SPRAY COATING – A CONTACTLESS COATING PROCESS FOR PAPER FINISHING

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Summary

The coating of surfaces is done by atomization in a lot of technical processes (e.g., painting). Spray coating has many different advantages: The coating is carried out contactless, and a contour coat can be applied to uneven surfaces. With a spray a tear sensitive web material can be coated; low coating weights are possible at high web velocities.

The challenge of coating a web homogenously over its entire surface with a spray is discussed. Three relevant atomizers are introduced; their mode of operation and their properties are explained. Different paper grades were spray-coated using different processes. The resulting characteristics and qualities were measured and compared to standard coated paper.

Introduction

The objective in atomization processes is the disintegration of a liquid volume into discrete droplets of a desired diameter. The most relevant technical applications of atomization are:

1. The atomization of fuel (e.g. fuel injection)
2. The production of particles (e.g. spray drying)
3. Heat and mass transfer operations (e.g. cooling towers and extraction columns)
4. The coating of surfaces (e.g. painting)

For a good result it is necessary to choose the right atomizer.

Benefits of Contactless Coating

Spray coating is a contactless coating process. The topography of the substrate has no influence on the coating weight. On uneven surfaces a contour coat can be applied; a closed film can be achieved with a decreased amount of liquid. This could result in a reduction of costs and an improvement of quality. The lack of a metering coating gap leads to a decreased sensitivity for coating defects and a reduction of web breaks - even for very low coating weights.

Process Steps

The objective of spray coating is the homogenous, holohedral coating of a web. The separate process steps outline the challenges of the whole process.

For the atomization of the liquid a suitable atomizer is needed. There are two relevant mechanisms of drop formation:

a) Disintegration of liquid lamella
b) Disintegration of liquid jets

To achieve a uniform coating weight distribution, a flat spray fan is the best solution. The single nozzles have to be positioned at the right distance apart from each other. The single spray fans, however, have to be overlapping to achieve a uniform coating weight distribution over the total web width.

Due to their velocity the drops are released from the atomizer onto the substrate. To reduce overspray, the drops should be aerodynamically or electro statically guided to the web surface.

\[
\sigma_{s,g} = \sigma_{liq,g} \cos \Theta + \sigma_{s,liq}
\]

\[\begin{align*}
\Theta &= 0^\circ \quad \text{total wetting} \\
\Theta &< 90^\circ \quad \text{partial wetting} \\
\Theta &> 90^\circ \quad \text{no wetting}
\end{align*}\]

\[\lambda = \frac{\sigma_{liq,g}}{\sigma_{s,g}}\]

\[\lambda \geq 1 \quad \text{total wetting} \\
\lambda < 1 \quad \text{partial wetting} \\
\lambda = 0 \quad \text{no wetting}
\]

**Figure 1.** Contact Angle, Young’s Relation

The wetting of the web surface is the next challenging process step. To characterize wetting, the three phase contact angle needs to be considered. The contact angle results from the energy (the interfacial tension) of the three boundary layers, described by Young’s relation [1] (see Figure 1). The desired film formation has to be completed by coalescence of the drops, before the drying of the liquid starts.

**Tested Atomizers**

Three different spray coating systems with three different types of atomizers were proved.

**Figure 2.** Rotary Disc Atomizer, Pneumatic Atomizer, Pressure Nozzle [2]

A coating system based on rotary disc atomizers was tested. In this atomizer a continual stream of liquid is placed on the middle of a rotating disc. The liquid is accelerated by the centrifugal force. At the edge of the rotating disc a liquid lamella or many liquid jets are generated. The size of the arising droplets is uniformly distributed. A variation of the flow rate is possible as the operation window is relatively wide.
This kind of atomizer is only suitable for low viscous liquids (with water like viscosity). A disadvantage of this coating system is the inner circulation of more than 80% of the liquid with air contact. The coating of chemicals often leads to foam formation, a change in the liquid composition and to deposits inside the coating system.

A second coating system based on pneumatic atomizers was tested. In this atomizer the liquid is dispersed by a high velocity gas phase. The disintegration of the liquid phase is caused by the kinetic energy of the gas. Pneumatic atomizers generate relatively small droplets. This kind of atomizer is also suitable for liquids with a higher viscosity. On the one hand this system has many degrees of freedom, for example the nozzles and the pressures of the gaseous and the liquid phase. On the other hand a controller is necessary for this complex system. A disadvantage of this coating system is the intensive contact with the atomizer gas. This could lead to the drying of liquid directly at the nozzle orifice, when chemicals are coated. A change in the spray pattern caused by bearding or the plugging of nozzles was observed as a result.

A third coating system based on pressure nozzles was tested. In this atomizer a pressurized liquid flows through a small orifice. The liquid pressure is converted into kinetic energy and surface energy. The geometry of the nozzle defines the efficiency of the conversion. The optimal operating window is very small. A significant increase of the flow rate is only possible via the activation of further parallel nozzles. Pressure nozzles generate droplets with high velocities. This kind of atomizer is suitable for liquids with low and medium viscosities. The coating system is relatively simple. The atomization of a liquid is influenced by the liquid pressure and the nozzle diameter. The final coating weight is also a result of the web velocity.

The coating of chemicals with pressure nozzles was tested in a spray coating device in pilot scale.

**Coating Trials in Pilot Scale**

A complete spray coating system was tested on the impregnation of crepe paper in pilot scale. The holohedral spray coating of both web sides is possible in one operation with this device. Two crepe papers, which are used as a backing in adhesive tapes for masking applications, were impregnated. The coating weight was adjusted in accordance to the liquid properties at a given web velocity by modification of the liquid pressure and the nozzle diameter. The web width was more than 500 mm wide. This coating device has a lot of features to manage the challenges of the spray coating process. No bonded deposits were observed in the spray chamber. No droplets leaked out of the device.

**Paper Impregnation Quality**

To evaluate the effect of the spray coating, the quality of the spray impregnated paper was analyzed and compared to a standard impregnated paper, from the company tesa.

To judge the mechanical stability of the paper the maximum tensile force and the elongation at break were measured. The mechanical stability in wet and dry conditions is equivalent to standard impregnated paper. No difference in paper thickness was measured.
The analysis using a scanning electron microscope showed no differences between the standard and the spray impregnated papers: the paper fibers and also the fiber cross points are surrounded with impregnation. The impregnation fluid permeated completely through the paper. The relevant force for the mass transfer inside the paper seems to be the capillary force. Holes are visible in the coating on the surface of the paper in both cases.

The air permeability of the spray coated paper is considerably higher.

In conclusion, the spray impregnated papers meet the specified requirements from the company tesa.

**Product Quality**

The impregnated papers were converted to rolls of adhesive tape, to be precise tesa masking tape, and the product quality was checked. There was no measurable difference between spray and standard impregnation observed. All measured results were clearly within the specifications. The application tests showed comparable results to our standard products. In these tests no difference in impregnation quality could be found.

**References**


TECH 31 Technical Seminar Speaker

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Niels Czerwonatis, Ph.D., is a technology manager responsible for new technologies at tesa AG in Hamburg, Germany, a position he has held for three years. Prior to that, he was a tesa AG process engineer. Czerwonatis received his master’s degree in chemical and process engineering and his Ph.D. in thermal process engineering, heat and mass transfer, both at Technical University Hamburg-Harburg in Germany. His Ph.D. thesis was titled “Disintegration of Liquid Jets and Drop Drag in Pressurized Gases Using the Example of the High Pressure Spray Extraction Process.”