Die-cutting and creasing

In the conversion of paperboard the die-cutting and creasing operations are usually performed simultaneously in the flat-bed die-cutting station, which can be off-line or in-line with the printing press. In-line processing dominates for cigarette cartons; most other carton work is done off-line. Die-cutting and creasing are frequently combined with embossing.

To achieve a consistent, accurate result, it is important to choose the right tools, machine settings, types of paperboard and conditions for the paperboard. Detailed technical information on tool design, machinery and settings is available through established suppliers of machines and tools. Less information, however, is available regarding the interactions between the machinery, tools and paperboard.

**Key paperboard characteristics**

It is important to recognise the differences between the different types of paperboards, mainly Solid Bleached Board (SBB), Folding Box Board (FBB) and White Lined Chipboard (WLC). All grades can be cut and creased but to achieve the best result for each application it is important to fine-tune the treatment to give the desired result. Due to the type and individual properties of the different paperboard grades, die-cutting, creasing and embossing can be performed to different levels of achievement.

Common to all paperboards is the fact that results differ depending on the grain direction, moisture content and thickness, amount and type of surface treatment (pigment, plastic, or metal foil coatings).

Runnability through the die-cutting and creasing station is important. The paperboard web or sheet should be efficiently cut and creased, partly separated and rapidly pushed (or pulled) away. To run satisfactorily, the machine settings are vital. The moisture content, shape and dimensions of the web/sheet and cut blanks are important. The partly cut sheet must have enough integrity to be transported to the stripping unit. Even minor variations and disturbances can cause a breakage and jam the whole production line. After the type of paperboard, consistency in moisture and thickness are the next two most important factors.

**Die-cutting**

A good cut should be clean and free from loose fibres and particles. This will give accurate and clean edges and avoid contamination problems during further processing of the paperboard or in the packaging operation.

Die-cut blanks remain linked to one another by nicks. To prevent unwanted separation of the sheet during the transfer to subsequent stations, the strength of specific nicks is of great importance for a high production rate. At the same time it is important that the paperboard blanks can be easily separated in the stripping operation, which removes the paperboard waste. Having an optimum nick quality is necessary in order to achieve the best result regarding these two contradictory needs and to obtain a clean and clear cut.

**Description of the die-cutting tool**

The die consists of the cutting and creasing rules. When performing the die-cutting operation, the die reciprocates up and down towards the paperboard, which is placed on the make-ready. After one cycle the cut paperboard sheet is removed and a new one is fed into the machine.

Please refer to the fold-out at the end of this manual for an example of die-cutting.
The task of the ejection rubber is to hold the sheet in a fixed position during cutting and to eject the paperboard blanks from the cutting die.

A nick is obtained by making a notch into the cutting rule. The geometry of the nicks (shape and size) varies and depends mainly on the type of paperboard used. The height of the notch should be slightly higher than the paperboard thickness.

**Key paperboard characteristics**

Chemical fibres in the paperboard give strength and efficient bonding, which gives a cut with clean edges. Due to its strength, chemical fibre-based paperboard therefore allows smaller nicks. The different strength properties in the machine direction compared to the cross direction are important in the design of nicks. Generally nicks are two times stronger in the machine direction than in the cross direction.

To achieve clean, debris-free edges it is important to have the correct cutting conditions. Due to its strength, toughness, and density, paperboard requires sharp, well-adjusted knives and good control of the die-cutting machine. The high force required to cut through has to be well controlled to minimise what is called the “overshoot” of the moving die. Otherwise the knives will hit the counter plate too hard which will quickly damage the knives and degrade the quality of the cut edges.

The most important strength properties of the paperboard are tearing and tensile strength. The nick strength is proportional to tensile strength and grammage. The moisture content level is essential for both runnability and quality during the die-cutting process. Too high a level will make the paperboard strong, tougher and more difficult to cut. Too low a moisture level will make the paperboard more brittle and difficult to safely transfer. Difficulties in cutting through can be caused by the paperboard thickness, moisture variation, or tool wear and adjustments.

