SOFTAL ELECTRONIC
Report
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Corona Treatment in Practice

Plastic processing companies, especially those producing and converting plastic film, are confronted every day with the problems of improving adhesion, quality, and of increasing the economic efficiency of processing machines. This report illustrates the technology behind the corona treatment equipment, how it operates, and how it can be applied to the production processes in these companies.

High-frequency corona treatment is widely accepted as a process for improving the adhesion of printing ink, lacquer, glue and other coatings on plastic film, paper and metal foil. The reasons for its success are the good results, controllability and easy handling. The techniques and the effectiveness of the process have gradually been improved to keep pace with the developments of the production machines.

Principle of corona equipment

The central features of the corona equipment are a high-frequency generator, and an electrode configuration mounted at a nominal distance of 1.5 mm from an earthed backing roller, forming the corona station.

The generators are usually equipped with IGBT amplifiers, and, in conjunction with a high voltage transformer, produce a sinusoidal output up to 40 kV_{pk-pk} at frequencies between 20 and 50kHz, depending an the type of generator.

The generated energy is discharged from the electrode system to the surface of the material to be treated, as it passes through the corona station between the electrode and the backing roller.

SOFTAL generators are equipped with automatic control to eliminate irregularities in production. This controls the generator output and compensates for changes in temperature, electrode gap, type, width and thickness of material and dielectric thickness. It is then possible to have a turn down ratio of 10:1 with this system.

There are two variants of the electrode system, and their application depends on the properties of the material web. For non-conductive materials, for example plastic or paper, metal electrodes are used. More than 14 years ago SOFTAL developed the highly effective MM multi-blade electrode which has now been patented all over the world.

In this system the backing roller is coated with a dielectric material such as silicone or ceramic, essential to obtain regular, homogeneous corona discharge.

The second variant of the electrode system must be applied in cases where conductive materials are to be treated, such as aluminium, metallized paper, plastics, and laminates containing such materials. In this case it does not matter whether discharge on to the conductive layer is direct or whether the conductive material is in a laminate or on the reverse side of the material web.

The system for this application consists of dielectric electrodes, such as the SOFTAL KB (MMD) ceramic electrodes filled with a metal conductor. The backing roller does not necessarily have a dielectric coating, since the ceramic electrode provides the dielectric.

While metal electrodes can only be used for non-conductive materials, it is possible to use dielectric electrodes for the treatment of conductive as well as non-conductive webs. However, for the power rating of the corona equipment it is important to note that the effect of these electrodes on plastic, for example, is poorer than the effect of metal electrodes. This must be compensated by increasing the output of the generator or by using an additional dielectric coating on the roller surface, which will increase the efficiency of this system.

Electrode systems

The effect of corona treatment basically depends on the electrode system. The most common electrodes are single blade electrodes, whose shape and configuration have an important influence on the efficiency.

Over the past 12 years SOFTAL has paid a great deal of attention to the development of electrodes, as experience has shown that increasing generator output alone, to treat difficult materials brings disadvantages in most cases.

High generator outputs can only be obtained with a high ignition voltage which leads to a separation of the corona discharge into single sparks. This not only produces oxidation of the plastic surface but at the same time decomposition products are no longer bound to polymer chains, and adhesion problems occur, which is exactly the opposite effect that corona treatment should produce.

Our electrode development therefore concentrated on transferring the entire available load as evenly and gently as possible to the surface of the material. The aim was to have uniform discharge, avoiding long single sparks and cooling the surface of the web at the same time. This resulted in a completely new concept in electrodes, the MM multi-blade electrode.

Treating stations with MM or KB (MMD) electrodes are manufactured in an open design, which means that there no enclosure is necessary for covering the treating station, essential for conventional treating stations. As a result, the threading of the web material is considerably easier and maintenance is simplified. This is achieved by covering the electrodes only. The ozone is extracted through an aluminium extraction tube onto which the insulated electrodes are mounted. Insulated covers on both sides of the electrode ensure protection against touching, efficient ozone extraction, and good cooling of the electrode system. The MM electrode is manufactured in different configurations, from 4 to 10 blades depending on the application. By design, the special shape of the electrode produces a smooth discharge which causes no damage to the material.

