Corona Treatment: Why is it necessary?

Introduction: Why corona treatment?

The problem with writing or printing on plastic films is well known. You have a plastic bag and you would like to write on it with a pen, but unfortunately the ink doesn't stick to the plastic since the untreated plastic has a structure, which makes it impossible to both write and print on due to poor adhesion.

The problem has increased as we use more and more plastic materials, especially for packing. Actually if you go through an ordinary shop with convenience goods almost everything is somehow packed in plastic. In making this possible, either you want to laminate, coat, extrude or print on the plastic, you need to corona treat first or you will get a very bad result like poor adhesion or bad print quality. There are few other options like flame treatment, chemical treatment or no treating at all. I would here like to inform about the corona process, which I believe to be the most effective, controllable and environmentally right solution.

What causes the adhesion problems?

Whether a liquid wets a material well or poorly depends primarily on the chemical nature of both the liquid and the substrate. Wetting is defined as the ratio between the surface energies of the liquid and substrate.

In general, the following rule is true: “A material will be wetted, if its surface energy (=dyne/cm) is higher than that of the liquid and if not there will be an adhesion problem.” The figure beneath is showing the theoretical way of measuring the surface tension of materials. You place a defined liquid drop on the surface, and then measure the angle between the drop and the surface with a tension meter. The left figure shows a material with a high angle, which means it has a low energy and therefore a low adhesion. The figure to the right has a low angle, which means it has a high energy and therefore a high adhesion. When you corona treat you move from the left side to the right side of the figure. The figure also shows the basic dyne-level of a material and what's required in the different applications.

![LOW SURFACE ENERGY](image1)

![HIGH SURFACE ENERGY](image2)

<table>
<thead>
<tr>
<th>Material – Basic</th>
<th>Dyn/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP</td>
<td>29</td>
</tr>
<tr>
<td>PE-LD</td>
<td>31</td>
</tr>
<tr>
<td>PE-HD</td>
<td>32</td>
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<tr>
<td>BOPP</td>
<td>32</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Process – Application</th>
<th>Dyn/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Print – solvent based ink</td>
<td>40-42</td>
</tr>
<tr>
<td>Print – water based ink</td>
<td>46-48</td>
</tr>
<tr>
<td>Coating</td>
<td>44-54</td>
</tr>
<tr>
<td>Lamination</td>
<td>46-56</td>
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The most common way to measure the surface energy of a film is carried out by using the test method described by DIN 53364 and ASTM D2578-67, which is a liquid test. The liquid is applied as a broad line in a thin layer with either a brush or a pen. The surface tension is then determined visually by estimating how the liquid reacts within the first two seconds following application. The
test liquid can shrink and/or forms itself into globules (individual droplets) or it can remain unchanged. When a test liquid shrinks or forms into droplets it indicates that the film has a lower surface energy than the liquid applied. The test should be repeated as many times as necessary with a liquid of a lower surface tension until it remains unchanged for a period of two seconds. Once that has been achieved, the film can be said to have that level or surface energy at least equal to that of the liquid applied. Further applications should be made until shrinkage or droplets occur within two seconds. This last measurement should be taken as failure, and the surface energy of the liquid used for the previous measurement should be taken to be the surface energy of the film.

Here you can see the test with regular water, where the left side is corona treated.

**How to avoid adhesion problems**

To obtain sufficient wetting and adhesion on plastic films or metallic foils in-line, treatment just before the printing, laminating or coating unit is necessary. The solution is to optimise the wetting and adhesion is by using a corona discharge unit since this technique has proved to be highly effective, cost effective and can take place in-line.

**What is corona treatment?**

Corona is in short a high frequency electric discharge towards a surface, which has proven effect. The result from this is an improvement of the chemical connection (dyne/cm) between the molecules in the plastic and the applied media/liquid. This surface treatment neither reduces nor changes the strength and appearance of the material. The inventor of the corona system was my father Verner Eisby, who invented the system back in 1951. The molecular change that takes place is as follows:

The material is a polymer film seen from the side, where the film is moving from the right to the left. Above the film is the Corona Plus electrode, on the right is the OZONE that is created in the process.
The basics on plastic is that it is a man-made synthetic material, which contains long molecular chains that form a strong and uniform product. The plastic film consists of carbon and hydrogen atoms with 100,000 units per chain. The long molecular chains create the well known ruggedness of plastic and polymer materials. With the very long molecule chains it means very few end points, which gives a very poor adhesion as the adhesion can only be made at endpoints with an oxygen molecule.

