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THE ANALYSIS OF THE PARTICULARITIES OF FLEXIBLE DIES AND OF THE OPTIONS TO ENSURE QUALITY IN FLEXO DIE CUTTING

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Rezumat. *În tiparul flexografic, ștanțarea face parte din categoria operațiilor de finisare a produsului tipărit în vederea obținerii de produse finite pliabile, etichete autocolante, cutii. De interes în prezentul studiu este ștanțarea cu ansamblul ștanță flexibiliă – cilindru magnetic – contracilindru. Au fost analizate posibilitățile de asigurare a calității ștanței și a procesului de ștanțare, prin remedierea neconformităților și defectelor ștanței.*

Abstract. *In flexographic printing, die cutting is classified among the operations needed to finish the printed product into pliable end-products, self-adhesive labels, boxes. For the present study, die cutting with the flexible die – magnetic cylinder – anvil ensemble is of interest. The following were analysed: the possibilities for ensuring the quality of the die cut and of the die cutting process, by remedying die cut nonconformities and defects.*

Keywords: flexible dies, flexo die cutting, flexo die cutting problems, flexible die defects, die cutting errors.

1. Introduction

In flexographic printing, the presses have a modular design, making it possible to include extra die cutting elements and die stations. The finished product determines the production method and, implicitly, the die cutting method [1]. Three types of die cutting are possible:

a) top-bottom die cutting: the material is cut from the front, resulting in self-adhesive labels, perforated and/or cut-out products;

b) bottom-top die cutting: the linear cut of the material, from the opposite side of the material. This type of die cutting is frequently followed by top-bottom die cutting, in order to get self-adhesives with partially adherent areas, perforated products and/or cut-out products;

c) simultaneous up and down die cutting entails cutting the face and the opposite side of the material following different contours, in order to make special use self-adhesives; the contours are cut at the same time as the detachment of the product from the empty printing areas/waste areas and there is the possibility to fold the products made from fine cardboard.

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Depending on these three possibilities, a single die station may consist of:

a) magnetic cylinder – anvil, the flexible die mounted on the magnetic cylinder;

b) engraved cylinder – anvil; the role of the die cut being taken up by the engraved cylinder, with the shape of the cutting/ punching contour.

c) anvil – magnetic cylinder (or, as needed, engraved cylinder);

d) magnetic cylinder – each magnetic cylinder is fitted with a die cut; for economic reasons, the magnetic cylinder and the die can be replaced by an engraved cylinder in one or both configurations.

These die stations are always placed in the machinery after the last printing or refining unit.

Thus, the die cutting of the products is made "in-line" with the print by rotating the two cylinders. The repetition of the cylinders is identical to that of the printing cylinders (called sleeves in flexo).

This paper analyses the magnetic cylinder – flexible die – anvil ensemble by its effects in the printing process. To illustrate, the Omet Variflex VF530 F1 was chosen, as it is a machinery which is representative for the frequency of long run jobs that involve significant load exerted on the die cut station. Then, within a defined timeframe, data has been monitored and collected on all types of die cuts which compromise print quality, as well as the nonconformities and the defects they cause.

The main objective was to determine the causes that lead to the degradation in die cut durability during the printing process, by using at least one of the seven classic graphic instruments pertaining to quality survey [2]: the Pareto analysis, the cause-effect diagram, survey cards, the process diagram, the histogram, the spread diagram, the flow diagram.

The ways in which this objective has been achieved are based on the Pareto analysis applied to determining the groups of nonconformities and defects arising during die cutting, as well as identifying the die cuts that were used.

The resulting conclusions led to a comparative analysis of two troublesome die cuts and between one of these die cuts and a benchmark (defining the qualitative parameters of the die cut).

The following were identified: the main causes which can lead, over time, to a decrease in die cut quality with a negative impact in the printing process; the way in which the technological parameters of the die cut can be preserved during long-term use.

2. Current Status

The particularities of flexible dies come from the geometry of the die cut and from the characteristics of the materials they are made of. The die cut is flat-shaped, and on one of the faces the cutting blades are shaped following the contour of the product which is to be printed. It is made of a metallic, flexible material which allows the die cut to be mounted on the magnetic cylinder by rolling (Fig. 1). The front face of the die cut is considered to be the one with the cutting blades (Fig. 2). This side is chemically treated to get special structures of the material in the cutting blades. Depending on the treatments applied, the die cuts have different quality levels with properties recommended for various printing conditions.

