STUDY ON SURFACE TREATMENT OPTIONS ON VARIOUS PRINTING SUBSTRATES

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ABSTRACT: Printing is a process for reproducing text and images using a master form or template.. The main aim of the attractiveness of printing is to catch the attention of the consumers so every manufactures in the market compete with each other to get a major market share. Most plastics such as polyethylene, polypropylene and polyester have chemically inert and nonporous surfaces with low surface tensions causing them to be non-receptive to bonding with printing inks, coatings and adhesives. Surface Treatment Systems increase surface energy to promote adhesion for printing, coating, laminating and other converting processes. Most all substrates including paper and foil will exhibit increased adhesion to inks, adhesives and extrusion coatings after surface treatment. This thesis aims to study about the surface treatment options on printing substrates and to find the various surface factors determining quality printing and also analyze the advantages and disadvantages of existing surface treatment options on various printing substrates and suggest possible alternative options.

I. INTRODUCTION

Most plastics such as polyethylene, polypropylene and polyester have chemically inert and nonporous surfaces with low surface tensions causing them to be non-receptive to bonding with printing inks, coatings and adhesives. Surface Treatment Systems increase surface energy to promote adhesion for printing, coating, laminating and other converting processes. Most all substrates including paper and foil will exhibit increased adhesion to inks, adhesives and extrusion coatings after surface treatment.

Corona Treatment

An electrical process that uses ionized air to increase the surface tension of substrates. Typically, corona treating systems operate at an electrical voltage of 10 kV. The high voltage is applied across an electrode which ionizes the air in the electrode/web gap, creating a highly energized corona.

Plasma Treatment

Like corona, plasma is the electrical ionization of a gas. Unlike corona, plasma is created at much lower voltage levels and the rate at which electron bombardment occurs is up to 100 times greater. Plasma facilitates the use of chemical gases which can produce controlled chemical reactions to functionalize surfaces.

Flame Treatment

The process of burning away surface contaminants by forcibly spraying a flame onto a substrate surface. This is accomplished by burning an ultra-lean gas mixture, whose excess oxygen is rendered reactive by the high temperature.

Treatment - Determining the Treatment Level

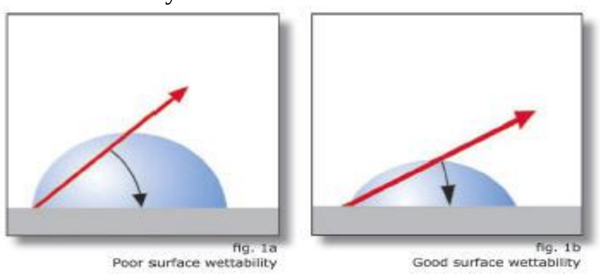
Dyne Test

Solutions of various percentages of Ethyl Cello solve Form amide and Water. Dyne solution levels range from 30 to 60+. The “treatment level” is based upon the specific solution number that wets out the surface vs. the next level up those beads up. Easy and cheap test method well suited for use on the shop floor. Procedure can be subjective but is reasonably accurate if adequate care is taken and the solutions are kept fresh.

Contact Angle

Contact angle is the angle formed by a liquid at the three phase’s boundary where a liquid, gas and solid (substrate) intersect. Very precise measurement with high repeatability. Requires a relatively expensive test instrument that is not well suited for shop floor use. The lower the contact angle, the higher the treatment level. Surface treatment mainly deals with Surface energy of solid materials and the need for surface treatment of polymers. It is often necessary to bond plastic materials to metals or other plastic materials, or simply print on a plastic surface. In order to successfully accomplish this liquid adhesive or ink should be able to wet the surface of the material. And this is where Corona Treatment and Plasma Treatment technologies are necessary. Wettability depends on one specific property of the surface: Surface energy, often referred to as surface tension. Surface energy, like surface tension is measured in mN/m. The surface energy of the solid substrate directly affects how well a liquid wets the surface. The wettability, in turn, is easily demonstrated by contact angle measurements. The contact angle is the angle between the tangent line at the contact point and the horizontal line of the solid surface. When a liquid droplet is set on a smooth solid horizontal surface, it may spread out over substrate and the contact angle will approach zero if complete wetting takes place. Conversely, if wetting is partial, the resulting contact angle reaches equilibrium in the range 0 to 180 degrees.

