CONSIDERATIONS ON QUALITY ASSURANCE FOR FLEXOGRAPHIC PRINT PRODUCTS

Gabriela Valeria FOLEA[1], Emilia BĂLAN[2], Cristina MOHORA[3]

Rezumat. *Lucrarea prezintă aspecte ale asigurării calității produselor de tip cutii preformate, din carton subțire, realizate prin tipărire flexografică. Sunt analizate elementele specifice procesului tehnologic, urmate de stabilirea nivelelor de conceptualizare ale produsului cutie după analiza funcțiilor acesteia și a caracteristicilor definitorii ale calității ei optime. De asemenea, în lucrare se prezintă câteva dintre procedurile specifice asigurării calității procesului de tipărire flexografică care s-au implementat în tipografia în care s-a realizat studiul de caz în vederea certificării procesului conform SR EN ISO 9001:2015.*

Abstract. *The paper presents considerations on quality assurance for products such as preformed boxes, made out of thin cardboard, created through flexographic printing. The elements specific to the technological process are analysed, followed by the setting of the levels of product conceptualisation after the analysis of its functions and the defining characteristics of its optimal quality. In addition, the paper covers some of the procedures which are specific to the quality assurance of the flexographic printing procedures which were implemented in the typography where the case study for certifying the process in compliance with SR EN ISO 9001:2015 was carried out.*

Keywords: flexographic printing, quality, procedures, preformed box

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1. Introduction

In the technological process of flexography [1], the quality assurance of the end-product is influenced by the capacity of preventing defects and foreseeing the appearance of their sources directly on the production flow.

The main elements that occur in the process and their influencing factors are: • the material through: thickness and type – paper, cardboard, foil, self-adhesive, multi-layer film; • the flexographic printing machine through the associated equipment: printing and die cut assemblies, slitting elements, waste disposal possibilities; • the human factor involved directly in production – printing worker, printing worker assistant, ink worker, through the ability of making adjustments and

[1]Eng. PhD student, Doctoral School of Industrial Engineering and Robotics, University "Politehnica" of Bucharest, Romania, (e-mail: gabriela_folea@yahoo.com).
[2]Assoc. Prof., PhD Eng., Faculty of Industrial Engineering and Robotics, Robots and Production Systems Department, University "Politehnica" of Bucharest, Romania, (e-mail: emilia.balan59@yahoo.com).
[3]Prof., PhD Eng., Faculty of Faculty of Industrial Engineering and Robotics, Robots and Production Systems Department, University "Politehnica" of Bucharest, Romania, (e-mail cristinamohora@yahoo.com).

preparing inks. All of them bring their contribution to obtain a print impression at a quality comparable with the proof [2] or the sample received from the client.

The Pareto analysis [3] regarding the cumulative impact of these elements on the quality of the product obtained through flexographic technology highlighted the fact that the defects and the non-conformities that generate the biggest losses are those which occur suddenly without having clearly determined the causes, their urgent disposal being the optimal solution for reducing the effects [4].

The chosen product for this case study is a *preformed box* (Fig. 1) made out of thin cardboard for boxes, "coated folding boxboard" type of 240 g/m^2. The technical data relevant for the design stage of the product are given in Fig 2.

The study was conducted in a typography equipped with a flexographic printing machine *OMET VF 530 F1*, equipped with 8 printing assemblies (Fig. 3), die cut assembly, with printing possibility of maximum 8 colours and with a minimum set of evaluation and quality control elements of the print impression: Pantone Capsure™ tool (Fig. 4) – having integrated in the software Pantone® libraries [5] and it is used for identifying through the measurement of the pantone colours printed on the material; the Pantone® Plus Series Formula Guide library; typographic magnifier 10x and/or microscope 500x, depending on the needs.

