University of Sopron

Faculty of Wood Engineering and Creative Industries

József Cziráki Wood Science and Technologies
Doctoral School

EXPLORATION OF CRITICAL POINTS IN THE PRODUCTION OF FLEXO-PRINTED FLEXIBLE-WALL PACKAGING MATERIALS, RESEARCH INTO POSSIBLE AREAS OF DEVELOPMENT

PhD dissertation thesis booklet

Created by: Várza Ferenc

Supervisors: Joóbné Dr. Preklet Edina,

Dr. habil. Horváth Csaba

Sopron

2024

1. Actuality of the research topic, objectives

Hygiene requirements that are gradually getting stricter, requirements of circular economy, innovative manufacturing processes and changing customer needs all demand powerful developments concerning the material, appearance and application methods of flexible food packagings. The majority of that are printed products, therefore the requirements for the flexographic printing process will be higher and higher in the future. All this generates numerous theoretical and practical problems in which the methods of scientific research may provide solutions.

Improving print quality and preventing printing problems reduce the amount of waste, and result in a more efficient and energy-saving production process. This requires accurate knowledge of the behaviour and mechanism of action of raw materials in the entire printing process.

The use of surface (direct) flexo printing promotes the spread of mono-material packagings that can be recycled more easily. The criterion for this is the approach to the quality level of reverse (mirror) printing.

Reducing the amount of raw materials used during the varnishing processes and the length of the work process ensures a more efficient, economical and environmentally conscious operation.

The primary goal of the research is to display and solve the most important problems in the practice of flexo printing, within which the sub-tasks have been defined as follows:

- Investigating polyester mirror printing, analysing whether it is possible to increase the 4-colour and 7-colour (CMYK and CMYKOGV) gamuts of solvent printing with properly selected, new plate surface patterns and ink, converging to UV flexo, thereby expanding interoperability between the two printing technologies.
- Further goal of the colour gamut tests is to promote the production of monostructure packaging by bringing the quality level of surface printing closer to the quality of reverse printing.
- Cause and effect investigation of ink viscosity changes in order to ensure the development of standardizable viscosity setting methods.
- Analysis of opacity and drying problems, since the quality of the white ink layer is crucial in respect of colour gamut and print image.
- Instead of the previous two levels (varnished, non-varnished), creating multiple gloss/matte levels with a single varnish plate, including plate surface structures with different geometries, without

applying autotypical screening, and with no ink buildup.

2. Research materials and methods

Print substrate: 12-micron F-AUT PET foil
Plate types:

- Flint (XSYS) ACE-D
- Flint (XSYS) ACT-D
- MacDermid LUX ITP-60
- DuPont EASY ESE

Ink types:

- Doneck Pronat Euro-Base product family
- Flint Group Flexocure Ancora 50 B3 low migration colour inks
- JKM Pronat UV Flexo Low Migration White NLM - low migration white ink

Varnish types:

- Doneck Pronat products
- Actega Wesso product family 3615 and 26.351.28

Applied printing presses:

- SOMA Flex Midi II, central impression cylinder, solvent, 8-colour
- Bobst M6, inline, UV, 9-colour

Applied measuring devices:

- Biuged BGD 516/3 glossmeter
- X-Rite eXact 1 colorimeter
- X-Rite i1iO 2 colour chart reader
- Peret FLEX³PRO flexo plate analyzer

- Horiba Partica LA-950V2 size distribution analyzer
- MYR V1 type rotational viscometer

Methods

Method of white coverage value analysis: We laminated the test prints onto a black base foil, and measured the achievable whiteness on the laminate in CIE L*a*b* values with an X-Rite eXact spectrophotometer. Here, we examined absolute values, that is how much we could approximate the ideal colorimetric white (L*=100 a*=0 b*=0). The level of coverage always depends on the backing material. We may also measure the ΔE (L*a*b*) colour difference between the covered/uncovered parts of the base material. However, it is important in every case to exactly identify the backing material in order to be able to provide the same for future measurements as well. Under these conditions, we need to focus mostly only on the L* value of the CIE L*a*b* measurements, and the absolute values of a* and b* need to remain less than 2-3. The exact parameters of the backing material: Black PE foil, thickness: 100 microns; L*10.42; a*0.31; b*1.21.