During the corona discharge treatment, electrons are accelerated into the surface of the plastic causing the long chains to rupture, producing a multiplicity of open ends and free valences are formed. The free valences are then able to form carbonyl groups with the atoms from the ozone created by the electric discharge, which gives the improved adhesion. The more power / electrons, the shorter the chains and the more adhesions points. This means that the adhesion improves dramatically, but only on the surface. Actually it only affects the top layer with as little as 0.1 µ, which means that is has absolutely no effect on the plastic other than the approved adhesion.

The downside of corona treating is the ozone gas that is formed during the process of corona discharge. The gas plays an important part in the chemical and molecular changes that take place in the surface of the plastic, but is hazardous to health and has an unpleasant smell, even at relatively low levels. The average human can smell ozone at 0.01 ppm. and the threshold of safety of the gas in the area occupied by personnel is 0.1 ppm. Most corona equipment is therefore designed to remove ozone effectively from the treater station by means of an ozone protected fan, and a specially designed exhaust system. The removal of ozone is absolute necessary when you treat larger amounts. If removed properly, the ozone will create no problems at all.

An option to ducting the ozone through the roof to atmosphere is to use an ozone eliminator. This is an independent, catalytic filter system that accelerates the decomposition ozone, eliminating it completely.

**Determination of treatment power**

In the early days of corona discharge treatment, there was very little known about what happened to the surface during treatment. Therefore Verner Eisby made intensive studies of the phenomena trying to discover why the surface characteristics changed so much under the influence of the electronic treatment. After many years of research, where he also cooperated with the Danish Technological University, he concluded that both a chemical and physical reaction took place on the surface. These were caused by the “electron excitation” in the material surface, where very long molecules were formed. The long molecules broke up and recombined with oxygen atoms, which together with local ionisation and other minor changes, created an excellent bond for inks, lacquers, glues and coatings.

It was Verner Eisby who in the early sixties named the watt density “E-VALUE”, which today is adopted internationally throughout the industry and known as w/m²/min. More precise is defines the electron value pr m², which is necessary for determining the power requirements for a successful treatment of various substrates.
Above to the left you can see an atomic force surface topographic, which is a measurement made on the top layer of untreated polymer material. On the right you can see the mechanical changes on the surface after corona treatment, made by the oxidisation and the heat in the corona process.

The effectiveness of corona treatment depends on the material being used. There are no limits with regard to the materials that can be corona treated, although the required treatment/watt density (watt/min/m²) may vary within a wide range. The treatment level depends on the material being used, the required dyne-level, the machine speed and the number of sides to be treated. Regarding the material the following has to be taken into consideration: the age and width of the material and whether the material has been pre-treated.

The treatment level can be calculated by using the following formula:

\[
\text{Power (watt)} = T \times S \times W \times M
\]

- **P** = Total Power (Watt) required
- **T** = Number of sides to Treat (single/double sided)
- **S** = Line Speed (in metres per minute)
- **W** = Film Width (in metres)
- **M** = Material factor (required Watt per m² per minute)

The exact value is best determined by testing a sample of the actual film that is used for a specific application.

To ensure that the treatment level always stays the same, the Automatic Power Regulation has been invented to some of the corona treater units. When the needed treatment level (watt/min/m²) has been determined, the corona unit is set and due to the automatic power regulation the film is now influenced by the same energy irrespective of the speed or the width of the film.

**Durability**

As mentioned when determining the treatment level, it also depends on the age of the film. Over time the obtained dyne-level will fall and it can be necessary to corona treat the material again just before use. The decay of the material depends on storage conditions, temperature and whether or not the material contains slip. The less slip and the better storage conditions, the less decay in dyne level.

Thicker and older film stocks are more difficult to treat as slip agents may have migrated to the surface. Material which has not been treated under extrusion can be difficult to treat afterwards, it is recommended to use pre-treated film that just needs a corona refreshment.
As can be seen from the graph, the level of treatment decays more quickly immediately following treatment, and less rapidly as the time passes. The decay is depending on the different dynes/cm start level.

**Maintenance**

One of the worst problems in dealing with corona equipment is maintenance. To obtain the desired dyne-level it’s important that the insulators are kept clean. The latest major innovation to optimise set-up of electrodes and maintenance is the unique Quick Change (QC) system. The complete Corona electrode is mounted in a specially designed pull-out / push-in cartridge, which makes maintenance a lot easier. You simply pull the electrode out when cleaning, and then push it back in when finished with no tolls required. This means that the operator can easily perform daily maintenance without removal of the treatment material – this has proven very popular with many customers.

**Status**

The corona treatment has proven effect on plastic materials as you can read through this paper. Ever since the discovery of the corona system by Verner Eisby in 1951, there have been constant focus on improving the process through different kinds of innovations, which has succeeded very well.

2 VETAPHONE Technical Handbook issue 2001
4 VETAPHONE Technical Handbook issue 2001

**References:**


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