067	0,0877
DC 1.17 3	0,2789	0,3619	0,3985	0,4019	0,3677	0,3112	0,2474	0,1855	0,1396	0,1064	0,0871
DC 1.1+1.17 1	0,1442	0,2108	0,2443	0,2506	0,2185	0,1672	0,1177	0,0744	0,0482	0,0328	0,0249
DC 1.1+1.17 2	0,1455	0,2123	0,2458	0,252	0,2198	0,1683	0,1186	0,0752	0,0488	0,0333	0,0253
DC 1.1+1.17 3	0,1469	0,2143	0,248	0,2543	0,2221	0,1705	0,1203	0,0762	0,0491	0,033	0,0248
DC 1.13 1	0,2816	0,3651	0,4016	0,4048	0,3705	0,3139	0,2497	0,1871	0,1408	0,1072	0,0877
DC 1.13 2	0,29	0,3734	0,4097	0,4126	0,3781	0,3212	0,2566	0,1936	0,1469	0,113	0,0932
DC 1.13 3	0,2699	0,3523	0,3887	0,3923	0,3583	0,3019	0,2387	0,1776	0,1328	0,1007	0,082
DC 1.07 1	0,2913	0,3735	0,4098	0,4132	0,3797	0,3239	0,2602	0,198	0,1517	0,1179	0,0981
DC 1.07 2	0,2974	0,3804	0,4167	0,4197	0,3859	0,3296	0,265	0,2018	0,1543	0,1195	0,0991
DC 1.07 3	0,2964	0,3794	0,4157	0,419	0,3853	0,3291	0,2643	0,2007	0,1531	0,1183	0,0977
DC 1.07+1.13 1	0,1407	0,2064	0,2397	0,2461	0,2142	0,1633	0,1143	0,0717	0,0459	0,0309	0,0232
DC 1.07+1.13 2	0,1456	0,2124	0,2461	0,2525	0,2203	0,1688	0,1189	0,0754	0,0488	0,0332	0,0251
DC 1.07+1.13 3	0,1422	0,208	0,2413	0,2475	0,2156	0,1646	0,1155	0,0728	0,0469	0,0317	0,0239
C 1.16 1	0,298	0,3859	0,4248	0,4288	0,393	0,3334	0,2662	0,201	0,1535	0,1193	0,0991
C 1.16 2	0,2952	0,383	0,422	0,426	0,3901	0,3306	0,2635	0,1986	0,1513	0,1175	0,0976
C 1.16 3	0,285	0,3717	0,4102	0,4141	0,3785	0,3195	0,2534	0,1897	0,1436	0,1108	0,0916
C 1.17 1	0,2935	0,3812	0,4203	0,4244	0,3882	0,3282	0,2608	0,1958	0,1487	0,115	0,0952
C 1.17 2	0,2936	0,3804	0,4189	0,4227	0,387	0,3278	0,2611	0,1965	0,1496	0,116	0,0963
C 1.17 3	0,2883	0,3738	0,4121	0,4163	0,3813	0,3231	0,2574	0,1938	0,1474	0,1142	0,0946
C 1.16+1.17 1	0,1514	0,2216	0,2576	0,2651	0,2318	0,1781	0,126	0,0805	0,053	0,037	0,0286
C 1.16+1.17 2	0,148	0,2178	0,2533	0,2605	0,2273	0,174	0,1225	0,0778	0,0511	0,0358	0,0279
C 1.16+1.17 3	0,1525	0,2232	0,2591	0,2663	0,2326	0,1785	0,126	0,0802	0,0527	0,0367	0,0283
A 1.04 1	0,2892	0,3769	0,4189	0,4276	0,3979	0,3442	0,2801	0,2162	0,168	0,1326	0,1119
A 1.04 2	0,2855	0,3728	0,4148	0,4237	0,3942	0,3407	0,2766	0,2127	0,1651	0,1304	0,1099