Surface Wettability



Above figure illustrate the difference between good and poor wettability. The higher the surface energy of the solid substrate in relation to the surface tensions of the liquid, the better its wettability, and the smaller the contact angle. In order for a proper bond to exist between a liquid and a substrate surface, the substrate's surface energy should exceed the liquid's tension by about 2-10 mN/m.

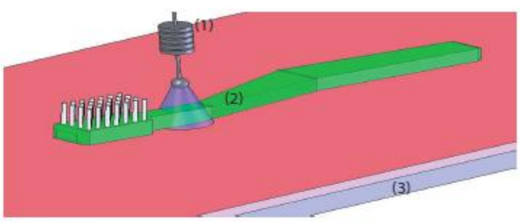
Surface energy of base material:		Needed surface energy for adhesion with:		
PTFE	< 20 mN/m	UV ink	48-56	mN/m
Silicone	< 20 mN/m	Waterbased	50-56	mN/m
PP	30 mN/m	Coatings	46-52	mN/m
PE	32 mN/m	UV glue	44-50	mN/m
PS	34 mN/m	Waterbased glue	48-56	mN/m
PC	34 mN/m			
ABS	34 mN/m			
XLPE	32 mN/m			
PUR	34 mN/m			

This figure shows absolute values of surface energy for solid materials and the surface tension of many plastics including polyethylene and polypropylene is often insufficient for bonding or printing. These materials have very useful properties such as chemical inertness, a low coefficient of friction, high wear, puncture and tear resistance, etc. However, the poor wettability of these polymers presents the designer with the problem of bonding or decorating these materials. Surface treatment can improve wettability of the material by raising the material's surface energy and positively affect adhesive characteristics by creating bonding sites. The most advanced and successful methods of surface treatment are based on a principle of high voltage discharge in air.

Basics of High Voltage Discharge in Air and Its Application to Surface Treatment

In the presence of a high voltage discharge in an air gap, free electrons, which are always present in the air, accelerate and ionize the gas. When the electric discharge is very strong, collisions of high velocity electrons with molecules of gas result in no loss in momentum, and electron avalanching occurs. When a plastic part is placed in the discharge path, the electrons generated in the discharge impact the surface with energies 2 to 3 times that necessary to break the molecular bonds on the surface of most substrates. This creates very reactive free radicals. These free radicals in the presence of oxygen can react rapidly to form various chemical functional groups on the substrate surface. Functional groups resulting from this oxidation reaction are the most effective at increasing surface energy and enhancing chemical bonding to the resin matrix. These include carbonyl (-C=O-). Carboxyl (HOOC-), hydro peroxide (HOO-) and hydroxyl (HO-) groups.

Surface treatment with high voltage discharge modifies only the surface characteristics without affecting material bulk properties.



(1) Electrode fig. 3
(2) Counter Electrode (grounde reference)
(3) Treated parts

Tantec three-dimensional electrical surface treatment (EST) technology is based on the high voltage high frequency discharge in air. Three-dimensional objects are passed through a discharge region between two electrodes (Figure 3). The discharge is sustained in a large gap between the electrodes by establishing a high potential difference between the electrodes. High applied voltage is only one condition for effective treatment. A uniform treatment of parts moving at high speed requires high efficiency energy transfer from the power source to the discharge region. Corona discharge at frequencies of 15-25 kHz accomplishes high efficiency energy transfer as electrons oscillate in the gap between the electrodes. It has been shown that the higher the frequency the lower the power to achieve a given treatment level.