The advantages of these electrodes are obvious. As can be seen in diagram 1, less than half of the generator output power is required, than with conventional metal electrodes, to obtain a surface tension of 42 dyn/cm on, for example, polypropylene films which are difficult to treat. On the other hand, the same surface tension can be obtained with the same generator output at twice the speed. This results in a considerable economic advantage, both in investment costs and in operating costs.

Furthermore, the 4-10 single blades, which heat up during operation, can expand independently and by this, bending can be avoided, and a uniform air gap held.

The comparison with dielectric electrodes is even more significant. These electrodes consist nowadays of ceramic, and operate against a bare backing roller. They are less effective and should therefore only be used in the corona treatment of metal foils or laminates containing metal, when used with a bare metal roll.

If the application requires a ceramic electrode for conductive materials and also nonconductive materials have to be treated, a silicone or ceramic coating on the roller is recommended in order to improve the efficiency on non-conductive materials (see diagram 1).

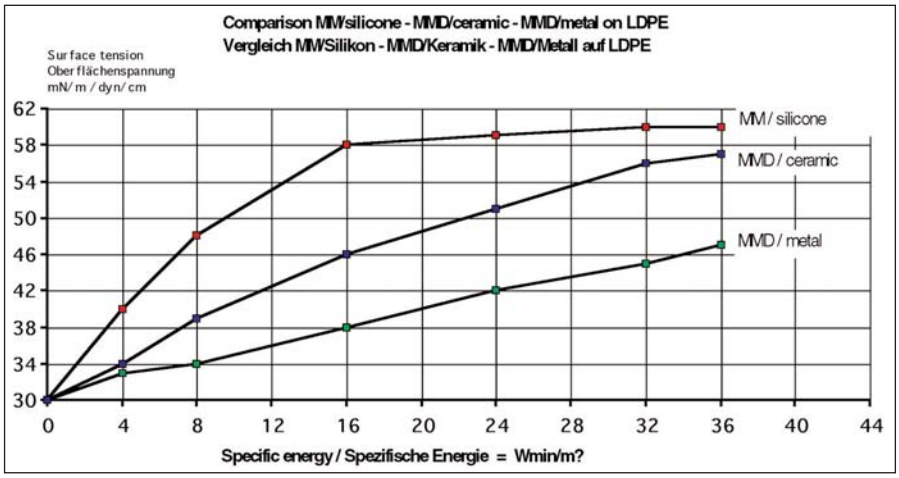


Diagram 1

A more important benefit of multi-blade electrodes lies in the fact that higher levels of surface tension can be obtained than have been possible. As diagram 1 shows, the linear increases in surface tension approach limit values, meaning that increased generator output will bring less and less improvement in treatment effect.

This limitation can only be broken by the design of the electrodes. With the multi-blade type, it is possible to have surface tension up to the point of water wetting (72 dyn/cm), depending on the type of polymer. Evidence shows that the design has a positive effect on adhesion. It has also been shown that in the case of pure polymers, without significant slip additives, the surface effects obtained are more storage-proof than with conventional electrode systems (see diagram 2). There is a delay in the drop in surface tension over the storage period and the residual values are higher, when the film is treated by the multi-blade electrode system.

