TECHNICAL GUIDE

AN INTRODUCTION TO SUBSTRATES

Second Edition

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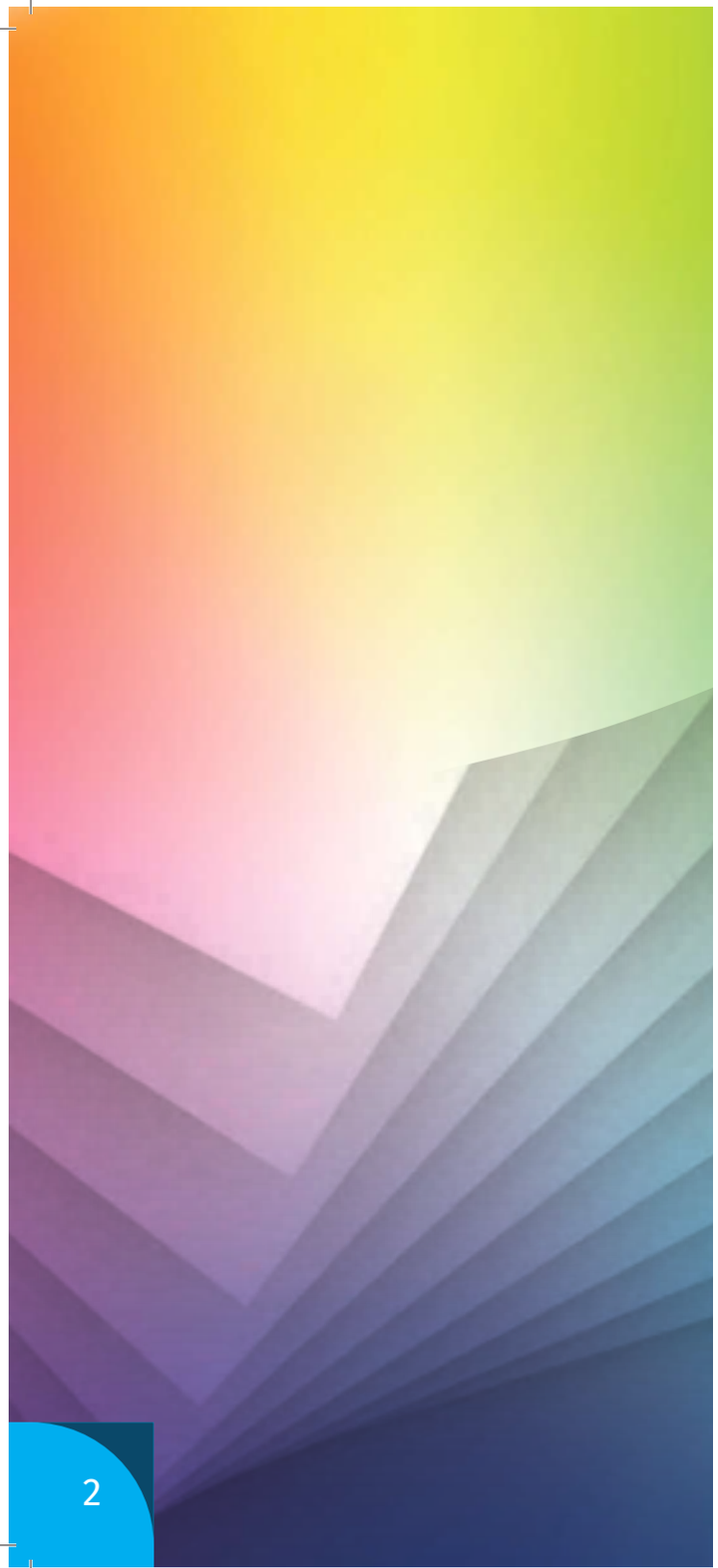

What lies beneath

The substrate is the most important and costly part of a printed product, because in many ways it is the product. The material selected for a job shapes everything from the budget to output quality and finishing options. For this reason the graphics industry is awash with options for different types of substrate. Everyone wants to stand out. But understanding substrate behaviour under particular printing, cutting, finishing and installation conditions is fundamental to the business, both for printing companies and print buyers. The wrong substrate for a given print process can compromise print output quality, add costs and create excess waste. Knowing what to expect from a given substrate and ink combination can be difficult, not least because the substrate constitutes the bulk of the materials cost for a print project. Substrate choice also determines colour appearance and overall quality, and finishing options. It influences the final printed product's characteristics and behaviour, from how well the material works for the chosen printing method, to the perceived value of the final printed product.

