Paperboard converting

Paperboard has the ability to achieve or exceed the same excellent image reproduction as for the best fine papers. Paperboard offers equal possibilities to achieve new, challenging shapes as competing packaging materials. However, increasing demands on performance of the material in various converting processes have become evident when speeds in both printing processes and post-press converting have increased. Additionally, the acceptance level for impurities or slight deviations in quality in the final product has dropped noticeably as a result of both end-user demands and the use of modern quality control equipment in the various converting machines.

Productivity is the material’s and defined process’s ability to meet the defined goals and is difficult to define quantitatively since expectations differ from company to company. The same paperboard in the same type of machine but for a different end use can have higher or lower results in terms of productivity. Productivity can be measured in many ways, in both fixed and relative numbers, and for a whole plant or per specific machine:

- Number of man hours spent per converted sheet.
- Overall equipment effectiveness, capacity utilisation.
- Number of approved converted sheets per man hour.
- Amount of waste.

The material and its properties will have an effect on all of the above parameters in terms of the material’s ability to withstand increased mechanical stress during higher converting speeds and from higher demands on ink-surface interactivity, and to function without interruptions in converting due to inconsistency of these properties.

The increasing demands in the brand promotion process for graphic design and the use of non-print surface enhancements are creating innovative shapes and multi-sensory experiences for the consumer or user who handles the product. An understanding of the interaction between paperboard properties and converting efficiency is essential for designers and converters, since the ultimate design of the product together with the choice of paperboard will impact on crucial conversion factors like printability, flatness, and creasing/folding properties. Considering all the variables, it is probably true to say that consistency in the behaviour of the paperboard product is the key to high efficiency.

Printing presses and post-print converting machinery will accept a wide range of paperboard types at decent levels of productivity. However, tolerance for irregularities in critical parameters is diminishing as speeds and complexity rise. Critical parameters where consistency is important for high productivity include:

- Ink-surface interaction for uniform ink- and glue setting and drying.
- Dimensional stability for correct register and accurate die-cutting.
- Flatness for efficient feeding and glue seam alignment.
- Clean edges and surfaces to avoid unnecessary cleaning interruptions.
- Correct folding action for quick carton erection and subsequent glue seam alignment for accuracy in shape, which promotes high speeds during the carton filling stages.

The following sections describe the features that support both high-quality and trouble-free production for the most common processes.
Excellent print quality
It is essential that paperboard for graphical applications should provide excellent print quality. To achieve this, the paperboard must meet stringent requirements in terms of its appearance and performance during the printing process. The ability of the board to fulfil these requirements is referred to as printability. High print quality is, in the main, characterised by uniform print results, high ink gloss and true colour reproduction.

Uniform print results
To achieve uniform print in both half and full tones it is essential that both the ink transfer and ink setting are adequate. Good ink transfer from the ink carrying plate to the paperboard is essential. A uniform surface tension enables sufficient wetting of the surface by the ink. This is particularly important in flexo applications, digital printing (liquid toner), or when printing on extruded plastic surface or surfaces coated in some other manner prior to printing.

Uniform ink setting is important regardless of the printing process used. This is achieved by ensuring the uniform absorption of oil and/or water (depending on the ink vehicle). For oil-based inks in conventional offset printing the uniform absorption of both water and oil is required as ink transfer can be obstructed by the presence of fountain water on the substrate surface. In offset printing irregularities in ink setting can cause mottle or back trap mottle.

To achieve uniform ink transfer and setting it is important that the paperboard has a coating layer with an even thickness; this is of particular importance for blade coating, and prior to coating causes local variations in coat weight that lead in turn to variations in calendering and glazing. A well-controlled coating operation contributes to uniform print results by ensuring a monitored coat weight and a controlled coating composition.

High ink gloss
High ink gloss is a property of a very flat, levelled ink film. This is true for any ink film and should not be confused with the term “high gloss inks.” Having a coating with uniform absorption properties is crucial. With a very smooth paperboard surface, the ink levelling will be more rapid and occur more easily. Because a thicker ink film can fill cavities in the paperboard surface, the thicker the ink film the more likely the ink is to form a smooth surface. It is for this reason that the thick ink films in screen printing often result in higher ink gloss.