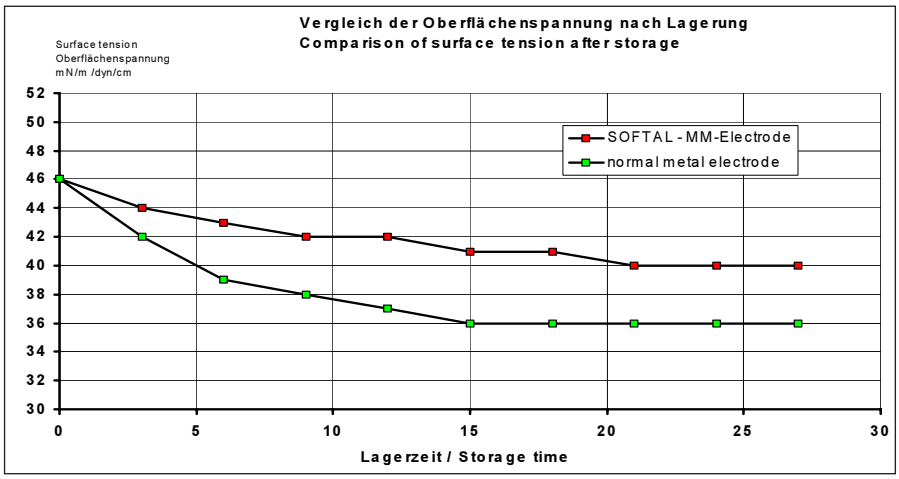
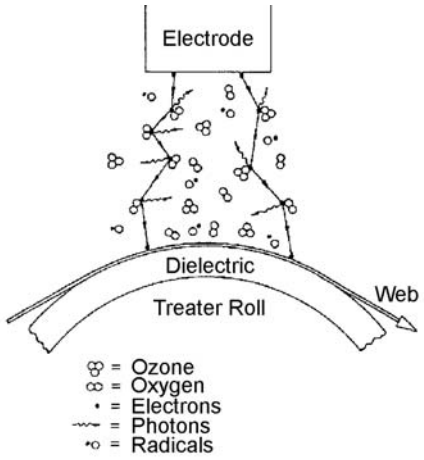


Diagram 2

Function of corona process

Although corona treatment has been used in the manufacture and treatment of plastics for more than 35 years, there was uncertainty for some time about the effect produced on the surface of the plastic, and about the corona process itself. After detailed research in this field, we know today that the corona treatment effect is based on bombarding the surface of the polymer with electrons. These leave the electrode and are accelerated under high tension towards the passing material web. In doing this they collide with air molecules which transmit light and react in part to ozone and nitrogen oxide. When the electrons come into contact with polyethylene for instance, they have so much energy that they can break the bond between carbon-hydrogen or carbon-carbon. Reactions with the corona gas take place at these free radicals, mainly towards oxidation. The functional groups thus formed are polar and so provide the basis for adhesion of applied printing inks, lacquers, etc.



Reactions in the corona discharge

In practice, the surface of aluminium foils, even when annealed, is not free from organic residue. Petroleum fractions and additives are used as lubricants when rolling foils and bands. Depending on the surface roughness, up to 20 mg/m? residue can be measured. During the annealing process the majority of the oil is removed by distillation and oxidation, but the surface is not in fact free from residue. Particularly at the centre of the web there remain rolling oil residues of some mg/m?. They are oxidized and therefore wet out, but have a negative effect on adhesion.

By intensive corona treatment these substances will continue to oxidize and cross-link so that adhesion becomes more certain. The corona „equalizes" the aluminium surface in the machine and transverse directions, and helps to reduce wastage in the case of unevenly annealed foil.

Power rating

The power rating of the corona equipment depends largely on the type of material, width of web and the production speed. All three factors are equally important. As far as the material is concerned, it is very important if, for example, a plastic film is treated inline with an extruder in the freshly extruded state or treated later on a processing machine after a certain period of storage. Treatment on an extruder requires a much lower treating power.

In the treatment of stored films on the other hand, an important factor is whether they have been treated at the time of manufacture on the extruder or not. Even traces of slip additives have adverse effects on the required rating.

The width of web and the speed are a linear function of the power rating.

The unit of measurement for specific energy is watt x min/m?. This formula contains the necessary parameters such as generator output (Watts), processing width (m) and machine speed (m/min).

At the SOFTAL technology centres in Germany and Japan we have simulators to define specific energy for any required material. When the specific energy necessary to treat a material to a defined surface tension is known, the required generator output can be calculated for any speed and treating width.

