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LIGHT PERMANENCE WRAP PRINTS PRODUCED WITH CMYK UV INKJET INKS

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Abstract: Nowadays, Inkjet technology has become one of the most widespread printing technologies in car industry (car wrapping = printing and wrapping the whole vehicle or a part of a vehicle in printed foil). Printed wrap foils are, after the wrapping process, exposed to the same conditions as a lacquered vehicle: intensive sunlight, high and low temperatures, rainfall, snow, ice, particles or bugs that the vehicle encounters while driving, etc. In this paper we tested different types of wrapping foils (Orajet, 3M Scotchcal and 3M Controltac) and solvent inkjet inks to investigate the influence of different types of wrap foils on the real reproduction of UV ink jet coloured imprints, as well as their stability fluctuations during ageing. The inkjet prints age faster under the influence of UV light (Xenon lamp in SolarBox) in a period of 240 hours. The results show that the 3M Scotchcal foil has the best CMYK stability.

Keywords: car wrap foil; Inkjet printing technology; light permanence; UV curing inks

1 INTRODUCTION

When selecting materials, a wide number of processes and factors decide about the quality and performance of the final product. When considering car wrapping, the following parameters determine the quality and technical requirements: foil manufacturers, vehicles, printing offices and distributors of all those technologies that are a contact point between the manufacturers and brand owners.

When working with foils, cutting is a very important step in the production. E-cut foils are specially developed for cutting machines (e-cut refers to electronic cutting – with a computer controlled cutting knife and with the purpose of getting different kinds of precisely cut shapes). E-cut foils can be classified into non-transparent (or opaque) and transparent (or translucent) foil types. Depending on the application, there are also other types of wrapping foils: foils for glass decorating, Di-Noc films and protective films. [1]

1.1 Wrapping foils

During the nineties of the 20th century, the revolution in foil application occurred. The reason for that was the possibility of personalized printing by acceptable prices, the development of highly productive foil cutters, inkjet printers that use inks resistant to outdoor influences and the development of self-adhesive foils. The most popular producers of foils on the market today are the following: 3M, Grafityp, APA, Avery Dennison and Arlon. Apart from the standard glossy foils (white and coloured), it is possible to print on mat and chrome foils. One of the popular classifications is given by the quality of production. Based on that classification, there are **premium foils** (the best quality), **intermediate foils** (medium quality) and **foils for promotional purposes**. [2]

One special category includes foils for interior decoration and special foils for glass application, where the Di-Noc foils are a typical representative of that category, mostly used in architecture, for walls.

The most important classification of foils is the one by structure, that is, the number of materials that the foil is made of: **cast foils** (usually made from vinyl) and **calendered foils** (mostly made from PVC). All the layers of foils have similar thickness. The final layer is usually used for fixing the ink in the printing process (Figure 1).

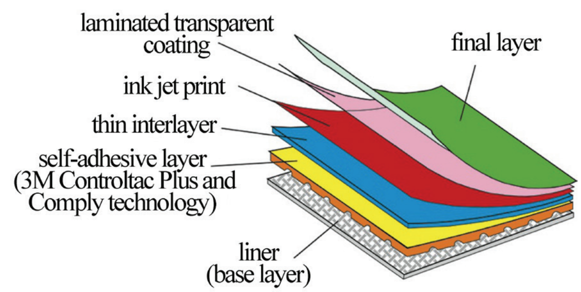

Figure 1 Basic construction of a wrapping printable foil with the 3M Controltac and Comply technology [3, 4]

1.1.1 Production of foils

Cast foils are made by mixing all the ingredients together and pouring them in a liquid aggregate condition on the paper carrier. This process produces a film which has the thickness of 1-2 mm. It is a durable, flexible, adaptable and dimensionally stable film that holds the inkjet colour very well. Such foils are ideal for wrapping complex surfaces such as those on vehicles, where a slick finish is expected. Calendered foils are made by applying the molten mixture through the mould, after which the mixture is passed through a series of calendering rolls.