The analysis of the flexible dies shown in nonconformities and defects brought about during the printing process was accomplished by observing for 7 months the following factors: problems generated by the die station and the material; defects resulting from the mechanical destruction of the die cut by punching, by bending or by failure to follow the correct preparation procedures of the die station; nonconformities caused by defective adjustment of the die-carrying cylinder – too low or too high; defects generated by cutting blade wear.

Among the nonconformities and defects visible on the die cut or on the die cut material in the printing process and which were studied during the analysis period are the following: die cut with mechanically destroyed blades, die cut that removes the labels, cuts the liner, cuts the material or has ink-loaded blades, die cut overlaps when mounted on the magnetic cylinder, unpaired die cuts.

3. Visible Nonconformities and Defects in the Die Cut

3.1. Cutting blades mechanically destroyed by misuse of the die

Cutting blades can be destroyed by incorrect handling and bumping.

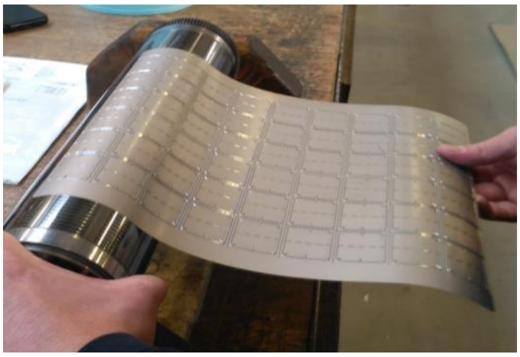


Fig. 1. The die is flat-shaped. It is mounted on the magnetic cylinder by rolling.

Fig. 2. A flexible die. Its front face is the part with shapes defined by the cutting blades.

Once destroyed, the edges will not cut correctly anymore, the labels will stay attached to one another through a paper bridge, and the waste will break in that spot (Fig. 3-5). Sometimes this leads to the impossibility of lifting and running the waste matrix by breaking it.

When using the die for a width of material narrower than the die itself, the die is destroyed by the wear of the blades free of material, pressed on the anvil (Fig. 6). On successive printings, the labels in these areas will no longer be cut properly – the die cut removes the labels.

Apparently, the material is saved by using differences from cutting-off a large roll, but in reality the wear of the die cut requires a much earlier replacement. Given the high costs, these types of defects are continuously monitored.

3.2. Cutting blades mechanically destroyed by the admission of impurities under the die cut

Mounting a die cut on a magnetic cylinder involves preliminary operations designed to ensure the quality of the die cutting process. It is a case of removing impurities from the surface of the magnetic cylinder and removing any deposits from previous prints off the back of the die cut. Failure to comply with these requirements results in an elevation of the die cut in the problem area. In that spot, the cutting blade will be destroyed in the tightening of the die station during printing.

If there is such a mechanical destruction of a die cutting nest (Fig. 7) and this is not observed in due time during the printing process - most often because of the high working speed -, the finished product suffers qualitatively: the waste cannot be removed by die cutting, it remains trapped in the finished product (Fig. 8).

The removal of the defect is done by replacing the die cut. Such cases are rare, but important, due to the large losses they cause.

Fig. 3. The label remains trapped in the waste matrix.

Fig. 4. The waste matrix is broken.

Fig. 5. Incompletely cut labels that remain attached.

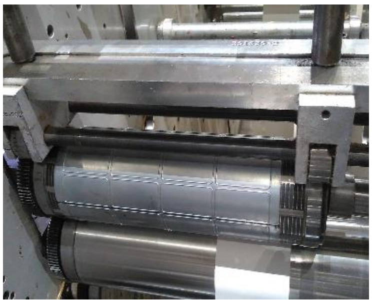


Fig. 6. Die cutting a width of material narrower than the die itself wears out the die.

Fig. 7. Die cut with a partially destroyed nest – see the "X" red mark.

Fig. 8. Waste not removed by die cutting. The product is nonconforming.

3.3. The die cut that overlaps when mounted on the magnetic cylinder

Failure to respect the die cut / magnetic cylinder cleaning procedures prior to mounting may have yet another result: an elevation of the die ends on the surface of the magnetic cylinder. This causes the puncture of the material in the area or even material breakage while in the machine [3].