Applications

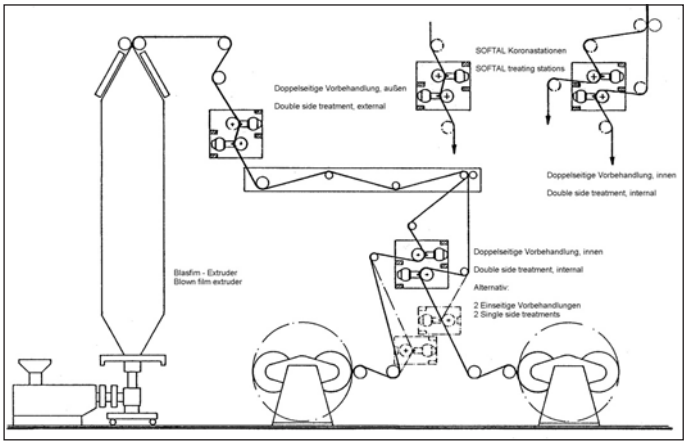
The applications of corona treatment are many, and range from pre-treatment of drinking cups and yoghurt beakers in cup printing machines, to pre-treatment in extrusion coating and laminating lines, as well as surface treatment of BOPP films up to 8,5 m wide in biaxial orienting machines. We shall go into further detail about the most common applications.

Blown film extruder

The most frequent and at the same time the simplest application of corona treatment is the use with blown film extruders. In most cases the materials are polyethylene films which normally have to be treated on both sides. Although these films sometimes contain considerable amounts of slip additives, it is normally no problem to obtain surface tension of 44-46 dyn/cm or more. At the time of treatment shortly after extrusion, the slip additives are still spread over the thickness of the film and therefore are not a major obstacle.

A negative effect of slip additives can be seen during storage, as they often lead to a rapid and dramatic drop in surface tension, especially with thicker films.

The reason for this is to be found in the fact that the slip additives which are intended to lubricate the surface of the film, tend to migrate to the film surface within a few days and strongly reduce surface tension at the same time. It is therefore all the more important to pre-treat films containing slip additives on the extruder, since it is practically impossible to sufficiently treat an untreated film with high



slip additive content after storage, under economically acceptable conditions.

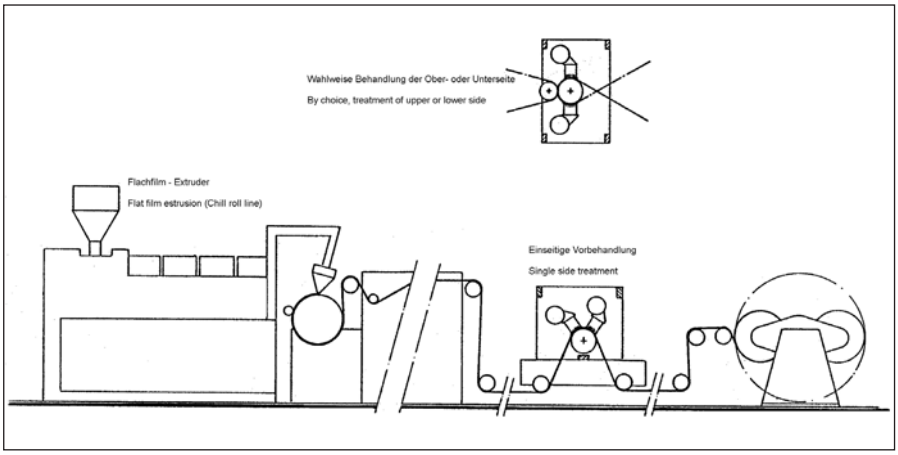
The corona stations installed on blown film extruders have one electrode on each side in most cases. We designed the DM electrode for this application, a variant of the multi-blade electrode with four blades.

If required, the corona station can also be fitted with segment electrodes with 3 to 10 mm segments to leave the desired strip width untreated for heat sealing at a later stage. This is necessary because corona treated areas have poor sealing strength after heat sealing.