By rolling and stretching, thick layers of foil (usually 3-4 mm thick) are produced with uniform properties. This results in a somewhat less dimensionally stable and less adaptable coating foil which will exhibit shrinkage when exposed to heat. However, such wrapping foils are cheaper and more resistant to scratching. [5, 6]

1.1.2 Adhesives

A typical wrap foil is coated with a solvent-based adhesive layer (an adhesive that is activated by stronger contact of a silicone squeegee). [7, 8]

There are different types of adhesives. The most common are: PA (Pressure-Activated Adhesive) that is activated by increased pressure and heat, SP (Strong Pressure Adhesive) that is activated by high pressure, and PSA (Pressure Sensitive Adhesive) that is activated by low pressure. In some of these adhesive layers, the Comply Adhesive Technology can also be found. This is actually a film with air ducts through which air is exfoliated during the cladding (to remove even the smallest air bubbles). This technology solved a problem that would otherwise require a decollation of the foil part and re-bonding, which in some cases causes the film to deform, which would then become unusable. [9, 10]

1.2 Inkjet printing technology

The Inkjet printing technique implies NIP printing systems (Non Impact Printing). This means that liquid ink apply through micro size nozzles directly on printing substrate (without contact with imaging unit). The assumption for dripping is correct Weber number (must be greater than $W_k>12$).[3] Inkjet printing techniques can be divided into two basic categories: Continuous Inkjet and Discontinued (or DoD - Drop On Demand) Inkjet. In Continuous Inkjet, the binary and multiple dropout systems differ, while in DOD Inkjet there are three different ways of forming droplets: Piezo Inkjet, Thermal Inkjet and Electrostatic Inkjet.

1.2.1 UV inkjet inks

UV and LED UV inks provide high thicknesses of application regardless of the thickness of the printing substrate. The composition of this color consists of: pigments (15%), prepolymers (20-35%), monomers and oligomers (10-25%), photoinitiators (5-10%) and additives (1-5%). One of the most important UV ink components are certainly photoinitiators. By absorbing UV light from the appropriate source, they enhance the polymerization processes, thus initiating the drying process itself.

1.2.2 UV electromagnetic radiation

The UV region includes only a small part of the electromagnetic radiation spectrum and is expressed in wavelengths measured in nanometers (1 nm = 10^{-9} m). The UV wavelengths are extremely short and range between 200 and 380 nm and have been shown to be the most suitable for UV ink and varnish drying. The UV spectrum is divided into three possible subregions with different UV drying characteristics: UVC, UVB and UVA electromagnetic waves. The UVC ranges from 200 to 280 nm. Such high UV radiation energy provides instant drying and is most often used for surface UV drying of inks and coatings. The UVB ranges from 280 to 315 nm. The light in this wave range penetrates deeper into the layer of ink film, i.e. this UV radiation (with longer wavelengths) allows a better drying of the medium printed ink layers. The UVA ranges from 315 to 380 nm. This type of UV rays is the closest to the visible part of the spectrum. It can reach deep layers of highly pigmented colors and ensure the drying of thick layers of lacquer.

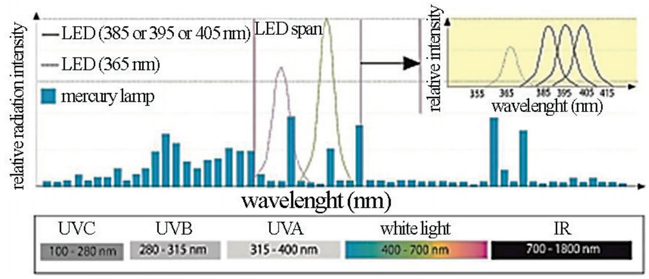

Figure 2 Radiation spectrum of typical UV sources

1.2.3 UV ink drying

UV light sources are mostly called UV lamps. They are usually made up of quartz glass tubes that contain mercury. The body of the lamp is constructed of high-quality quartz glass which passes at least 90% of generated UV rays. The quartz lamp body must be resistant to the internal temperature exceeding 1100°C, while the temperature on the surface of the lamp is about 900°C. In order to avoid damage to the surface of the lamp, an adequate cooling system must be installed.

