Dyne Information General

The ability of a substrate to adhere inks, coatings, or adhesives is directly related to its surface energy. If the substrate surface energy does not significantly exceed the surface tension of the fluid which is to cover it, wetting will be impeded and a poor bond will result. In a dyne test, wetting tension liquids are spread over a film surface to determine printability, coating laydown, and heat sealability of treated films. Solutions of increasing wetting tensions are applied to the polymer film until a solution is found that just wets the polymer surface.

The term "surface energy," or wetting, is normally used to describe the reactivity of the surface of a solid substrate, while "surface tension" is used in reference to a liquid. Frequently, the two terms are used interchangeably, since both refer to the same force at which molecules at the surface of the substrate ultimately cling to one another. The phenomenon of surface energy is based on the relative energies of the solid substrate and the liquid in contact with it. For converters of plastic films, knowing the surface energy of a polymer surface is critical in assuring good coating and print quality, as well as the adhesion of laminated films - particularly with the growing popularity of water-based inks, coatings, and adhesives. The surface energy of a solid polymer cannot be measured directly because solids typically show no reaction to the exertion of surface energy. Consequently, practical measurements of surface energy involve the interaction of the solid with a test liquid to determine wetting tension as a measure of surface energy.The surface energy of a film should be between 3 dynes/cm and 10 dynes/cm greater than the surface tension of the ink in order to ensure acceptable performance. Thus even pre-treated films should be checked before use to make sure proper dyne energy is present.

Surface tension is expressed in units of force per unit of width, similar to web tension. However, since surface tension forces are so much smaller, it is more convenient to express them in dynes per centimetre, rather than pounds per inch. Hence, the act of measuring surface energy, or tension, is typically known as a "dyne test."

DYNE TESTING

For most solvent based printing, plastics need to be treated to 36 to 40 dynes/cm; water based inks usually require 40 to 44 dynes/cm; some laminating and coating applications require surface energies of 50 dynes/cm or more. Clearly, surface energy must be assessed before printing, coating, or laminating is attempted.
Dyne testing has found countless applications throughout industry, in functions as varied as basic research, product development, process control, incoming inspection, finished product dis-positioning, sales, and marketing. Typically, it measures the treatment level of polymers which have been exposed to flame or

corona surface modification; but many less traditional applications have also been explored.

• Cleaning systems can be monitored by the dyne test. The surface energy of metals is much higher than that of surface contaminants; thus, the higher the dyne level, the cleaner the part is. Always use test fluids to measure cleanliness - even the spring-loaded Liquid Dyne Pens will eventually be overwhelmed by repeated exposure to contamination.
• The presence of mould release on many plastic parts can be similarly identified. Again, test fluids are indicated for this application.
• It is often possible to identify patterns of treatment variation on a sample piece by doing a full-size drawdown. Methodical troubleshooting analysis will often lead back to the specific cause. For example, increasing treatment across the roll suggests the treater electrode is misaligned to the roll; periodic variations along the web may relate to non-concentricity.
• An easy test for back-treat on PE or PP is to use a 34 dyne/cm Liquid Dyne Pen. Any wetting – even for less than two seconds - indicates some treatment.
• Polyester film which reads consistently below 42 dynes/cm is almost certainly "print primed." This chemical process actually decreases the surface energy a bit,but makes the surface attractive to a far broader range of compounds used in inks and coatings.
• Whenever feasible, test with supplies, samples, and ambient temperature at 20° to 25°C. If this is impossible, it is advised that a test study be run to relate temperature variations to numerical results.
Keep test supplies at ambient temperature at all times.
• Remember that dyne level decay is extremely rapid directly after corona treatment. A virtually immediate loss of 10 dynes/cm is possible! This is due to contact with process rolls (especially heated metal ones), surface blooming of additives, and interfacial transfers between treated and untreated surfaces within the finished, wound roll. If you are a slitter, rewinder, or extruder, either test far downstream in the process, or increase your specification to account for greater losses before your customer tests at incoming inspection.
• Film extruders should test extensively - every roll from every machine without fail. Potential product liability and customer satisfaction losses far exceed the cost of an effective QC program.
• Printers, coaters, and laminators should pull samples and perform the test as soon before the print station (or similar) as possible. It may be worthwhile to dyne test the roll before it goes on the machine, and compare these results to material which has run through the web handling process to the print station. This will indicate the treat loss attributable to process roll contact and web handling.
• Never leave bottles or markers uncapped! Evaporation, water vapor, and airborne contaminants all affect dyne level, and can invalidate them long before expiration.
• The recommended expiration date for dyne pens is 6 months after receipt of the product.