The EST technology achieves a uniform treatment of surfaces of three-dimensional objects on high-speed lines through maintaining a potential difference between electrodes up to 80 kV at frequencies between 15-25 kHz. Under these conditions objects with cross-sections as large as 4 inches (100 mm) can be treated on-line as they continually move through a treating chamber. An Electrical Surface Treatment system consists of high frequency generator, high voltage transformer and treating electrodes. The generator produces an output signal whose frequency is automatically adjusted in the 15-25 kHz range depending on the load impedance, thus optimizing the power available for treatment. The high voltage transformer steps up the output signal from the generator to the level needed to generate the discharge of desired intensity. The treating station is designed around two electrodes: a treating electrode and counter electrode (usually at a ground potential). The electrodes are engineered for each application. Tantec offers a selection of plasma treaters for plasma surface treatment of different materials.

Applications of Tantec Electrical Surface Treatment Technology (EST)

The following materials have been successfully treated using EST technology:

Polyethylene (PE) * Plexiglas (PMMA)
Polypropylene (PP) * Teflon (PTFE)
Polystyrene (PS) * Polycarbonate (PC)
EPDM-rubber * Polyurethane (PUR)
ABS etc.

Here are some specific applications:

•Treatment of surfaces of bio-medical testing devices to improve wettability of surfaces for confluent liquid flow. Treatment of syringe barrels prior to printing.

•Treatment of the inner surface of needle hubs prior to bonding a stainless steel needle.

•Treatment of electronic cable insulation to improve adhesion of inks and coatings.

•Treatment of lids and covers of chemical containers prior to gasket material application or printing.

•Treatment of plastic bottles prior to application of adhesive labels.

•Treatment of automotive profiles made of EPDM rubber prior to application of an adhesive for retaining flocking bristles or decorating fabric.

Shelf life of Treated Surfaces

The shelf life of pre-treated materials ranges from hours to years, depending on the plastic, its formulation, how it was treated and its exposure to elevated temperature after treatment. Material purity is the most important factor. Shelf life is limited by the presence of low molecular weight components such as antilock agents, mould release, antistatic, etc. Eventually, these components migrate to the surface of clean polymers. It is therefore recommended to print or bond to the material soon after treatment. However, once the treated surface has been interfaced with a coating, ink, adhesive, or another material, the bond becomes permanent.

II. RESEARCH OBJECTIVES

Most plastics such as polyethylene, polypropylene and polyester have chemically inert and nonporous surfaces with low surface tensions causing them to be non-receptive to bonding with printing inks, coatings and adhesives. Surface Treatment Systems increase surface energy to promote adhesion for printing, coating, laminating and other converting processes. Most all substrates including paper and foil will exhibit increased adhesion to inks, adhesives and extrusion coatings after surface treatment.In this research we can analyze the advantages and disadvantages of existing surface treatment options on various printing substrates and can suggest possible alternative options. The experiment will be carried out on variety of substrate with prescribed printing conditions.

III. RESEARCH METHEDOLOGY

In this research we can analyze the effect of various surface treatments on printing substrates by qualitative and quantitative assessment. Modification will be suggested on existing treatment systems in order to overcome the draw backs.Data analysis will be carried out on the basis of relevant methodologies and equations that are adopted for the determination of surface parameters like surface energy, surface tension etc. In accumulation to this, analysis of print quality in terms of possibility of printing defects are also be evaluated with the aid of various quality control elements.

IV. DATA COLLECTION & result ANALYSIS

Different Substrates

Paper and cardboard

In the case of paper and cardboard non coated, gloss coated, matt coated), the surface condition is characterised by the smoothness. The smoothness enables the degree of polish or evenness of a paper to be evaluated. Paper that is very smooth has a uniform surface. On the other hand, a low degree of smoothness is characterised by a surface with numerous asperities and a rough appearance. The smoother the paper, the better its printability.

Papers undergo different types of treatment that allow a greater or lesser amount of surface smoothness to be obtained:

• Mechanical finishes: smoothing, calendaring, etc.
• Top coating finishes: surfacing, spread coating, etc.

Synthetic Substrates

The most widely used synthetic substrates are polyethylene, polypropylene, polyester, PVC or vinyl, polycarbonate, etc.

