https://doi.org/10.24867/GRID-2022-p71 Original scientific paper

THE EFFECTS OF FLATBED CREASING TOOL ON PRINTED PAPERBOARD

Josip Bota, Jesenka Pibernik, Dorotea Kovačević, Maja Brozović
University of Zagreb, Faculty of Graphic Arts, Zagreb, Croatia

Abstract: *Flatbed cutters are in increased demand and usage due to their developments in tool speed and size of the cutting area. The creasing tool on flatbed cutters are mostly creasing wheels as opposed to flat knives in die cutters. The wheel creases the paperboard in a way that can damage the top layer causing breaking in the printed surface visible after folding and sometimes even before. The end result can decrease the attractiveness of packaging and other creased paperboard products. This paper investigates the results of flatbed creasing of different types of printed paperboard and suggests possible solutions to the problem. Examined paperboards differed in grammage, grade, and thickness, and they were creased with different depth levels. The results indicated that some types of paperboard are not suitable for packaging even if they are adequate grammage. Furthermore, controlling the creasing depths can reduce ruptures of the top layer and improve final folding quality.*

Key words: Creasing tools, flatbed cutter, damaged print, packaging, folding

1. INTRODUCTION

The most common type of creasing in packaging production is die cutting This type of production is widely used due to its high level of automation and a large amount of cut and creased sheets in a short amount of time. The downside is that each packaging needs its own die-cut plate and counterplate template production. This becomes a problem when there is a need for a smaller production amount due to limited edition packaging, promotional packaging, custom packaging smaller selling possibilities. Then most packaging producers opt for production using flatbed cutters. The main difference is in the creasing tools used. Die cutters use creasing rulers (stationary tool) and flatbed cutters use creasing wheels (rotational tool). One of the other production differences is the result on the back of the paperboard. Die cutting form has a counterplate with groves for the creased paperboard to indent while flatbed creasing has a fleece background that allows the wheel to slightly impress in the sheet. This way die cutting form results in a better creasing formation on the front and especially on the back of the unfolded packaging sheet (Leminen et al., 2019).
Paperboards have multiple layers depending on the type and grade of cellulose, coatings and fillers. Mainly paperboards are made up of three layers: top, middle and bottom layers (Nygårards et al., 2005). The middle layers mainly contain the bulk of the material and carry the main structural weight of the material. The outside (top) layer usually is prepared for printing. Because different types of printing technology need certain properties for accepting printing ink some paperboards are not for universal use across the board. The paperboard making process and the cellulose used makes the material extremely anisotropic (Nygårards et al., 2005). Another factor that influences the material properties is permeability to water vapor. Higher levels of water vapor can decrease the structural stability of paper. This disadvantage makes finite models difficult to develop. There are some attempts published but are mostly for commercial use (Beldie et al., 2001; Fadiji et al., 2018; Huang & Nygårds, 2010; Luong et al., 2019; Marin et al., 2021; Nygårards et al., 2005; Nygårds et al., 2009; Park et al., 2020). The found models are mostly for die-cutting tools so there is an under researched category of creasing on flatbed cutters. Higher demand for limited edition and/or customizable packaging increases the need for research on the creasing properties of flatbed cutter results. This paper investigates the results of flatbed creasing of different types of printed paperboard with three different levels of creasing height. The researcher sheets will be printed on a laser printer which is most common for small issues of packaging which correspond with the researched creasing problem. The paperboards that demonstrate breakage of the top layer will be laminated with polyethylene (PE) foil as a possible solution to the problem. This solution is based on research from Andersson and Fellers that demonstrated increased Z directional properties of paperboard (Andersson & Fellers, 2012).

2. METHODS

2.1 Materials

The available paperboards for testing (DIN graded) are commonly used for printing paper with higher grammage. Paperboard specifications, and grades (according to DIN Standard 19303 "Paperboard - Terms and grades") are seen in Table 1. The paperboard was conditioned according to the ISO 187:1990 standard at a temperature of 23°C ± 1°C and humidity RV 50% ± 2% before and during the process of forming packaging samples.