Paper is the most commonly used substrate in most sectors of the printing industry but, as print technologies advance, other materials are gaining in popularity. The base material used to create printed products can be almost anything as the rapid growth in digital inkjet printing applications shows, and technology has evolved to exploit innovations and different types of surfaces, most notably in packaging printing. Innovations in digital printing have brought us technologies for printing direct to shape, and for creating 3D objects. And we are seeing a rise in the range and use of metallic effect papers and boards, including pearlescent papers.

Expanding choices

Developers are constantly introducing new print substrates to support new technologies and applications. Papers are made from various natural fibres including hemp, cotton, rags and wood, by far the most common raw material. We can also print on plastics, Aluminium Composite Materials (ACM), glass, natural materials and synthetic textiles, metals, ceramics, and even food. Aluminium panels are now available with special powder coatings to give them anti-graffiti qualities.

Substrates and inks evolve in tandem with printing technologies, and in line with new print applications. The methods used to print different materials depends on the demands of the application, however digital printing is unique in the range of applications it can support and in its substrate constraints. Digital printing technology advances create new opportunities for print buyers and service providers, and for substrate developers.

There are thousands of papers and other substrates on the market and growing numbers for digital printing systems. The types of substrates used in the graphics industry can be roughly categorised into flexible and rigid media, roll or web fed and sheet or board fed.

Substrates can be created from all manner of raw materials, some of which are quite exotic compared to common substances such as the plastics used in banners, signage and the like. For instance twin wall polypropylene sheets are used in roofing and for other building purposes, but they are also great for signage. Cast acrylic thermoplastics such as Perspex are available as coloured or transparent sheets and are used in all sorts of signage applications, plus interiors. Add to the mix the huge array of corrugated boards, bespoke fabrics, including woven self-adhesive labels with black out layers, and textiles. It's obvious

that marketing professionals can use printed communications in virtually any environment.

The choices of substrates for wide format digital printing are almost endless, and different types of fabrics are amongst the fastest growing category.

The various sectors of the graphic arts industry have diverse expectations for a substrate's performance, and especially for paper. Besides classifications such as coated and uncoated, the industry also uses specific designations to describe papers and their ingredients. Uncoated papers are grouped according to the applications for which they are suited, based on general properties. A seemingly endless array of designations specify different types of paper. and are loosely based on how the product is expected to perform for a given application, so there are for instance a large number of types of corrugated paper and board, newspaper and magazine papers, graphic papers, office and hygiene papers. That said there are basically four primary paper categories: coated, uncoated, specialty and synthetic papers which are made of plastic. Unlike materials such as Biaxially Oriented PolyPropylene (BOPP, used for labels), polypropylene, (a thermoplastic), styrene and rigid vinyls, synthetic papers are

fully chemical resistant. They are also heat tolerant, easy to use and not prone to cracking or distortion.

Categorisation systems for paper exist to help print buyers and print service providers to select the ideal substrate for a given job. Some, such as the European EN 643 classification that the Confederation for European Paper Industries publishes, have been collectively developed. The classifications for non-paper substrates, are nothing like as thorough reflecting the fact that no other print substrate has evolved over such a long period of time, nor is as widely used, as paper. Other substrate lists are published by press manufacturers who certify substrates for use with their printing technology, and by substrate providers.