Without such a situation existing, the next case study was carried out on a new die cut which overlaps when mounted. In addition, it had a longitudinal cutting blade on each side which had to ensure the width cut-off of the finished product. For proper cutting, these blades must overlap at the ends of the die cut.

In the analysed case, this area was observed through a 60x magnified image (Fig. 9). Here, the die was cut too short, the longitudinal cutting blade has offset ends, and in the immediate vicinity the die cut overlaps visibly (Fig. 10).

These non-conformities in the execution of the die cut have caused the printing to be interrupted. The pressed material was cut in the elevated area of the die cut, and the lateral cut-off was not possible. These cases are monitored continuously.

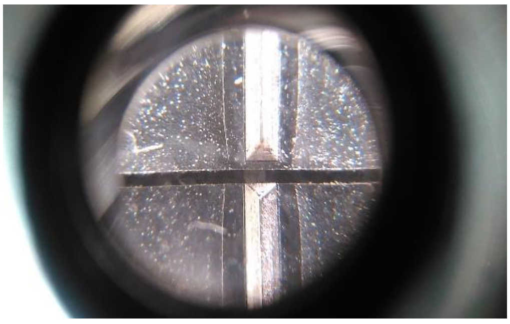


Fig. 9. At the ends of the die cut, the longitudinal cutting blades are spaced apart, do not overlap.

Fig. 10. New, non-conforming die cut. The die cut overlaps when mounted, causing the material to cut/tear.

Fig. 11. The die does not correctly cut the face of the material.

Fig. 12. The die cuts the material, in different places. The area is random on print repetitions.

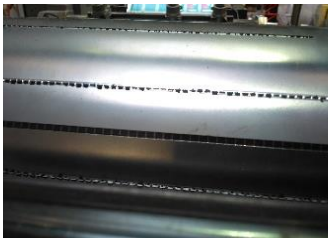


Fig. 13. Destroyed die in the perforation area. It is mounted on the magnetic cylinder

4. Nonconformities and Visible Defects on the Material

4.1. Effects of non-uniform thickness in the material

There is a particular set of problems in the die cutting process: the ones due to areas with different thicknesses intermittently appearing in the structure of the material. In each case, the origin of the material rolls was analysed by identifying the batches and conformance markings provided by the vendor/manufacturer. Apparently, none of the cases showed exceptions requiring additional analyses.

During production, it was the printing worker who noticed the moment when the die cut stopped cutting the face of the printing material (Fig. 11) or it cut through the material (Fig. 12). The working procedure in these cases involves stopping the workflow, restoring the adjustment to the die, resuming the printing process, recording the losses. So far, no elements that lead to the advance detection of rolls with such problems in advance have been identified.

The analysis of the short-term effects of these events highlighted the rapid wear of the cutting blades in random areas (Fig. 13), followed by the definitive destruction of the die cut.

4.2. Effects of independent execution of matching die cuts

The case of self-adhesive products for which execution requires two die cuts was analysed. The two die cuts were performing simultaneously: one from the top down and the other from the bottom up. In production, it was found that the two die cuts cannot be adjusted to properly cut the finished product.

After investigating, it was found that, even though both die cuts were correctly mounted on the cylinders, they were cutting asynchronously (Fig. 14). In order to determine the cause, the following were analysed: the geometry of the cutting blade drawing from each die cut, along with the physically executed die cut and the finished product obtained in production.

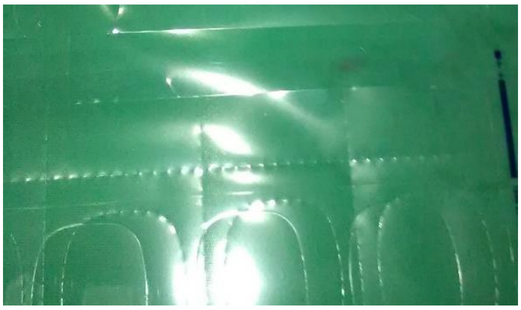


Fig. 14. The die cut print generated by perfectly paired die cuts executed independently. The shift in the drawing of the die cut nests is noticeable.