A 1.04 3	0,2817	0,3693	0,4112	0,4199	0,3902	0,3366	0,2725	0,2088	0,1612	0,1264	0,1061
A 1.31 1	0,2487	0,3351	0,3776	0,3873	0,3571	0,3029	0,24	0,1785	0,1342	0,1027	0,0845
A 1.31 2	0,2584	0,3446	0,3868	0,3962	0,3663	0,3126	0,2496	0,1877	0,1425	0,1101	0,0914
A 1.31 3	0,244	0,3301	0,3726	0,3824	0,3522	0,298	0,2354	0,1744	0,1304	0,0992	0,0814
A 1.04+1.31 1	0,1299	0,1958	0,2335	0,2454	0,2174	0,1689	0,1199	0,0763	0,0498	0,0343	0,0263
A 1.04+1.31 2	0,1336	0,1998	0,2372	0,2487	0,2206	0,172	0,123	0,0794	0,0527	0,0368	0,0285
A 1.04+1.31 3	0,132	0,1982	0,2359	0,2476	0,2192	0,1703	0,1212	0,0776	0,051	0,0353	0,0272

	Wave length, nm										
Colour Name	600	610	620	630	640	650	660	670	680	690	700
B 1,18 1	0,0753	0,0676	0,0637	0,0629	0,0657	0,0742	0,0834	0,0873	0,0865	0,0801	0,0688
B 1,18 2	0,0791	0,0713	0,0671	0,0662	0,069	0,0776	0,087	0,091	0,0902	0,0835	0,072
B 1,18 3	0,0754	0,0677	0,0637	0,0628	0,0656	0,074	0,0833	0,0873	0,0865	0,08	0,0686
B 1,06 1	0,0888	0,0802	0,0756	0,0747	0,0779	0,0873	0,0975	0,1017	0,1006	0,0934	0,081
B 1,06 2	0,088	0,0795	0,075	0,0743	0,0776	0,087	0,0972	0,1014	0,1004	0,0932	0,0807
B 1,06 3	0,0835	0,0753	0,071	0,0701	0,0732	0,0823	0,0922	0,0962	0,0952	0,0883	0,0763
B 1,06+1.18 1	0,0227	0,0201	0,0188	0,0182	0,0188	0,0214	0,0244	0,0256	0,0254	0,0232	0,0195
B 1,06+1.18 2	0,0244	0,0217	0,0204	0,0199	0,0205	0,0231	0,0261	0,0274	0,0272	0,025	0,0212
B 1,06+1.18 3	0,0232	0,0206	0,0193	0,0187	0,0193	0,0219	0,0249	0,0262	0,026	0,0238	0,0199
B 1.17 1	0,0761	0,0681	0,0639	0,0628	0,0654	0,0739	0,0833	0,0875	0,0869	0,0802	0,0684
B 1.17 2	0,0236	0,0211	0,0198	0,0193	0,0198	0,0221	0,0249	0,0262	0,026	0,0239	0,0203
B 1.17 3	0,0227	0,0202	0,0189	0,0183	0,0188	0,0212	0,024	0,0252	0,0251	0,023	0,0194
B 1.13 1	0,0797	0,0717	0,0674	0,0664	0,0691	0,0775	0,0869	0,091	0,0904	0,0837	0,072
B 1.13 2	0,084	0,0757	0,0711	0,0701	0,0729	0,0815	0,0909	0,0951	0,0945	0,0877	0,0759
B 1.13 3	0,0795	0,0715	0,0671	0,0661	0,0688	0,0772	0,0865	0,0907	0,0901	0,0835	0,0718
B 1.13+1.17 1	0,0213	0,0188	0,0177	0,017	0,0174	0,0198	0,0225	0,0238	0,0236	0,0216	0,018
B 1.13+1.17 2	0,0237	0,0211	0,0198	0,0193	0,0198	0,0223	0,0252	0,0264	0,0262	0,0241	0,0205