The decision to choose one substrate over another gets more complicated as new materials come onto the market. The characteristics of different substrates will vary, depending on what was used to manufacture them and their design for a given print process. Textiles for instance can be made of polyesters, including metalised polyesters, cotton, linen or silk and blends. Each of these will place different demands on the print process and inks. Polyester fabrics need a dense and compact structure, so the yarn used to make it is important.

Paper is by far the most common substrates used in printing, both conventional printing and digital. Paper can be used from a range of plant fibres, but wood make up the bulk.

Optional extras

In order to better understand your substrate options, keep in mind the fact that some performance requirements are common to pretty much all substrates. In the sign and display market, substrates handling matters because materials that attract a lot of static for instance will be hard to manage and protect. Substrates must be fit for purpose, so determining functional criteria, such as durability, depends on more than just cost. Cheap substrates will be fine for some applications, as long as they are strong enough to do the job. But such materials could turn out to be very expensive if they compromise print, scoring, cutting, finishing and installation processes, or cause harm for instance to the press or the people installing the signage. Rough substrates that produce dust are ill-suited to digital inkjet printing. They may be cheap but they can increase the risk of nozzle clogging and even of a printhead strike.

Determining the ideal base material is a juggling act based on many variables, but for most applications the choices are fairly obvious. For new applications

and ideas most printers will want to meet their customers' needs, and even increase the scope of the project. Appreciation of substrate options expands the services printers can offer, especially to ambitious clients with creative ideas. They may want to consider pearlescent and metallic films, or laminating or self-adhesive products such as pressure sensitive labels and window films. Magnetic substrates combine a magnetic adhesive base with printable ferrous films or PVCs. Magnetic materials can also have a textured surface and composite materials can include RFID or Near Field Communications technologies for additional dynamic data capture and interactivity.

Numerous criteria can be used to evaluate a material, many of which can be applied to pretty much any substrate. The application, quality expectations and print method are the starting point, and we can use evaluation and inspection criteria for paper as a model for how to evaluate other substrates. Although the specifics for a given material are out of scope for this guide, the principles outlined below should provide a reasonable model for evaluations. We start with expectations for paper, the most ancient and most developed of graphic arts substrates.

Paper is made from either entirely mechanically ground down wood, or pulp that has gone through a chemical process to break it down further. Photo from Husum paper mill, part of M-Real.

Paper making

Mechanical pulp is produced by mechanically grinding down the wood in order to reduce it to the raw fibres. Its raw material is logs or woodchip waste obtained from saw mills or other wood processing facilities. The grinding process does not get rid of all of the lignin in the wood however. This nonfibrous component holds together the cellulose fibres but it reduces the pulp's brightness and durability. The reduced brightness and permanence means that many mechanical pulps are really only suitable for such things as newspapers and comics, paper towels and tissues.

Technology is changing so that new mechanical methods can produce higher grades of pulp and thus more paper product options. Some pulping processes combine chemicals and mechanical processes, adding mild chemicals to increase brightness during the grinding process. Mechanical pulp is generally combined with some quantity of chemical pulps to improve its quality.

Chemical attractions

The majority of the pulp used in paper production is chemical pulp. Chemical pulp relies on chemicals to break down wood and other raw materials such as jute, cotton or bamboo. Chemical pulps generally have more supple and firmer fibres with more whiteness than mechanical pulps. However the firmness and whiteness plus other characteristics are influenced by the precise chemical mix used to produce the pulp. These considerations are important because they may affect how the paper behaves on press and its suitability for different print applications. Additives and fillers, such as kaolin and calcium carbonate, added to the pulp determine the final paper's qualities and its basic properties. HP Colorlok for instance is an additive incorporated into some papers during manufacture to lock pigments at the substrate's surface during printing. Optical Brightening Agents (OBA) which can also be added to wool, acrylics and polyester, can help improve the paper's brightness by adding a hint of blue to it.