The open construction of the SOFTAL corona station for blown film extruders offers the possibility of treating either the two inner sides or the outer sides, if the tube has been cut to provide two single films.

Cast film extrusion

Another area of application in the manufacture of films is cast film extrusion. As far as corona treatment is concerned, the application is not very different from that of blown film extrusion. Cast film extruders are often used in manufacturing polypropylene films and these require a considerably higher specific energy than polyethylene films. Depending on the type of raw material, the difference can be as much as a factor of three. Apart from that, cast film extruders usually produce at higher speeds of up to 200 m/min and more. This means that generators with higher output and 2 or more electrodes per side must be used.

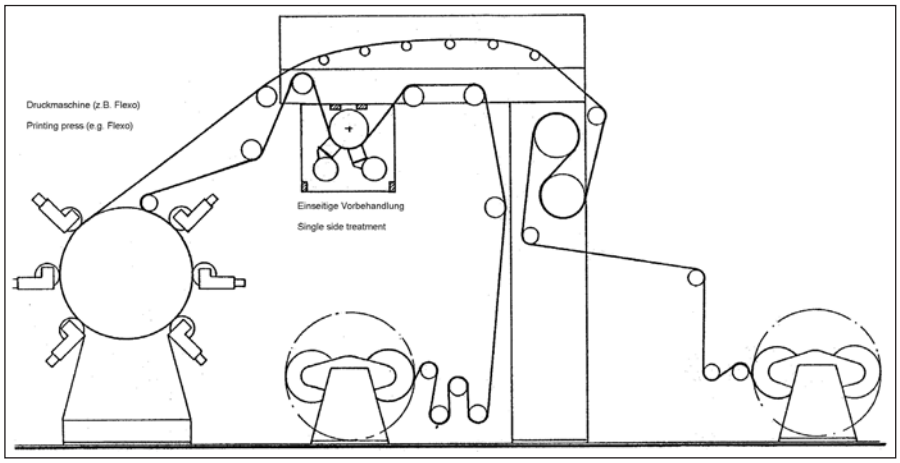


SOFTAL offers corona stations with MM or the advanced SMM electrodes with 7 or 10 stainless steel blades for this application.
For the power rating of the corona stations for blown film extruders and for cast film extruders it is certainly advisable to provide for a surface tension of 42-44 dyn/cm on polypropylene films and approximately 44-46 dyn/cm on polyethylene films. These surface tensions ensure that further processing can be done without problems, even after long storage times with low slip additive contents. They also provide a good basis for refreshing the surface tension in-line with further converting processes.

Printing machines

One of the converting processes is printing such films or other webs of flexible material. Further corona treatment is often necessary, even though materials are used which have already been corona treated during manufacture. However, long periods of storage mean that the surface tension is no longer enough to guarantee satisfactory adhesion of the ink.

This process requires a surface tension of at least 38-40 dyn/cm for printing inks containing solvents, and 44-46 dyn/cm for water based printing inks which are being used more and more in the printing industry for environmental reasons. If the surface tension falls below these values it is necessary to refresh the treatment before printing to ensure good adhesion between the film and the ink.