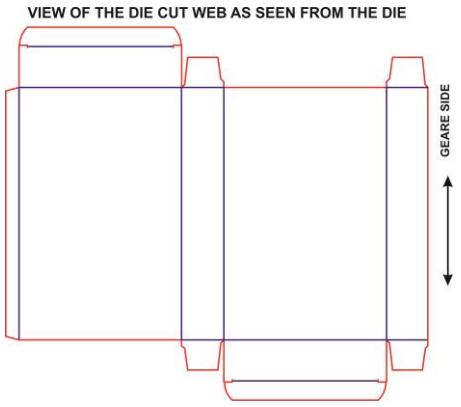


Fig. 1. Die cut drawing for a *preformed box.*

Technical information	Unit ISO	Value
Grammage	g/m^2	240
Thickness	µm	400
Moisture content	%	8
Smoothness top	µm	1
Brightness top	%	87
Brightness back	%	74
Colour CIELAB L* top	-	94.3
Colour CIELAB a* top	-	1.2
Colour CIELAB b* top	-	-1.5
Gloss	%	50

Fig. 2. Technical data for the material.

Fig. 3. Printing assembly of the flexographic machine.

Fig. 4. Pantone Capsure™ tool.

2. Characteristics of the flexographic printing technological process

In order to obtain a product through flexographic technology, the following materials are used in the production flow:

a) raw material, also called material, is delivered on the roll and can be: self-adhesive with the frontal side made out of paper of BOPP foil, PE; paper; cardboard; films made out of plastics: PE, PET, BOPP, CPP, PVC, PO; metallic multi-layer foil with *Al* or without *Al*; specialities obtained from combining them.

b) tubes on which the material is wrapped: they have an internal diameter imposed by the client; their walls have different thicknesses depending on the type of material and the external diameter of the end-roll, imposed by the client;

c) printing plates (Fig. 5) – flexible photopolymer – which ensures the transfer of ink from the anilox [6] on the material;

d) double-adhesive bands for fixing the printing plates on the printing cylinder;

e) inks, varnishes, adhesives for lamination, adhesives for adherence;

f) solvents for cleaning printing plates; solvents for cleaning anilox, die cuts.

The printing assemblies that intervene in the printing process have characteristics which are specific to the flexographic machines and include the following elements (Fig. 6) [7]:

a) ink fountain;

b) rubber ductor cylinder which takes the ink from the ink fountain and transfers it onto the anilox;

c) anilox – is the ink dosing cylinder which is disposed on the printing plate;

d) scraper as known as "doctor blade" in the printing vocabulary, which removes the excess of ink from the anilox;

e) printing cylinder which can be compact block or sleeve; it has the role of supporting the printing plate through the double adhesive tape;

f) pressure cylinder for printing an impression on the material;

g) lamp for drying UV inks, UV adhesives.

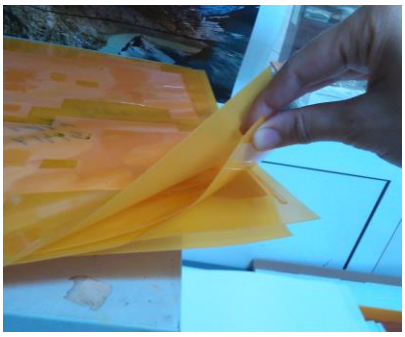


Fig. 5. Set of printing plates for only one product.

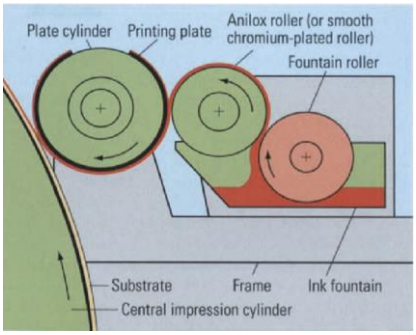


Fig. 6. Flexographic inking unit with ink feed via roller system (fountain roller system) [7].

Each die cut assembly involved in the production consists of: magnetic cylinder (on which the die cut is installed), the actual die cut and counter-cylinder called "anvil" by specialised manufacturers.

The slitting assemblies contribute to the semi-finishing / finishing of products and are equipped with disc knives / cutting blades; some machines also have rotary slitting assembly called "fly cutter" in the specific machine documentation, and its role is to cut the end-product into sheets.