Paper machines are enormous and quite amazing feats of engineering. They turn raw pulp into paper using a combination of water, drainage, dewatering, drying and calendaring. Calendaring involves pressing the paper web through rollers that are under considerable pressure, with applied friction and heat. The process gives the paper a satin finish and determines the paper's final surface structure and its gloss and glaze. Different means of calendaring are used to produce paper types that have fine or coarse or even specialised surface structures.

Brightness and whiteness can be improved for both mechanical and chemical pulps using bleach which can also get rid of residual lignin. Mechanical pulps generally do not have much bleach added, since they are used for relatively undemanding applications such as newspaper printing, and too much bleaching may damage the fibres and so reduce the pulp yield.

Once produced, papers are finished which involves additional processes, most frequently coating and laminating. Coating is probably the most important since this is where the base paper is coated with additives and binders to aid ink adhesion, as well as pigments to colour the substrate surface. They can also influence ink consumption for given colour densities and drying performance.

The final paper is distributed either as cut up sheets, or delivered on pallets or as large rolls. The designer can choose among many paper grades through paper samplers.

Coatings, or their lack, influence the substrate's surface and performance on and off press, so they are vital for print performance. For paper, coatings determine the overall surface structure, smoothness or roughness, colour and lightness. Glossy, matte and semi-matte surfaces for instance have different levels of printability, because the printing inks will respond in different ways to these surface characteristics. Coatings hold the colourants high on the surface by managing the ink colourant and absorption. This encourages evaporation to maximise density and potentially increasing colour gamut. It also minimises cockle and curl which can occur when presses run at high speed. Water based inks require substrate treatment in order to run on high speed inkjet presses, and treatments are either added during substrate manufacturing or by precoating the substrate on press. Either way there is a price premium.

Uncoated papers absorb more ink and generally yield relatively dull results, whereas a coated stock can considerably improve the look of the print. Uncoated stocks can hide printing flaws, whereas coated ones demand absolute precision in the printing process.

Coatings, like inks, also affect a substrate's recyclability once it reaches end of life. Paper and board are widely recycled, 85.8% of European paper and cardboard packaging waste was recycled in 2018. For metal and glass packaging the rates were 78.3% and 74.1% respectively.

The efficiency and cost effectiveness of turning waste paper into new paper products depends on how the paper was printed and its deinkability. If the print is sent to landfill or incinerated, deinkability and print method won't matter much. But if the waste prints are to be used as raw material for a new paper product deinkability, as determined by the print method, matters. The deinkability determines what new paper products can be made from the deinked paper. If deinking methods are basic, printed materials produced with a flexo press and some digital processes will result in pulp that is relatively low grade and unlikely to command a high price. However deinking processes have advanced, and all forms of print can be deinked and recycled.

The structure of a substrate determines its performance: metals used to package liquids will leak, if they are too thin; plastics that are overly brittle will split too easily to be useful. Substrate structure depends on how the raw materials used to produce it have been treated and the manufacturing processes required to produce the given substrate.

Printability

What matters most is how a substrate behaves on press and in finishing, and its quality and behaviour in use. With paper, as for other base materials, the printability determines the printed product's optical characteristics. Performance on press influences such things as how quickly the press can run, how much handholding the press needs in order to print a given material and the stability of the substrate while being printed. Ink and toner chemistries, especially their drying, melting and flexing temperatures, may impact the substrate. Substrate resistance to heat on press is especially important, as excess heat will distort and can even damage thin substrates.

How well a substrate accepts ink and the ink options available for it are a key consideration, as is how long it will take to dry and its adhesive properties. Another key consideration is the gloss of the printed result: is it shiny enough, or too shiny for your customer? Customers may also care about the extent to which the print sits proud on the surface. For most sign and display applications this will not matter, but some clients might prefer printed images that are completely smooth and flush with the substrate surface. Run some tests to see how even the printed surface will be and make sure that this evenness, like gloss and adherence and other characteristics will be consistent from print to print. This is especially important for a job that is being produced in quantity and at multiple sites.