When cutting sheets into carton blanks it is important to achieve the desired shape to feed the blanks properly. Depending on the moisture equilibrium and the possibility of tension being released during cutting, the blanks can be curved or twisted into shapes that disrupt the converting and packing operations.

Moisture content variations and dimensional variations cause misregister between the printed image, cuts, creases, and embossed impressions.

The wear of die-cutting tools is not well understood. Coating and fibre composition, inks and varnishes may have an influence.
Die-cutting and creasing

Die-cutting in practice

Tool preparation

All cutting rules must be of the same height to cut through the entire thickness of the paperboard across the die. Fine-tuning the level of each cutting rule is important but complicated. Patching up, as it is called, in one area of the sheet might induce disturbances in other areas. Machinery suppliers will be able to provide more specific information on this topic. The nick strength depends on factors such as:

- paperboard grain direction
- method of making notches
- rubbering of cutting die
- nick dimensions
- arrangements of nicks
- number of nicks
- humidity of the paperboard
- type of fibre.

The ideal position for the nicks is in line with the gripper force. The flaps of a blank should be linked with another blank by two nicks placed as far apart as possible. Nicks should not be made on glue flaps. Nicks are produced by grinding a notch in the cutting rule with a grinding wheel.

The dimensions of nicks should be as small as possible. Generally, the width of the nicks varies from 0.4 mm to 1.0 mm depending on the strength of the paperboard.

It is important that the climate is controlled in order to keep the paperboard moisture content unchanged. Variations in moisture content will cause dimensional changes due to shrinkage and expansion, which will cause misregister. Constant moisture is also important to avoid distorting the shapes of sheets or blanks, which could otherwise interfere with the cutting tools and cause machine stops. The toughness of the paperboard varies with moisture. High moisture makes the paperboard difficult to cut and the blanks tough to separate, and low moisture makes the paperboard brittle and may cause unwanted blank separation.

Rubbering of the cutting die

The rubbering of the cutting die plays a very important role for the quality of the final result. Correctly done the rubbering also supports productivity by allowing higher speeds and minimising the risk of stops due to waste coming loose in the machine or sheets not ejecting properly from the die.

In the cutting operation the rubbers fix and secure the sheet before and during the cutting and help to strip the cut material from the sheet. All die rules around the outer edges of the design should be rubbered with “closed” rubber types. These will trap and compress air within the design and help to eject the sheet from the cutting die.

To avoid unwanted stress on the nicks the notches should not be ground through the rubbers. This would put extra stress on the nicks during the cutting operation and may decrease their strength by up to 30%, risking premature breaking.

Recommendations

Rubbers for blank separating rules with notches: The rubber is generally positioned between 1.0 and 2.0 mm from the cutting rule in order to prevent breakage of nicks. The use of profile rubber (shape-designed to distribute the stress in the compression stage in a more accurate way) has proven to give better results: stronger nicks, fewer pressure marks, and a more accurate fixing of the paperboard during the cutting operation.

A very hard profile rubber (7 mm wide) is recommended. Please note: If undesired pressure marks should occur, reduce the hardness and if possible increase the width.

Rubbers for rules without notches: The rubbers for such an area serve only to eject the sheet after it has been die-cut. The most important paperboard property in this context is good elasticity. The rubber should be compressible to at least 50% of its normal height.
Rubbers for paperboard printed on both sides: When die-cutting a paperboard which has been printed on both sides, it is important to increase the hardness of the rubber. In this way, ink flaking on the reverse side is avoided. This is especially important when using a UV curable (hard) ink or varnish.

A cork rubber or a hard elastomer is recommended. The rubber profile should be mounted as close as possible to the cutting rule.

**The ram punching operation**

Ram punching is a powerful cutting technique used to cut numerous amounts of small shapes such as labels, envelopes, and cards. Unlike die-cutting, which cuts one sheet at a time, ram punching is used to cut through a pile of substrate. This means, of course, that ram punching and creasing cannot be performed simultaneously.