B 1.13+1.17 3	0,0231	0,0206	0,0194	0,0187	0,0192	0,0218	0,0247	0,026	0,0258	0,0237	0,0199
AB 1.18 K 1	0,0906	0,0825	0,0783	0,0768	0,0796	0,09	0,1016	0,1058	0,1042	0,0961	0,0825
AB 1.18 K 2	0,0894	0,0814	0,0773	0,0758	0,0784	0,0887	0,1002	0,1044	0,1029	0,0948	0,0813
AB 1.18 K 3	0,0867	0,0789	0,0748	0,0734	0,076	0,0859	0,0971	0,1011	0,0996	0,0918	0,0787
AB 1.18 D 1	0,0889	0,0809	0,0768	0,0754	0,0781	0,0887	0,1004	0,1047	0,103	0,0949	0,0811
AB 1.18 D 2	0,0917	0,0835	0,0793	0,0779	0,0806	0,0912	0,1029	0,1071	0,1054	0,0973	0,0835
AB 1.18 D 3	0,0961	0,0877	0,0835	0,0821	0,0851	0,0959	0,1079	0,1121	0,1104	0,102	0,088
AB 1.18+1.18 1	0,0268	0,024	0,0226	0,0217	0,0221	0,0251	0,0285	0,0298	0,0292	0,0266	0,0222
AB 1.18+1.18 2	0,0269	0,0241	0,0227	0,0218	0,0223	0,0252	0,0287	0,0299	0,0292	0,0267	0,0223
AB 1.18+1.18 3	0,027	0,0241	0,0226	0,0217	0,0221	0,0253	0,029	0,0303	0,0297	0,027	0,0223
AB 1.3 1	0,0706	0,0637	0,0603	0,0592	0,0618	0,071	0,0812	0,0847	0,0832	0,0762	0,0645
AB 1.3 2	0,076	0,0688	0,0652	0,0642	0,0668	0,0762	0,0866	0,0902	0,0886	0,0815	0,0694
AB 1.3 3	0,0722	0,0653	0,0618	0,0607	0,0632	0,0726	0,0828	0,0866	0,0851	0,078	0,066
AB 1.24 1	0,0802	0,0727	0,069	0,0678	0,0704	0,0803	0,0911	0,0949	0,0932	0,0857	0,0731
AB 1.24 2	0,086	0,0782	0,0743	0,0731	0,0759	0,0861	0,0973	0,1012	0,0994	0,0917	0,0787
AB 1.24 3	0,0866	0,0787	0,0748	0,0736	0,0765	0,0868	0,0981	0,102	0,1002	0,0922	0,079
AB 1.3+1.24 1	0,025	0,0225	0,0212	0,0204	0,0207	0,0233	0,0262	0,027	0,0264	0,0241	0,0205
AB 1.3+1.24 2	0,0253	0,0228	0,0216	0,0207	0,021	0,0235	0,0265	0,0274	0,0267	0,0245	0,0208
AB 1.3+1.24 3	0,0246	0,022	0,0207	0,0198	0,0202	0,0228	0,0259	0,0268	0,0261	0,0238	0,02
Z 1.11 1	0,1028	0,0939	0,0893	0,0883	0,0917	0,1025	0,1144	0,1191	0,1179	0,1098	0,0957
Z 1.11 2	0,0987	0,09	0,0856	0,0846	0,088	0,0986	0,1103	0,115	0,1139	0,1059	0,092
Z 1.11 3	0,0971	0,0884	0,084	0,0829	0,0861	0,0966	0,1081	0,113	0,1119	0,1039	0,0899
Z 1.17 1	0,0933	0,085	0,0808	0,0799	0,0832	0,0935	0,1049	0,1094	0,1083	0,1006	0,0874
Z 1.17 2	0,0926	0,0841	0,0798	0,0788	0,0821	0,0924	0,1038	0,1083	0,1071	0,0994	0,0861
