Appearance properties

The appearance properties are related to the visual impression of the paperboard surface.

One of the essential requirements of the paperboard is that it should be printable. This means that it must be capable of meeting specific targets in terms of its appearance and performance during, and as a result of, the printing process.

In this manual the term printability refers to the visual impact from the images printed on the paperboard. The term print runnability is used to describe the performance of the paperboard during printing and converting.

The following is discussed in this chapter:
- coating contents
- whiteness
- bleaching
- lightfastness
- surface structure and smoothness
- unwanted surface defects
- printability and varnishability
- absorption, setting, drying
- gluable
- rub resistance
- surface strength.

Measurable properties

The measurable properties listed below are those which are usually used when providing a technical description of a paperboard grade. The methods described are those in common use. They are also used by Iggesund Paperboard.

For further information about specific apparatus, please see the manufacturers’ product catalogue (e.g. Lorentzen & Wettre).

The test methods for the properties listed are described in the following pages:
- surface strength
- IGT Surface strength
- Dennison number
- surface tension
- whiteness and brightness
- opacity
- surface roughness
- gloss
- surface pH
- ink absorption
- Fluorescence
- L*, a*, b* coordinates.
Coating contents

A great variety of chemicals are added to coating formulations. The most important components of a coating are the pigment and the binder. This section will therefore consider only these two components under the assumption that a slightly deeper discourse on the major components of the coating will be more informative than a cursory introduction to the large variety of chemicals that are routinely included in coating formulations. The largest component by mass of a coating formulation is the pigment. This is usually a mixture of calcium carbonate and clay. Various varieties of calcium carbonates and clays are available. Clay has a lower whiteness and its use results in a smooth surface with a higher gloss level and higher opacity.

Calcium carbonates
Calcium carbonates are distinguished from one another by their particle size distributions. Particle size distributions are often measured using sedimentation methods based on Stokes law.

\[ V_o = \frac{d^2 (\delta - \rho) g}{18 \eta} \]

- \( V_o \): Limiting sedimentation velocity
- \( d \): Particle diameter
- \( (\delta - \rho) \): The difference in density between the material forming the sediment and the medium in which it is suspended
- \( \eta \): Viscosity of the medium

Stokes law rearranges to

\[ d = \sqrt{\frac{18 \eta h}{(\delta - \rho) gt}} \]

- \( h \): Distance settled
- \( t \): Time

Pictures of calcium carbonate and clay taken with a scanning electron microscope
Thus the rate at which the particles in a pigment slurry settle gives information about the size of those particles. There are alternative methods for determining the particle size distribution; these include the analysis of images of the pigment taken under high magnification and the analysis of the manner in which a sample of the pigment scatters light.

This chart shows the particle size distributions for three different calcium carbonates. The average diameter is a log scale, with the particle size becoming smaller towards the right. The gradient of this graph indicates the number of particles of a certain size. The steeper the gradient, the more particles of that size range there are in the pigment. The coarse GCC (ground calcium carbonate) has a gentle gradient compared to the other two samples shown. This indicates that the pigment consists of a broad range of particle sizes. The fine GCC with a broad particle size distribution has a similar gradient to the coarse GCC line but the gradient is shifted to significantly smaller particle sizes. The fine GCC with a narrow particle size distribution has a steeper gradient than the other lines. This indicates that the particles of this pigment are of more uniform size than the particles of the other pigments shown.

Most of the calcium carbonates used in paper coatings are produced by grinding up a suitable mineral deposit and then filtering to produce the requisite particle size distribution. Calcium carbonate pigments can also be produced by deposition: the result of this process is a pigment with a relatively narrow distribution of particle sizes.

To understand the significance of the particle size distribution, imagine a mixture of three types of balls: footballs, handballs and tennis balls, which represent large, medium-sized and fine particles respectively. Imagine filling a box with a mixture of these balls to represent the coating process. When imagining the box, visualise three factors: the variation in the surface produced, the size and number of the openings in the surface and the amount of free space in the packing. The first of these factors is obviously surface smoothness. The other two factors are important because narrow pores absorb ink vehicles more rapidly than large pores do. This may seem illogical, but in fact, the capillary pressure which drives the absorption is inversely proportional to the pore radius. The pore volume available also has an influence, if the pores are full then no further absorption can take place.
If starting with a roughly equal number of each ball type, then the resulting surface will be quite rough because of the large footballs. The smaller balls will fill the gaps between some of the footballs, thereby reducing the pore volume but the pore size at the surface will be large. The ink absorption will therefore be slow because of the combination of large pores at the surface draining into a small pore volume.

If then the footballs are replaced with a mixture of handballs and tennis balls, then the surface will be smoother, and pore size will be small but the pore volume available will be limited. The small pores will rapidly fill with ink. This change of ball size equates to the step change involved in moving from a coarse calcium carbonate to a finer calcium carbonate.

If the tennis balls are replaced with more handballs then there are only handballs left. The surface will then be rougher than in the previous step, the pores will be larger and the pore volume will increase because there are no longer any small balls to fill in the gaps. The ink absorption will be slower than in the previous step but the pores will be able to absorb a significantly greater quantity of ink. This equates to making the change from a fine calcium carbonate to a fine calcium carbonate with a narrow distribution of particle sizes.

Summary

This simple thought experiment illustrates the fact that particle size distribution is a key important factor which influences surface smoothness and the interaction between the paperboard and the ink during the printing process. However, keep in mind that a great many other important factors also influence the performance of pigments in a real-life situation.
Clays
Clays are distinguished both by their particle size distribution and also by a property called the aspect ratio or shape factor.

A high aspect ratio indicates a very platy clay (a platy clay particle is one which is thin and wide like a plate as opposed to being thicker and narrower).

The aspect ratio varies depending on the size of the clay particles examined. Large clay particles tend to have high aspect ratios.

Smaller particles that have smaller aspect ratios tend to form surfaces that absorb ink rapidly compared to surfaces formed with a clay that has a high aspect ratio. Fast ink absorption requires a large number of narrow pores in the surface. It is easy to understand that a very platy clay will form a surface that has fewer pores than a surface formed with a clay that is less platy.

The ratio of clay to calcium carbonate used in the coatings depends on a number of factors. Clay is a very yellow pigment compared to calcium carbonate and has a significantly higher opacity. The higher opacity of the clay makes this pigment less compatible with OBAs (optical brightening agents) than calcium carbonate. Thus, if high whiteness is desired, there are advantages to having only a very small amount of clay in the coating. If high opacity is required then a higher clay content is advantageous.

Clay is softer than calcium carbonate. Clay has a Mohs ranking of 2.5 while calcium carbonate has a Mohs rating of 3.

Mohs scale
The Mohs scale is not a true scale but in fact an ordered list. The German mineralogist Friedrich Mohs took ten easily available minerals and arranged them in order of their ability to scratch one another. If a specimen can be scratched by a mineral on the list then it is softer than that mineral and has a lower Mohs rating, if it scratches the mineral then it has a higher Mohs rating than that mineral.