Ram punching is often used to cut paper but can also be successfully used with multi-ply paperboard to cut simple shapes. To avoid waste, the paperboard is first cut down in an ordinary cutting machine to fit the size of the intended shape, leaving a margin of 5 to 10 mm.

The ram punching tool consists of a punch mounted on a jig. To prevent edge delamination and other damage, counter pressure, i.e., that a hydraulic piston is used to press the paperboard pile against the punch, is recommended. Under demanding conditions, the choice of a suitable varnish that can lubricate the knife may also prevent edge damage.

A high density paperboard such as SBB is more suitable for ram punching operations than other paperboard types.
The laser cutting operation
Laser cutting is by far the most elaborate and exclusive cutting method. It allows very small details and very complex designs. The operating principle is rather simple. The original design is etched through a copper template, which is positioned over the paperboard sheet. A sharply focused laser beam runs back and forth over the template and wherever there are etched areas, the laser beam vaporises the paperboard.

The paperboard used in laser cutting should be as lightly coated as possible for two reasons. The first is that the lighter the coating is, the faster the laser cutting works. The second is that the operation leaves a slightly brownish discolouration on the reverse side of the paperboard, and this is more noticeable on a heavily coated paperboard. This discolouration can be covered by printing, but it may also be considered as a part of the design.

Since the sheets are fed into the laser cutting machine with the print side down, a protective varnish to avoid scratches on the print is recommended. The use of paperboard thicker than approximately 500 μm should be avoided, due to limitations in the laser cutting process. Please contact a supplier for advice and if possible a test.

The benefits and limitations of multi-ply paperboard products in laser cutting are shown in the following table.

<table>
<thead>
<tr>
<th>Paperboard type</th>
<th>Benefits</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Folding Box Board, FBB</td>
<td>Low density compared to thickness means less energy is needed for cutting (economical production).</td>
<td>Lower strength than SBB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid Bleached Board, SBB</td>
<td>The strong network in SBB baseboard allows a design with finer details (better strength in the most fragile designs than alternative grades).</td>
<td>Two-side fully coated SBB gives more discolouration, since the coating amount is higher compared to the thickness than for single-side coated paperboard.</td>
</tr>
</tbody>
</table>
Creasing
Creasing is an operation which facilitates the folding operation. During creasing the paperboard is weakened along well defined folding lines, which then act as hinges for folding packaging and graphical products. It is very difficult to fold paperboard with a good result without creasing. The surface plies will crack and/or the folding line will be undefined. When converting paper (less than 180 g/m²) the folding operation is often performed without any surface preparation. Paperboard with a grammage above 600 g/m² requires more than one crease or must be scored before folding.

To achieve a perfect crease the relationship between its width and depth is of great importance.
Creasing is carried out using a thin strip of steel with a round smooth edge and an accurately cut groove in a thin hard material known as the make-ready (matrix or counter-die). The creasing rule pushes the paperboard into the groove of the make-ready, located under the paperboard, creating a permanent crease.

The creasing tool’s construction and performance are essential elements in obtaining a satisfactory result.

Description of the creasing tool
The creasing rules are fitted into the die. When performing the creasing operation, the die reciprocates up and down towards the paperboard, which is placed on the make-ready. After one cycle the creased paperboard sheet is removed and a new one is fed into the machine.

The thickness of the creasing rule, the groove width, the make-ready thickness, and the paperboard thickness must correspond to each other. Different types of paperboard require different tool geometries.

