# Evaluation of Creasing and Folding Performance on Printed Paperboard Packaging

Yu-Ju Wu & Tom Reeves

**Keywords:** creasability, folding performance, paperboard packaging

**Abstract**

The major functions of a package are to protect, contain, and promote products. Paperboard can be converted into packages by relatively straightforward operations such as cutting, folding, and gluing. To make the paperboard packages appealing for consumers, the fold lines must be neat and undamaged. However, a difficulty in paperboard converting is the cracking of paperboards during folding. Cracked folds render printed packages less appealing to consumers. The purpose of this study is to evaluate creasing and folding performance of different grades of printed paperboards. Paperboards printed with water-based flexo ink, oil-based offset ink, and pigment-based ink-jet ink were tested. Three grades of solid bleached board (SBS), 10-point, 12-point, and 13-point, were used in the test. A flatbed sample maker from Gerber was employed to perform die-cutting and creasing. Creasing is carried out with creasing rules, which have rounded ends. Different creasing settings (with a scale ranging from numbers 17, 33, 42, and 50) were experimentally applied to determine the creasing property of tested paperboards. It was found that the creasing settings No. 33 and No. 42 creates better and well-defined folding lines during the subsequent folding, especially with CD crease. The crease rule used in this study works well with the 13-point paperboard. It forms great shape of crease bead, creates thin, multilayer structure for either CD or MD, resulting in clear defined fold lines.

## 1. Introduction

The major functions of a package are to contain, protect, transport and promote products. Paperboard carton is very economical in material cost as well as in fabrication and assembly. They can be converted into packages to form semi-rigid

---

Graphic Arts and Imaging, Technology and Environmental Design, Appalachian State University, Boone, NC, 28608

or rigid containers by cutting, creasing, folding, and gluing operations. They comprise a significant proportion of the packaging found in the retail sector.

### 1.1. Types of Paperboard

Paperboard is usually multilayered and may comprise layers of more than one type of pulp. Surfaces of paperboard are usually coated with a mineral-pigmented coating based on china clay and/or calcium carbonate to enhance appearance (such as color, smoothness, gloss level, etc.) and printability (Nygårds, Just & Tryding, 2009). There are several different types of paperboard differing in the types of pulp used in their construction. The main types of pulp are chemical bleached, chemical unbleached, mechanical and recycled. The mostly used paperboard is solid bleached sulfate (SBS or SBB), which dominates the food, pharmaceutical, cosmetic, and other applications. They provide strength, marketing appeal, and high-speed packaging-machine performance. Another type of paperboard is solid unbleached sulfate (SUS or SUB). SUS is used in the beverage-carrier field and other applications where great strength and moisture resistance are important. Other types of paperboards also include folding box board (FBB or GC1 or GC2) and white lined chipboard (WLC, GT or Newsboard). Today, many packagers are switching to boards that have some post-consumer-recycled (PCR) content. For example, a bleached board with up to 30% PCR is acceptable for food contact (Hanlon, Kelsey & Forcinio, 1998; Kirwan, 2005).

Paperboard is measured in pounds (lb) per ream (1000 ft2). Basis weights of paperboards range from 26 lb to about 90 lb with thickness from 0.009 to 0.030 in. Another common measurement of thickness in paperboard materials is called the "point," which is equal to 0.001 in. Such a material is stiff enough to be formed into a three-dimensional shape with fixed quantifiable sizes, volumes, and rigidity. Today, paperboard-based products are commercially available in a wide range of grammages and thickness. Paperboard must have bending qualities that allow them to be creased and folded without cracking. Previous studies show that weights heavier than 32 points may become very difficult to cut and crease on standard equipment (Hanlon, Kelsey & Forcinio, 1998; Kirwan, 2005).