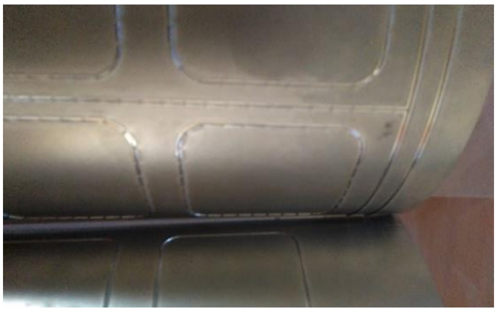


Fig. 15. Matching die cuts independently executed. Checking the nest overlap is done by matching the die cuts at the edge.

It was found that the geometry of the drawing differed between the two die cuts, implying different dimensions for the active area of each die cut. This may mislead manufacturers if they do not consider the fact that the two die cuts must cut the finished product by overlapping in the rotating motion. These die cuts must be perfectly matched.

Ignoring the perfect matching requirement led to separate die cut execution, by placing the cutting blades following independent Cartesian coordinates (Fig. 15), instead of a unique Cartesian marker. In production, the case caused losses until settled. After being approached, the manufacturer remade the die cut.

5. Ensuring the Quality of Die Cutting Using Graphic Analysis Instruments

5.1. The Pareto Diagram - classic quality analysis tool

A Pareto analysis uses a diagram to indicate the causes that need to be prioritized to ensure a quality progress [4]. It is the result of the observation that 20% of the causes determine 80% of the problems.

This graf-analytical product is given by the Pareto Principle, created in 1937 by Joseph Moses Juran (1904-2008) [4] and named after Italian economist Vilfredo Pareto (1848-1923), who noted his observations on the 80/20 ration in his first paper “Cours d’économie politique” published in 1896 in Lausanne [5].

The Pareto Diagram is formed using vertical bars representing the analysed events. They are ordered on the horizontal axis from the highest value to the smallest. Vertically, two axes are generated: the one on the left shows the frequency with which the events occur, while the one on the right shows cumulative event frequency – in percentages. All these data lead to the generation of an upward curve which, when intersecting the 80% horizontal, shows that 80 percent of the effects are produced by only 20 percent of the recorded events.

5.2. Analysis of the influence of the quality of the die cut process on the printing

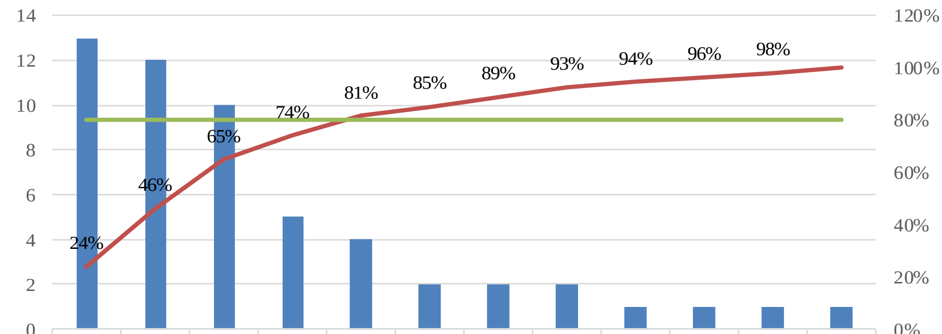
For the planned Pareto analysis, production data from three shifts of printing workers were collected on a single flexographic printing machine – Omet Variflex VF530 F1. The time period for this study was September 1, 2017 – March 31, 2018.

The die cuts used in the die cutting process presented, until the end of the analysed period, the following groups of nonconformities and defects: removal labels, ridge damage, breaking the material, blocking the material in the die station, not cutting the material, puncturing the liner, displacement by rotation on the magnetic cylinder, blocking on the die station, loading the blades with adhesive, loading the blades with ink, die cut fracture, mechanically destroying the blades by accidental bumping.

The Pareto diagram presented in Figure 16 shows that, in order to improve the quality of the die cutting process by 80%, the following 20% of the non-conformities and defects produced by die cuts must be eliminated: removal of labels, ridge damage, not cutting the material, breaking the material.

5.3. Analysis of the influence of the die cut quality on the printing process

Knowing the types of nonconformities and defects which must be eliminated in order to increase the quality of the die cutting process, all of the die cuts that generate these problems have been identified.