Z 1.17 3	0,0971	0,0884	0,0838	0,0828	0,0861	0,0967	0,1083	0,1131	0,1119	0,1038	0,0898
Z +1.11+1.17 1	0,0265	0,0234	0,022	0,0213	0,0221	0,0256	0,0297	0,0315	0,0311	0,0282	0,0231
Z +1.11+1.17 2	0,0284	0,0252	0,0236	0,023	0,0239	0,0276	0,0319	0,0338	0,0335	0,0304	0,025
Z +1.11+1.17 3	0,0291	0,0258	0,0242	0,0235	0,0245	0,0284	0,0328	0,0348	0,0345	0,0313	0,0258
BZ 1.05 1	0,0866	0,0778	0,0735	0,0732	0,0771	0,0869	0,0973	0,101	0,0995	0,0923	0,0802
BZ 1.05 2	0,0924	0,0833	0,0787	0,0783	0,0823	0,0924	0,1033	0,1071	0,1054	0,0979	0,0853
BZ 1.05 3	0,0868	0,078	0,0737	0,0734	0,0773	0,0871	0,0975	0,1012	0,0997	0,0924	0,0803

BZ 1.22 1	0,0813	0,0729	0,0689	0,0686	0,0722	0,0816	0,0916	0,0952	0,0937	0,0868	0,0753
BZ 1.22 2	0,0806	0,0726	0,0686	0,0683	0,0719	0,0812	0,0909	0,0943	0,0928	0,0862	0,0751
BZ 1.22 3	0,0801	0,0719	0,0679	0,0675	0,0711	0,0804	0,0902	0,0937	0,0922	0,0855	0,0742
BZ 1.05+1.22 1	0,0213	0,0187	0,0176	0,0172	0,018	0,0208	0,0238	0,0249	0,0245	0,0223	0,0187
BZ 1.05+1.22 2	0,0233	0,0206	0,0195	0,019	0,0198	0,0227	0,0259	0,0269	0,0264	0,0242	0,0204
BZ 1.05+1.22 3	0,0218	0,0192	0,0181	0,0177	0,0184	0,0211	0,0241	0,0252	0,0248	0,0227	0,0191
DC 1.1 1	0,079	0,0709	0,0669	0,0664	0,0697	0,0788	0,0885	0,0919	0,0904	0,0837	0,0724
DC 1.1 2	0,0832	0,075	0,0709	0,0704	0,0737	0,083	0,0929	0,0964	0,0948	0,0879	0,0764
DC 1.1 3	0,0788	0,0708	0,0668	0,0663	0,0694	0,0782	0,0876	0,0909	0,0894	0,0829	0,0719
DC 1.17 1	0,0776	0,0697	0,0659	0,0654	0,0686	0,0775	0,0869	0,0901	0,0886	0,0821	0,0713
DC 1.17 2	0,0773	0,0694	0,0656	0,0651	0,0683	0,0771	0,0865	0,0896	0,0881	0,0817	0,071
DC 1.17 3	0,0764	0,0685	0,0646	0,0641	0,0673	0,0761	0,0854	0,0886	0,0871	0,0806	0,0698
DC 1.1+1.17 1	0,0217	0,0193	0,0182	0,0178	0,0184	0,021	0,0238	0,0248	0,0243	0,0223	0,019
DC 1.1+1.17 2	0,0222	0,0197	0,0185	0,0181	0,0188	0,0215	0,0244	0,0253	0,0248	0,0227	0,0194
DC 1.1+1.17 3	0,0215	0,0188	0,0177	0,0173	0,018	0,0207	0,0237	0,0247	0,0242	0,0221	0,0186
DC 1.13 1	0,0767	0,0687	0,0648	0,0643	0,0677	0,0768	0,0864	0,0896	0,0879	0,0814	0,0705
DC 1.13 2	0,0822	0,0741	0,0702	0,0698	0,0733	0,0828	0,0927	0,0959	0,0941	0,0874	0,0762