As clay is less abrasive than calcium carbonate, it causes less tool wear when the board is cut either during sheeting or converting operations. Coatings with a relatively high clay content therefore have an advantage in this respect.

The clay content of a coating has a large impact on gloss, but this is a complex issue. When referring to gloss one must specify whether it is sheet gloss, print gloss or the difference between these two values (Snap) that is desirable. The clay content of the coatings is only one of a number of factors that affect gloss and it is beyond the scope of this discussion to consider this matter.
Latices

Latices is the plural form of the word latex. Within the paper industry styrene-butadiene or styrene-acrylate latices are most commonly used.

The properties of latices can be varied by varying the proportion of the relevant monomers used, the molecular weight of the polymer molecules formed and the size of the latex particles formed.

Latices are often described by their glass transition temperature.

The glass transition temperature (Tg) is defined as follows: Tg refers to the temperature below which the polymer chains no longer have freedom of motion; above the Tg the polymer can be irreversibly deformed. In behavioural terms, below the Tg the latex is a hard, brittle substance, above the Tg the latex softens and its behaviour can be likened to that of chewing gum. A latex with a high Tg is often described as being hard while a latex with a low Tg is described as being soft. The properties of the latex used affect the properties of the coating layer formed.

The top diagram illustrates how gloss can be affected by the glass transition temperature of the latex. The gloss levels reported in the diagram refer to uncalendered samples. Calendering is an operation whereby the board is pressed between a number of cylinders with the intention of smoothing the surface. This process usually increases sheet gloss. A coating layer formed with a soft latex (low Tg) is generally more easily deformed than a coating layer formed with a hard latex (high Tg) and so calendering tends to have more of an effect when a soft latex is used.

Other properties, most notably surface strength, are negatively affected by a high glass transition temperature. Surface strength is particularly important in offset printing, when a paperboard with a low surface strength is more likely to exhibit picking. Picking is a print defect that occurs when the paperboard surface is not sufficiently strong to maintain its integrity during the printing process and areas of the coating are ripped out of the surface leaving white spots in the printed area.

Water/mass retention

In the blade coaters the coating is applied to the baseboard using an applicator roll or a jet applicator. The sheet continues up to a blade that removes the excess coating. The excess coating is recirculated and reused. Because the coating is applied to a porous surface, some of the constituents of the coating formulation can be absorbed prior to a portion of the applied coating being removed by the coating blade. This coating is recirculated but is not quite the same as the fresh coating. As a result, over time the constant recirculation of the coating results in changes to the coating composition.

The above simplified diagrams are visual aids for understanding the changes that the coating undergoes during the coating process.
The white lines represent the coating prior to use: the blue lines represent the coating after an extended period of time in the coating circulation systems. The graphs are bimodal: the peak at lower particle size is from the latex and the peak at higher particle size is from the calcium carbonate.

A representation of a coating containing both calcium carbonate and clay would have at least two pigment peaks, at least one for each pigment used.

The diagrams on the previous page illustrate the fact that during the production process, both latex and fine pigment particles are lost from the coatings. As a result, the proportion of large pigment particles increases and the pigment becomes increasingly coarse. The coating shown in the middle graph changes significantly less than the coating in the bottom graph. This means that there is a good chance that the sample in the middle will perform with greater consistency than the sample at the bottom. The sample in the middle has the better water/mass retention.

Summary
To summarise this section:
- Particle size distributions are often used to classify the pigments used in paper and board coatings.
- The particle size distribution of the specific pigments used affects the resulting paperboard properties such as smoothness and ink absorbency.
- The properties of the latex impacts on surface properties such as gloss and surface strength.
- The coating operation itself effects changes in the composition of the coating.
Whiteness

Whiteness is, in some respects, a difficult concept to explain easily. In a physical sense a white surface is a perfect diffuse reflector. No such surface exists in reality although some substances such as snow can come close. Whiteness is something quite different: a surface has a high whiteness if it is perceived as being very white.

Whiteness is therefore a property defined by the human perception of white; this differs from an actual physical white. In the paperboard industry a high whiteness is preferable to a truly white, or near white surface.

Interaction between materials and light
Visible light is part of the electromagnetic spectrum. The spectrum includes radio waves and X-rays, as well as ultraviolet and infrared light. Light can be described by its wavelength, for which the nanometre (nm) is a convenient unit of length. One nanometre is 1/1,000,000 mm. Light with a wavelength between 400 and 700 nm is visible to the human eye.
Light from the local light source, for example a tungsten bulb, impacts upon the object. The light is absorbed, reflected, transmitted or scattered according to the nature of the object. Colour perception is strongly linked to the absorption of certain wavelengths of light. A perfectly white object will reflect all the light at all the wavelengths; a sample with high whiteness will reflect most of the light; a red object will absorb most of the light and reflect only the light in the red portion of the incident light; a blue object will also absorb most of the light but it will reflect the blue light in the incident illumination. A black object will absorb most of the incident light.

The colour of the object can be considered in terms of its spectral reflectance curve. This is an indication of how much light of a specific wavelength will be reflected.

The images below illustrate the difference in spectral response between an OBA-containing paperboard and an OBA-free board under different illumination. Under normal daylight (left) the incident light contains a fair amount of low wavelength radiation activating the OBA thus making the two samples reflect different amounts of light in the blue spectrum. If the light is more like a tungsten light (right) the lack of low wavelength radiation make the samples look more alike due to the fact that the reflective powers at higher wavelengths are similar.
Transmission is when light can pass through a material essentially unchanged. The light is said to be transmitted through the object and the material is described as transparent. If some of the light is absorbed then the object remains transparent but it will be coloured. For example, if the blue light is absorbed then the transmitted light is yellow, if red light is absorbed then the transmitted light is green and vice versa in both cases. If all the light is absorbed then no light is transmitted and the object is black and opaque.

Scattering is caused when light interacts with small particles in a material with a different refractive index to that of the surrounding material, which is usually air. Examples of light scattering are common; the blue colour of the sky and the white appearance of clouds and snow are all due to scattering.

If the scattering is sufficiently intense that very little or no light passes straight through the object then the object will be opaque: it will have a high opacity. If the same amount of scattering occurs at every wavelength and there is no absorption then the object appears white.

**Measurable properties**

Opacity (ISO 2471)

The opacity of a sample is its lack of transparency. A sample with an opacity of 100% does not allow any light to be transmitted through it and therefore fully obscures anything lying under it. A sample with an opacity near to zero is almost completely transparent and hides nothing. This standard still specifies the C illuminant rather than D65.
Whiteness
The term, “white”, should not be applied to paper board as white refers to the perfect diffuse reflector. Instead, it is meaningful to discuss paper board in terms of whiteness. Because no paperboards are white, no paperboard should be described as being whiter than another but a paperboard can have a higher whiteness level than a competing product. (In reality very few people are this careful of their language when discussing paperboard.)

Many studies have been carried out and many formulae proposed to describe whiteness. The CIE whiteness and tint measurements are currently favoured (ISO 11475).