	Snatch labels	Tear waste matrix	Do not cut	tear the material	Tear liner	Blade with adhesiv	Blade with ink	Die cracked	Block the material	Shift on cylinder	Dies station locked	Blades destroy ed
Frequency	13	12	10	5	4	2	2	2	1	1	1	1
% Cumulative	24%	46%	65%	74%	81%	85%	89%	93%	94%	96%	98%	100%
"80/20"	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%

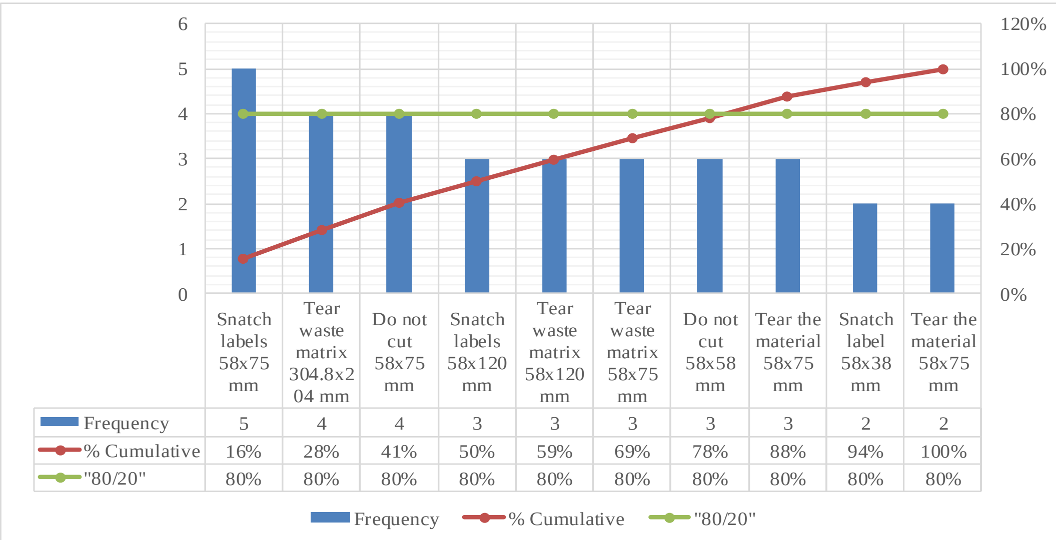
Fig. 16. Nonconformities and defects recorded in the printing process between September 2017 – March 2018.

The production data were aggregated monthly, each die cut was matched to the defect found. Thus, information was identified for various types of dies and individual results with non-conformities and defects. In the analysed period, 80% of the negative effects produced in the printing process were generated by 10 combinations of die cut defects. Each die cut was named after the size of the die cut contour, expressed in millimetres. The die cuts involved were: 58x38 mm, 58x58 mm, 58x75 mm, 58x120 mm, 107x53 mm, 304.8x204 mm. The analysis revealed that the first four showed an accumulation of defects, which, if eliminated, can lead to an increase in print quality by 80% (Fig. 17).

5.4. Comparative analysis of die cuts

a) In order to determine the causes that can produce different degrees of destruction in a die, in the first step it was taken into account the fact that one can compare dies that cut the same width of material. These are the die cuts: 58x58 mm, 304.8x204 mm, 58x120 mm and 58x75 mm. The volume of defects generated by them (Fig. 18) shows the highest values for the 58x75 mm and 58x120 mm dies.

b) In the second step, the 58x120 die cut was chosen for the study. The die cut was ordered in February 2016 and has rectangular-shaped nests, with sides measuring 58 mm and 120 mm. The material of which this die cut was made is recommended for large printing numbers and metal-on-metal die cutting (punching, cutting). The material for which the die cut was ordered is Thermal Eco Light, die cutting type: top-down, continuous cutting face self-adhesive material up to the liner.



	Snatch labels 58x75 mm	Tear waste matrix 304.8x204 mm	Do not cut 58x75 mm	Snatch labels 58x120 mm	Tear waste matrix 58x120 mm	Tear waste matrix 58x75 mm	Do not cut 58x58 mm	Tear the material 58x75 mm	Snatch label 58x38 mm	Tear the material 58x75 mm
Frequency	5	4	4	3	3	3	3	3	2	2
% Cumulative	16%	28%	41%	50%	59%	69%	78%	88%	94%	100%
"80/20"	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%

Fig. 17. Print problems related to the type of die.