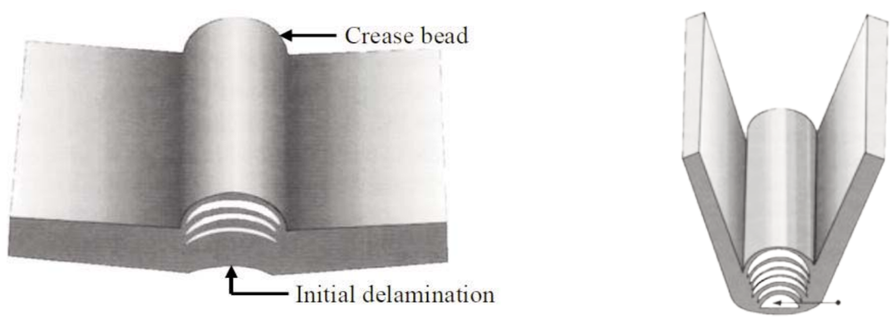
The major processes for paperboard printing today are offset lithography, flexography and gravure. Digital printing, the most recently introduced process, can be used for dynamic prototypes and short-run production (Kirwan, 2005).

### 1.2. Creasing and Folding

To make the paperboard packages appealing for consumers, the fold lines must be both neat and undamaged. The quality of the folds depends on the manufacture of fold lines (creasing), together with the subsequent folding. Creasing is one of most important mechanical processing techniques for the box making with paperboard.

The purpose of a creasing operation is to reduce the folding resistance of a material, so that when the fold is performed, no surface cracks appearing along the creased and folded line (Nygårds, Just & Tryding, 2009; Nagasawa, Fukuzawa,Yamaguchi, Tsukatani & Katayama, 2003; Beex & Peerlings, 2009).

A crease is a groove in paperboard, which facilitates bending or folding along a clearly defined line. Creases define the edges of the panels and flaps and behave like hinges, which enable adjacent panels to move through specific angles (usually 90°) and remain there. Creasing is carried out with creasing rules, which have smooth rounded ends indenting the board surface and pushing it into an accurately cut groove on the underside of the paperboard. The depth and width dimensions of the creasing grooves depend on the paperboard product being used. Studies show that depth of the creasing groove causes a certain amount of stretching in the surface. The bead formed by the groove in the cutting and creasing press breaks down the bond between the piles of paper, resulting a partial internal delamination of paperboard. When the crease is folded, further internal delamination occurs where the board bulges out into a bead that relieves the stress on the outside layer (Figure 1). It is important that the bulge itself does not rupture or become distorted (Kirwan, 2005; Carlin, S., Dunder, I. & Edholm, B., 1997).




(a) Creasing forms partial internal delamination

(b) Delamination is completed as the paperboard folds

***Figure 1:*** *Creasing causes delamination.*
*Source: Kirwan, M. J. (2005). Paper and Paperboard Packaging Technology, p. 290.*

In die cutting manufacture of paperboard packages, it is important to apply the correct creasing conditions, i.e. sufficient rule height and creasing depth to achieve sufficiently low folding resistance without any cracks along the folding lines (Figure 2). A good crease shows no liner cracking on the printed side with no signs of crumpling on the reverse side. Good creasing is crucial for the visual appearance of the carton, efficient performance on the packing line, as well as maintaining the compression strength of the carton in storage, distribution and use (Kirwan, 2005; Carlin, S., Dunder, I. & Edholm, B., 1997).