The performances that a printing machine can achieve are specific to each manufacturer. These, along with the equipment specific to the flexography, have an essential contribution to the quality of the obtained product.

Thus, on the technological flow specific to the flexographic printing the following types of processes are performed in sequence: pre-printing process, actual printing process and post-printing process with the role of obtaining the end-product.

Furthermore, the elements specific to these technological processes [8] which contribute to obtaining a *preformed box* – the product chosen for the case study, are schematically presented.

2.1. Pre-printing processes

a) obtaining the *technological working sheet* product:

INPUT ELEMENTS	PRE-PRESS ACTIVITIES	OUTPUT ELEMENTS
• **Client requirements:** **- sample / material** **- drawing / graphics** **- end-product restrictions** • **Technological data:** **- material type** **- inks/ varnish / lamination**	• **Research:** **- material possibilities / machine capabilities** **- possibility of graphic adjustment to the flexographic-printing** • **Design technical drawing** • **Finishing of product framing on the machine**	• **Technological working sheet**

b) obtaining the products *printing plates + proof* and *die cut*:

INPUT ELEMENTS	PRE-PRESS ACTIVITIES	OUTPUT ELEMENTS
• **Technological working sheet** • **Material technical sheet** • **Technical drawing** • **Graphics**	• **Proof order + Printing plates order** **- printing plates set-up evaluation** **- printing plates execution approval** • **Die cut order** **- die cut set-up evaluation** **- die cut execution approval**	• **Printing plates + Proof** • **Die cut**

2.2. Printing + die cutting processes

a) obtaining the *print impression according to proof / client sample* product:

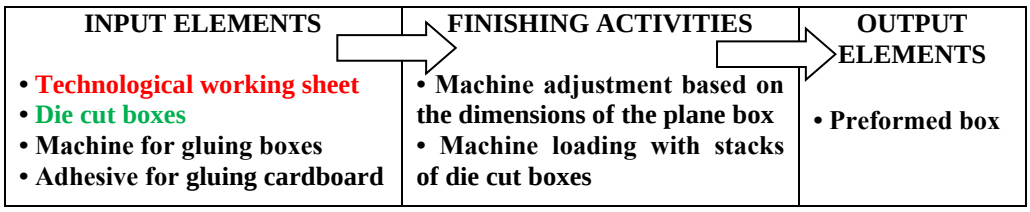
INPUT ELEMENTS	PRINTING ACTIVITIES	OUTPUT ELEMENTS
• Technological working sheet • Proof / client sample • Material + tubes + printing plates + die cut • Elements for printing assemblies • Elements for die cut assemblies • Colour printing inks + pantone + varnish • Evaluation tools of spot colours through comparison / measurement: - The Pantone® Plus Series Formula Guide Coted library - Pantone Capsure™ tool	• Material set-up in machine + route • Inking unit pressure adjustment • Printing assembly pulling in registry • Die cut assembly / magnetic cylinder + die cut set-up • Die cut pressure adjustment • Die cut pulling in printing + waste disposal • Actual printing: printing an impression + die cutting • Colours evaluation: - print impression comparison with library / proof / sample - measurement with the tool • Anilox final decision • Pantone colours recipes decision	• Semi-finished / end-product print impression according to proof / client sample • Recyclable / unrecyclable waste

b) obtaining the *die cut box* product:

INPUT ELEMENTS	PRINTING ACTIVITIES	OUTPUT ELEMENTS
• Technological working sheet • Material: cardboard 240 g/m^2 • Machine for flexographic printing with 8 printing assemblies, elements: anilox, sleeves, printing plates • Die cut assembly in line with the printing assemblies, elements: - magnetic cylinder, die cut • Inks: 4 process + 2 pantones + folio + varnish • Evaluation tools: - The Pantone® Plus Series - Pantone Capsure™	• Cardboard roll sett-up in machine + route in machine • Printing pressure adjustment at 8 inking units • Pulling in the register of the 8 printing assemblies • Magnetic cylinder + die cut • Die cut pressure adjustment • Die cut pulling in printing + waste disposal • Printing + die cutting - Colours evaluation through comparison with the Pantone® library and measurement with tool • Anilox final decision • Pantone recipes completion	• Die cut box • Recyclable waste