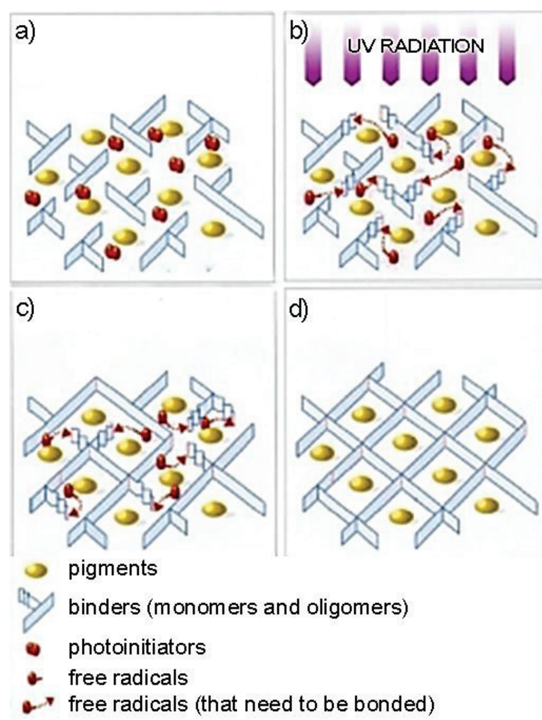

Figure 3 UV ink polymerization process: a) wet coating (liquid or viscous), b) UV radiation, ink is still liquid, c) the photoincitiators are bonding and macro-molecules are formed, d) final stage: all molecules are linked except the pigments

In the case of UV drying, the printing ink film polymerizes and completely dries as soon as radiation arrives. The UV drying method, however, requires special printing ink containing a binder and additional photoinitiators. The photoinitiators are active at the wavelengths between 365 and 415 nm, which results in a solidification process. This cross-linked reaction of UV-dyeing and varnish takes place for one second.

2 EXPERIMENT

For the experiment purposes, a CMYK test form with a 0-100% rasterton value – RTV (with a 10% step) was made. A PDF document was then made and sent to Roland's RIP Versa Works. The printed form was printed on a Roland LEC 300 (with UV ink). Three experimental wrap films were used for printing: 3M Scotchcal, 3M Controltac and Orajet.