Table 1: Paperboard sheets specifications

Paperboard name	grammage	DIN grade*	thickness	manufacturer
Incada Silk	240 g/m^2	GC1	365 µm	Antalis®
Incada Silk	280 g/m^2	GC1	445 µm	Antalis®
Maxi gloss	250 g/m^2	N/A	184 µm	UPM
Maxi gloss	300 g/m^2	N/A	225 µm	UPM
Maxi offset	250 g/m^2	N/A	275 µm	UPM
Maxi offset	300 g/m^2	N/A	330 µm	UPM

**DIN Standard 19303 "Paperboard - Terms and grades" (Publication date: 2005-09)*

2.2 Samples

Paperboards were obtained and printed with Xerox Versant 2100 Press in a local print studio. Xerox Versant 2100 Press printing machine was used for A3++ (229 x 483 mm) format sheets. All sample cutting layouts were prepared using EngView Packaging and Display Designer Suite software and cut on a Zund M-800 flatbed cutter/plotter. For cutting layout sheets a Z10 drag blade was used and a creasing wheel C203 with a diameter of 15 mm, a width of 0,7 mm, and a depth of a maximum of 1 mm. Which, according to previous research, is most similar in size of a die-cut creasing ruler (Giampieri et al., 2011; Huang and Nygårds, 2011; Leminen et al., 2021) The samples were creased in 3 depth levels: 0,5 mm, 0,7 mm and 0,9 mm with the measured force of 6,88 N, 10,2 N and 13,58 N respectively. The samples were named according to the variables presented in Table 2. The samples with the most damage to the top layer were laminated using a SERON FM-360 Roll-to-roll laminator and Superstick Nylon Gloss 30/320/1000/75 PE foil.

Table 2: Creasing sample's nomenclature

Sample name	grammage	Paperboard
240_	240 g/m^2	Incada Silk
280_	280 g/m2	Incada Silk
250_gl	250 g/m^2	Maxi gloss
300_gl	300 g/m^2	Maxi gloss
250_of	250 g/m^2	Maxi offset
300_of	300 g/m^2	Maxi offset
Plastification	**Foil thickness**	**Sample name annex**
yes	30µm	**pl_**
Creasing depth	**Sample name annex**	
0,5 mm	**05_**	
0,7 mm	**07_**	
0,9 mm	**09_**	
Fiber direction	**Sample name annex**	
Cross direction	**CD_**	
Machine direction	**MD_**	

2.3 Measurement and grading procedure

Creasing depth was measured using the Z-axis definition option on the Zund flatbed cutter. Using the same procedure, the force was determined using a scientific scale under the creasing tool and converted to Newton (N). After cutting and creasing the samples were folded and glued by hand simulating a standard process. Samples were automation given to 10 experts in the field of graphic technology to access the area of the folded crease acceptable or not acceptable for commercial use. The experts could use four grades: acceptable with no remarks; acceptable with visible damage to the top paperboard layer; unacceptable with visible damage to the top layer and unacceptable with significant damage to the top layer.