We used a Peret Flex3Pro device for *measuring fill ratio and geometrical values* in case of the white test prints.

Size distribution analysis of TiO_2 pigments was performed at Budapest University of Technology and Economics with a Horiba Partica LA-950V2 device.

Gloss value measurement was performed with a Biuged BGD 516/3 device.

Colour chart measurements were carried out with an X-Rite i1iO 2 device and GMG OpenColor software. The software determined the volume values of each colour gamut, and was able to compare 2 sets of colour gamut data with the possibility of making plane cross-sectional images at any L (Lightness) value. In our analyses we took plane cross-sectional images for L values of 20, 50 and 80. This method is capable of examining colour gamut differences, their expansibility, and the degree of interoperability between them.

For our *ink rheology tests*, we used a MYR V1 type rotational viscometer that is suitable for measuring liquid viscosity under different shearing stresses. The constant and accurate ink temperature was ensured by a WEB MLW PRÜFGERATE – WERK MEDINGEN/SITZ FREITAL U15C type equipment.

3. Summary of new scientific results

3.1. Interoperability of UV and solvent technologies

I intended to prove that with properly selected new plate surface patterns and ink it is possible to extend the colour gamut of 4-colour and 7-colour (CMYK and CMYKOGV) solvent printing, converging to UV flexo, thereby expanding interoperability between the two printing technologies.

In case of UV technology, the maximum colour gamut volume was 1033598 that we could achieve with reverse printing and with the white printed by a rubber sleeve. When white was printed with a plate, the achievable maximum colour gamut showed a gamut volume value of 984369 that was performed with a square-grid ACT-D white plate. These tests also prove the importance of white background printing. The two different white printing technologies resulted in a difference of 4.8% regarding the achievable printed colour gamut. Based on our measurements, we found that the greatest differences between the colour gamuts were in the range of midtones. In case of direct printing, with UV technology we reached the maximum colour gamut without varnishing, with an ACT-D type white plate having special "G" pattern, getting a colour gamut volume value of 1116529.

In solvent technology, in order to achieve the maximum colour gamut – 1004039 – we needed to apply a glossy varnish. In this case, both the glossy varnish and the white ink were transferred to the surface with the help of a rubber sleeve. The difference of the colour gamut achieved this way was 10%. We found significant differences in the ranges of midtones and shadows.

Solvent technology provided a larger colour space for shades of green and magenta, while UV technology in the cyan and violet ranges. The results of the test print analysis proved my hypothesis.

Thesis 1: With HD FLEXO/Pixel+ plate surface patterns and highly pigmented ink it is possible to extend the 4-colour and 7-colour (CMYK and CMYKOGV) gamuts of solvent printing, converging to UV flexo, thereby expanding the possibility of interoperability between the two printing technologies.

3.2. Interoperability of surface and reverse printing

With my research, I looked for a solution so that the quality of surface printing could get closer to the quality of reverse printing. Regarding solvent technology, by using properly selected microcelled printing plates and varnish, we were able to reduce the difference between the colour gamuts of mirror and direct printing below 1%. In this case, we got a colour gamut volume of 1004039 with direct printing, and 997140 with mirror printing. In direct printing, without varnish, the colour gamut volume was only 821829, despite applying special microcelled plate. This also shows how beneficial the usage of a glossy varnish may be in view of the enhancement of product colour dynamics. Besides, the varnish also provides physical protection to the ink layer. When using glossy varnish for solvent direct printing, we could accomplish an increase of 18% in colour gamut.

With UV technology, during our research we were able to reduce the difference between the colour gamut volumes of surface and reverse printing below 10%.

Thesis 2: By introducing an adequate glossy varnish and 4000 dpi line screen plate surface pattern, it is possible to realize interoperability between surface and reverse printing with the parameters applied by us. The difference between the obtainable colour gamuts of mirror and direct printing can be reduced to less than 1% in terms of volume percentage with solvent technology, and to less than 10% with UV technology.

3.3. Rheological analyses

In the course of my analyses, I investigated the rheological properties of the inks and performed measurements under varying shear stress and temperature. Instead of the pseudoplastic behaviour usually expected in the case of inks, cyan and black inks behaved dilatantly at 22.4 degrees Celsius, above 100 RPM shear stress. I formulated a physical explanation of the given phenomenon. My rheological research provides a suitable basis for the development of inks that can be used to eliminate unexpected viscosity problems caused by changes in shear stress.