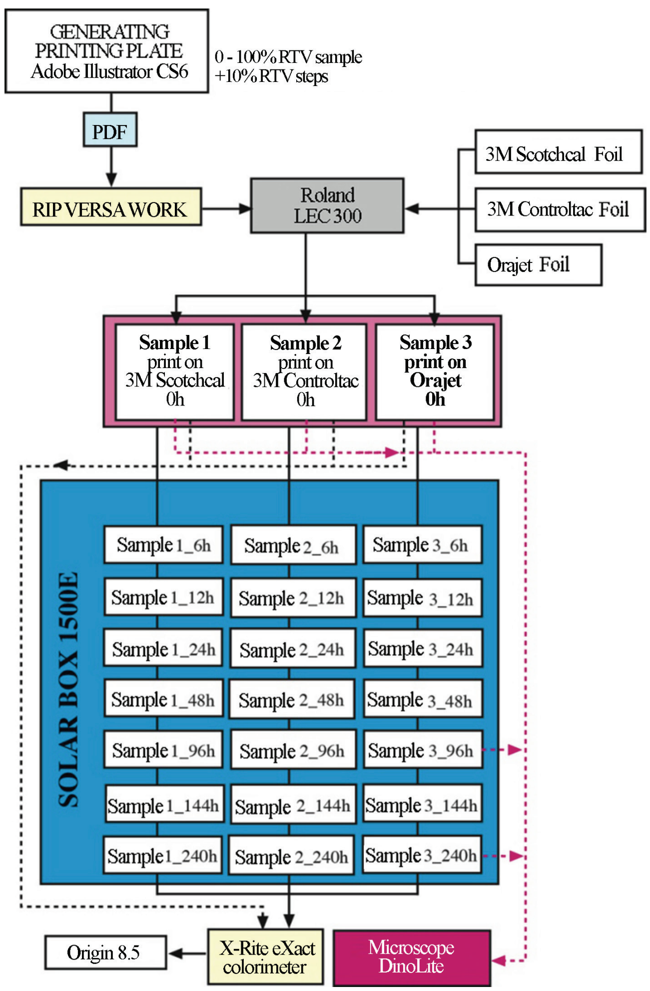

Figure 4 Scheme of the performed experiment

After the printing, a null measurement followed. It included the measurement of colorimetric values of typical fields with 20% and 100% RTV with the X-Rite eXact spectrophotometer. Thereafter, a set of three previously measured samples was subjected to fast aging in the SolarBox 1500E chamber on a 280 × 280 mm bracket that was adapted to the dimensions of the aging chamber. The aging conditions in the chamber were pre-defined: 50 °C temperature and 550 W/m^2 radiation, in time periods of 6h, 12h, 24h, 48h, 96h, 144h and 240h.

The measured results were analyzed in the Origin 8.5 program, where the results depicting the value of the change in coloration (ΔE_{00}) were shown in the graphs, depending on the aging time (fields with 20% and 100% RTV values were analysed). [11, 12]

3 RESULTS AND DISCUSSION

The aging process of the printed foil is a process of atmospheric influence (temperature, relative humidity, insolation, etc.) over a longer period of time. Since the changes in coloration during the aging process can be caused by changes in the substrate itself, it was necessary to determine how much the substrates themselves change (Figure 4).

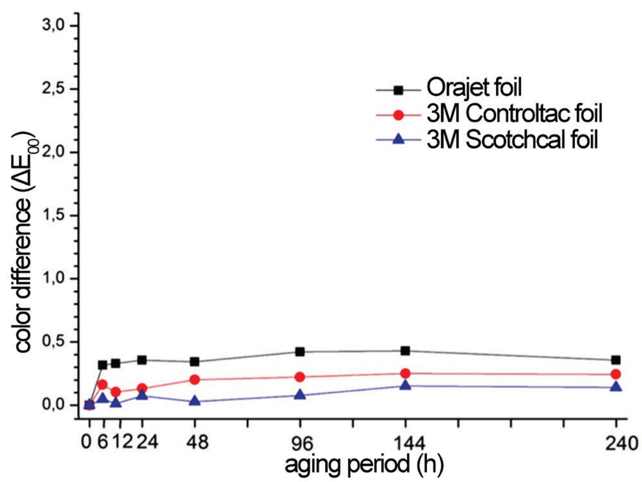

Figure 5 Differences in the colouring of white wrap foils within 240 hours

For all three foils it can be said that they are very stable and that during the aging process (after the period of 240h) no apparent changes (seen by the naked eye) have been observed. However, from Figure 4, it is obvious that the biggest changes occurred on the Orajet foil and that the least changes occurred on the 3M Scotchcal foil. The utmost changes occurred at the beginning of experimental aging (after 6h in the chamber), and their numerical values are the following: ΔE_{Orajet}=0.31, $\Delta E_{Controltac}$=0.16 and $\Delta E_{Scotchcal}$=0.05. During the 240-hour period, no color changes occurred, and the values at t=240h are: ΔE_{Orajet}=0.35, $\Delta E_{Controltac}$=0.24 and $\Delta E_{Scotchcal}$=0.14.

UV inkjet ink is dried by polymerization that starts with the exposure to ultraviolet electromagnetic radiation. Due to the short drying time, the print has a relatively thick layer of ink, which does not diminish over time. Moreover, such inkjet ink is much more resistant to atmospheric conditions than solvent inks because the other contain a high percentage of solvents.

Figures 5, 6, 7 and 8 show the results of the measured CMYK surfaces printed with 20% (bright tones) and 100% RTV (full tones). [13, 14]

Figure 5a shows the differences in the colouring of cyan UV inkjet ink, measured on 20% RTV fields. The largest changes in ΔE_{00} were achieved after t=240h ($\Delta E_{Scotchcal}$=0.37, $\Delta E_{Controltac}$=0.76 and ΔE_{Orajet}=1.02). The difference in full tone colouration (Figure 5b) abruptly changed after the first six hours, after which the colour differences reached the following values: Scotchcal ΔE_{144h}= 0.95, Controltac ΔE_{40h}= 0.41 and Orajet ΔE_{240h}= 0.91. As it was expected, the highest changes occurred on the PVC Orajet foil, and the smallest on the vinyl 3M Scotchcal foil.