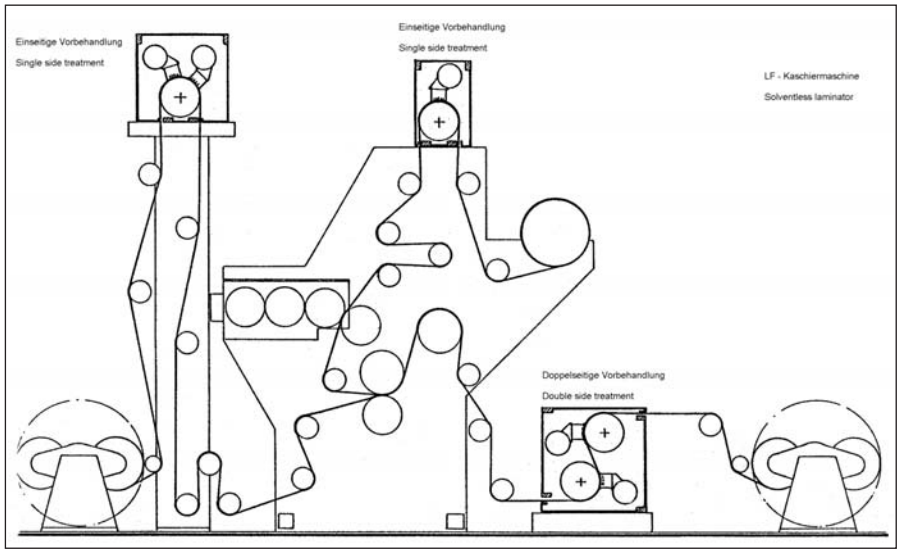


In addition to plastic films aluminium foils, usually of soft, annealed aluminium, are also treated before printing. The use of KB ceramic electrodes in the corona stations, as described before, is needed for this purpose. In this case corona treatment can replace anchor coating which would otherwise be necessary to print on pure aluminium.

Laminating machines

The same rules apply to wet or dry laminating of flexible materials as to printing. It is recommended to treat the carrier web and the laminate web with corona since it is very important for both parts of the laminate to have good adhesive properties.

The corona station should be situated as close as possible to the coating or laminating unit in order to keep the risk of contamination of the treated surfaces on guide rollers to a minimum.
Special pressurized types of corona station are available for operation in hazardous areas.



Extrusion coating and laminating machines

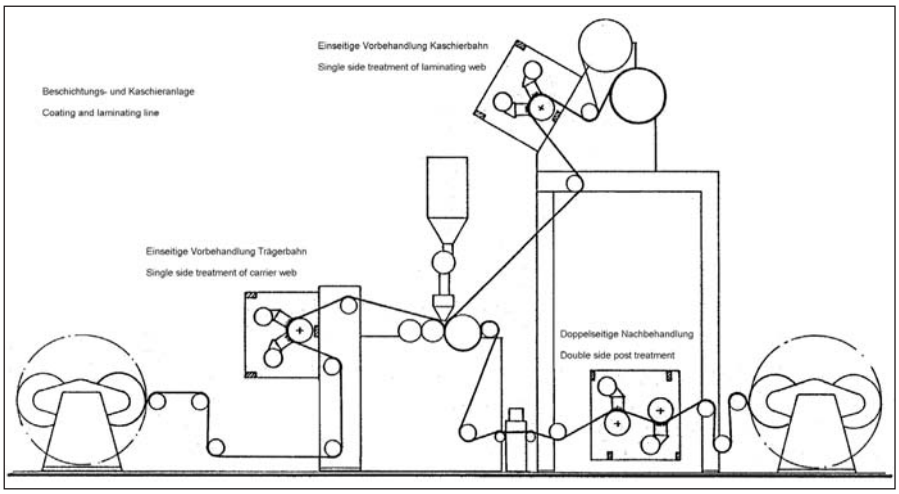
Another most important application of corona treatment is extrusion coating and laminating. Base materials such as paper, cardboard, aluminium and plastic are used here in various forms. These are laminated together using a plastic melt, or are coated with plastic melt. All materials of the laminate must be corona treated in-line before coating or laminating to achieve an acceptable degree of laminating strength.

In this case, the corona treater is installed as close as possible to the laminator respectively before the anchor coating unit. Depending on the material and demand of bond strength, in many cases the LDPE coating can be carried out without anchor coating by use of the corona treatment with considerably lower costs.

In addition, it is often necessary to treat the plastic coating, usually LDPE, for further processing. In this case, the type of cooling cylinder used on the laminator is important for the power rating. The glossier a chill roll is, the more specific energy must be calculated for the treatment.

For the post treatment of LDPE coated paper and board the decrease of surface tension must be taken into consideration. Due to contamination of the LDPE coated side by the uncoated paper side the decrease of the surface tension is much higher than on paper or board coated on both sides. Depending on the period of the storage until further processing it might be necessary to carry out a second treatment in-line with the processing machine.