2.3. Post-printing processes

Obtaining the *preformed box* product:



All products obtained after each process are a part of the processed materials products category. One can observe that, until obtaining the *Preformed box* end-product, all products obtained in the previous processes interact, participating as input elements in the subsequent processes.

3. Product models required for the study

The first model of box products was created in compliance with the product model suggested by Philip Kotler, known as the founder of the "marketing management" [9]. Starting with the analysis of the functions of a box whose role is to pack the end-product, its conceptualisation levels were established (Fig. 7). By studying this product model, the manufacturers can establish more accurately a series of defining characteristics for their future products of this type.

The second product model is called "optimal quality" and can be defined as being the actual, palpable, objective quality of the obtained product, through which it meets the conditions provided by both the technical documentation and the client's requirements. This product model takes into consideration both the technical equipment of the typographic organisation and its personnel, and its creation allows establishing the activities which are specific to the quality assurance of the analysed product.

The model for the *preformed box* product analysed in this article is presented at Fig. 8. The characteristics provided in the technical sheet – where the machine capabilities / equipment is indicated – are included in circle *A*, namely: • material: cardboard 240 g/m^2; • printing with printing plates executed at 180 Lpi; • CMYK + 2 pantones + applying gold foil + varnishing; • packing method: 200 pieces / box with dimensions optimally correlated with those of the product.

The characteristics created through this printing process are presented in circle *B*: • trapps of 0.03 – 0.06 mm at cracks in white; • reproduction of an image with a quality similar to that obtained through offset printing; • consistency of the printing colours throughout the entire printing; • packing method: dedicated boxes, palletized with a number of product pieces, indicated on the label of the box and pallet.

The characteristics required by the client are those included in circle *C*: • preformed box, easy to shape, resistant to careless handling; • liner: cardboard 240 g/m^2; • printing performed according to the graphics, with gold foil on the graphic elements and varnishing; quality at printing; • packing method: batches of 10 banded products, 20 batches/box each; • short delivery term compared to the requested number of models.

Potential product: – reflects the possible, yet unknown level.	• Including in printing certain elements of security: holographic foil, microtext (the height of the letter's body is less than 1 mm), inks invisible in daylight and visible in UV light, elements which can be read by electronic sensors. • Suggestion: keeping the shape of the box, the lids can be open only by destruction – anti-theft solution for the product packed in the box.	 Holographic foil
Amplified product: – adds differentiated advantages.	• Printing finishing: graphic elements have application at cold of gold foil (cold foil) + selective varnishing. The aspect of the box suggests a qualitative textile content / product. • The claps close and open only by manual operation, the packed product does not fall out of the box after repetitive handling.	
Expected product: – comprises a plus of characteristics known by the buyer.	• Box with printing / polychromic imagines graphics + spot inks + full varnishing. • The graphic elements distinctly suggest the content of the box.	
Generic product: – product with minimal necessary elements.	• Box with printing / graphics in 2 colours 100% application + full varnishing. • The text transmits information regarding the content of the box.	
Basic product: – the simplest product.	• Box with no printing for general use.	

Fig. 7. Conceptualising the *preformed box* type of product.