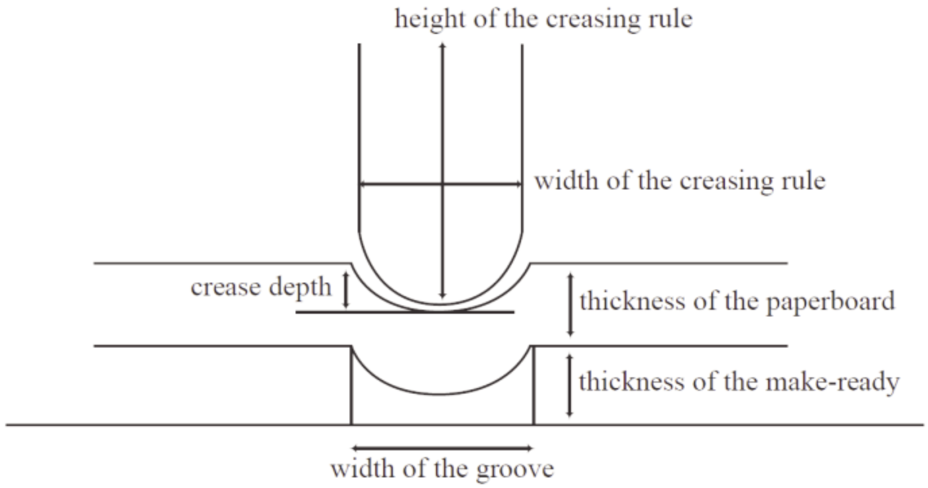



***Figure 2:*** *Creasing of Paperboard.*
*Source: Kirwan, M. J. (2005). Paper and Paperboard Packaging Technology, p. 290.*

## 2. Methodology

This work performed creasing and folding experiments of printed paperboards with water-based flexo ink, oil-based offset ink, and pigment-based ink-jet ink. Ink drawdown was performed with offset and flexo inks by using a DOE ink proofing kit and an Echocel Junior toolkit, respectively. An Epson Stylus Pro WT79000 printer was used to print on the tested paperboards. Three types of solid bleached board (SBS), 10-point, 12-point, and 13-point, were used in the test. Each paperboard was tested in both machine direction (MD) and cross direction (CD). In this study, the MD crease (across the grain crease) is defined as a crease at right angle (90°) to the machine direction of the board.

A flatbed sample maker from Gerber was employed to perform die-cutting and creasing. Creasing is carried out with creasing rules, which have rounded ends. The width of creasing rule is 0.1 cm. Different creasing settings (with a scale ranging from 17, 33, 42, and 50, see Figure 3) were experimentally applied to determine the creasing property of tested paperboards. The greater the creasing number setting, the higher the rule height or the deeper the creasing depth is. Three grades of paperboards, having the initial crease, were folded completely by hand.


***Figure 3:*** *Creasing Settings*

## 3. Results and Discussion

In the creasing operation, it is important to damage the paperboard enough to enable subsequent forming. Figure 4 shows the 40X photomicrograph of crease/fold results for the creasing setting No. 17, which created shallow depth of crease. The microscopic image obtained after folding shows that the mid-layer itself has been split up into several paper plies. The 35-point paperboard forms many thin, undamaged paper piles, which sufficiently reduce the folding resistance. For the 10-point paperboard, however, thin paper piles formed only for the upper portion. The lower portion, including the printed layer, is loaded in in-plane tension, which may cause the printed layer to break. It also shows that CD crease forms better shape than MD crease.