Thesis 3: I prove that in case of flexo inks, out of the four basic colours, the cyan and black inks show behaviour characteristic of the dilatant system instead of the expected pseudoplastic behaviour, the reason for which is the appearance of strong hydrogen bridge bonds formed between the hydroxyl groups of the

molecules at a given temperature, which significantly increases shearing force.

3.4. Analysis of white ink transfer problems

Applying solvent inks, I investigated which combination of a surface pattern type and a matching Shore A hardness polymer plate would ensure near-ideal coverage, ink transfer, dot gain and raster dot appearance at the same time. The ink containing matte TiO_2 pigments showed maximum coverage for all tested plate types. From this, we conclude that matte TiO_2 pigments provide greater coverage. In case of the halftone range of 30% and above, the lowest dot gain values were achieved by ACT plate and the test3 ink. Regarding dot gain, the use of slow-drying white ink is advantageous. Based on our surface pattern tests, we achieved the highest coverage and the best dot appearance – among the patterns we used – with the MG25 pattern, on the basis of which we determined that the highest coverage can be achieved with a line surface pattern in case of printing white.

Thesis 4: In flexo printing, the quality of the white ink layer is decisive in terms of the colour gamut and print image. I prove that in case of solvent flexo technology, the soft (74 Shore A hardness) polymer plate made with line screen surface pattern type ensures near-ideal white coverage, ink transfer, dot gain and raster dot appearance. Matte TiO_2 pigments increase the level of coverage.

3.5. Analysis of the structure of matte varnished surfaces

An objective of the research was to develop a new approach and method with which, instead of the previous two levels (varnished, non-varnished), we can achieve multiple gloss/matte levels with a single varnish plate, including plate surface structures with different geometries, without applying autotypical screening, and with no ink buildup. With the help of the test results, we got a more accurate picture of what gloss values the type of varnish we developed produces when using plates with different surface patterns. With regard to the anilox parameters applicable in practice, the lowest gloss values were accomplished with the XSYS ACT-D plates. From this, we conclude that the matteness of the varnished surface can be increased by using softer plates. Within a print, the greatest gloss difference of 66.7 between the minimum value of 27.8 and the maximum value of 94.5 can be achieved by using 360/5.5 anilox and Flint ACE-D plate. The most matte surfaces were performed by a surface pattern with a 45-degree line geometry. In all cases, the lowest gloss values were achieved with Flint ACT-D plates. When using a matting agent with large particle size, the matteness of the printed surface cannot be influenced by the surface pattern.

Thesis 5: I developed a new method by which, instead of the previous two levels (varnished, non-varnished), we can achieve multiple gloss/matte levels with a single

varnish plate, including 4000 dpi plate surface structures with different geometries, without applying autotypical screening, and with no ink buildup. The matteness of the varnished surface can be increased by using lower Shore A hardness plates. The most matte surfaces were performed by a surface pattern with a 45-degree line geometry.

4. Publications related to the dissertation topic

1.
Várza, Ferenc ; Horváth, Csaba; Joóbné, Preklet Edina
Innovatív felületnemesítés flexonyomtatásban: a matt lakkozásban rejlő speciális lehetőségek vizsgálata
MAGYAR GRAFIKA 67: 1 pp. 42-48., 7 p. (2023)

2.
Horváth, Csaba ; Várza, Ferenc ; Manúrová, Klaudia
Analysis of the Matte Varnishing Structure of Flexible-walled Packaging Materials In the Case of Flexographic Printing Technology
In: s., n. Proceedings of the Technical Association of the Graphic Arts, TAGA
Oklahoma City (OK), Amerikai Egyesült Államok: Technical Association of the Graphic Arts (TAGA) (2022) pp. 1-10., 10 p.
Scopus

3.
Horváth, Csaba ; Várza, Ferenc ; Manúrová, Klaudia
Analysis of the flexo printed matte varnishing structure of polyester substrate
In: Proceedings - The Eleventh International Symposium GRID 2022
University of Novi Sad, Faculty of technical sciences, Department of graphic engineering and design (2022) pp. 343-348., 6 p.
DOI SOE Publicatio repozitórium Scopus