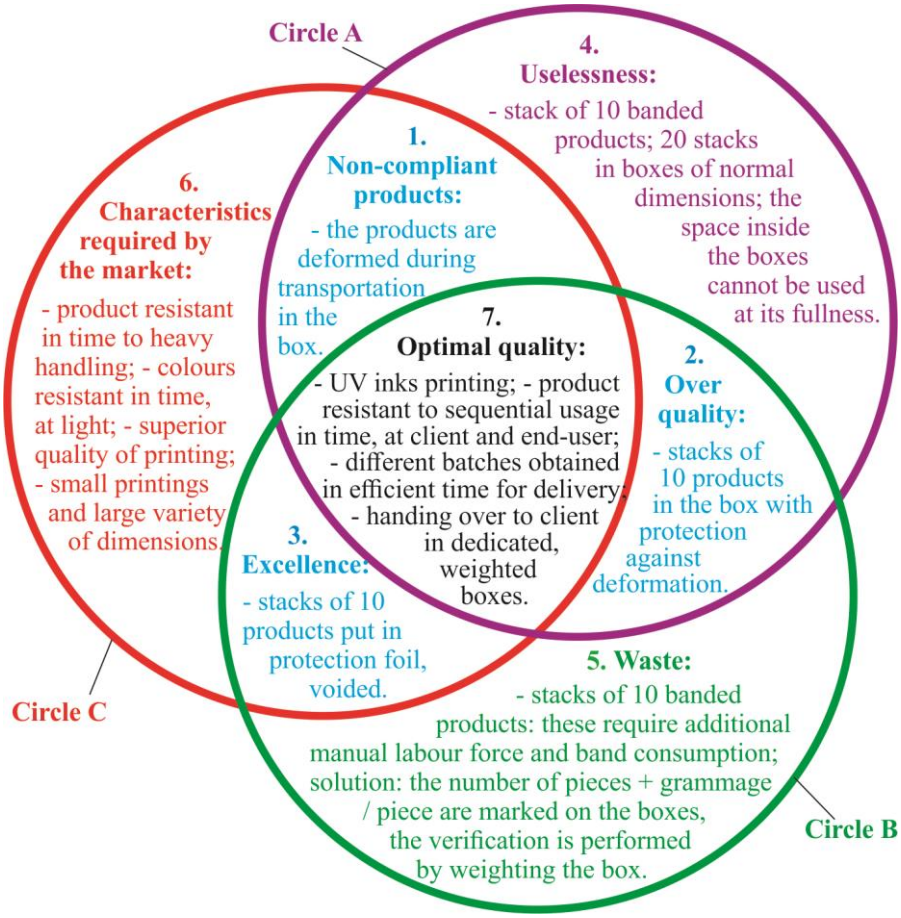


Fig. 8. Optimal quality of the *box* product: Circle *A* – characteristics provided in the technical sheet; Circle *B* – characteristics created physically; Circle *C* – characteristics required by the client.

Product name:	350.5x307.5_BOX_135x35x210				
dimensions (mm)	350.5x307.5	l x h x L (mm)	135x35x210	sleeves	A1(2) Z170 (539.75)
material type	Cartonboard 240 g/m²	pieces/pack	20	die-cut	A1(2) Z85 (539.75)
material width (mm)	370			edges (mm)	(0)
				gap al. (mm)	(0)

1	2	3	4	5	6	7	8
C 520/3	M 520/3	Y 520/3	K 520/3	P485 160/6.9	Kdense 160/6.9	ColdFoil 100/9.9	Varnish 160/6.9
M	M	M	M	H	H	H	M

1 2 3 4 5 6 7 8

Fig. 9. Technical data for the printing – die cutting process from the technological sheet.

There is noted that the client's requirements (characteristics *C*) consist in input / start elements in the process of obtaining the technological work sheet (Fig. 9) which is completed including the actual possibilities of obtaining the *preformed box* end-product (characteristics *A*).

For the Romanian printing industry, these two product models represent at the moment, as well, a necessary support for establishing some realistic contracts between manufacturers and beneficiaries. Many times, the requirements addressed to the flexographic typographies reveal the lack of knowledge of the technological processes and their specific limitations.

4. Quality assurance procedures

To ensure and improve the quality of its activities, the typography in which the case study analysed in this paper was carried out, proposed the implementation of the SR EN ISO 9001:2015 standard.