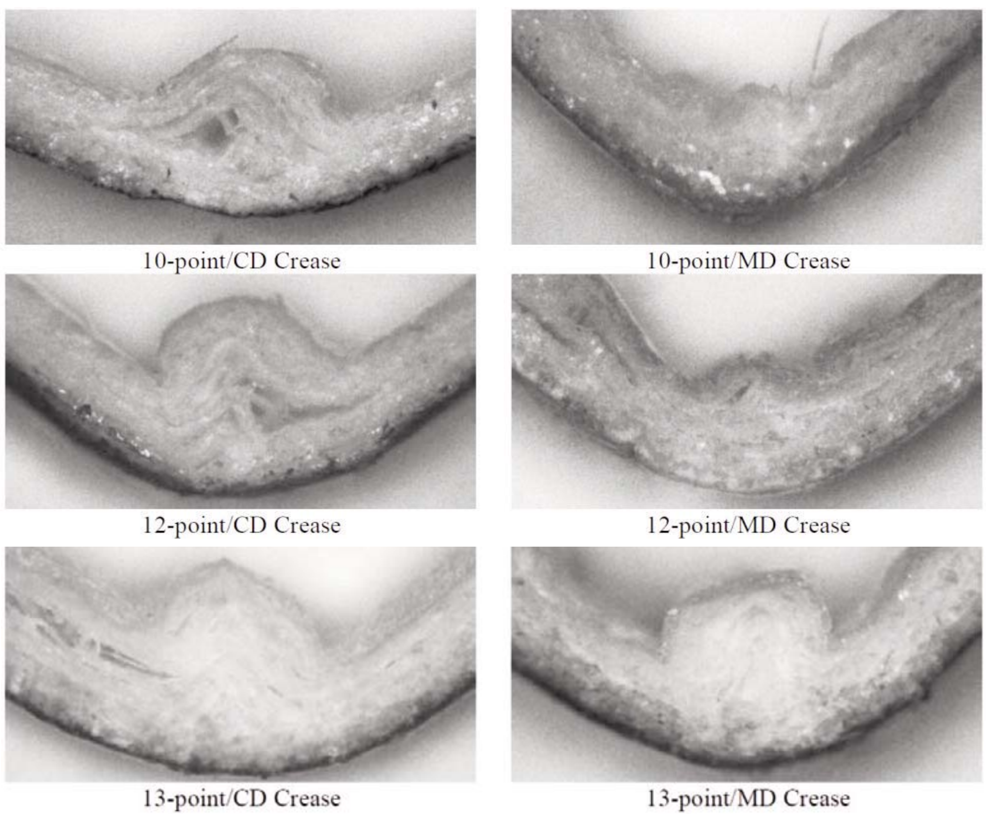



***Figure 4:*** *Microscope images (@40X magnification) for creasing setting no. 17.*

The microscopic image of crease/fold results for the creasing setting No. 33 and No. 42 are shown in Figure 5 and Figure 6, respectively. Again, the mid-layer has been split up into several paper plies. The number of plies formed depends on the grade of paperboard used. The upper plies have been bent inwards and they have buckled, resulting in the typical shape. It is interesting to note that the crease bead formed in MD crease has been push away from the center.