Good wetting properties enable sufficient ink adhesion and subsequent setting

Fountain solution that is either non-emulsified or non-absorbed may obstruct ink transfer to both printed and unprinted surfaces

Areas of compressed coating and base board resulting in local density variation

Areas of compressed coating and base board resulting in local density variations
The key to high ink gloss often lies in allowing the ink film to level out into a flat surface before setting. This means allowing the ink to stay “wet” for a little longer. It should be noted that good ink setting requires rapid absorption and so the levels of ink gloss achieved are to some extent limited by the necessity of achieving satisfactory ink setting. The composition of the paperboard’s coating is the principal factor affecting the speed of ink drying. A coating with large pores absorbs ink more slowly and thus supports better ink levelling.

True colour reproduction
The factors that have the greatest impact on true colour reproduction are ink density, dot gain (mechanical and optical), and the magnitude of the colour gamut that it is possible to obtain with a given set of inks.

• The ink density is directly connected to the amount of ink pigments transferred to the paperboard surface. In some cases the result depends on the water and oil absorption of the coating layer. Too much moisture on the paperboard surface may result in poor ink transfer for an oil-based ink (this is known as ink refusal). This moisture may be due to condensed water from a cold paperboard pallet, or excess fountain water from a previous printing unit, or excess fountain water that has not emulsified correctly with the ink.

• Dot gain can be discussed as both mechanical dot gain and optical dot gain. In offset printing most of the mechanical dot gain occurs before the ink hits the substrate surface and therefore variations in the paperboard’s coated surface contribute little to variations in mechanical dot gain. However in flexo applications or digital printing (liquid toner) the surface tension and permeability of the paperboard surface could cause the ink to spread more
or less on the surface or inside the coating/baseboard structure.

- Optical dot gain is influenced by the light absorption of the coating and baseboard and their light-scattering properties. Good surface smoothness is also thought to have a positive effect on optical dot gain, but this has not been conclusively demonstrated.
- The reproducible colour gamut depends primarily on the ink quality, ink layer thickness, and ink density achieved. Other factors that affect the colour gamut are high ink gloss and the optical properties of the paperboard surface. For the secondary and following colours the ink trapping properties are crucial. Good clean trapping will enable the reproduction of a larger colour gamut; it is essential that as much of the secondary and following inks as possible is transferred in an even pattern on top of the first ink with no irregularities in ink density. The ink setting properties and ink tack of the various ink layers influence each other; for this reason the colour sequence may be important.

Runnability and efficiency

Good runnability comprises the different factors that let the jobs run efficiently through the press and finishing equipment with low down time and low material waste. Multi-ply paperboard has many important features that support cost-effective printing and finishing operations, as well as the total quality image of the finished products. The prime building block for efficient converting of the paperboard is a product which behaves consistently in both printing and post-press converting. Consistency makes the product predictable, which means in many cases shorter make-ready. Reliability will also play a role to maintain expected production rates from batch to batch year in and year out.

In-feed and operation

How quickly the in-feeder can be set up and how well the substrate runs are factors that affect the total economy of a print- or converting job. The factors that mainly determine how quickly the job can be set up and processed are efficient feeding, flat sheets, dimensional stability, and dust-free stock.

Efficient feeding

The main paperboard properties that affect consistent feeding from pallet to pallet or reel to reel are friction, uniform thickness and paperboard flatness/shape (of which the latter is described in the section below). The friction originates from several different sources but the main factors are the surface chemistry and the surface topography.

The sheets may adhere to each other due to electrostatic attraction. This is mostly applicable to thinner paper, but may occur with lower grammages of paperboard. The best way to prevent electrostatic charges from being built up is not to let the paperboard dry out too much. If the surface is somewhat rough, you risk mechanical interlocking between the sheets to obstruct the feeding. On the other hand, too smooth a surface will present a larger contact area between the sheets, which might enhance the inter-locking caused by surface chemistry. This effect could be compared to the force that makes it hard to separate two glass plates that are piled together.
Flat sheets
The flatness of the sheet affects the press speed and sometimes even the print result itself. Flatness irregularities are described as twist or curl. Both will cause difficulties in feeding and running the press or finishing machine. The best way to avoid twist or curl is to maintain the original moisture content of the paperboard.