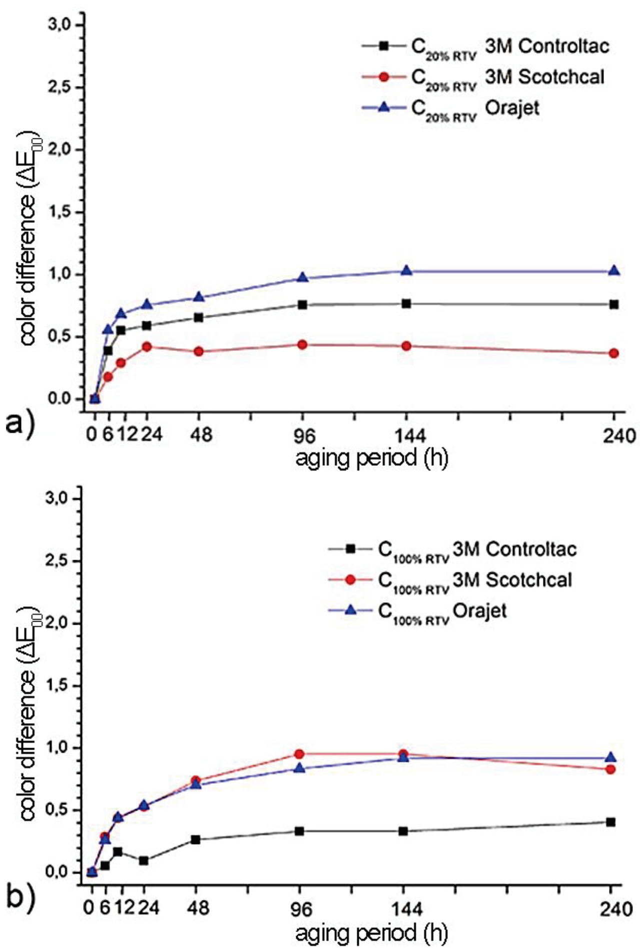

Figure 6 Changes in the cyan UV inkjet colours after 0h and 240h; a) ΔE_{00} for 20% RTV fields; b) ΔE_{00} for 100% RTV fields

For magenta full tones (Figure 6a) it can be seen that the results for the 3M Scotchcal and Orajet foils are almost identical. The only differences appear after 240 hours, when the change on the 3M Scotchcal foil is lesser than the one on the Orajet foil (difference between the two is ΔE=0.05). At this point, the resulting colour changes are: $\Delta E_{Scotchcal}$=0.57 and ΔE_{Orajet}=0.62. The largest deviations are visible on the magenta prints on the 3M Controltac foil ($\Delta E_{Controltac}$=0.68).

The results of colour changes for the fields with 20% RTV (Figure 6b) show a trend that, when increasing the aging time period, the measured values on the Orajet and 3M Controltac foils equalize (they overlap after 240h). At that point, the differences in colouring were: ΔE_{Orajet}=0.73, $\Delta E_{Controltac}$=0.72. The measured values for the 3M Scotchcal foil are the lowest in the same time measured, and reach the value $\Delta E_{Scotchcal}$=0.50. Such colour changes remain the same even after the period between 48 and 96 hours of aging.