A first step was the introduction of the sheets for registering objective data. Based on them, a series of studies regarding the quality of flexographic process were conducted. For instance, Fig. 10 [4] presents the results of the evaluation, taking into consideration the following aspects: inks and varnish, printing defects, constructive elements of the machine, raw material defects, non-conformities caused by the die cut, defects produced by the printing plates. Through the Pareto analysis of the data registered during June 2016 – March 2017 deriving from a machine and three shifts of printing workers, it was noticed that 80% of problems derived from the group composed of inks + varnish, then from printing defects and constructive elements of the machine [4].

Taking into consideration the results obtained in the previous studies and product models proposed for the preformed boxes made out of thin cardboard, a series of procedures which are specific to the quality assurance of the printing process analysed in the flexographic typography were drawn up and implemented [8, 10]. We should mention that until now the typography did not use such procedures.

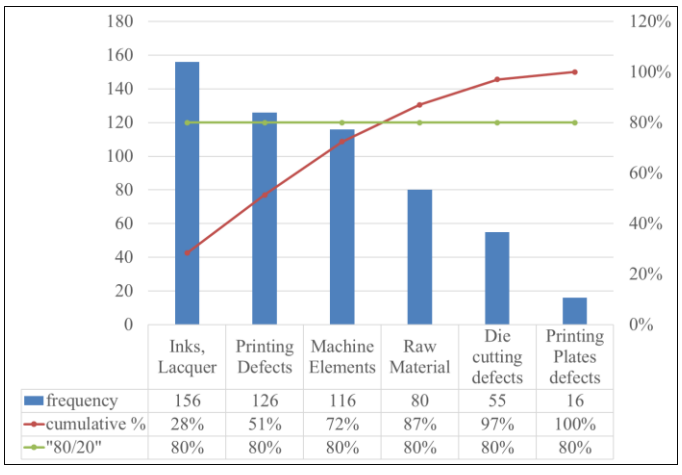


Fig. 10. Evaluation of the flexographic printing process quality [4].

Fig. 11. Example of rolls labelled at sight and covered in foil.

Some of these procedures are presented below, with the mention that each operation within each procedure has clear deployment indications by strictly applying the security and work safety regulations.

4.1. Printing preparation procedure

a) Before in feeding the machine with raw material, all the cardboard characteristics written on the identification label placed on the roll are assessed. The technical data regarding the type of cardboard, grammage and thickness have to be identical with those from the Technological sheet of the printed / die cut product.

Responsible personnel: Printing worker,
Printing worker assistant.

Note: The cardboard roll is marked in a visible place (Fig. 11) with an identification label that includes: manufacturer's name / type of cardboard / dimensions / grammage (g/m^2) / thickness (micrometres) / rolling method (with the frontal side of the rolled cardboard outside or inside) / batch number / production date.

b) The cardboard roll is checked visually to see if it is intact. The roll does not have to present any defects: damages / edge bends, puncture marks / folds (pressed bends) on the frontal side of the cardboard. If the roll presents at least one of the indicated defects, it is withdrawn and replaced immediately.

Responsible personnel: Printing worker,
Printing worker assistant.

Note: As long as the cardboard is pulled into the machine, including during the actual printing, the printing worker continues to carefully verify the deploying surface of the material: not to present folds (pressed bends), not to appear thickness variations or any other event which endangers the printing / die cutting quality. During work, at any time, if it is noticed that at least one of the indicated defects is present, the printing is stopped, the roll is removed from the machine and replaced. At all times, the removed roll will be claimed / returned to the manufacturer, according to the existing procedures.

c) The printing plates are set-up on the sleeves of the machine – these sleeves are fixed on a rotary spindle, together fulfilling the role of the printing cylinder. At each printing assembly, the ink and anilox are verified to be in compliance with the information from the Technological sheet.

Responsible personnel: Printing worker,
Printing worker assistant.

d) The magnetic cylinder and the die cut necessary for the work are identified in the archive. The die cut assembly can be removed from the machine, the cylinder

from the previous work is dismantled and archived in special boxes and then, the magnetic cylinder assembly of the current work is set-up. The die cut is set-up on the magnetic cylinder, the die cut assembly is coupled in the machine.