3. RESULTS AND DISCUSSION

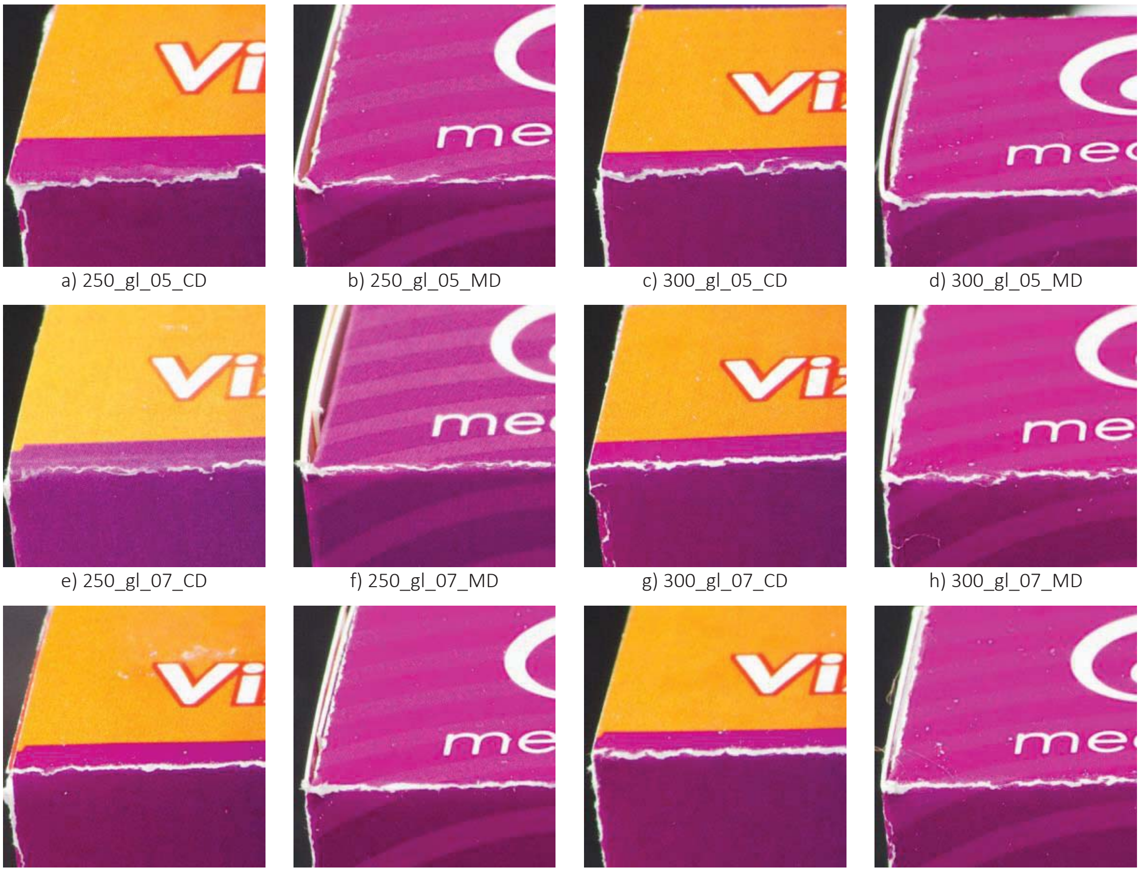
The goal of the experiment was to evaluate the quality of creased and folded paperboards as well as the laminated samples. The samples were evaluated by 10 experts in the field of graphic technology and print. For the purpose of this paper, the samples are presented as close-up images at the same position to ease comparison. In the production process, multiple samples were made from each paperboard type and creasing depth. The results of the folds were practically identical so experts were presented with just one packaging per sample type to avoid assessment fatigue. The packaging samples were examined in their folds parallel to the machine direction (MD) and cross direction (CD) fiber direction of the paperboard.

Figure 1. shows the control sample (Incada Silk) which is commonly used for folded graphic products of laser prints. This sample was not creased more or less than 0,7 mm in depth and was no PE lamination because it produces an acceptable packaging result. All experts (N = 10) agreed on these samples as acceptable without visible damage to the top layer.

a) 240_07_CD b) 240_07_MD c) 280_07_CD_ d) 280_07_MD

Figure 1: Incada Silk paperboard samples

Figure 2. shows two paperboard (250 g/m^2 and 300 g/m^2) creased with three different creasing depths (0,5 mm, 0,7 mm, and 0,9 mm). Folds parallel to the fiber direction are presented in the figure. Due to the different fiber directions in the paperboard sheet the sample images are taken at the opposite positions than in the Incada Silk and Maxi offset samples. Experts (N = 10) deemed almost all the samples unacceptable with significant damage to the top layer. The only exceptions were three experts (N = 3) that assest the 250_gl_07_CD sample (Figure 2. e) as unacceptable but with just visible damage and the sample 250_gl_09_CD (Figure 2. i) that was also graded as unacceptable but with just visible damage by one expert (N = 1). Both of the samples have folds parallel to the fiber direction which usually has better folding properties (Giampieri et al., 2011; Leminen et al., 2021). The damage to the top layer is less which can be seen in the previously mentioned sample figures. It is important to note that during the production phase his paperboard was hard to fold as the creasing indents were not embossed enough. There is some difference visible in different depths of the creasing wheel but only in the MD parallel fold. The 250g/m^2 demonstrated better results in 0,5 mm and 0,7 mm (Figure 2. b and f) depth while in the 300 g/m^2 a better result is only seen in the 0,7 mm depth (Figure 2. h). This can indicate that 0,7 mm depth could give the best result that can be achieved for this type of paperboard.