DC 1.13 3	0,0718	0,0643	0,0607	0,0603	0,0634	0,0719	0,0809	0,0838	0,0822	0,0761	0,066
DC 1.07 1	0,0869	0,0786	0,0745	0,074	0,0773	0,0866	0,0963	0,0994	0,0975	0,0908	0,0796
DC 1.07 2	0,0874	0,0789	0,0747	0,0744	0,078	0,0876	0,0977	0,101	0,0991	0,0922	0,0807
DC 1.07 3	0,0859	0,0774	0,0732	0,0727	0,0763	0,086	0,0962	0,0994	0,0976	0,0906	0,0791
DC 1.07+1.13 1	0,0202	0,0177	0,0166	0,0162	0,0169	0,0194	0,0221	0,023	0,0225	0,0205	0,0174
DC 1.07+1.13 2	0,0219	0,0193	0,0182	0,0178	0,0185	0,0212	0,0241	0,0251	0,0245	0,0225	0,0191
DC 1.07+1.13 3	0,0207	0,0183	0,0172	0,0168	0,0174	0,02	0,0228	0,0237	0,0232	0,0213	0,018
C 1.16 1	0,0876	0,0792	0,0749	0,0737	0,0766	0,0863	0,0971	0,1015	0,1005	0,093	0,0801
C 1.16 2	0,0863	0,078	0,0736	0,0725	0,0754	0,0849	0,0956	0,0999	0,0988	0,0914	0,0787
C 1.16 3	0,0807	0,0727	0,0686	0,0675	0,0702	0,0793	0,0893	0,0934	0,0924	0,0854	0,0733
C 1.17 1	0,084	0,0758	0,0715	0,0704	0,0733	0,0828	0,0933	0,0975	0,0964	0,0891	0,0766
C 1.17 2	0,0852	0,0769	0,0725	0,0715	0,0744	0,084	0,0946	0,0988	0,0977	0,0904	0,0777
C 1.17 3	0,0836	0,0755	0,0713	0,0702	0,073	0,0823	0,0925	0,0965	0,0955	0,0884	0,0762
C 1.16+1.17 1	0,0252	0,0224	0,0211	0,0205	0,021	0,0239	0,0271	0,0285	0,0281	0,0258	0,0217
C 1.16+1.17 2	0,0246	0,022	0,0207	0,0201	0,0206	0,0232	0,0262	0,0274	0,0272	0,0249	0,021
C 1.16+1.17 3	0,0248	0,0221	0,0207	0,0201	0,0206	0,0235	0,0268	0,0281	0,0277	0,0254	0,0214
A 1.04 1	0,1	0,0914	0,087	0,0859	0,0894	0,1004	0,1125	0,1171	0,1156	0,1072	0,093
A 1.04 2	0,0983	0,0897	0,0854	0,0844	0,0877	0,0986	0,1106	0,1152	0,1138	0,1055	0,0914
A 1.04 3	0,0946	0,0862	0,0819	0,081	0,0843	0,095	0,1067	0,1113	0,1101	0,102	0,088
A 1.31 1	0,0747	0,0675	0,0641	0,0632	0,0661	0,0753	0,0855	0,0895	0,0885	0,0816	0,0698
A 1.31 2	0,081	0,0734	0,0696	0,0688	0,0719	0,0814	0,0919	0,0962	0,0952	0,0879	0,0753
A 1.31 3	0,0718	0,0647	0,0612	0,0605	0,0633	0,0722	0,0821	0,0862	0,0852	0,0785	0,0668
A 1.04+1.31 1	0,0231	0,0205	0,0192	0,0187	0,0193	0,0222	0,0256	0,027	0,0267	0,0242	0,0201
A 1.04+1.31 2	0,0251	0,0224	0,0212	0,0206	0,0213	0,0244	0,028	0,0294	0,0291	0,0265	0,022
A 1.04+1.31 3	0,0238	0,0212	0,0199	0,0193	0,02	0,0231	0,0266	0,028	0,0277	0,0252	0,0209