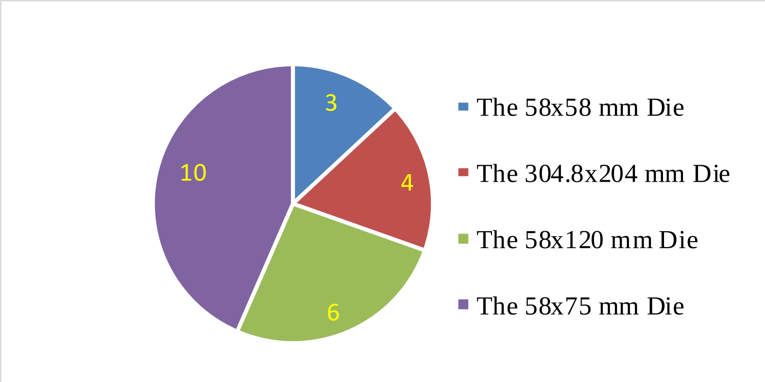


Fig. 18. The volume of defects caused by the dies which cut the same width of material.

The analysis of the die cut history in production data (Fig. 19) highlights the fact that the die was used to cut 3 types of materials: Thermal Eco Light (the one for which the die cut was ordered), Thermo Eco, Thermal Standard Top. Their features, of interest for the design and subsequent use of the dies in production, are shown in Figure 20.

It was noted that the material for which the die cut was ordered, the Thermal Eco Light type, has a thickness for the face of the self-adhesive material of 85 µm and its liner has a thickness of 41 µm, which brings the total to 126 µm. The next material, the Thermal Eco type, has a thickness of 134 µm, the notable difference coming from the liner of 52µm in thickness. The third material is the Thermal Standard Top type and has a thickness of 133 µm, but the same liner thickness as the Thermal Eco type.

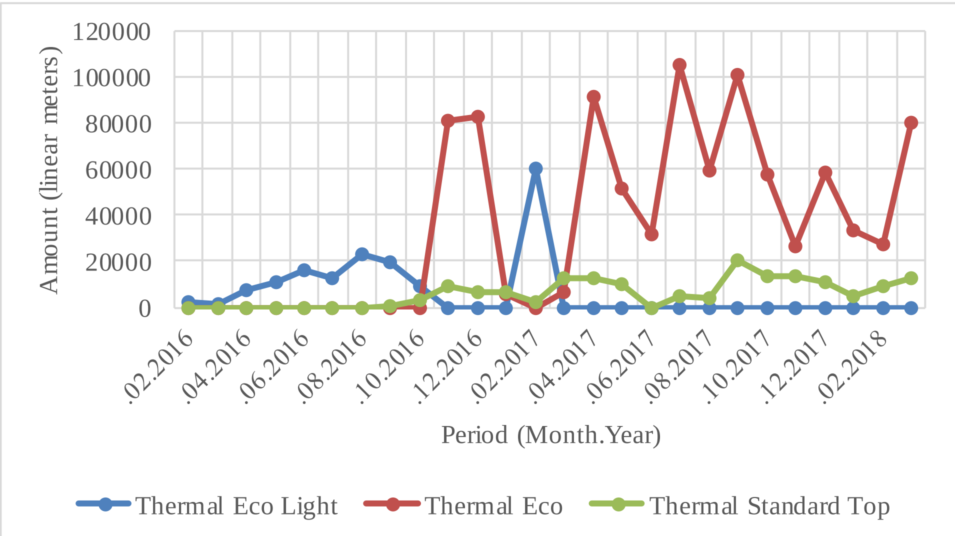


Fig. 19. The 58x75 mm die: Print history on three types of materials between 02.2016 – 03.2018.

Thermal Eco Light			
	Face material		
	Unit of measurement	Value	Margin
Basis Weight	g/m^2	74	ISO 536
Caliper	µ	85	ISO 534
	Backing		
	Unit of measurement	Value	Margin
Basis Weight	g/m^2	45	ISO 536
Caliper	µ	41	ISO 534

Thermal Eco			
	Face material		
	Unit of measurement	Valoare	Margin
Basis Weight	g/m^2	74	± 4%
Caliper	µ	82	± 5%
	Backing		
	Unit of measurement	Value	Margin
Basis Weight	g/m^2	62	59-65
Caliper	µ	52	50-58

Thermal Standard Top			
	Face material		
	Unit of measurement	Value	Margin
Basis Weight	g/m^2	75	ISO 536
Caliper	µ	81	ISO 534
	Backing		
	Unit of measurement	Value	Margin
Basis Weight	g/m^2	61	ISO 536
Caliper	µ	52	ISO 534

Fig. 20. Technical data for the materials used:
Thermal Eco Light, Thermo Eco, Thermal Standard Top.