Creasing – a deformation
The paperboard is creased by being pressed into a channel or groove in the make-ready. The forces created deform the paperboard in a predetermined way and the deformation is permanent. The result is a reduction in the bending resistance of the crease. The paperboard is therefore weaker along the crease than elsewhere. During the creasing operation, the paperboard sheet is bent in four narrow zones and in each of these the paperboard must endure high tensile forces or compression forces.
To calculate the creasing parameters the following formulae may be used:

\[
\text{Crease depth } h_1 = t + t_n - (H - H_r) \\
\text{Penetration } h = H - (H_r + t_n) \quad (\text{DIN}) \\
\text{The height of the creasing rule } H_r = H - t_n \quad (\text{DIN})
\]

- If the penetration is \( h = 0 \) mm then the crease depth = paperboard thickness
- If the penetration is \( h > 0 \) mm then the crease depth < paperboard thickness
- If the penetration is \( h < 0 \) mm then the crease depth > paperboard thickness

According to the DIN standard, penetration equal to the thickness of the paperboard is denoted as \( \pm 0 \). The penetration is denoted as + when the crease depth is less than the paperboard thickness and – when it is more than the paperboard thickness. Unfortunately there is not a universal agreement about the notation + and – as applied to penetration. Iggesund Paperboard uses the same notation as that described in the DIN standard.

It is not always possible to have a make-ready or counter-die of exactly the same thickness as that of the paperboard. As a general rule, choose the next larger thickness e.g. 0.40 mm for a 0.35 mm paperboard.

The width of the creasing rule is typically 0.70 mm in the thickness range 0.20 – 0.55 mm and 1.05 mm for paperboard thicknesses above 0.55 mm.

The groove width is generally 1.5× the thickness of the paperboard plus the width of the creasing rule. The groove width should be narrower if the crease is performed in the machine direction (MD).

**Key paperboard characteristics**

Different types of paperboard react differently and need the appropriate tools to give the best result.

**Different paperboard ply constructions**

Most paperboards are made of several plies. The fibre composition and physical properties vary considerably between different types of paperboard. To get well-defined creases and accurate folding with low folding resistance the crease should be deep and narrow. During creasing and subsequent folding the paperboard is subjected to severe stresses and deformations.

For successful creasing the paperboard must have strong surface plies and coating layers. Another important feature is the attainment of a good hinge. Ideally, the paperboard should delaminate into a finite number of thin unbroken plies throughout the thickness of the paperboard.

Due to the wide range of paperboards and their different physical properties, the graphical or packaging demands on creasing should be carefully matched to a suitable paperboard. Equally important is the adaptation of the creasing tools to the type of paperboard.

**Key properties**

Since the creasing operation causes a mechanical deformation, the measurable strength properties such as tensile strength, compression strength, elongation, and elasticity are important.

**Creasing in practice**

**Tool preparation**

The creasing rule width, the groove width and the make-ready thickness should be determined with regard to the paperboard type, the paperboard thickness and the direction of the creases (MD or CD).
Die-cutting and creasing

The following factors are essential for good creasing:
- the height and width of the creasing rule
- the thickness of the make-ready
- the groove width
- the accuracy and hardness of the make-ready
- the pressure of the die-cutter.

It is more difficult to produce a perfect crease parallel to the machine direction (MD) than it is parallel to the cross direction (CD). In demanding cases MD creases should be defined separately. If there are many creases, especially close to each other, it is advisable to have them parallel to the CD of the paperboard.

The operating accuracy of the creasing tool is important in order to correctly locate creases. An incorrectly located crease will give a poor appearance, especially when the carton is printed.

**Thickness**
Thickness, not grammage, is an important variable for the design of the creasing tools. If the paperboard thickness is changed, even within the same type of paperboard, the tools should be adjusted (according to the formula in the section "Description of the creasing tool"). It is important to distinguish thickness from grammage. Different types of paperboard have different thickness/grammage relationships and different physical properties. To obtain a good result the tools should be designed according to the paperboard type and thickness chosen.

**Paperboard type**
For each type of paperboard, there are recommendations which will help to obtain the best result when creasing. See the Product Catalogue for further information.

**Testing crease result**
The effectiveness or inadequacy of a crease should be checked by bending at an angle of 90° or 180° depending on whether the blanks are to be erected and glued or are to be glued for flat delivery.