Flatness is a decisive property of paperboard and will affect the efficiency of operation through the full conversion chain. During the paperboard manufacturing process control of curl and twist is a very complex process and starts in the forming of the multi-ply structure at the wet end of the board machine, where the following factors contribute to minimising inbound stress in the sheet:
• fibre composition in the respective layers of the multi-ply construction
• fibre orientation
• fines content
• controlled removal of water and rewetting
• controlled drying of the web
• web draws in the drying section.

A balance in these properties will produce a flat sheet and will minimise the risk of uneven tension caused by hygro-dimensional changes. The release of tension could occur later in the printing or finishing processes and result in distortion of the sheet.

Dimensional stability
In multi-step processing (or even in multi-colour printing) it is important to use a substrate with excellent dimensional stability. The substrate is exposed to many different forces that might stress the structure in such a way that the sheet changes its dimensions. The forces might come from hygro-expansion due to moisture exposure or from mechanical stress imposed on the sheet during the printing or finishing operations, either one or both. Different paperboard types are more or less prone to distortion under climate changes.

Dust-free stock
To achieve an efficient operation in the printing or finishing machine requires a substrate free from dust or fibrous debris. To minimise dust or debris (mainly coming from the sheet edges) the areas to focus on are pulp processing and the retention of smaller fibres.
• Clean edges depend substantially on the fibres’ ability to bond with each other. Fibres from chemical pulp are flexible and interlace easily with other fibres to form a strong network. For mechanical pulp the refining process plays a central role in increasing the binding abilities of the fibre network. Refining generates larger contact areas between the individual fibres. Fine-tuning of this process ensures a well-bonded network.
• With the help of retention chemicals the small parts of fibres (fines) are kept inside the sheet. This provides more contact points in the fibre network and helps to bind the fibres together. Fibre retention is essential for both mechanical and chemical pulp.

Ink application
Paperboard features that are especially important for the ink application are good surface strength and good plybond.

Good surface strength
In offset litho printing the inks have a very high tack. To resist the forces in the printing nip and to prevent coating picking, the coating must be well attached to the baseboard surface. A good bond between coating and baseboard is promoted by the following paperboard properties.
• To provide a strong bond to the coating, the fibres in the baseboard surface should adhere well to each other. If the fibres are not sufficiently bound together the coating can come off, taking some of the top fibres with it as well (this is known as pull outs). The good bond between the fibres is promoted by good fines retention. Uniform surface sizing of the baseboard is a strong base for the coating. Weaker spots may otherwise be torn off in the printing nip.
• Good internal bonding in the coating layer is a vital factor. This is not only an internal coating issue, but can also be influenced by the baseboard. Variations in the baseboard surface porosity may cause binder migration in the coating.
layer and thereby variations in the internal strength.

**Good plybond**

Good plybond is primarily applicable to offset litho printing, since the tacky inks impose a high force on the substrate. This force is a combination of pulling and shearing in the exit of the printing nip, which may cause delamination. Unlike coating picking, which may occur in the interface between the coating layer and the baseboard surface, delamination occurs within the baseboard structure, either within a ply or between different plies, often close to the surface.

Delamination is least of all desirable in the printing process, so the plybond must be sufficiently strong. However, in the creasing, folding and embossing operations delamination is necessary, so the plybond must not be too strong either. Therefore the properties of the baseboard need to be very well balanced.

Good plybond depends on the forming of a strong and elastic network inside the baseboard. This is influenced by the fibre characteristics and the formation of the sheet. The use of virgin fibres with different tensile strength, stiffness, shape and bonding abilities affects the strength of the final fibre network. The basis for producing a fibre network with the right strength is the use of virgin fibres in itself, together with controlled sheet forming on the paperboard machine.