POLYMER SURFACE TREATMENT

Plastic surfaces have little free energy and are essentially inert. This is most notably true of fluorocarbons, silicones, polyolefins, and vinyl’s. Unlike high energy materials (such as metals and ceramics), plastics lack the available bond sites offered by charged ions distributed over the surface. Without this molecular attraction, liquids fail to wet the surface, resulting in poor adhesion and coverage. This problem, while universal, is especially troublesome to printers and converters who work with fast-moving webs; in these processes, the free energy (ability to attract a liquid) of the surface must significantly exceed the surface tension (resistance to spreading) of the liquid, or de-wetting occurs readily, producing waste. Worst of all, some problems, like on-the-shelf delamination or ink lift off, cannot be seen until a job is finished and shipped to the customer.

Corona treatment is the commonest choice for converters. A corona treating system can be thought of as a capacitor. High voltage is applied to the electrode. Between the electrode and the ground roll is a dielectric, comprised of the web, air, and an insulator such as silicone or ceramic. The voltage buildup on the electrode ionizes the air in the electrode/web gap, creating the highly energized corona. This excites the air molecules, re-forming them into a variety of free radicals, which then bombard the surface, increasing its polarity by distributing free bond sites across it.

There are two basic treater designs; conventional (dielectric covered roll) and bare-roll (dielectric covered electrode). Only bare-roll systems can be used on conductive webs; conventional systems short out. But conventional systems are more efficient, and have fewer problems associated with heat build-up on the electrodes. Therefore, they are preferred by film extruders and extrusion coaters. Bare roll systems are ideal for converters who process various materials, especially foils and plastics which were pre-treated initially. They are well suited to "bump" treating - subjecting the web to treatment immediately prior to printing, coating, laminating, or metallizing. This not only re-energizes the surface, it also removes contaminants or bloomed additives which may have invaded it. Several manufacturers also offer convertible systems, which can be operated in either configuration.

Corona treaters are easy to install and use, can usually be adjusted for varying web widths, produce uniform treatment when operated properly, and are quite cost-effective. But there is a downside: Back treatment can cause blocking and poor heat-sealing; corona treatment decays rapidly with handling and age, especially in heat and humidity; static build up can require in-line deionization; attempting to increase surface energy by more than 10-12 dynes/cm is often inadvisable – pin holing, surface degradation, and accelerated treatment decay rate can result from overtreatment. Finally, the process produces ozone, which must be neutralized before release to the atmosphere.

Flame treatment is commonest for moulded pieces such as bottles, tubing, and automotive parts. However, it is also widely used to treat films, foils, coated board, and other substrates. Like corona, it induces an ionized airstream, which alters the surface as it impinges upon it. This is accomplished by burning an ultra-lean gas mixture, whose excess oxygen is rendered reactive by the high temperature. Advantages of flame treatment include freedom from ozone, pin holing, and back treatment. Also, flame treating can achieve treatment levels above 70 dynes/cm even on polyolefins. Moreover, flame treatment is far more stable than is corona; dyne level decay is much slower. A slight hazing may preclude use on optical grade films and some packaging materials.

Cold plasma treatment is typically run in batch mode, but recent improvements are making it more attractive to producers of high-end specialty substrates. Traditional cold plasma treatment requires a partial vacuum; a selected gas is introduced into an evacuated chamber and ionized by a radio frequency (RF) field. The RF field excites the gas molecules, creating a blend of neutral atoms and reactive radicals formed from free electrons. Three processes occur when these free radicals bombard the surface: ablation ("cleaning" it by removing its outer molecular layer); crosslinking (interconnection of long-chain molecules); and activation (impartation of reactive molecules, which, in an oxygen-rich atmosphere, increases surface energy).