Synthetic substrates are principally characterized by their surface energy: the interactions between the solid surface of a substrate and a liquid element (an ink or overprint varnish) is defined by the evaluation of the surface energy of the substrate and the surface tension of the liquid. These two energies are measured in dynes /cm and are physical characteristics that make it possible to quantify the affinity of the liquid for the solid substrate. Simple means are available to measure the surface energy of a substrate, such as Sherman type felt tip pens.

To ensure good printability, it is necessary that the ink and the substrate to be printed have compatible levels of surface tension and surface energy. The surface tension of the ink must be lower than the surface energy of the substrate.

Printability Criteria

Two main criteria influence printability: the nature of the substrate – characterised by the porosity – and its surface condition.

Porosity

Porosity induces the notion of permeability and therefore printability. It determines the capacity of the substrate to absorb inks and varnishes. The porosity of a substrate results from both the size and the number of pores present on its surface.

It allows us to distinguish 5 categories of substrate:

• Non coated papers
• Gloss coated papers
• Matt coated papers
• Cardboard
• Synthetics and non-absorbent substrates

Non coated papers are macro-porous, while coated papers and cardboards are micro-porous.

Synthetic and non-absorbent substrates are non-porous or very slightly micro-porous.

Surface Condition

The surface condition of a substrate may be characterized by different parameters such as the smoothness, the roughness, the surface energy and the cleanliness (absence of impurities such as grease, waxes, etc.). A large amount of treatments are available that allow the surface condition of a substrate to be modified or prepared in order to make it printable (in particular for synthetic substrates).

Plastic Surface Modification (Surface Treatment and Adhesion)

Primary Polymer Adhesion Issues with Inks, Coatings, and Adhesives

When addressing the adhesion of polymers to interfacing materials, the primary and foremost challenge is to understand the fundamental driving forces which can initiate the development of adhesion strength between polymer-to-polymer, polymer-to-metal, polymer-to-ceramic, or polymer-to-inks, coatings, and adhesives. These interfaces also exist in multivariate environments, such as heat and humidity, which also must be examined. Ultimately, it is the polymer and the interface chemistry that determine adhesion. However, there can be adhesion failure between the polymer and an inorganic, such as a metal, due to an oxide layer that is weakly attached. That being said, this work will focus fundamentally on the bonding issues associated with polymers because of their unique deformation character, low modulus, and long chain structure. Many polymeric materials inherently have a low surface energy that results in poor surface adhesion or even complete adhesion failure.Thismakes it difficult for inks, paints, adhesives and other coatings to properly wet-out and adhere to the surface of these substrates. Proper surface preparation of these materials will increase surface energy, improve surface adhesion properties, and add value to the product and the process. However, one must keep in mind that it is the bulk mechanical properties of the polymer that control the interfacial forces, which in turn influence adhesion. We will be subsequently reviewing various substrate orientations, from oriented and metalized films to spun bonded polyolefin's and moulded polymers, in order to examine their bulk structures for their ability to endure mechanically-induced deformations to allow for surface roughening and chemical covalent bonds to achieve requisite adhesions. It is well known that polymer chain entanglement is the primary source of a polymer's strength. It is also known that over time polymeric materials can become increasingly semi-crystalline, making their surfaces even more difficult to accept surface modification techniques. The process of axially or biaxially orienting polymer films, for example, strengthens these materials as their chains become stretched. It is therefore common practice for surface modification techniques, such as corona discharge, to take place immediately following the orientation phase.

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 lay down, and heat seal ability 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."