**Measurable properties**

**CIE Whiteness (ISO 11475)**
The CIE whiteness and tint equations can be stated as follows.

\[
W = 2.41L^* - 4.45b^*(1 - 0.009(L^* - 96)) - 141.4
\]

\[
T = -1.58a^* - 0.38b^* - 3 < T < 3
\]

\[
40 < W < 10.6L^* - 852
\]

This is not the normal way to define CIE whiteness but it is mathematically valid and serves to illustrate that a CIE whiteness value does not specify a point in \(L^*, a^*, b^*\) space but instead specifies a plane. If both CIE whiteness and tint are specified then the result denotes a line in \(L^*, a^*, b^*\) space. These are important considerations as it must be understood that samples with the same whiteness values need not have similar colour properties.

Although an increase in CIE whiteness usually corresponds to an increase in perceived whiteness, the whiteness scale is rather arbitrary. CIE lab coordinates can be very helpful in determining if a change in CIE whiteness values corresponds to a significant change in perceived whiteness.

Looking at the above equations is also helpful for understanding why FWAs and dyes are added to the paperboard. The dyes and FWAs both impart a blue colour to the paperboard. Blue is associated with negative values for \(b^*\) and, as the above equation indicates, the greater the negative \(b^*\) value the higher the perceived whiteness.

A CIE whiteness value should always be accompanied by a tint value (T), though this is often omitted. A positive tint value corresponds to a green tint; a negative tint value corresponds to a red tint.

For a meaningful understanding of the CIE whiteness equations we must first understand the three-dimensional colour measurement system used to describe colour at the time when these equations were constructed.

The human eyeball contains two types of light sensor: rods and cones. The rods are sensitive to black and white; the cones are concerned with colour perception. There are three types of cone, each absorbent at long, medium or short wavelengths. (They used to be described as red, green and blue but this description is now out of favour.)
A series of experiments was performed, in which a pure light, that is, light of a defined narrow band of wavelengths, was shown to a series of participants. The participants had then to match the colour that they were shown by filtering the output of three lamps, each of which lamp stimulated only one type of cone. The output from these experiments was a way of describing how light of a specific wavelength stimulates these three receptors.

These colour matching functions can be used in conjunction with a reflectance spectrum to calculate the tristimulus values X, Y and Z, which relate to the response of the long, medium and short wavelength cones respectively. The X, Y and Z values were used to form a three-dimensional representation of colour.

$$y = \frac{Y}{X+Y+Z}$$

$$x = \frac{X}{X+Y+Z}$$

The third axis is simply the Y axis: this is normally depicted as the vertical axis.

In further perceptual experiments it was shown that the perceived whiteness increased along a line between the x and y coordinates of the illuminant, denoted \(x_n\) and \(y_n\), and the edge of the colour shape at a wavelength of 425 nm.

$$W = Y + 800 (x_n - x) + 1700 (y_n - y)$$

This equation simply indicates that if the sample moves along the line described then the perceived whiteness increases. As this line describes the addition of a violet colour to a neutral sample the addition of violet dyes can increase the perceived whiteness. This equation has a number of boundary conditions and should always be accompanied by a tint value.

The scaling for CIE whiteness is quite arbitrary. A unit change in whiteness is not associated with any particular perceived change. It must be remembered that a whole range of samples with quite different appearances can have the same CIE whiteness value and even matching CIE whiteness and tint values.

A perfectly white sample has a whiteness of 100. Samples with CIE whiteness levels above 100 therefore give a greater impression of whiteness than a truly white sample.

**Summary**
Whiteness is strongly influenced by the raw materials used. When paperboard is made from fibres with a low whiteness level these are often covered with layers of white chemical fibres, white pigmented coatings, or a combination of the two.
**Colour and shade**

When measuring colour properties it is necessary to specify the illuminant used. At the time of writing it is normal to use the D65 illuminant when measuring the optical properties of paperboard. D65 indicates diffuse, that is, non-coherent, light with a colour temperature of 6500 Kelvin. Many graphic arts standards specify D50, which is diffuse illumination with a colour temperature of 5000 Kelvin. These two illuminants are broadly similar but D65 is significantly richer in ultraviolet light than D50.

**Measurable properties**

$L^*, a^*, b^*$ Coordinates (ISO 5631-2)

The $L^*, a^*, b^*$ system is a three-dimensional system for describing colour. This system is very useful for considering differences between samples. The coordinate system was designed with the intention that a unit difference in the coordinates space should correspond to a perceptible change in colour. With measurements from two samples under the same illumination conditions, the coordinates give a clear indication of the differences in colour between the two samples. By measuring the same sample under a number of different illumination conditions, the variation in appearance of the sample accompanying changes in illumination can be considered in terms of figures relating to the human perception of colour.
Bleaching

To make paperboard with a high whiteness value the major components of the paperboard must also have a high whiteness value. A pulp with a high whiteness level is obtained through bleaching. Bleaching reduces light absorption, particularly in the blue region of the electromagnetic spectrum.

Test methods
Brightness has traditionally been an important quality criterion and brightness values are often quoted in specifications for paperboard. It has, however, been increasingly accepted that brightness as it has been defined in current test methods is inadequate for specifying the optical properties of a paperboard.

Measurable properties
Brightness (ISO 2470)
Brightness is a good property to consider when controlling a bleaching process but it is not a useful property to consider when discussing a paperboard that may contain both dyes and FWAs. Brightness is not a property related to human perception studies. Brightness is the reflectance of an object measured through a blue filter with a peak pass wavelength of 457 nm. Brightness is reported as a percentage of the anticipated result from a perfect diffuse reflector.
The bleaching stages in this illustration are shown in the photos on the previous page. The unbleached pulp is represented by the blue line, step 2 by the yellow line and step 5 by the brown line.
Bleaching

An illustration of the difference in spectral reflecting power of an OBA-containing board and an OBA-free board given that there is UV radiation in the incident light (D65)

Fluorescent whitening agents and dyes
Fluorescent whitening agents (FWAs), sometimes referred to as optical brightening agents (OBAs), absorb ultraviolet light and emit visible light. In very rough terms the light from these FWAs increases the stimulation of the short wavelength-receptive cones while not stimulating the medium and long wavelength-receptive cones. Considering the tri-stimulus values mentioned earlier, Z will increase while X and Y are largely unaffected, therefore x and y will both be reduced and so according to the CIE whiteness equation the perceived whiteness will increase.

Dyes modify the colour of an object. The violet dyes used in the paperboard industry impart the violet shade that the whiteness equation indicates will result in an increase in perceived whiteness. The use of these dyes is limited by their tendency to cause the paperboard to take on a grey appearance.

Measurable properties
Fluorescence (ISO 11475)
Fluorescence is the difference in the CIE whiteness values of the same sample measured under D65 lighting and D65 with the ultraviolet portion of the illuminant filtered out. This measurement corresponds to the effect obtained from FWAs under D65 illumination.
Lightfastness

At the time of writing, there is no clear consensus as to how to quantify lightfastness for the paperboard industry. However, it can be stated that as a rule of thumb the lightfastness of FWA-containing grades is largely determined by the lightfastness of the effect obtained from the FWAs used. In FWA-free grades the yellowing of the wood fibres used in the paperboard is usually the dominant factor.