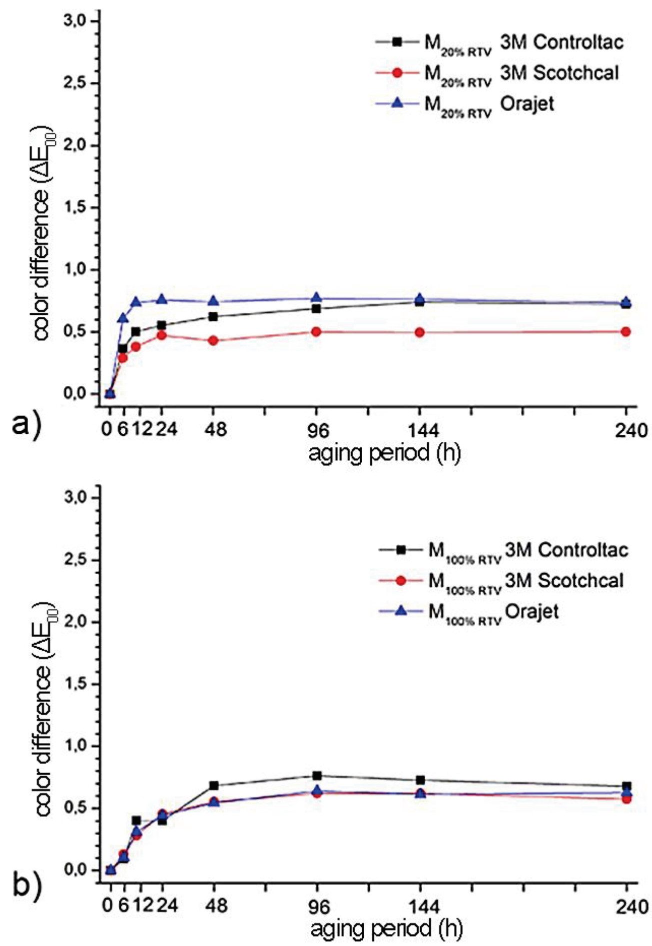

Figure 7 Changes in the magenta UV inkjet colours after 0h and 240h; a) ΔE_{00} for 20% RTV fields; b) ΔE_{00} for 100% RTV fields

On the yellow fields with 100% ink coverage (Figure 7b), the colour differences vary linearly to a period of 144h. From that moment on, the changes are constant. Therefore, after the t=144h, the colour differences are: $\Delta E_{Scotchcal}$=0.36, $\Delta E_{Controltac}$=0.42 and ΔE_{Orajet}=0.43, and after 240h, ΔE_{Orajet}=0.47. On the screened fields, the results are similar (Figure 7b). That means that during aging, the yellow prints on the 3M Controltac foil have changed the least. However, at the end of the experiment (t=240h), all values were equalized ($\Delta E_{Scotchcal}$=0.43, $\Delta E_{Controltac}$=0.41 and ΔE_{Orajet}=0.43). Such changes are minimal, but it is to be expected that, with the increase of the aging time period, the changes could increase too.

By analysing the full tonal field printed with black UV ink (Figure 8b), it is apparent that the differences have over time approximately linearly increased. After the period of 240h, the values of ΔE_{00} were: $\Delta E_{Scotchcal}$=0.76, $\Delta E_{Controltac}$=0.76 and ΔE_{Orajet}=1.64. Thus, these are the ones with the biggest changes in coloring if compared to other experimental results. It is especially important to point out the value curve for the Orajet foil that shows an exceptional tendency to increase the color difference value. On a graph that shows the color change results for the 20% RTV black field (Figure 8a), a non-characteristic change in color difference is observed after the first six hours of aging (ΔE_{Orajet}=2.78).