Responsible personnel: Printing worker,
Printing worker assistant.

4.2. Printing procedure for the first printing sample

a) The pressures on each inking unit are adjusted and then pulled in the register. The pressures on the die cut are adjusted and the die cut is pulled on the printing assembly. The first sample is taken to be checked, with the printing performed at printing speed.

Responsible personnel: Printing worker,
Printing worker assistant.

b) The print impression is analysed on the obtained sample, going through the following steps:

– the pressures on each inking unit are verified by analysing the pressure boxes (Fig. 12); verification tools: visually + typographic magnifier.

Responsible personnel: Verifier I: Printing worker,
Verifier II: Quality controller.

– the colour printing and pantones print impression is verified (Fig. 13); it is compared with the proof or the sample from the client; if there is no such sample, the Pantone colours are compared with the existing pantone libraries; verification tools: visually + typographic magnifier or microscope, by case, The Plus Series Formula Guide library or measurement with the Pantone Capsure™ tool, by case.

Responsible personnel: Verifier I: Ink worker / Printing worker,
Verifier II: Quality controller,
Supervision I: Production engineer,
Supervision II: Operations manager.

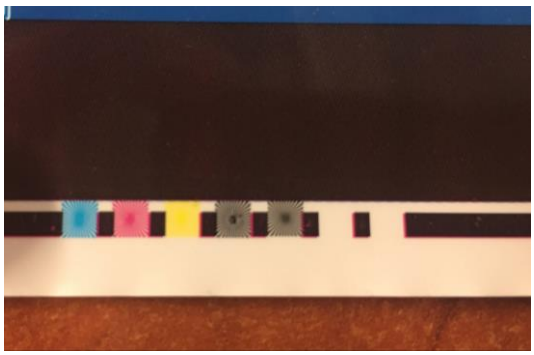


Fig. 12. The size of the 1 mm point formed at the intersection of the rays built in squares, indicate the correct pressure at the associated inking unit.

Fig. 13. The verification with the typographic magnifier is the usual method for permanently controlling the impression on the printing flow.

c) The sample receives BT and is archived. It is the standard sample for the subsequent printings. All the precision data of the printing are written on the sample and in the Technological sheet: material data / printing speed / inks / anilox / printing worker's name / calendar date.

Responsible personnel: Quality controller.

d) The actual production is started.

Responsible personnel: Printing worker,
Printing worker assistant.

4.3. Printing procedure for intermediary samples

4.3.1. At the beginning of roll

a) At the beginning of each printing or roll, if necessary, the steps from 4.2 a) full content to b) are repeated with the modifications: for comparison, the BT sample of the product shall be used, and the responsible personnel is:

Verifier I: Ink worker,
Verifier II: Printing worker,
Verifier III: Quality controller.

b) Any problem that might occur during inks printing is reported by the printing worker, in the order of succession, of the following personnel:

Responsible I: Quality controller,
Responsible II: Production engineer,
Responsible III: Operations manager.

4.3.2. At the end of roll

a) At the end of each roll, one sample is archived for identification in the printing batch. The sample shall include the following data: printing worker's name / calendar date / batch / roll number.

Responsible personnel: Printing worker assistant.

b) The samples are kept in special boxes for being archived for two years, for subsequent references in case of claims, modifications of graphic elements, as well as for amortisation of the guarantee period of the material / inks' quality. The client / product / production date / batch shall be indicated on each box.

Responsible: Quality controller.

4.4. Finishing procedure for die cut boxes

a) As they come out from printing, respectively from the die cut assembly (Fig. 14) the boxes are organised in stacks, on pallets. Each work shall be accompanied by the associated Technological sheet.

Responsible personnel: Printing worker,
Printing worker assistant.

b) The pallets are transferred from the printing area in the work area of the box gluing machine.