Mechanically processed pulps retain most of their lignin, this being the substance in wood that binds the wood fibres together and makes it possible for the tree to stand erect. When these types of pulps are exposed to light, the ultraviolet radiation in the light starts to break down the lignin, and the result is a yellow shade. Mechanically processed and unbleached chemically processed pulps also contain wood resin. Oxygen in the air initiates a resin oxidation process which can also yellow the fibres.

Chemically processed and fully bleached pulps are free from both the lignin and the resin and hence have a higher degree of lightfastness.

The paperboard choice

When choosing a paperboard, decisions must be made as to the colour properties required. Packages for luxury products usually have very high whiteness levels. The exact colour properties required are strongly influenced by the end use environment because perceived whiteness varies across cultures and markets. It is always worthwhile to examine the paperboard under realistic lighting conditions relevant to the intended end use.

The whiteness of the fibres has a strong influence on the whiteness of the paperboard. Bleached chemical pulp has a high whiteness level and is often used in the outer plies instead of other types of pulp. Any coatings used also have a large impact on the colour properties. The whiteness of the paperboard is often increased by the inclusion of fluorescent whitening agents (FWAs) and dyes.

Visualisation of the shade change pulp undergoes when exposed to light during 24h, commonly known as the yellowing effect.
Lightfastness

![Graph showing L* value exposure to Suntest over 48 hours for Bleached Chemical Pulp and Mechanical Pulp.](graph.png)
Surface structure and smoothness

Surface structure and smoothness are related. However, two paperboard products with the same rating of surface smoothness can still have different surface structures. The rating for surface smoothness is used to infer printability, ink absorption etc. but the rating does not give any information about the pattern of the surface structure or the issues this might cause during conversion of paperboard. Surface smoothness is assessed by measuring surface roughness.

Surface structure and smoothness are properties which have a major influence on:
• visual appearance in general
• print and varnish gloss appearance
• visual impact of laminated and plastic coated paperboard.

The paperboard acquires different surfaces depending on the choice of raw material, the production process, and finishing treatments. At first glance, the paperboard surface is even and flat, and when you sweep your hand over the surface no irregularities are revealed. But when you look closer with low angle illumination, a three-dimensional landscape becomes visible to the eye. This topographical pattern is called surface structure.

The structure of the surface can of course be deliberately modified by embossing. Surface structure usually describe unwanted topographical irregularities in the surface. The effects of the surface structure are, however, sometimes not revealed until the paperboard is printed, varnished, laminated, run through the packaging machinery or distributed. When revealed, surface structure is often regarded as a defect. In other applications it is unimportant, or could sometimes even increase, the aesthetic appeal of the product.

The paperboard choice
In instances where the visual appearance of the paperboard product is important, a smooth surface is vital. If lamination or hot foil stamping of the paperboard is intended, this will lead to even higher smoothness requirements. The surface structure is not visible normally until after the paperboard is printed, varnished, laminated, etc. Testing the conversion methods on the chosen paperboard grade is therefore important. When choosing paperboard it is important to know the printing method to be used, because the various methods have different smoothness requirements.

The raw material, coating composition, and application technique all have an effect on the smoothness. Bleached chemical pulp gives the smoothest surface and is used in the outer plies for several grades of paperboard. A number of methods are available for improving the surface smoothness, such as calendering and brush polishing.

Surface smoothness characteristics
Surface smoothness is one of the key paperboard properties when it comes to graphical presentation. The surface smoothness influences:
• printing and varnishing
• lamination and application of plastic coating.

When printing, it is not necessarily crucial to have the highest smoothness possible, although a smooth surface is necessary to achieve high definition in the print and brilliance in a picture. What is more crucial in obtaining a satisfying print result is to have a consistent level of smoothness over the entire surface.

The smoothness requirements depend very much on the printing method to be used. Offset litho printing generally has more moderate requirements than gravure printing. It is primarily the ink setting, ink absorption and ink drying mechanisms which drive the print quality; the connection between surface smoothness and print quality is weaker in offset than other printing methods within a reasonable range of smoothness. See the chapter From paperboard to product for more information on different printing requirements.
In some applications some roughness is required to ensure friction to prevent set-off in the printing process or to avoid blocking of sheets. This requirement is needed mostly with two-side plastic coating of the paperboard, where, to avoid these problems, the reverse side must not be too smooth.

**Different paperboard ply constructions**
The type of pulp in the outer plies of the paperboard has a major influence on the surface smoothness. This is why paperboard grades requiring a high quality visual appearance have bleached chemical pulp in the outer plies.

The construction of the drying section is important when making Folding Box Board as the surface smoothness can be obtained with retained thickness and stiffness by using a machine glazing cylinder which obviates the need for further significant calendering.

**Key properties**
The choice of raw material and the paperboard manufacturing technique are key parameters for achieving smoothness. A number of finishing treatments are used to improve the surface smoothness.

A major improvement in smoothness is achieved by calendering the paperboard. When calendered, the paperboard is passed between steel cylinders under pressure and the irregularities of the paperboard are decreased. Hard calendering might cause a loss of thickness and stiffness. Surface sizing means an impregnation of the baseboard with starch dissolved in water, often together with coating pigments, and can be said to be a simple precoating.

The surface coating operation is the final improvement of smoothness. The coating contains pigments and binders, and is applied in one or several layers. Brush polishing does not change the form of the surface but develops an even gloss.

**Measurable properties**
**Surface roughness (ISO 8791)**
Surface smoothness is described in terms of surface roughness. The lower the value the smoother the surface.

**Test method and equipment**
The measuring principle for the two commonly used methods is based on recording the air leakage between the paperboard surface and the reference surface of the instrument.

The most commonly used method/instrument for the assessment of coated paperboard surface roughness today is the PPS (Parker Print-Surf) roughness tester. The test result is expressed as an average of the surface profile in micrometres (μm), where a lower result indicates a smoother surface. Measurements from different paperboard grades are not directly comparable due to differences in surface structure, porosity and compressability. For rougher uncoated surfaces the Bendtsen method/instrument is more suitable. The readings are given as total leakage of air in ml/min, with a smoother surface giving a lower reading.
Gloss

The gloss of a paper surface is also a significant optical property. In this case, gloss refers to the degree of mirror reflection from the surface. We measure the gloss of a surface by illuminating the surface with a focused beam of light coming in at an angle. The surface reflects the light in various directions. The intensity of the reflected light is measured at these various angles. The intensity varies according to the direction because more light will be reflected in some directions than in others. Gloss is an experience which depends on the surface properties of the paper, the type of lighting, the angle at which the light is hitting the surface, and the human brain’s ability to perceive reflection.

Measurable properties

Gloss (ISO 8254-1)

A conventional gloss meter is a reflectometer with directional incoming light (75° between the incoming light beam and the normal through the point of impact). The gloss meter measures in the direction of the mirror reflection and usually measures the percent of light which is being reflected. There are also measurement methods which use other angles such as 20° or 60°.