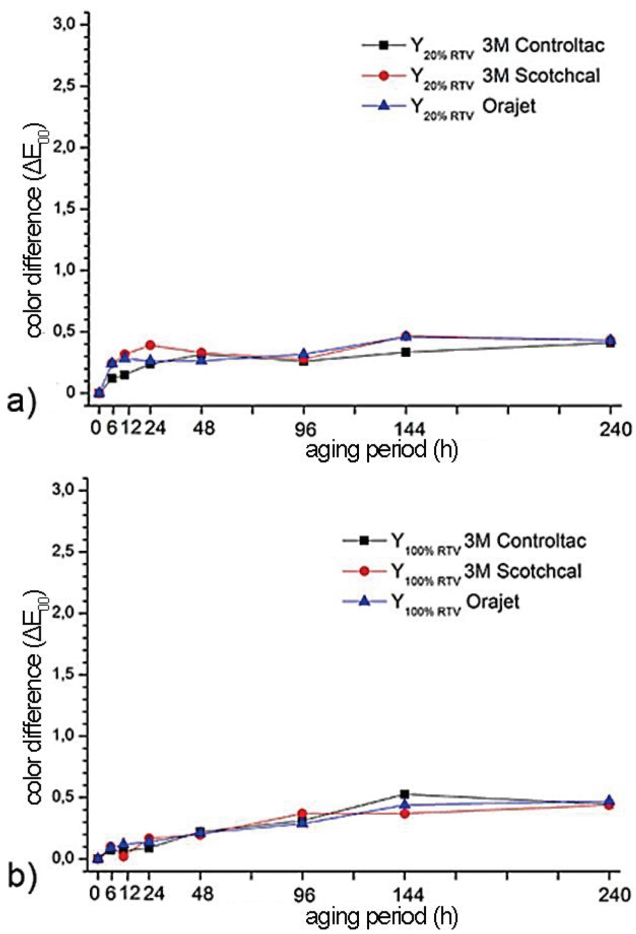

Figure 8. Changes in the yellow UV inkjet colours after 0h and 240h; a) ΔE_{00} for 20% RTV fields; b) ΔE_{00} for 100% RTV fields

Further aging will cause much less changes which are the following after t=240h: $\Delta E_{Scotchcal}$=0.28, $\Delta E_{Controltac}$=0.39 and ΔE_{Orajet}=3.03. This value for the Orajet wrap foil exceeds the limit of tolerance and is visible to the naked eye. The black UV ink on the Orajet substrate should, therefore, not be used for practices where the print would be exposed to aging conditions, because it would show a marked difference in coloration in a very short time. A possible solution to such a problem would be additional varnish or the application of an additional protective layer by special laminating.

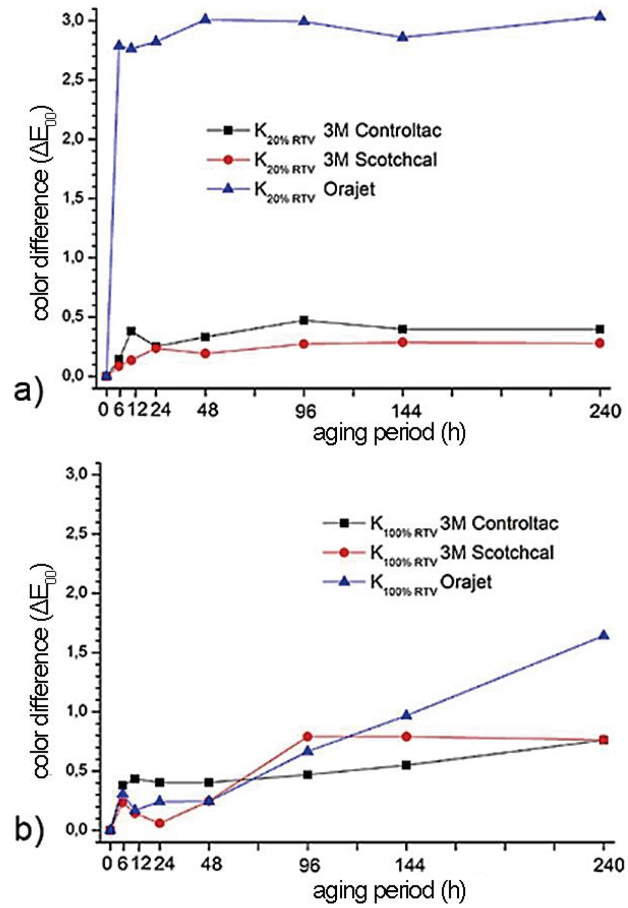

Figure 9. Changes in the black UV inkjet colours after 0h and 240h; a) ΔE_{00} for 20% RTV fields; b) ΔE_{00} for 100% RTV fields

4 CONCLUSION

In the analysis of experimentally aged wrap printing substrates, we found no significant changes in the colorimetric values during the period of 240 hours. Such changes are not visible to the human eye. By colorimetric measurements, it was found that the largest changes are exhibited on the Orajet foil ($\Delta E_{Orajet-240h}$=0.35), and the lowest on the 3M Scotchcal foil ($\Delta E_{Scotchcal-240h}$=0.14). Moreover, colour difference curves do not show a tendency of growth over time, and all three foils retained satisfactory colorimetric properties after a longer aging period.