**Quick turn around and reverse side printing**

To achieve high print speed and good economy it is important to be able to turn the sheet around and print the reverse side as soon as possible after the first print run. The most important factor for quick reverse side printing is ink drying. Too much ink, or the wrong pH in the fountain water may decrease the drying speed.

Since different ink types are designed to dry in different
ways, the drying is influenced by various surface properties. Therefore it is vital to match the ink type carefully to the surface properties of the paperboard. With offset ink for coated surfaces the ink must set fast enough to enable the drying process. Smaller pores in the coating absorb the low viscosity part of the ink oils quicker and the total pore volume will affect the speed of ink setting.

**No set-off**
To minimise the risk of set-off, fast ink setting and drying are crucial. The absorption properties correspond to the ones mentioned in the point above. Other paperboard properties that influence the set-off are surface smoothness and low density.

- The surface smoothness is a matter of matching the surface properties correctly on both the print side and the reverse side. On a rough surface, set-off from the “peaks” in the surface topography may occur. On a very smooth surface, on the other hand, the large contact area between the sheets may increase the risk of set-off. Particularly in this case it is extremely important to match the ink type carefully to the surface properties of the paperboard.
- A high density substrate, such as a thick, wood-free paper, will result in higher pressure on the underlying sheets in the delivery stack, compared to a high bulk paperboard. Given the same height of delivery stacks in a sheet-fed printing press, a high bulk substrate such as graphic paperboard decreases the risk of set-off.

**Make the most of the finishing options**
Graphic paperboard is a forgiving material. This becomes particularly obvious when it is time for the finishing operations. Below the strong, smooth, white surface lie all the strengths required for carrying out the most demanding applications. Whether it is just adding a varnish to highlight the graphic presentation or using the most advanced designs in multi-step processes, a predictable, good result will follow.

**Runnability in general**
Good runnability in the various finishing operations relies on the same factors as those described above in the section “in-feed and operation” and additionally on good rub resistance and no rub-off.

**Good rub resistance**
It is essential for an ink or varnish film to be durable and preserved through the finishing operations and when handling the finished products. Factors that influence rub resistance are ink type and surface abrasiveness.
- The best way to achieve good rub resistance is to choose an ink with a somewhat higher content of wax. As explained earlier, matching the ink type properly to the absorption properties of the substrate surface is of prime importance.
- A smooth surface contributes to a good rub resistance by having less peaks in the surface topography. Hence loss of ink or varnish in the finishing operations can be avoided. The surface abrasiveness is also thought to be influenced by the coating formulation and choice of coating pigment.

**No rub-off**
The ink pigments should be well bound to the surface and not come off during the finishing operations. It is – once again – a matter of careful matching of the ink type.
type to the substrate absorption properties. The surface should not absorb the ink binder, leaving the pigments somewhat less bound to the surface. This can be the case when using a substrate with too high or quick ink absorption, a problem that is primarily controlled by coating pore size and total pore volume.

**A wide range of finishing options**

The multi-ply construction and the surface characteristics of paperboard products facilitate a wide range of finishing options. However, the finishing techniques are very different. Therefore the runnability aspects in connection with the different sections are described in the chapter Finishing techniques.

In general terms, the following paperboard features allows the printer to make the most of the finishing options.

- Strength and toughness are measurable as tensile strength, tearing resistance, delamination strength, and compression strength. These properties are decisive for achieving sophisticated designs such as embossing and complex structural shapes.
- Creasing and folding abilities depend on a complex combination of factors such as tensile strength, compression strength, delamination strength, bending resistance, flatness, and dimensional stability. They are decisive for the paperboard’s ability to “forgive” the permanent deformation of deep and narrow creases, and to retain the intended shape of folds.
- Flatness and dimensional stability are decisive for excellent results in the finishing operations. The choice and composition of raw materials and carefully controlled manufacturing processes result in a paperboard that retains its flatness and dimensional stability throughout all operations. But since paperboard is a hygroscopic material, it should not be exposed to conditions that affect its moisture content. Please refer to the chapter Handling paperboard for information on how to prevent moisture problems.