Creases are subjectively evaluated regarding defects, cracks, etc. For good results the folding factor, explained later in this chapter, should be above 50%.

<table>
<thead>
<tr>
<th>Paperboard type</th>
<th>Paperboard characteristics</th>
<th>Creasing results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid Bleached Board</td>
<td>Dense, strong, and tough paperboard. Strong plies throughout to withstand demanding creasing.</td>
<td>Develops well defined permanent creases easily. Gives creases with low folding resistance and good foldability over a wide range of crease geometries. Accepts very narrow and deep creases without damage.</td>
</tr>
<tr>
<td>Folding Box Board</td>
<td>Low density, stiff paperboard. Strong surface plies to withstand the crease stress and deformation.</td>
<td>Develops well defined creases. The compressible interior gives less permanence of the crease as defined by the tools. The high stiffness in relation to the folding resistance gives good foldability.</td>
</tr>
<tr>
<td>White Lined Chipboard</td>
<td>Dense, intermediate to low strength and stiffness. Stronger surface plies to accept moderate creasing.</td>
<td>Develops creases provided the tools are matched with the chosen paperboard. The physical properties and pulp composition vary to a large extent. It is not possible to give typical values.</td>
</tr>
</tbody>
</table>
Scoring
The bookbinding industry is developing in many fields. Demands on shorter make-ready time, shorter runs and higher speed makes the traditional creasing technique less profitable. The use of inline scoring in the binder for both soft cover production and saddle stitching as well as for folders is the prevailing technique.

Description of the scoring operation
The paper or paperboard travels through a set of counter rotating tools with a male and female part which press a permanent groove into the substrate.

In the folding station the substrate travels through the tools mounted on shafts before going through the knife folding unit.

In the cover station for a saddle stitcher the cover is gripped and fed around a rotating drum with a male scoring wheel.

In the cover station for the perfect binder the covers are fed through two sets of shafts with tools. Tools for spine grooves as well as decorative grooves for front and back covers are fitted in an opposing manner.

The female wheel can be of three main types:
- A soft rubber counterpart which does not have a groove and which relies on the compressibility of the surface to be sufficient for developing the permanent deformation in the substrate.
- A metal surface with milled groove in fixed dimension.
- Two adjustable parts in metal, which enables the adjustment of the female groove width.

In the first case, the only adjustment that can be made during production is a pressure adjustment, which is done by pressing the male tool down harder into the substrate. In the second case, pressure can be increased up to the point where you risk cutting into the substrate. The width of the groove can be adjusted by fitting a new female tool with a different groove dimension. In the third case, both the pressure (depth of indentation) and the width of groove can be adjusted independently by using levers in the machine.

Folding performance
A study of SBB 240–260 g/m² and FBB 200–240 g/m² in 2008, identified the most important differences between traditional creasing and scoring with regard to the performance of the creased material.

Settings
The tool geometry for the scoring tools in this study were as follows: The width of the male scoring tool was set to 0.7mm which corresponded to the width of the creasing rule.
The width of the female groove was approximately 0.6 mm wider for the scoring tool compared to the groove of the make-ready used in the creasing study according to the manufacturer’s recommendations.

**Depth of the crease (h)**

In the case of both SBB and FBB products the depth of the groove of the scored material was found to be 25–30% shallower when scoring with h=0 penetration by the male tool. However, when the penetration was increased by 20% the SBB developed an equally deep groove as when properly creased but the FBB samples were still 15% shallower than the creased material. This can probably be attributed to the higher density of the SBB. In contrast, the compressibility of the FBB paperboard requires higher pressure to develop a permanent deformation of the same depth.
Die-cutting and creasing

Width of groove
The width of the groove inside the bulge was recorded (see the illustration above) and here the scored material showed a wider result than the creased material. The SBB samples were approximately 20% wider and the FBB was 15% wider. Increasing the pressure to a positive penetration did not affect the width of the groove significantly.