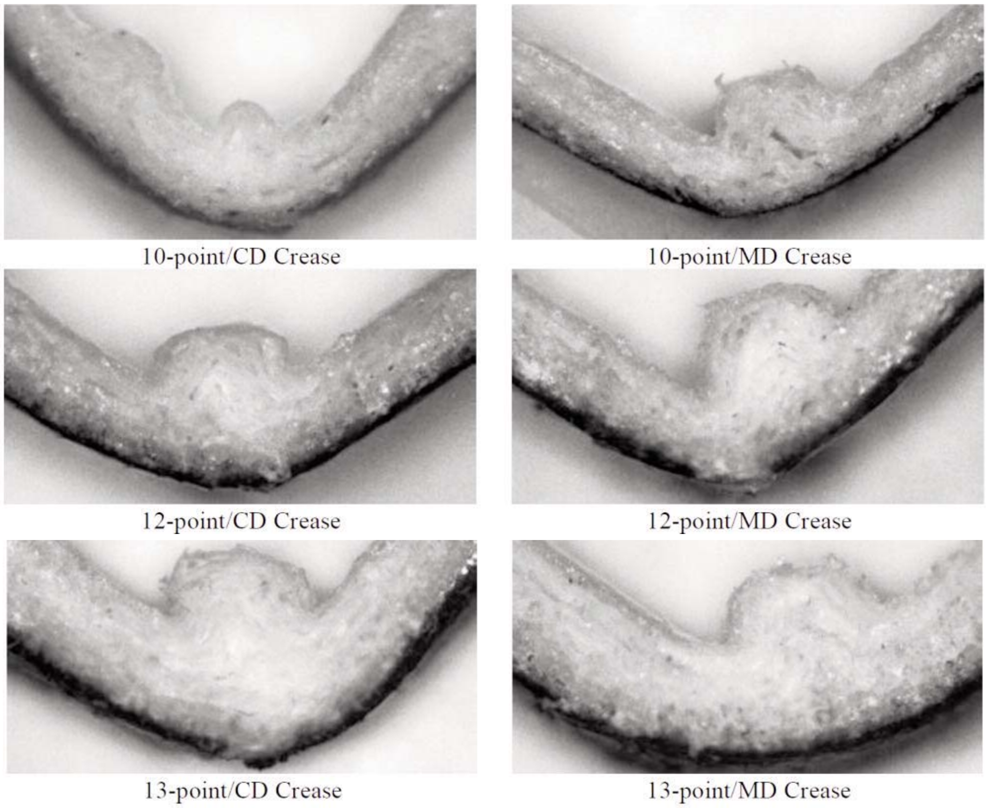



***Figure 5:*** *Microscope images (@40X magnification) for creasing setting no. 33.*

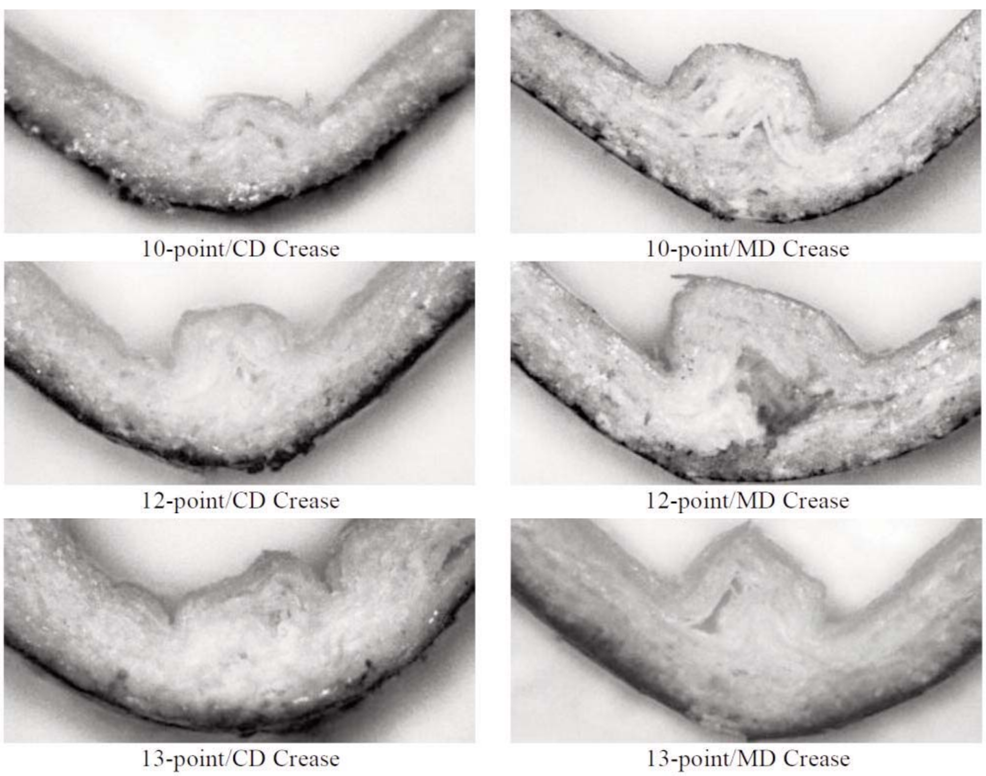



***Figure 6:*** *Microscope images (@40X magnification) for creasing setting no. 42.*

Figure 7 shows the 40X photomicrograph of crease/fold results for the creasing setting No. 50, which created greatest depth of crease. Depth of the creasing groove causes a certain amount of stretching in the surface. The 13-point paperboard has better shape with either MD or CD crease. Its multilayer structure in creasing is desirable for folding without surface cracks appearing along the creased and folded line.