There are many inspection tools you can use to test various aspects of a substrate. ISO Technical Committee 6 is dedicated to pulp and paper standards and has developed a large range of standards to aid quality control in pulp and paper production. Standards from ISO and industry associations such as FOGRA in Germany can help you test for such things as adhesion, wetability, bending strength, moisture expansion, opacity, curling, tear and fold resistance, grammage, gloss, grain direction and a host of other possibilities, all of which matter to someone somewhere in the graphics industry.

There are many ISO standards available to help evaluate the printability and durability of a certain substrate. Here a test of the opacity of white ink printed digitally on a dark substrate.

As part of this consideration look at the surface absorbency and show through for double sided work, as it affects colour appearance as the ink dries. Beware mottling due to unevenness in the substrate surface. If your preferred print method is digital, either liquid ink or toner, make sure that the substrate is rated for use with the technology you want to use. Also consider how the substrate will behave over time, as it may be subject to curling as can be the case with some thin films and lighter paper grades. If the substrate is to be used for external signage consider the light, rub and water resistance and overall robustness, especially if the job is to be installed somewhere very wet and windy. The material needs to be strong enough to withstand all sorts of weathering from strong sunshine and heat, to icy temperatures and howling gales. Printed textiles must be flame retardant and water resistant and comply with local safety standards. For garments they must be able to take sweat and washing in household detergents. For printed ACM and polypropylene composite panels corrosion resistance must also be part of any evaluation.

Through its interaction with the substrate surface, ink behaviour determines many of the aforementioned quality considerations. The interaction of ink and substrate depends on the ink's composition and the type of surface and print process for which it is designed. Oil based inks behave differently to water based ones and their recipes are tightly coupled to the print process and surfaces for which they are designed. There is a huge range of options especially of digital printing inks both for flexible materials and rigid ones. The range of screen inks is exceptionally broad because screen printing is used in so many applications, from textiles and balloons through to circuit boards. Whatever the method and applications, inks must react well with a surface and withstand the demands of the application. For instance they must be flexible without lifting from the substrate when used in vehicle wrapping.

Paper is by ignorance often thought to be a not so environmentally friendly material. In reality, when harvested in a responsible way, it's a natural and sustainable raw material.

Non-paper options

In the sign and display market vinyl is the most commonly used flexible substrate, but as with paper there are many variations and you get what you pay for. Also as with paper the characteristics of these substrates depend on how they are made. They can be cast using a process that follows similar principles to paper making, or calendared where a vinyl paste is flattened. There is a narrowing performance difference between the two but calendared vinyls still tend to be cheaper. Vinyl can be used to make laminate films adding textured finishes and surface effects such as matte or gloss that influence colour appearance. Laminates can be used to protect other materials too, for instance from general wear and tear or against the weather where strong light will cause fading. Textiles are a popular choice for signage because of their recyclability and convenience.

The finishing line

The continued explosion in choice of print substrates is constrained by what printing methods allow. However finishing and installation constraints must also factor into investment decisions. One often overlooked aspect of substrate selection is how the material behaves during the finishing and installation processes. For sign and display work this is especially important, because materials may need to be cut to shape or drilled. If they are friable this will increase the risk of damage during the finishing process and at installation. If such a material is the only one that will do, be prepared to spend extra time in finishing, sanding the edges of the work to make it presentable. Keep in mind that you might be better off spending more on the material in the first place and less on the hand finishing.

Similar considerations have to be made for the installation of signs and displays. If the prints are particularly brittle you may need specialist tools to fix rigid materials in place. Adhesive substrates such as thin window films need to behave well during installation and throughout their viewing lives, but they should also be easy to remove when it comes time to replace them. Make sure you understand the viewing environment for the print as it may be subject to stresses, such as extreme light or heat, that could undermine durability or the ease with which it can be removed.

As projects get more ambitious and runs shorten and rise in value, the industry is moving to higher premium substrates. Competition in substrate development and supply is fierce, especially for tactile surfaces used in label and packaging applications. The choice is yours, but make sure you choose wisely.

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