a) 250_gl_05_CD b) 250_gl_05_MD c) 300_gl_05_CD d) 300_gl_05_MD

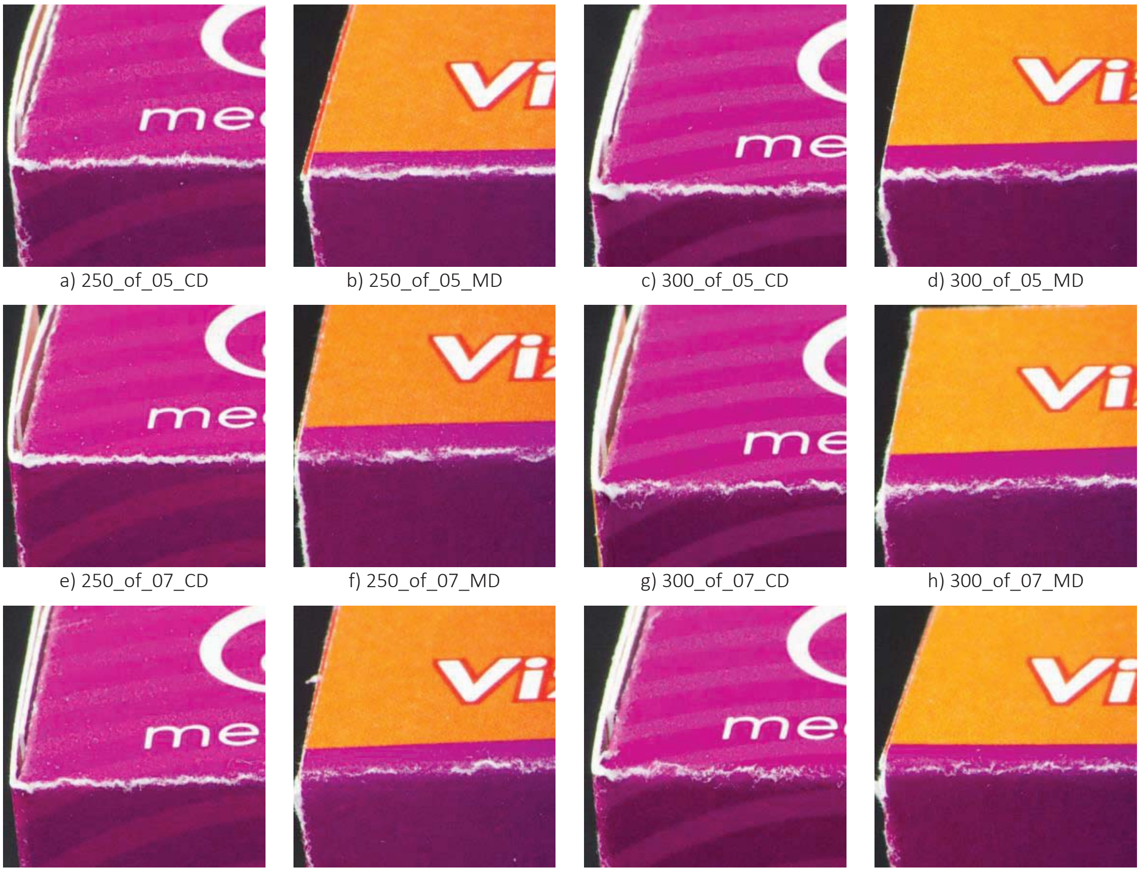
e) 250_gl_07_CD f) 250_gl_07_MD g) 300_gl_07_CD h) 300_gl_07_MD

i) 250_gl_09_CD j) 250_gl_09_MD k) 300_gl_09_CD l) 300_gl_09_MD

Figure 2: Maxi gloss paperboard samples

Figure 3 also shows two paperboards (250 g/m^2 and 300 g/m^2) creased with three different creasing depths (0,5 mm, 0,7 mm, and 0,9 mm). Experts (N = 10) deemed most of the samples unacceptable with significant damage to the top layer. The only exceptions were five experts (N = 5) who asset the 250_of_09_MD sample (Figure 3. j) as unacceptable but with just visible damage and the sample 300_of_09_MD (Figure 3. l) was also assessed as unacceptable but with just visible damage by seven experts (N = 7). Both of the samples also have folds parallel to the fiber direction that as in the previous sample can have better results. It is important to note that during the production phase his paperboard had a snapping effect when folded. This led to a rupture of the top layer. There is some difference visible in different depths of the creasing wheel where the deepest (0,9 mm) crease produced the best results. This effect needs future investigation to assess which creasing depth results in better folding quality.