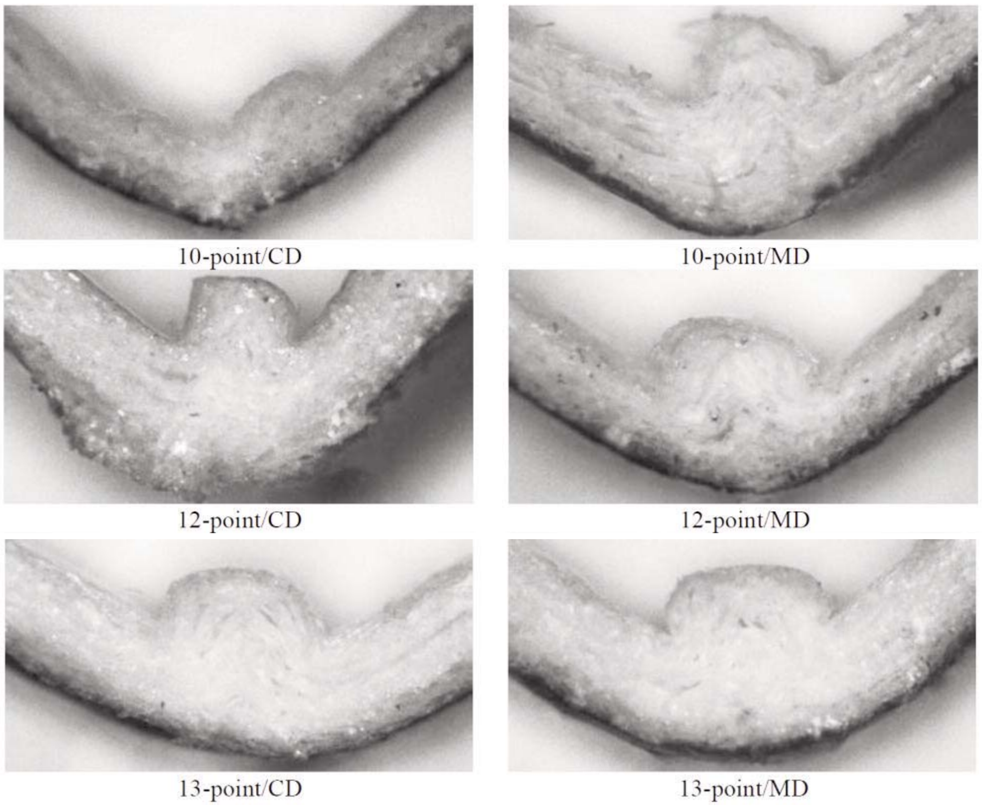
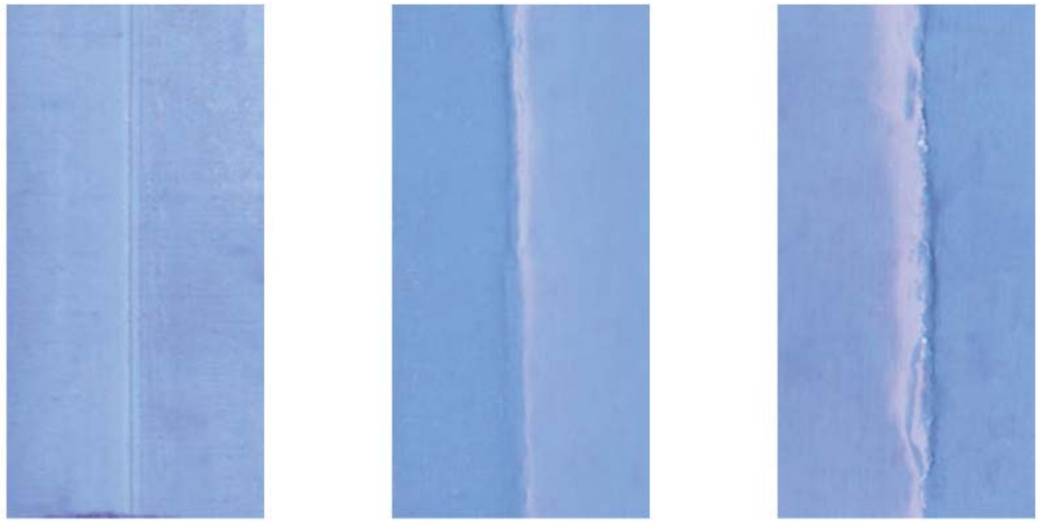