SUGGESTED TREAT LEVELS

		Printing Processes												Other Processes					
	Process:	Flexo and Gravure			Litho			Offset/Letterpress			Screen and Pad			Laminating			Coating		
	Coating Type:	Water	Solvent	UV	Water	Solvent	UV	Water	Solvent	UV	Water	Solvent	UV	Water	Solvent	UV	Water	Solvent	UV
Substrate	PE	38 44	36 40	38 50	40 46	37 42	40 50	40 46	37 42	42 54	42 48	38 44	44 60	42 50	38 44	42 54	42 48	38 45	44 54
	PP	38 44	36 40	40 50	40 46	38 42	40 50	40 46	37 42	40 54	42 48	38 44	44 60	42 50	38 44	42 54	42 48	38 45	44 54
	PVC	38 44	36 40	36 50	40 45	37 42	36 52	40 45	38 42	40 52	42 48	38 44	42 60	42 50	38 44	42 54	40 48	38 45	42 54
	PET	44 52	40 46	42 54	46 56	42 46	44 56	46 56	42 46	46 60	48 60	42 48	44 62	46 60	42 48	44 62	42 52	42 48	46 60
	PS	38 44	35 40	42 48	40 45	37 42	42 50	40 46	38 44	42 58	42 48	38 44	42 56	42 52	37 44	42 54	42 50	38 46	44 54
	PVDC	40 46	38 42	42 52	42 46	40 42	42 52	42 48	38 44	42 54	42 50	40 45	42 58	42 50	38 44	44 52	42 48	40 46	44 54
	PU	40 46	38 42	38 50	40 46	38 42	38 52	40 45	38 44	42 56	42 50	38 44	42 58	42 50	38 44	42 56	42 48	38 46	44 54
	ABS	42 46	40 44	40 52	42 46	40 45	42 52	42 48	38 46	45 52	42 48	40 45	46 56	42 52	40 45	42 56	42 48	38 46	44 54
	PTFE	40 44	34 39	36 52	40 45	35 40	38 52	40 48	38 44	42 60	42 52	38 46	42 60	42 56	38 46	42 56	42 50	40 48	42 54
	Silicone	40 44	35 40	40 50	40 45	38 42	38 52	40 48	38 44	40 56	42 50	38 46	42 60	42 56	38 46	42 56	42 50	40 48	42 54

Dyne testing has found countless applications throughout industry, in functions as varied as basic research, product development, process control, incoming inspection, finished product dispositioning, 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 (part #N001-002) 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 vapour, and airborne contaminants all affect dyne level, and can invalidate them long before expiration.

• Test fluids or markers which have turned green are no longer reliable. The recommended expiration date for dyne pens is 6 months after receipt of the product.

V. CONCLUSION

Surface treatment increases the printability of materials. It increases the smoothness, ink absorbency, levelness etc. Surface treatment technologies that are more efficient, more environmentally-friendly, more flexible and more economic than other options. Treatment of material surfaces using the corona process is effected using extremely fast high-voltage discharges on electrodes, between which place the film, profile or mould. The ionisation is caused by the energy discharged when oxygen and nitrogen molecules collide in the air. The existing atomic oxygen influences various adhesion mechanisms in and on the material surface, which facilitate subsequent processing of the material. The type of adhesion mechanism is dependent on the treatment climate and the material. The adhesion value is governed by the corona energy level, the treatment time and climate, and the material itself,corona treatment. It is now possible to combine the cost-effective inline application of corona surface modification with the quality and surface characteristics of cost-intensive offline methods. The system principle is both simple and logical. Instead of two production steps - pretreatment then coating - simply combine both processes. And without requiring complicated plant technology, e.g. low-pressure plasma.These systems are especially designed for the flexible use. They can be integrated easily into production lines. Three-dimensional surface optimisation with flexible adjustment to diverse sizes and shapes is possible for the first time without the need of tools low pressure or system adjustments. The modular design and simple control offer high flexibility with optimum process security. The system operates on the "plug & play" principle, meaning it is ready for use straightaway. The plasma pretreatment is part of the continual process.

The combination of both systems is also possible. The advantages are optimum system integration and high adhesion with optimum process and quality security. The systems are extremly compact and can be integrated either inline or offline. The advantages in a glance:

- Always the most efficiant and energy saving technology
- Integrated quality control- zero defect monitoring
- Combination of multiple corona and plasma methods
- Possible integration into excisting processing machines
- Specialised for complicated shapes e. g. instrument panels
- Easy combination with robotics and handling systems
- Short cycle times

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