Test method and equipment

Gloss readings are dependent on the angle of incidence with low angles giving low readings and high angles high readings, which means that high gloss surfaces should be measured at low angles to give a good differentiation. Low gloss surfaces will accordingly be better described using a high angle. Unprinted paperboard products are measured and specified at an angle of incidence of 75°. The gloss level of printed and varnished surfaces is measured at 60°.

Key characteristics

To enhance the gloss level of the coated paperboard surface, treatments like calendaring or brush polishing are used.

To avoid loss of thickness (and hence stiffness) calendaring must be performed using relatively soft material in the calender nip.

Important aspects which effect the potential gloss level are:
• coating composition (type of pigment and binder, and the ratio between the two)
• coating technique
• calendaring and brush burnishing equipment
• surface of the basic paperboard.

To avoid gloss irregularities (disturbance), uniform fibre distribution and treatment of the basic paperboard sheet is important.
Surface structure characteristics
Every paperboard has a surface structure that is like a fingerprint and makes the paperboard unique. The type of pulp, paperboard construction, coating technique, etc. determine the fingerprint. A skilled paperboard dealer can recognise a paperboard from the sight of the surface structure alone. The surface structure has an influence on the surface appearance, and as the structure is unique to the paperboard it can also contribute to the uniqueness of the final result. In most cases, however, a more or less regular, pattern-like structure influence is of minor importance. A certain type and level of surface structure are often acceptable as long as they stay unchanged. On other occasions, variations in structure can be critical. Sometimes randomly distributed defects can be accepted, sometimes not. In general, a more glossy appearance makes the underlying irregularities more visible.

Due to the irregular and porous character of the paperboard sheet a major challenge for the paperboard maker is to minimise irregularities, all the way from the choice and treatment of fibres, through the uniform distribution during forming, to defect-free coating and finishing.

Key properties
The following paperboard characteristics influence the surface structure:
• type of pulp, level of refining
• sheet forming, multi-ply construction
• paperboard machine clothing
• surface coating technique and coating composition
• surface finishing.

Test methods
There are no agreed industry standards for quantifying surface structure. The impact of the surface structure will be judged subjectively by eye. A number of test methods are used to determine parameters that have an indirect influence on the surface appearance. Some methods of viewing the surface structure are:
2. LandSco® lightning is used for viewing surface texture. This is a system of three intense, focused light beams directed, at a defined low angle, towards a large flat viewing area of the paperboard to provide even illumination of a large area.
3. For a permanent record of surface features, photography using camera fitted with a ×10 microscope and low angle fibre optic illumination is ideal.
4. An image analyser can be used on the microscopic image to characterise, via computer analysis, the surface features and estimate the severity of surface roughness.
5. Direct quantitative methods for surface contour mapping are available via three-dimensional surface profilometry. STURE, a laser profilometer, uses triangulation technique to create a three-dimensional map of the tested board. From this image, the number of irregularities, from small to large scale, can be calculated and summarised as a topography figure valid for the material. The lower the figure, the smoother the surface.
Unwanted surface defects

Defects in surface structure can be generated anywhere during printing, varnishing, lamination, packaging or distribution. In most cases the defects originate from the paperboard manufacturing procedure. It is thus a challenge to the paperboard manufacturer to obtain a surface as free from structure as possible. The basis of this ability is a profound understanding of the instances in the paperboard manufacturing process were surface problems are likely to originate and the knowledge of how to control the production.

Surface structure defects depend on the topography (three-dimensional irregularities) of the material as well as the in-plane (two-dimensional) irregularities that affect the absorption properties (for inks). Such irregularities can often have significant undesirable consequences.

The following table gives some examples of the most common defects caused by surface irregularities. These might not be visible until the paperboard is printed or varnished.

<table>
<thead>
<tr>
<th>Defect on printed sample</th>
<th>Conceivable origin in the paperboard</th>
<th>Possible cause in paperboard manufacture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing dots in print</td>
<td>Basic paperboard sheet</td>
<td>Insufficient surface smoothness or low compressibility of the surface in the printing nip or both.</td>
</tr>
<tr>
<td>Fibrous structure (fibre wicking)</td>
<td>Basic paperboard sheet</td>
<td>Fibres not well bonded on the surface.</td>
</tr>
<tr>
<td>Ink or varnish peeling</td>
<td>Improper combination of paperboard, ink and varnish. Poor surface wettability.</td>
<td>Choice of coating components. On plastic coated surfaces the cause can be insufficient corona treatment or incorrect handling of the paperboard.</td>
</tr>
<tr>
<td>Pinholes in plastic coated surface</td>
<td>Paperboard surface or plastic coating or both</td>
<td>Excessively rough surface. The thickness of the plastic film is too low.</td>
</tr>
<tr>
<td>Ink smear on the printed sample</td>
<td>Poor ink drying</td>
<td>Coating formula.</td>
</tr>
<tr>
<td>Mottling, print gloss variation</td>
<td>Absorption variation</td>
<td>Uneven density in paperboard plies and/or uneven coating. Gloss variation.</td>
</tr>
<tr>
<td>Orange peel structure (porous, uneven pattern which makes the surface look rough)</td>
<td>Coating</td>
<td>Coating technique and settings.</td>
</tr>
<tr>
<td>Graininess (Z-direction)</td>
<td>Basic paperboard sheet</td>
<td>Choice of pulp and pulp treatment. Sheet forming technique.</td>
</tr>
<tr>
<td>Scratches – blade lines in print</td>
<td>Straight lines in the machine direction (MD) on the coated surface from coating blade.</td>
<td>Particles in the coating blade which disturb the smoothing of the coating colour. Rheology of the coating formulation.</td>
</tr>
<tr>
<td>Indentations of different size experienced as unevenness on the surface</td>
<td>Machine equipment all the way from paperboard machine through to winders, sheeters, transport handling equipment and storing facilities for the paperboard.</td>
<td>Damage or impurities on rolls or other transport equipment for manufacturing, transportation handling and storage.</td>
</tr>
</tbody>
</table>
Printability and varnishability

The paperboard choice
Since one of the main purposes of paperboard is to convey a message, which can be informative or promotional, printability is a vital property to consider when choosing paperboard. Printability is mainly determined by surface features, that is, the surface coating composition and the ply properties of underlying baseboard.

The paperboard properties listed in the following text are important in obtaining high print quality. Good print runnability is also important for achieving efficiency because stoppages are costly. The paperboard printability must always be related to the printing method and the inks to be used. Test printing under press-room conditions will provide the specifier with valuable information.

Both Folding Box Board (mechanical pulp with chemical pulp in the surface plies) and Solid Bleached Board (pure chemical pulp) give excellent printability, mainly due to their predictable paperboard properties.

Printability characteristics
Printability can be defined as the paperboard’s ability to reproduce printed text, pictures and patterns. The printing might be in one or more colours. Several printing processes are used with paperboard and they have different characteristics which must be considered.

Good printability is achieved by a combination of features involving the use of primary fibre, the method of forming and manufacturing paperboard, the types and methods of coating, and the finishing operation.

Assessment of printability
Assessing printability is of critical importance in the quality procedures at Iggesund Paperboard and in our product and process development work. The printability of a paperboard can be assessed by eye, by instrumental techniques and above all by printing under press-room conditions.