***Figure 7:*** *Microscope images (@40X magnification) for creasing setting no. 50.*

Visual assessments of crease/fold are made. The performance of crease/fold is ranked in three different levels (Figure 8): clear defined crease/fold line, uneven crease/fold line without cracks, and damaged crease/fold line with cracks.

The results of creasing and folding performance are shown in Tables 1, 2, and 3. It shows that creases in the machine direction have worse folding properties with 10-point and 12-point paperboards, primarily due to the stiffness is higher in the machine direction. The paperboard with 13-point thickness, on the other hand, has good folding properties for either MD or CD. Its multilayer structure allows more tolerance for creasing and folding operations. Overall, cracked folds with CD crease for offset and ink-jet inks are less obvious.

For the paperboards with flexo ink (Table 1), the best creasing settings for 10-point paperboard are in the range from No. 33 to No. 50, while No. 33 and No. 42 result in a clear defined crease/fold line for 12-point and 13-point paperboards.



(a) clear defined crease/fold line (b) uneven crease/fold line without cracks (c) damaged crease/fold line with cracks

***Figure 8:*** *Visual assessments of crease/fold line*

| | Machine Direction (MD) Crease | | | | Cross Direction (CD) Crease | | | |
|---|---|---|---|---|---|---|---|---|
| | No. 17 | No. 33 | No. 42 | No. 50 | No. 17 | No. 33 | No. 42 | No. 50 |
| 10-point | × | × | × | × | Δ | √ | √ | √ |
| 12-point | × | × | × | × | × | √ | √ | Δ |
| 13-point | √ | √ | √ | √ | Δ | √ | √ | Δ |

***Table 1:*** *Creasing and folding performance of printed paperboards with flexo ink*

Note: √ represents clear defined crease/fold line.
Δ represents uneven crease/fold line without cracks
× represents damaged crease/fold line with cracks

For the paperboards with offset ink (Table 2), the best creasing settings for 10-point and 12-point paperboards are in the range from No. 17 to No. 42. No. 33 and No. 42 are good for 13-point paperboard.

| | Machine Direction (MD) Crease | | | | Cross Direction (CD) Crease | | | |
|---|---|---|---|---|---|---|---|---|
| | No. 17 | No. 33 | No. 42 | No. 50 | No. 17 | No. 33 | No. 42 | No. 50 |
| 10-point | × | × | × | Δ | √ | √ | √ | Δ |
| 12-point | × | × | × | × | √ | √ | √ | Δ |
| 13-point | √ | √ | Δ | Δ | Δ | √ | √ | Δ |

***Table 2:*** *Creasing and folding performance of printed paperboards with offset ink*

Note: √ represents clear defined crease/fold line.
Δ represents uneven crease/fold line without cracks
× represents damaged crease/fold line with cracks

For the paperboards with inkjet ink (Table 3), the best creasing settings for 10-point paperboard are in the range from No. 17 to No. 50. For 12-point paperboard, No. 17, No. 33 or No. 42 creasing setting gives a good, functional fold without cracks at the outer fibers. The best creasing settings for 13-point paperboard are

No. 33 and No. 42. No surface cracks appearing along the creased and folded line using creasing setting No. 50. However, a wrinkle-like creased and folded line occurs.