The unacceptable paperboard samples were laminated to observe the creasing and folding results as a solution to the rupture of the top layer. The results of the samples are presented in Figure 4. All experts graded the samples as acceptable without visible damage. The additional conclusion of the grading was that the laminated samples fold deemed of higher quality than the control samples. The folding process for the Maxi gloss samples were again hard to precisely fold and would still have lesser quality results due to the less precise folds. This is visible as wider folds in Figure 4. c) and g). It is important to note that the lighter segments on the folding segments in the images, dominantly in the 250_sj_07_CD_pl sample (Figure 4. c) are reflections due to the high glossiness of the laminated surface.

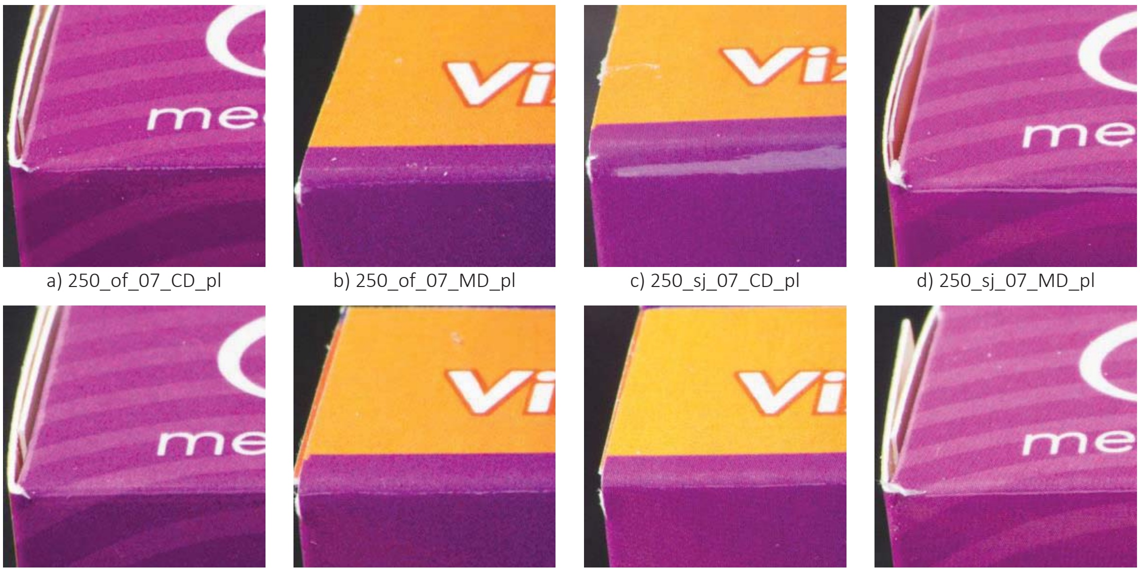


a) 250_of_05_CD b) 250_of_05_MD c) 300_of_05_CD d) 300_of_05_MD

e) 250_of_07_CD f) 250_of_07_MD g) 300_of_07_CD h) 300_of_07_MD

i) 250_of_09_CD j) 250_of_09_MD k) 300_of_09_CD l) 300_of_09_MD

Figure 3: Maxi offset paperboard samples



a) 250_of_07_CD_pl b) 250_of_07_MD_pl c) 250_sj_07_CD_pl d) 250_sj_07_MD_pl

e) 300_of_07_CD_pl f) 300_of_07_MD_pl g) 300_sj_07_CD_pl h) 300_sj_07_MD_pl

Figure 4: Laminated paperboard samples

4. CONCLUSIONS

This research was aimed to investigate the difference of creasing and folding between different paperboards grammage and type. The paperboards were creased with different depth levels, laminated and evaluated by experts. The results led to these conclusions:

- The examined 250 g/m^2 and 300 g/m^2 Maxi Offset and Maxi gloss paperboards are not suitable for packaging even if they are adequate grammage and stiffness
- Crease parallel to the machine direction of the paperboard fibers provide better folding and less damage to the top layer
- Using different creasing depths can reduce ruptures of the top layer and improve final folding result
- PE lamination achieves preservation of the top layer when paperboard is creased and folded.

These conclusions are limited to paperboards used in this research but they are an indication for a procedure for achieving best folding results for using flatbed cutters and available paperboards. This paper suggests users to thoroughly examine different creasing depths to achieve preservation of the folded top layer, and if there are no other options, lamination can be offered as a solution.
Further research should be expanded on comparing die cut and flatbed creasing and folding results as well as using a larger amount of different paperboards that are commonly used for smaller print orders on laser and inkjet printers. Also additional research should be made with other type of creasing wheels and drag creasing knifes used for flatbed cutters and complement the expert assessments with more objective measurements.

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