4.
Maňúrová, Klaudia ; Joóbné, Preklet Edina ; Horváth, Csaba ; Várza, Ferenc
A FLEXONYOMTATÁS ÉS NYOMDAI ELŐKÉSZÍTÉS STANDARDIZÁLÁSI ÉS OPTIMALIZÁLÁSI LEHETŐSÉGEINEK VIZSGÁLATA A MAGYARORSZÁGI NYOMDÁKBAN
In: Koncz, István; Szova, Ilona (szerk.) TIZENKILENC ÉVE AZ EURÓPAI MAGYARORSZÁG TUDOMÁNYOS MEGÚJULÁSA ÉS A FIATAL KUTATÓK SZOLGÁLATÁBAN : A PEME XXIII. PhD – Konferenciájának előadásai (Budapest, 2022. április 28.) Budapest, Magyarország: Professzorok az Európai Magyarországért Egyesület (2022) 163 p. pp. 114-125., 12 p.

5.
Várza, Ferenc ; Horváth, Csaba
A fehérnyomtatás fejlesztési lehetőségei: vizsgálatok a flexográfiai nyomtatás területén
MAGYAR GRAFIKA 66 :1 pp. 4-8., 5 p. (2022)

6.
Várza, Ferenc ; Horváth, Csaba ; Joóbné, Preklet Edina
Hajlékonyfalú csomagolóanyagok struktúrájának elemzése flexográfiai matt lakkozási technológia esetén
In: Obádovics, Csilla; Resperger, Richárd; Széles, Zsuzsanna (szerk.) PANDÉMIA – FENNTARTHATÓ GAZDÁLKODÁS – KÖRNYEZETTUDATOSSÁG: Konferenciakötet (Lektorált tanulmányok) Sopron, Magyarország: Soproni Egyetemi Kiadó (2022) 485 p. pp. 448-453., 6 p.

DOI SOE Publicatio repozitórium

7.
Ferenc, Várza ; Edina, Preklet ; Csaba, Horváth
APPLICATION ANALYSIS OF WHITE FLEXOGRAPHIC PRINTING INKS ON BIODEGRADABLE FLEXIBLE FOILS
In: Karlovits, Igor (szerk.) Proceedings of the 2nd International Conference on Circular Packaging
Ljubljana, Szlovénia: Pulp and Paper Institute (2021) 333 p. pp. 311-320., 10 p.
DOI SOE Publicatio repozitórium

8.
Ferenc, VÁRZA ; Csaba, HORVÁTH ; Edina, PREKLET
ANALYSIS OF THE MATT LACQUERING STRUCTURE OF FLEXIBLEWALLED PACKAGING MATERIALS IN THE CASE OF FLEXOGRAPHIC PRINTING TECHNOLOGY
In: Csanák, Edit (szerk.) 8TH INTERNATIONAL JOINT CONFERENCE ON ENVIRONMENTAL AND LIGHT INDUSTRY TECHNOLOGIES
Budapest, Magyarország: Óbudai Egyetem (2021) pp. 83-88., 6 p. SOE Publicatio repozitórium

9.
Várza, Ferenc ; Joóbné, Preklet Edina ; Horváth, Csaba
A fehér festékek alkalmazási problémáinak vizsgálata a flexográfiai nyomtatási folyamatok technológiájában
In: Koncz, István; Szova, Ilona (szerk.) XXI. PEME–PhD (Online) Konferencia: TIZENNYOLC ÉVE AZ

EURÓPAI SZINTŰ TUDOMÁNYOS MEGÚJULÁS ÉS A FIATAL KUTATÓK SZOLGÁLATÁBAN
Budapest, Magyarország: Professzorok az Európai Magyarországért Egyesület (2021) 219 p. pp. 207-214., 8 p.

10.
Várza, Ferenc
Adaptációs lehetőségek az UV-Flexo nyomtatási technológiában (2. rész)
MAGYAR GRAFIKA 65: 1 pp. 12-14., 3 p. (2020)

11.
Várza, Ferenc
Adaptációs lehetőségek az UV-Flexo nyomtatási technológiában (1. rész)
MAGYAR GRAFIKA 64: 6 pp. 14-17., 4 p. (2020)