SURFACE TREATMENT FOR THREE-DIMENSIONAL OBJECTS

If you've attempted to print, label, or otherwise decorate a three-dimensional (3-D) product, you've probably been frustrated by an ink or adhesive that refused to adhere to the part's surface. You may have tried different types of ink or adhesive formulations to get the job done, perhaps even used chemical primers or batch-treating processes. Still, the ink refused to bond with the material. What you experienced was low surface energy, making the material repel printing inks and other coating materials. Contending with low-surface-energy substrates is a frequent concern for screen- and pad-printing businesses that decorate 3-D parts. But it's an obstacle that can be overcome most easily with in-line surface-treatment technology.

Why is Surface Treatment Necessary?

Surface treatment is frequently used in printing and other converting processes to alter the surface characteristics of a material. Treatment processes may be designed to improve a substrate's wetting properties, which influence how well inks and coatings will flow out over the material's surface. Treatments may also be used to enhance the bonding between the substrate and the applied material or eliminate static charges that have accumulated on the substrate surface. Surface treatment technologies play a key role in preparing the surfaces of many commonly used packaging materials (paper, plastic, foil, etc.) for subsequent processing steps. Most inks, paints, coatings, and adhesives resist wetting on the surface of virgin-plastic parts, which are newly thermoformed or moulded items characterized by an inert, non-porous, low-energy surface. Virgin-plastic parts that screen and pad printers typically work with include items made from polyethylene, polypropylene, and other polyolefins. These materials tend to be very slippery and feel greasy to the touch. Getting coatings to permanently adhere to such materials is unlikely without the intimate contact created through wetting.

Where is In-Line Surface Treatment Useful?

In-line surface treatment of 3-D objects helps enhance product quality and facilitate efficient production in a vast array of applications and industries. The goal of surface treatment is to ensure a durable print or coating that will withstand any conditions or environments that the part might face. These conditions may include exposure to the elements outdoors, regular cleaning with harsh detergents, and extremes in temperature, to name a few. Five of the most common industries or application areas in which in-line surface-treatment systems are used include the following:

Printing This segment includes industries and technologies such as screen printing and pad printing. Surface treating parts prior to printing ensures proper and complete ink adhesion and can often make the printing process run more efficiently. Some materials are impossible to print unless they have undergone surface treatment.
Painting Painting 3-D parts occurs mainly in the automotive industry. Injection-moolded or thermoformed parts are surface treated prior to painting. Surface treatment not only encourages the paint to adhere to the substrate surface, but also increases the life and durability of the paint.
Coating Some parts require surface treatment before they'll accept a coating. Doors, frames, extrusions/profiles, and medical devices are examples of such products. The coatings themselves may be used to provide protection from harsh environments, serve as finishes that produce a more decorative appearance, or meet certain industrial standards. The medical industry, for example,
requires certain plastic devices to support adhesion of antimicrobial/antibiotic coatings that reduce patient exposure to bacteria.
Bonding Surface treatment in bonding applications is generally used to increase adhesive strength between the parts to be joined. In the medical industry, surface treatments are applied to increase the bond strength of needle hubs and other surfaces requiring a dependable joint. The automotive industry uses surface treatments to increase the bond strength of seal housings, panels, side mouldings, and trim.
Labeling The continual introduction of new plastics and adhesives in the packaging industry forces label producers to use surface treatment to promote label adhesion. Surface treating caps, bottles, and lids ensures that labels will not peel off earlier than desired. After establishing what surface-energy level you need, treating the substrates to achieve this surface energy, and printing the parts, you should test the finished product to make sure the print will withstand the handling and abuse it might be subjected to in the real world. If you know what conditions the part might face, try to duplicate them. Depending on the application, your tests might include submerging parts in water or other chemicals, exposing them to extremes in temperature, or storing them for extended periods. Surface energy is critically important to many converting operations. Unfortunately, it is not the sole determinant of product suitability. Other factors, such as surface topography, coating rheology, and chemical incompatibility, must also be considered. This is why broad-based communications with vendors and customers is so important. But at least by systematically measuring substrate surface energy, you will have a sound starting point from which to resolve other problems which may arise.

Content supplied by Russ Smith President of Diversified Enterprises

Manufacturers of Accudyne Dyne pens.