As mentioned earlier, corona treatment has a negative influence on the sealing strength after heat sealing. For materials which have to be printed and heat sealed on the printed side by further processing ,a uniform surface tension which must neither be higher nor lower than 37-38 dyne/cm is essential. This surface tension is sufficient for a good adhesion of printing inks as well as for good sealing strength. A uniform surface tension can only be achieved by a speed dependent power control of the generator in order to ensure the same surface tension at different speeds. This power control is an optional device in all SOFTAL generators and can be used where necessary.



Ozone treatment

On extrusion coating and laminating lines it is also possible to improve adhesion, and increase the speed at the same time, by additionally applying ozone treatment for oxidation of the plastic melt. Ozone, an intensive oxidizing agent, is produced in an ozone plant at a rate of up to 1000g/hour and blown with dry air at the extruder die on to the plastic melt which then oxidizes and increases its adhesive property on the ozone treated side.

The SORBEX ozone plants produced by SOFTAL in Germany and Japan are used extensively for LDPE coating and laminating and have also been in use for several years for LLDPE coating.

Applying ozone treatment, it is possible to keep the melt temperature of the plastic below 300 °C with the same laminating strength. The oxidation of the plastic, otherwise produced by the high melt temperature, of up to 320 °C and more, is caused solely by the ozone and only on the coating side. This means that a laminate produced in this way has no sealing problems, since the exterior has less oxidation because of the low melt temperature. The advantage, especially for the production of foodstuff packing, is that the effect on taste and smell, also caused by oxidation at high melt temperature, is greatly reduced.

The ozone treatment is mainly used for LDPE coating on paper, board and aluminium, for example for milk packaging. In this case a dry bond strength of 400 g more per 15 mm on aluminium as well as fibre tear adhesion on paper and board can be achieved.

Additionally it should be mentioned that the coating thickness also has an influence on the bonding strength. With thicker LDPE coating, higher bonding strength is achieved.

For some years now, particularly in Japan, ozone plants have been in use for the production of flexible laminates with LLDPE coatings. These laminates can be produced much more economically on extrusion coating machines than on dry laminating machines requiring more energy. Several manufactures of raw materials, have developed special types of LLDPE for this purpose and are promoting the use of ozone plants.

LLDPE is mixed together with LDPE and coated on an anchor coated film, often polyamide and polyester, at a temperature of 290 °C, treated before with ozone. The composite produced in this way is in no way inferior to laminates produced in dry laminating machines with regard to laminating strength, sealing strength and hot tack.

Other applications

Apart from the applications described before, there are a number of other applications, such as cup printing combined with hole detector, coating machines for webs and sheets, cable printing, label printing, folding box machines and other special areas which will not be covered in this document.

Measuring surface tension

There are two main methods of measuring surface tension in the plastics processing industry, wetting angle measurement and test ink measurement.

The wetting angle measurement method is mainly used in laboratories, but the test ink method is one that is applied in practice and is common in the factory, at the machine.

In wetting angle measurement, a defined drop of water is applied to the surface of the material to be measured. There are different kinds of measuring equipment on the market and so the wetting angle of the water drop to the surface of the material is defined in different ways. The smaller the wetting angle, the higher the surface tension and vice versa. An untreated PE for example has a wetting angle of 90°.

Measuring surface tension with test inks is done in mN/m, although the traditional dyn/cm designation is still more common. There are different methods of measuring, but the results are the same for identical materials. One method applied, and not only in Europe, is the DIN 53 364 method according to the German standard for measuring polyethylene and polypropylene surfaces. This method is used in practice for other plastics also. Another measuring method is the American ASTM method which is similar to the German DIN 53364.