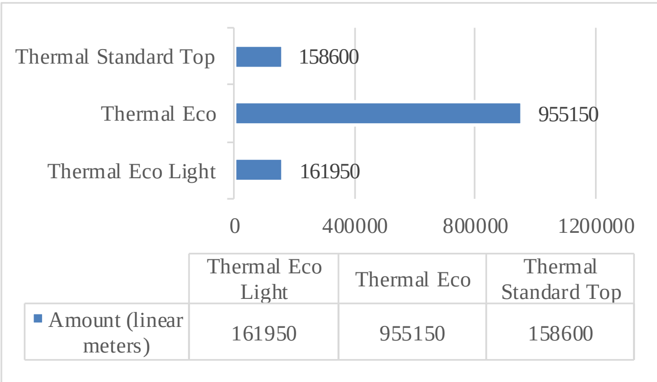


Fig. 21. Amount (linear meters) cut from each material
(February 2017 – March 2018)

In order to compensate for the differences in material thickness, the pressures on the die setting were greatly increased in production. It is one of the primary causes that led to the destruction of the cutting blades by pressing.

It was difficult to obtain proper die cutting through quick adjustments of the die, and this was only possible after multiple attempts. Losses were registered, with the 58x120 mm die turning out to be a source of nonconformities and defects: removal of labels, ridge damage.

Figure 21 shows how the die was mainly used for cutting materials for which it was not designed. The great number of manoeuvres for the assembly / adjustment of die repositioning on the magnetic cylinder also contributed to the destruction of the die (Fig. 22).

The analysis of the two charts (Fig. 21–22) shows that the printing numbers for the Thermal Standard Top and Thermal Eco Light –type materials were small but very frequent, while the printing numbers for the Thermal Eco –type material were large and constant.

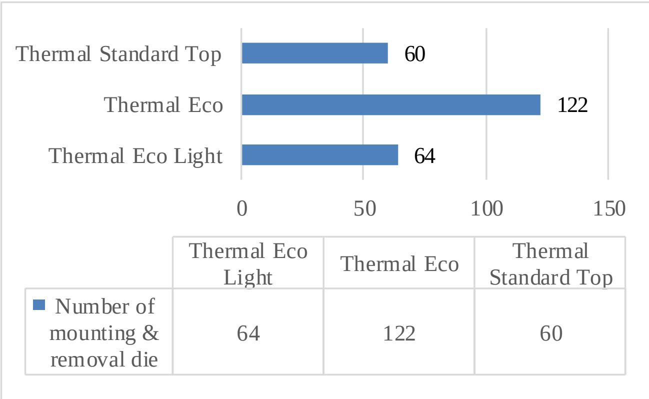


Fig. 22. Number of times the die was mounted & demounted (February 2017 – March 2018)

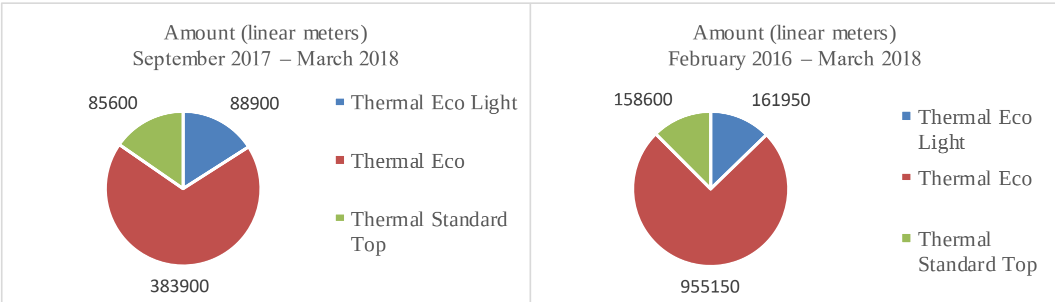


Fig. 23. The 58x120 mm die: comparison between the analysed period (left) and entire period of use until removing the die (right).