Key properties
The following paperboard features are involved in achieving good printability:
• whiteness (colour)
• opacity
• smoothness
• board gloss
• ink absorption, drying, and setting
• surface strength
• flatness and dimensional stability
• moisture content
• print rub resistance
• ink and varnish gloss enhancement
• clean edges and surfaces
• surface pH
• solvent release
• surface tension for plastic-coated surfaces.
Absorption, setting and drying

The surfaces of graphical and packaging products are printed and varnished to meet a range of promotional and functional requirements. An essential requirement is that the printed and varnished surfaces must be fully dry to withstand normal conditions of use without marking, scuffing, rubbing or smearing.

Gluing is used to join paperboard surfaces together, providing permanent shape. Gluing is also used to erect and close cartons and to provide several functions with graphical products. Gluability is therefore an important property.

Predictable and reliable interactions between the surface and the inks and adhesives is built into the paperboard by the careful selection of the coating pigments, as well as by the surface sizing system and interlaminar strength.

Printing

During printing and varnishing the inks and varnishes require fluid mobility to facilitate their transfer from a duct or reservoir via a plate, cylinder or roll, to the surface being printed or varnished. The ink or varnish component which provides fluid mobility is known as the vehicle. Typical vehicles are drying oils which are chemically related to linseed oil, organic solvents and water. The choice of vehicle depends on the type of ink or varnish and printing process or other type of application system. If the surface is plastic coated or film laminated, the surface tension might be too low for printing. The surface can then be treated to achieve better printability properties. This can be done by a gas flame or corona treatment.

Measurable properties

Surface tension

The surface tension of a specified liquid that, when applied to a surface (as a thin film) does not reticulate for at least two seconds, gives a measure of surface wettability. The surface tension of a plastic surface is normally too low for printing or gluing. The surface is therefore treated with an electrical corona discharge. This gives a slight oxidation of the plastic surface, changing the polarity of the surface. This can be observed by surface tension measurements.

Test method and equipment

Pens containing solutions giving defined surface tension levels are used. To test the surface tension a wide line of solution is drawn on the corona-treated plastic surface. If the liquid film created by the test solution remains unchanged for more than 2 seconds a solution with higher surface tension is tested. If the time is less than 2 seconds a solution with a lower level is tried. By continuing systematically in this way the right level is found. The value is specified in dynes/cm.

Printing surfaces are either non-absorbent, such as plastic, metal or glass surfaces, or absorbent as is the case with pigment-coated paperboard surfaces. To achieve satisfactory drying of ink and varnish it is necessary to either remove the vehicle, for instance by evaporation, or change it chemically from a liquid to a solid state. In printing and varnishing there is therefore an important connection between the absorbency of the paperboard and the drying process.

During printing the degree of drying must ensure a dry print free from set-off or marking and, where necessary, meet specific end use requirements for the avoidance of odour and taint. At the subsequent stages of conversion, printed and varnished surfaces must be dry to ensure durability and the avoidance of rub-off in handling and finishing processes.

The end user requires fully dried printed and varnished surfaces in order to avoid rub-off during packaging and handling and from surface to surface friction during distribution. The end user is also concerned that the consumer does not experience ink or varnish rub-off during handling. Adequate drying of ink and varnish is essential to avoid flavour or aroma changes in sensitive packaged products such as chocolate, confectionery and tobacco.

The paperboard choice

If the paperboard is printed or varnished, especially in a high speed operation, the absorption and drying properties are vital. Insufficient absorption and unsuitable drying properties may lead to scuffing or smearing. The paperboard absorbency must also be uniform over the entire surface, to avoid printing problems which could cause colour variations or mottle.

The fibres, paperboard treatments, and coating composition are features which, to a high degree, determine the absorption properties of the paperboard. The composition of inks and varnishes also has an impact on absorption and drying.

Both Folding Box Board (bleached chemical pulp in the outer plies with mechanical pulp in the middle) and Solid Bleached Board (pure bleached chemical pulp) are good choices with regard to absorption and drying. This is mainly due to their predictable properties.
Absorption and drying properties
Drying is achieved in one of several possible ways depending on the type of ink or varnish and the method of application. The fluid vehicle must either be removed or transformed to the solid state.

Drying by evaporation
Where the vehicle is composed of organic solvents such as aliphatic alcohols, esters, ketones, toluene, or water, heat can be used to remove the vehicle. Hot air is applied on gravure and flexo presses immediately after each printing unit so that solvent removal is virtually instantaneous leaving little scope for any absorption. When organic solvents are used on gravure presses it is necessary to ensure very high levels of solvent removal since in addition to the drying requirement there is an additional need to control residual solvent levels for odour and taint sensitive applications such as tobacco packaging.

Emulsion coating on sheet-fed offset litho presses where water is the vehicle has become popular in recent years with water removal being achieved by hot air and infra-red driers.

Once the vehicle has been removed by evaporation, the resins and, in the case of inks, the pigments, coalesce and become securely bound to the surface of the paperboard.

Drying by chemical change
Pigment coated and uncoated paperboard surfaces are absorbent to inks and varnishes. The absorption properties are particularly important where oil-based inks are used in the sheet-fed offset litho and letterpress processes. In these processes absorption is the first stage of the drying process. When the high viscosity ink is transferred to the surface of the paperboard, there is a rapid filtration and penetration of the less viscous components. This results in what is called “setting”. Setting immobilises the ink or varnish on the surface to a sufficient extent such that set-off is prevented. Rapid setting is the key to high speed printing of high quality work on such surfaces.

Setting is controlled by the paperboard manufacturer through:
- The formation and treatment of the layer of fibre to be coated.
- The particle size and shape of the mineral pigment (china clay, calcium carbonate).
- The type and amount of binder.

These features provide selective filtration by capillary attraction of the low viscosity components of oil-based inks. If the setting is too rapid, excessive penetration of the ink or varnish can occur, resulting in poor print impression (piling) and poor drying. Penetration is increased at higher temperatures when the viscosity of the ink or varnish is reduced.

Drying continues in the stack due to an oxidation polymerisation of the drying oils leading to durable rub-resistant print and varnish. Linseed oil itself dries unaided but very slowly. Oil-based inks today are based on synthetic drying oils supplemented by drying agents which accelerate the drying process.

Another range of inks and varnishes has been developed for use in the offset litho, letterpress, and gravure processes and in sheet varnishing, which do not have a specific vehicle component. These inks and varnishes can be viscosity-modified for application by all the processes listed and they are dried or cured virtually instantaneously by UV radiation on the press or varnishing machine. The process of drying is a cross-linking polymerisation of a resin system. The reaction has to be light-initiated using a compound which absorbs UV radiation and activates the cross-linking of the other monomers. It is important to expose the printed or varnished sheet to the UV radiation as quickly as possible after application. This is to ensure that any absorption by the substrate of the ink or varnish does not prevent the complete reaction of all the components.