The DIN 53 364 test method consists of wetting the surface of plastic films with a liquid. The test ink is applied thinly in stripes. The edges of these stripes must remain intact for approximately 2 seconds. If this is the case, the surface tension of the film corresponds exactly to the surface tension of the ink. If the edges of the liquid contract within 2 seconds of application, the surface tension of the material is lower than that of the ink and the test must be repeated using ink with a lower surface tension. If the edges of the liquid remain intact for longer than 2 seconds the test is to be repeated using ink with a higher surface tension until the time of 2 seconds is obtained. Brushes for the different test inks must be kept apart.

The test ink bottles must be kept tightly closed and stored in a cool place as far as possible. The inks should be discarded and replaced after not more than 3 months, because, if they are in constant use, water builds up in the liquid and particles from the material surface adhere to the brush after repeated testing, mix with the ink and change its composition.

Unfortunately, in many companies there is still too little attention paid to handling, storing and replacing the test inks. This leads to unnecessary loss due to production waste or even customer complaints later.

Test inks are available in surface tension ranges from 30 - 56 dyn/cm and as dyed distilled water of 72 dyn/cm.

A simple method of ink test measurement is with a felt-tip pen. This method should only be used for surface tension of 38 dyn/cm for rapid results on the production line, for example to determine which side of a film has been treated. Felt-tip pens are absolutely unsuitable for accurate measurements.

Measurements of corona treated paper is only possible within a limited range as the liquid is immediately absorbed by the paper or board. However, it is possible to measure the effect by measuring the period of absorption of a defined liquid drop. A treated material will absorb the liquid much quicker.

Essential features of corona equipment

Easy operation, maintenance and reliability are the main criteria today for selecting corona equipment. One important aspect of high-tech machines with expensive downtimes is that the user can not accept failures caused by additional equipment. The first principle for the manufacturer of this equipment must be to face up to these conditions and use every technical means available to pursue without compromises the aim of maximum operation reliability, easy maintenance and simple handling.

For this purpose the generators must be short-circuit-proof and must include practical functions and control features such as adjustable alarm system, fault indicator, power display, automatic generator tuning and infinitely variable output regulator.

It must be possible to install the equipment easily and within a short period of time. This means that the equipment is delivered ready for installation with screened cables for power transmission between the generator and the station without complicated cable laying. Output transformers should be already mounted and connected to the corona station at the manufacturer so that high-tension cables are as short as possible and complex installation at the place of assembly is not necessary.

The corona stations should be made of rust-proof materials such as aluminium, stainless steel, ceramic or high quality plastic, like all SOFTAL standard stations. Safety features such as zero-speed switch, ozone extraction control and safety switches to control the electrode position are just as essential as the setting of the electrode gap during operation and the expansion possibility for electrodes on heating to prevent deformation. All installation components of the station must be easily accessible for cleaning in order to prevent surface leakage current and short-circuits. The major insulation components of the SOFTAL corona stations are made of arc-resistant ceramic.

Dielectric

Finally let us mention briefly the most sensitive module in the corona system, the backing roller dielectric.

Although the dielectric is a necessary wearing part of the corona station and subject to frequent replacement and repair, this can be influenced by the selection of the dielectric material and its care. There is a choice mainly between two materials, ceramic and silicone.

According to the state of the art, ceramic is the best material available as it is unbeatable with regard to temperature resistance, high-voltage strength and wear resistance. One disadvantage however is the investment cost. Therefore the application must be considered as to whether the added costs of ceramic coating can be justified by saving expensive machine downtimes.

The most commonly used dielectric is silicone rubber which has been developed so far that today it can have a service life of 6-12 months and more, if it is well looked after.

Silicone is available as a coating or also in the form of sleeves for various roller sizes. In particular, sleeves for roller sizes with a diameter of 100 - 200 mm are inexpensive and easy to handle. Small defects can be repaired in minutes with moisture interlacing silicone rubber.

Outlook

In the future the aim of further development of corona technology will be to optimise the generator technology and the electrode systems and in this way to increase the efficiency of the equipment. Users, machine manufacturers, and the manufacturers of raw materials can make an important contribution by presenting their practical experiences, ideas and requests to the manufacturers of corona equipment so that also this may be included in future developments.

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