When the ratio between the 7-month period chosen for the present study and the entire usage period of the die cut of 2 years and 1 month (Fig. 23) is considered, it can be observed that the two graphic representations are approximately the same: the ratio between the printing values on Thermal Eco Light and Thermal Eco–type support is 1.8, while on Thermal Standard Top–type support it is 2.4.

The destruction through mechanical wear of the blades gradually and constantly set in, so that during the reference period for this study, the recorded printing speeds decreased unnoticeably.

The value reported at the beginning of September 2017 was 150 linear meters/minute, and at the end of the reference period – March 2018, the speed decreased to 130 linear meters/minute. None of them justifies keeping the die cut in production.

c) In the third stage, a comparison analysis was carried out on the 58x75 mm die. This die has rectangular-shaped nests, with sides measuring 58 mm and 75 mm.

The order history shows that during the reference period, various 58x75 mm dies were used, depending on the type of material. The last was ordered in February 2016, and drew attention through the material from which the die was ordered.

It is a material of a quality superior to the one in the previously analysed 58x120 mm die, a material recommended for: very large printing numbers, paper/cardboard materials, abrasive materials, and in the case of printing using Opaque White ink on the cutting areas.

Heat transfer materials are part of the abrasive materials category, which means that the 58x120 mm die did not benefit from the start from an execution from a material correlated with the material to be die cut.

Conclusions

a) The comparative analysis of the behaviour of two die cuts within a defined time interval highlighted the fact that the lack of correlation between the quality of the material from which the die cut is executed and the printing conditions starting right from the ordering of a new die cut leads to die cutting problems in the printing process and creates a shortage in the expected lifespan of the die cut. Printing conditions refer to the type of material, the expected average printing numbers, cutting through areas covered in Opaque White ink, the type of die cutting.

b) Using a die in the die cutting process for any other type of material with technical characteristics different from the material for which it was designed results in a rapid wear of the die. This is directly visible in the printing process, primarily because of the frequent interruption of the production flow in order to adjust the die cut.

Different technical features mean, in the first place, other material thicknesses in relation to the material or the liner. That is why this category can also include the materials which exhibit unevenness in the structure of the support.

But here, the effects are amplified: if the material makes too swift an entrance in the die station, it is possible for the station to block and for the material to break inside the machine, or in the worst case, the blocked material is folded between the cylinders, mechanically destroying the cutting blades in that area.

The die cut becomes immediately unusable.

c) From the production practice specifically applied to the Omet machine [7], a new die, correctly executed, cuts with a speed of 200 linear meters/minute and it retains this feature about 2/3 of the period of use, then gradually decreases to 180 linear meters/minute.

It is possible that, from one die cutting to another, this value drops sharply to 150-160 linear meters/minute, when the die cut wears out.

In the case of the 28x120 mm die that was analysed, the high degree of wear was directly reflected in the decrease of the printing speed below these values. Registered losses include low productivity and inefficient use of labour.

The continuation of this study will see the analysis of whether the composite material in the die cut is the one indicated by the manufacturer and whether it meets the requirements in the printing production process as recommended.

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R E F E R E N C E S

[1] Kipphan, H. (2001). *Handbook of Printmedia: Technologies and Production Methods*, Springer-Verlag Berlin Heidelberg GmbH, Berlin Springer, ISBN 978-3-540-29900-4, pp. 782-785.

[2] Nancy R. Tague (2004). *Seven Basic Quality Tools. The Quality Toolbox.* Milwaukee, Wisconsin: American Society for Quality. p. 15. Retrieved **2010**-02-05., web p., http://asq.org/learn-about-quality/seven-basic-quality-tools/overview/overview.html.

[3] Folea, G.V. and Cazac, V. (2017). *The Analysis of Particularities and Possibilities for Ensuring Quality in Flexo Printing*, Annals series on Engineering Sciences, **vol. 9**, item 2 - **2017** ISSN 2066 – 6950, p. 47.

[4] *Pareto analysis,* web p., https://en.wikipedia.org/wiki/Pareto_analysis.

[5] *Juran, Mission & History,* web p., http://www.juran.com/about-us/.

[6] *Pareto principle*, web p., https://en.wikipedia.org/wiki/Pareto_principl.

[7] OMET Goup, Operator Manual VF 530 F1, **2009**.