Surface structure and smoothness

Surface structure and surface 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.