Responsible personnel: Repository handler.

b) The infeed unit of the gluing machine is adjusted depending on the dimension of the box. The adhesive for the cardboard is verified and the reservoir is fed. The correct gluing of the closing clap for forming the box is tested. The production of the preformed boxes starts. The infeed unit of the gluing machine shall be permanently supervised and loaded with stacks of die cut boxes (Fig. 15).

Responsible personnel: Manual worker I,
Manual worker II.

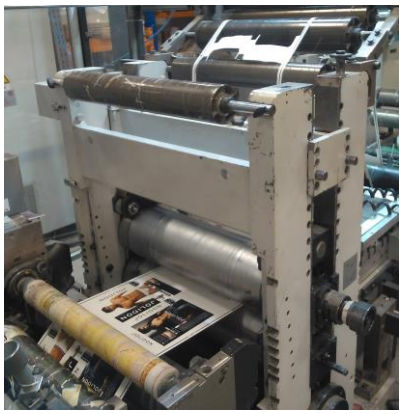


Fig. 14. Entry in the die cut assembly.

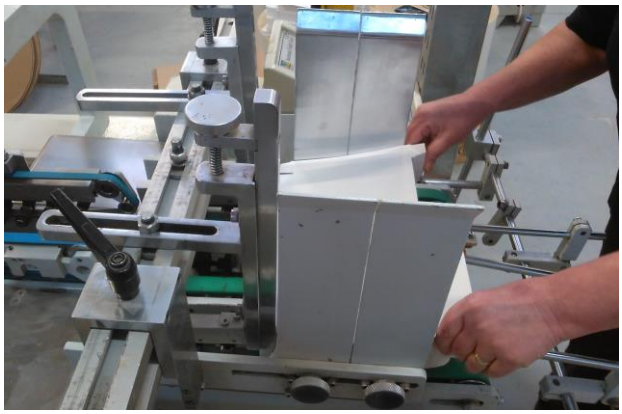


Fig. 15. Matching the stacks of boxes in the infeed unit.

c) As they come out on the gluing machine belt, the preformed boxes are packed according to the indications from the Technological sheet associated to the product.

Responsible personnel: Manual worker I,
Manual worker II.

4.5. Final provisions

Any printing issues, other than those related to colour, which affect the production flow or which might have negative effects on the technological processes, are reported immediately to:

Responsible I: Production engineer,
Responsible II: Operations manager.

Conclusions

In the technological process of flexography, the quality assurance of the end-product is influenced by the capacity of preventing defects and foreseeing the appearance of their sources directly on the production flow.

This paper presents a part of the actions carried out within a typography in order to certify the flexographic technological process in compliance with SR EN ISO 9001:2015.

The case study was carried out for a preformed box made out of thin cardboard; the product was frequently created through this technological process. Its specific elements have been identified, taking into consideration the standardised recommendations.

Product models for identifying the quality characteristics, which constitute a support required to establish some realistic contracts between manufacturers and beneficiaries, have been proposed.

Based on the data collected after implementing the proposed procedures, new case studies shall be carried out in order to highlight their efficiency and efficacy for ensuring the quality of the flexographic technological process within the typography.

Notations and/or **Abbreviations**

BOPP = *Bi-Oriented Polypropylene*

BT = shorthand notation in Romanian of the usual expression "bun de tipar" (good for printing) in printing industry

CMYK = represents the symbolistic of the ink colours used at printing, in order to reproduce an image in colour printing, respectively: cyan = C, magenta = M, yellow = Y and black = K

CPP = *Cast Polypropylene*

Lpi = lines per inch

PE = Polyethylene

PET = *Polyethylene Terephthalate*

PO = *Polyolefin*

Proof = print obtained in order to simulate the product which shall be printed in production and is created in such a way as to visually resemble as much as possible to the future printing

PVC = *Polyvinyl Chloride*

trapp = difference of dimensions at the overlap of colours in the areas surrounded by white

UV = *ultraviolet, -s,* (About) high frequency electromagnetic radiations, located beyond the visible spectrum of the human eye

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