| | Machine Direction (MD) Crease | | | | Cross Direction (CD) Crease | | | |
|---|---|---|---|---|---|---|---|---|
| | No. 17 | No. 33 | No. 42 | No. 50 | No. 17 | No. 33 | No. 42 | No. 50 |
| 10-point | × | × | × | × | √ | √ | √ | √ |
| 12-point | × | × | × | × | √ | √ | √ | Δ |
| 13-point | √ | √ | √ | √ | Δ | √ | √ | Δ |

***Table 3:*** *Creasing and folding performance of printed paperboards with inkjet ink*

Note: √ represents clear defined crease/fold line.
Δ represents uneven crease/fold line without cracks
× represents damaged crease/fold line with cracks

## 4. Conclusions

Paperboard packages are usually printed on the outside surface with text, illustrations and decorative designs. Neat and undamaged fold lines are basic requirement for the paperboard packages. Apply the correct creasing conditions without too much creasing in order to avoid cracking is the goal. The crease depth is an important parameter for the creasing/folding result. This parameter defines how far the rule presses the board into the channel. For a paperboard to be considered to have good creasability, it should give good creasing over a range of crease settings. This study tested out crease settings on three grades of paperboard. Table 4 summaries the best settings for each paperboard: the lower limit presents necessary rule height to reduce the folding resistance sufficiently; the upper limit presents rule height to avoid cracks. Overall, the creasing settings No. 33 and No. 42 creates better and well defined folding lines during the subsequent folding with CD crease for all tested paperboards. MD crease has lower elongation properties, resulting in the reverse side layer rupturing. It was found that the crease rule used in this study works well with the 13-point paperboard. It forms great shape of crease bead, creates multilayer structure for either CD or MD, resulting in clear defined fold lines.

| | Flexo | | Offset | | Inkjet | |
|---|---|---|---|---|---|---|
| | Lower limit | Upper limit | Lower limit | Upper limit | Lower limit | Upper limit |
| 10-point | No. 33 | No. 50 | No. 17 | No. 50 | No. 17 | No. 50 |
| 12-point | No. 33 | No. 50 | No. 17 | No. 50 | No. 17 | No. 42 |
| 13-point | No. 33 | No. 42 | No. 33 | No. 42 | No. 33 | No. 42 |

***Table 4:*** *Best creasing settings for the tested paperboards*

When it comes to the folding of the paperboard products, consistency of quality relies upon a number of factors. The thickness of the paperboard is certainly an important factor affecting creasability. Since paperboard is usually comprise layers of more than one type of pulp. The changes in the paperboard may also influence the creasability of the board, e.g. changes in the fiber raw material, fiber orientation, drying conditions, the uniformity of the substrate, etc. Further investigation can take paperboard properties into account to exam the their effects on creasability of paperboard.

## References

Beex, L. A. A. & Peerlings, R. H. J.
2009 "An Experimental and Computational Study of Laminated Paperboard Creasing and Folding," International Journal of Solids and Structures, 46, pp. 4192-4207.

Carlin, S., Dunder, I. & Edholm, B.
1997 "Creasability Testing by Inclined Rules – a Base for Standardized Specification of Paperboard," Packaging Technology and Science, Vol. 10, pp. 191-207.

Hanlon, J. F., Kelsey, R. J. & Forcinio, H. E.
1998 "Handbook of Package Engineering (3rd ED)," Lancaster, PA: Technomic Publishing Company, Inc.

Kirwan, M. J.
2005 "Paper and Paperboard Packaging Technology," Ames, IA: Blackwell Publishing Professional.

Nagasawa, S., Fukuzawa, Y., Yamaguchi, T., Tsukatani, S. & Katayama, I.
2003 "Effect of Crease Depth and Crease Deviation on Folding Deformation Characteristics of Coated Paperboard," Journal of Materials Processing Technology, 140, pp. 157-162.

Nygårds, M., Just, M. & Tryding, J.
2009 "Experimental and Numerical Studies of Creasing of Paperboard," International Journal of Solids and Structures, 46, pp. 2493-2505.