When analysing the UV inkjet print, it is concluded that each process colour behaves differently. On cyan prints, after six hours, larger changes took place, which over a period of 240h increased to a maximum of ΔE_{240-6h}=0.3. Due to low production costs, the biggest changes were, as expected, on the Orajet foil, and the smallest on the 3M Scotchcal foil. However, all changes do not exceed the value of ΔE=1. Magenta prints were almost identically changed on the Orajet and 3M Scotchcal foils, on fields with 100% RTV, while the biggest differences for the 20% RTV fields were noticed on the 3M Controltac foil. All changes did not exceed the value ΔE=1 until the end of experimental aging.

The yellow colour has shown the slightest change in colouring. Overall differences do not exceed the value of ΔE=0.5, and the values are approximately the same for the prints on all three foils on fields with 20% and 100% RTV. The black colour demonstrated the largest changes. Full-tone fields exhibit a linear growth tendency throughout the experiment. The maximum value is $\Delta E_{\text{Orajet 20\% RTV}}$=3.03. After the initial change at t=6h, this curve demonstrates an approximately stable growth gradient. The black UV prints were the only that after a very short time (6 hours of aging) showed a big difference in coloration, $\Delta E_{\text{Orajet 20\%}}$=3.03. This difference is clearly visible, which is why the black UV ink is not recommended for use in practice (especially for small RTV values).

The 3M Scotchcal foil has, in most cases, shown the best and the most stable results in measurements. The majority of the measured colour differences show a value lesser than ΔE=0.5 for all CMYK colours on the 3M Scotch cal foil (even the black UV ink on 20% RTV fields).

5 REFERENCES

[1] Print – magazin 6/2, Obljepljivanje vozila (6.2015), 44.
[2] http://multimedia.3m.com/mws/media/451422O/sell-sheet-for-7725-and-7125.pdf (Accessed: 16.7.2016)
[3] Majnarić I., Osnove digitalnog tiska, Sveučilište u Zagrebu, Grafički fakultet Zagreb, (2015), 21-25
[4] Wrap magazine 1/1, (1.2016), 42-45.
[5] http://www.tekra.com/resources/tek-tip-white-paper/tek-tip-cast-vs-calendered-vinyl, Tek tip - cast vs calendered vinyl (Accessed: 16.7.2016)
[6] Wrap Magazin, Folije – osnova kvalitetnog wrap-a, 1/1, (1.2016), 20.
[7] http://multimedia.3m.com/mws/media/253349O/instruction-bulletin-and-application-guide.pdf (Accessed: 20.7.2016)
[8] http://multimedia.3m.com/mws/media/731671O/product-bulletin-1080-series.pdf (Accessed: 16.7.2016)
[9] http://multimedia.3m.com/mws/media/664607O/product-bulletin-80.pdf (Accessed: 16.7.2016)
[10] https://kpmfusa.com/history-of-vehicle-wrap/ - History of vehicle wrap (Accessed: 20.4.2016)
[11] http://multimedia.3m.com/mws/media/1002230O/instruction-bulletin-5-5.pdf (Accessed: 14.7.2016)
[12] http://arlon.com/Objects/Documents/Tech%20Manuals_ Guides/Vehicle%20Wrap%20Removal %20Guide-2014.pdf (Accessed: 14.7.2016)
[13] Možina K., Medved T., Rat, B., Bračko S., Influence of Light on Typographic and Colorimetric Properties of Ink Jet Prints, Journal of Imaging Science and Technology 54(6), 2010. 060403-1
[14] Bolanča, I., Bolanča Z., Lozo B., Influence of digital prints ageing on process recycling of waste paper, REWAS'04, Global symposium on recycling, waste treatment and clean technology, vol. II. (2004)

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