To summarise, the result of scoring can be expected to be shallower and wider than the result of creasing. An example of the effect this has on the folding resistance (moment) is illustrated by the graph on the previous page.

The FBB paperboard and SBB paperboard show equal resistance to folding at 90° despite the difference in their base weight. The resistance is approximately 25% higher for the scored samples at 90° due primarily to the incomplete bulge geometry of the scored material. The remaining resistance after folding 90° drops and has been recorded over a 15 second period. This is an important property to monitor, since this corresponds to the clamping period in a perfect binder where the force with which the paperboard wants to spring back after clamping risks the integrity of the glue seam. Once again the moment to which the paperboard wants to spring back after 15 seconds is 25% higher for the scored material compared to the creased material.

Scoring in practice
The main difference between traditional scoring and carton blank creasing is the direction of the score. Whereas the bulge is always directed inwards into the fold in carton creasing, scoring for books and brochures is mainly done the opposite way. There are two reasons for this. First, the technique is mainly used for thinner fine paper where the prospect of creating a well-defined delamination within the structure to facilitate a good fold with low resistance is low due to its monolayer construction and high internal bond.

Second, there are clear practical reasons in three different cases:
• When folding the bulge would, if turned the “correct” way, obstruct the accuracy of the folding knife in the folder when the bulge is pushed between the folding rollers. This leads to misregister and variations through the run.
• If the bulge develops towards the insert of the magazine, the alignment of the insert in relation to the cover could be obstructed. This leads to misregister between artwork which spreads over both cover and insert and reduces the ability to have a controlled and consistent operation.
• When applying the cover onto the insert in a perfect binder, the bulge will obstruct either the tight fit of the spine or the integrity of the side glue seam on the face and back page.
Key paperboard properties
It is evident that traditional creasing results in a deeper and narrower crease which improves the folding performance. When scoring, you need to adjust the tooling and settings to negative penetration (according to the DIN standard) and you need to select or set the width of the female tool to an absolute minimum without inflicting a cut in the surface.

Key paperboard properties for foldability in scoring
• Strength and toughness in the MD and CD, tensile strength, compression strength, elongation and elasticity
• Stiffness in the MD and CD
• A strong and elastic coating.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Cause and remedies</th>
</tr>
</thead>
<tbody>
<tr>
<td>The outside of the paperboard cracks during folding.</td>
<td>Too high stress along the edges of the crease. Widen the groove or reduce the height of the make-ready.</td>
</tr>
<tr>
<td>The sides of the erected box bulge out.</td>
<td>The grooves on the make-ready are too wide. Increase the height of the creasing rule. To correct the creasing, remake the make-ready.</td>
</tr>
<tr>
<td>Irregular creases, the paperboard folds either to the left or to the right of the crease.</td>
<td>The grooves on the make-ready are too wide. Increase the height of the creasing rule. To correct the creasing, remake the make-ready. The folding resistance is too great</td>
</tr>
<tr>
<td>The liner splits.</td>
<td>Insufficient penetration or depth of crease. The groove width too narrow. The paperboard is too dry.</td>
</tr>
<tr>
<td>Crumpled roll (or bead)</td>
<td>Insufficient penetration. The groove width is too wide, possibly due to a worn matrix.</td>
</tr>
<tr>
<td>Cutting through</td>
<td>Poor alignment of the rule with the groove.</td>
</tr>
<tr>
<td>Back splitting</td>
<td>Bottoming of the bead in the groove as a result of an insufficiently thick matrix, or debris in the groove.</td>
</tr>
<tr>
<td>Bursting</td>
<td>Localised splitting of the crease due to the presence of debris etc. in the groove.</td>
</tr>
<tr>
<td>Shattering (Cobbing)</td>
<td>Tears in the reverse side adjacent to the cut edges. Prevent this by using a hard ejection rubber set approximately 1 mm from the knife.</td>
</tr>
</tbody>
</table>