Assessment of absorption and drying
Absorption is assessed by applying ink to the paperboard surface and evaluating the result. Printing and varnishing are operations which require a paperboard with uniform absorption properties.
Key absorbency properties
Paperboard either has a pigment-coated surface or an uncoated surface. In both cases the surface is absorbent to ink and varnish.

Absorbency is dependent on the fibre, sheet formation, treatment of the paperboard and, where present, on the pigment coating formulation, quality, application, and smoothness. These features of the paperboard also control the surface smoothness and surface wettability. These properties influence how the ink and varnish lie on the surface and influence absorbency on absorbent surfaces.

Uniformity in absorbency is important within an order and from order to order to ensure uniform printing and varnish results and to avoid absorbency-related mottle effects.

Test methods
Ink absorption is assessed by applying a specified ink film to a surface and wiping off the unabsorbed part after a certain time. The amount of absorbed ink is measured as the brightness decrease caused by the ink. The higher this value is the higher the absorption.

The ink-setting property of an absorbing paperboard surface is generally tested by pressing a fresh paper surface to a newly printed one. The more ink that is transferred after a certain setting time the poorer is the absorption or ink setting of the printed surface. The test can be carried out using a laboratory press such as IGT or Prüfbau. Time spans involved are from 10–20 seconds up to 5–10 minutes.

Ink drying is tested by rubbing the printed area and noting the time needed until no ink can be rubbed off from the drying print. Drying times are normally from around one hour up to several hours. The shorter the time the better.

Measurable properties
Ink absorption
By ink absorption we mean the ability of the paperboard surface to absorb printing ink during the offset litho process. If the ink absorption is too slow, there might be a risk of set-off.

Test method and equipment
This test is performed according to the SCAN standard (SCAN-P 70:09) and generally known as the K & N test or Lorilleux Porometrique test depending on the test ink used. The special testing ink is applied to the paperboard surface to an ink film thickness of 0.1 mm. After exactly 2 minutes any unabsorbed ink is wiped off. A grey coloured area where the ink has been absorbed remains.

The test area can also be used to visually evaluate the evenness of absorption over the surface. An even surface absorption is required. If the area is mottled or stippled, then there is a risk of mottle during printing, especially in large areas of solid print.

Key characteristics
Ink absorption is strongly influenced by the make up of the coating such as the type and size of pigment and type and proportion of binder. To obtain a mottle-free ink absorption both the baseboard and the coating must have uniform absorption properties.

Key drying properties
Where drying takes place by oxidation polymerisation, i.e. offset litho and letterpress printing, the surface pH is an important property. If the surface pH is below 5.0 the drying process is inhibited.

The setting speed of oil-based offset litho and letterpress inks is an important property. It relates to the avoidance of set-off of wet ink and varnish on the reverse side of the sheets in the freshly printed or varnished stack.

Test methods
Ink drying is tested by rubbing the printed area and noting the time needed until no ink can be rubbed off from the drying print. Drying times are normally from around one hour up to several hours. The shorter the time the better.

Measurable properties
Ink drying
Ink drying is tested by rubbing the printed area and noting the time needed until no ink can be rubbed off from the drying print. Drying times are normally from around one hour up to several hours. The shorter the time the better.
Gluability

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Both Folding Box Board (mechanical pulp with chemical pulp in the surface plies) and Solid Bleached Board (pure chemical pulp) give exceptionally good gluability.

Gluability properties

The established way to assess gluability is to examine the tear behaviour of a glue seam between a pigment-coated surface and, usually, the reverse side of a carton flap. The paperboard must be strong (interlaminar strength) to give good gluability. If the paperboard is weak, the paperboard fibres will tear quickly and the gluability is wrongly determined to be good. Gluability is actually a factor of both paperboard strength and fibre tear.

If the glue seam itself fails, or if the bond failure occurs in the pigment coating, the rating will be poor. The method will not reveal the true seam strength in comparison between different materials since it is always a function of the weakest link in the construction. The gluability of a paperboard can vary depending on the gluing system used (such as water-based systems or hot melts).

Gluability for water-based systems refers to the tear behaviour of the fully developed, dry glue seam between two paperboard surfaces.

The bond formed by gluing must be strong enough to be handled as soon as the carton leaves the gluing machine. Therefore the glue needs to be chosen while keeping in mind the absorption properties such as setting time that suit the paperboard and the process in the gluing line.

It is preferable to have a high ratio of surface strength/ internal strength. When tested, a good glue bond will show both fibre tear and reliable strength. The gluability must be balanced against printing properties such as ink absorption and set-off.
Assessment of gluability

A glue seam will break at the weakest point. Gluability is a dimensionless property which describes the behaviour of a glue seam when exposed to a load designed to break the bond. If the glue seam can only be torn so it gives a fibre tear fracture, the glue seam is good. The situation corresponds to a favourable ratio between the glue seam strength and the internal strength of the substrate. The adhesive itself is the strongest part of the bond.

\[
\text{Gluability} = \frac{\text{Glue seam strength}}{\text{Internal paperboard strength}}
\]

If the glue seam itself fails or if the bond failure occurs in the pigment coating, the rating will be poor.

Hot melt gluability

Gluability with hot melt refers to the tear behaviour of a hot melt glue seam between a pigment-coated surface and, usually, the reverse side of a carton flap. Here it is also necessary to have a high ratio of surface strength/internal strength as well as good wettability. A good bond will show full fibre tear (that is, the torn-off paperboard strip will remove the whole glue seam, the coating layer of the baseboard and also some fibres from the other paperboard surface). In contrast, a brittle glue bond which separates at the pigment coating interface indicates poor performance.

A good, well developed bond will show fibre tear if the surface of the paperboard is strong enough. As a rule of thumb, a pigment coating which shows good gluability will also have good hot melt gluability. For a given pigment composition the coating strength and hot melt gluability must be balanced against printing ink absorption and set-off.

Different paperboard ply constructions

Good gluability is an important feature of an optimised paperboard surface.

The pigment coating, which is applied after the surface sizing, must be made strong enough with binders to meet the needs of the printing process and provide gluability. However, if too much binder is used, the coating may not be absorbent enough for the printing process. This indicates the complexity of the property balance of a pigment coating.

A plastic coating has relatively low surface tension because of the chemical nature of the plastic. Most glues will not wet the surface. Therefore the coating must always be modified on the surface by treatment such as an electrical corona discharge or an oxidising gas flame to give the plastic a more polar nature by the introduction of oxygen into the surface molecules.

Key properties

For gluing operations the following paperboard properties are crucial:

- surface strength
- tensile strength
- compression strength
- flatness and dimensional stability
- creasing efficiency
- surface tension and wetting properties
- absorption and glue setting
- delamination, interlaminar strength.

Measuring equipment

Gluability is tested both during process control, which means that a quick test method is required, and during product control, which correlates with practical use and may take more time.

This situation may to some extent explain why there is no generally recognised international standard for gluability testing. The variety of demands is so great that a number of methods have been developed.

Testing a glue seam with the glue seam parallel to the index finger
<table>
<thead>
<tr>
<th>Method</th>
<th>Apparatus</th>
<th>Adhesive</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gluability test</td>
<td>PIRA adhesive performance tester</td>
<td>Hernia 2334 (good glue)</td>
<td>The gluability test involves the application of glue to the printing side of the paperboard. The glue seam is pressed towards the paperboard’s reverse side so a bond is formed under standardised conditions. The bond is left to dry for at least six hours and is then torn and evaluated with regard to fibre tear.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hernia 1161 (weak glue)</td>
<td></td>
</tr>
<tr>
<td>AsstI bond setting speed</td>
<td>ASSTI = Adhesive setting speed test instrument</td>
<td>Emulsion adhesive</td>
<td>ASSTI bond setting speed involves creating a glue seam with emulsion adhesive. Samples are held under constant instrument pressure for increasingly longer periods of time until a point is reached when the seam remains intact when the pressure is removed.</td>
</tr>
<tr>
<td>Time to fibre tear</td>
<td>75 μm Sheencube test rig</td>
<td>Emulsion adhesive</td>
<td>Time to fibre tear involves creating a glue seam with emulsion adhesive. The method measures the closed time needed to create a fibre-tear bond of paperboard to paperboard.</td>
</tr>
<tr>
<td>Acetate bond test</td>
<td>75 μm Sheencube test rig Instron</td>
<td>Emulsion adhesive</td>
<td>The acetate bond test involves creating a glue seam with emulsion adhesive between the paperboard surface and cellulose acetate film. After 24 hours, dry bond strength and failure type are evaluated.</td>
</tr>
</tbody>
</table>
Rub resistance

It is essential for an ink or varnish film to be durable in normal handling. This means that the ink or varnish film must not become marked, scuffed or smudged when the printed or varnished surface is in moving contact with other surfaces, usually metal or plastic. Moving contact of this type takes place on conveyors and during processing on machines such as gluers, packaging machines, and those used in print finishing in graphics end uses. Rub can also occur in print surface to print surface contact in conversion and distribution.

Wet rub resistance is important in some end uses where printed and varnished surfaces may experience contact with water or condensed moisture, such as frozen and chilled foods.

The presence of excessive anti-set-off spray may also increase the danger of abrasive damage from rubbing. Achieving good rub resistance depends on the paperboard, the printing or varnishing process, and the formulation of the ink and varnish.

Cooperation is therefore essential between the manufacturer of the paperboard, the printer and the ink or varnish producer. Any special hazards of subsequent post-printing conversion and use must be understood and taken into account in the choice of paperboard, inks and varnishes, and printing process.

The paperboard features involved in achieving good rub resistance are connected to the smoothness, absorption and drying properties of the surface. The uniformity of all paperboard surface properties within orders of paperboard and consistency in these properties between one order and another of the same grade are an essential starting point. The printer should ensure that the print process and choice of inks will meet the rub resistance requirements of the subsequent conversion and use of the printed or varnished product.

The paperboard choice

The manner in which the paperboard is handled after printing and varnishing will dictate the importance of rub resistance in the choice of paperboard. Packing, distribution and handling by the consumer may also result in scuffing. Rub problems are prevented by using rub-resistant ink and varnish which is compatible with the absorption, setting, and drying properties of the paperboard. To increase rub resistance for special end use needs, the paperboard may need to be extrusion coated or laminated with plastic film.

Rub resistance characteristics

Rub resistance describes the ability of printed paperboard to withstand marking, scuffing or smudging during handling in conversion, packaging, distribution and use.

Assessment of rub resistance

Poor rub resistance is apparent if, after normal handling and use, the printed or varnished paperboard surface is marked, scuffed or smudged.

An extremely demanding environment or special end use may require extra protection against rubbing. This protection might be provided by such treatments as extrusion coating or lamination.

Key properties

The following paperboard surface properties are involved in achieving good rub resistance:

- absorption and drying (oil-based inks)
- smoothness
- surface strength (oil-based inks)
- surface pH (oil-based inks).

It is important that the coating pigments are well bound within the coating so that they do not separate from the coating as a result of any mechanical influence such as rubbing. For the same reason the coating’s own strength and adhesion to the baseboard are also important to ensure that the entire coating does not loosen from the baseboard.

Measuring equipment

Laboratory rub testing of dry print can be done using an optional number of rubs and pressure. The results are assessed visually against standards.

A block is either moved back and forth over an area of printed sample or moved by rotary motion in an orbital path over the print depending on the instrument used. A record is made of the number of rubs e.g. 50 or 100 and weight e.g. 1 or 2 kg. The degree of surface rub is subjectively compared to reference standards.
Surface strength

During modern multicolour printing using the offset process, high print speeds in combination with tacky inks place very high demands on the surface strength of the paperboard. (Compare to a tape strip rapidly lifted from a paper.)

The term surface strength is used to describe the strength between the paperboard’s coated surface and inks, varnishes or films, or the strength perpendicular to a level just underneath the surface.

This property is very similar to delamination or interlaminar strength and is measured using similar techniques and with the same types of difficulties applying. Surface strength is an important parameter which relates to the forces created during printing. Due to the printing speed and viscosity of inks and varnishes, the surface must withstand lifting forces. Numerous methods are used which combine various tacky inks or waxes to simulate the lifting forces during printing, or which use peeling to check how well coatings or films bond to the paperboard surface. Depending on the method used, many different results are obtained.

Surface strength test methods cannot fully express the complexity of the opposed forces but experience over the years has established certain levels that indicate satisfactory performance. Many factors influence the surface strength. The delamination strength of the interior of the paperboard is important, as is the strength of the coating and its bonding to the paperboard. The viscosity, tack of inks and the speeds used during printing may vary considerably and affect the intensity and type of loading applied to the paperboard surface. Therefore, values for surface strength, as for many of the other less well-defined physical properties, should be regarded as indicative of the actual performance on the printing press.

Measurable properties

Surface strength, IGT (ISO 3783)

Surface strength in this context means the ability of the paperboard surface to resist the pulling forces, thus avoiding delamination or picking of the printed surface, or both.

Test method and equipment

The commonly used test method for evaluation of surface strength is the IGT printability test. The test instrument simulates, in a simplified way, the offset litho printing process. By using an ink of specified viscosity (e.g. IGT medium viscosity oil), the speed at which delamination and picking occur may be determined by comparison with a distance/velocity chart. The result is usually recorded in metres per second (m/s).

Key characteristics

Surface strength properties are strongly influenced by the type of fibre used (long fibres improving the strength), the treatment of fibres, surface sizing, type of coating pigment, and type and proportion of binder in the coating.
**Surface strength**

**Measurable properties**
Surface strength, Dennison number (CPI RTM 30)
Tack-graded waxes can be used in a similar manner to the tack-graded inks as used in the IGT test. They are, however, only suitable for uncoated surfaces and should not be used on coated surfaces.

**Test method and equipment**
A series of tack-graded waxes are melted, applied to the paperboard surface and allowed to set. The cooled wax stick is then pulled from the surface and any evidence of surface disruption identified. The picking resistance is the highest wax number that does not disrupt the surface.

**Key characteristics**
Surface strength properties are strongly influenced by the type of fibre used (long fibres improving the strength), the treatment of fibres, and the surface sizing.