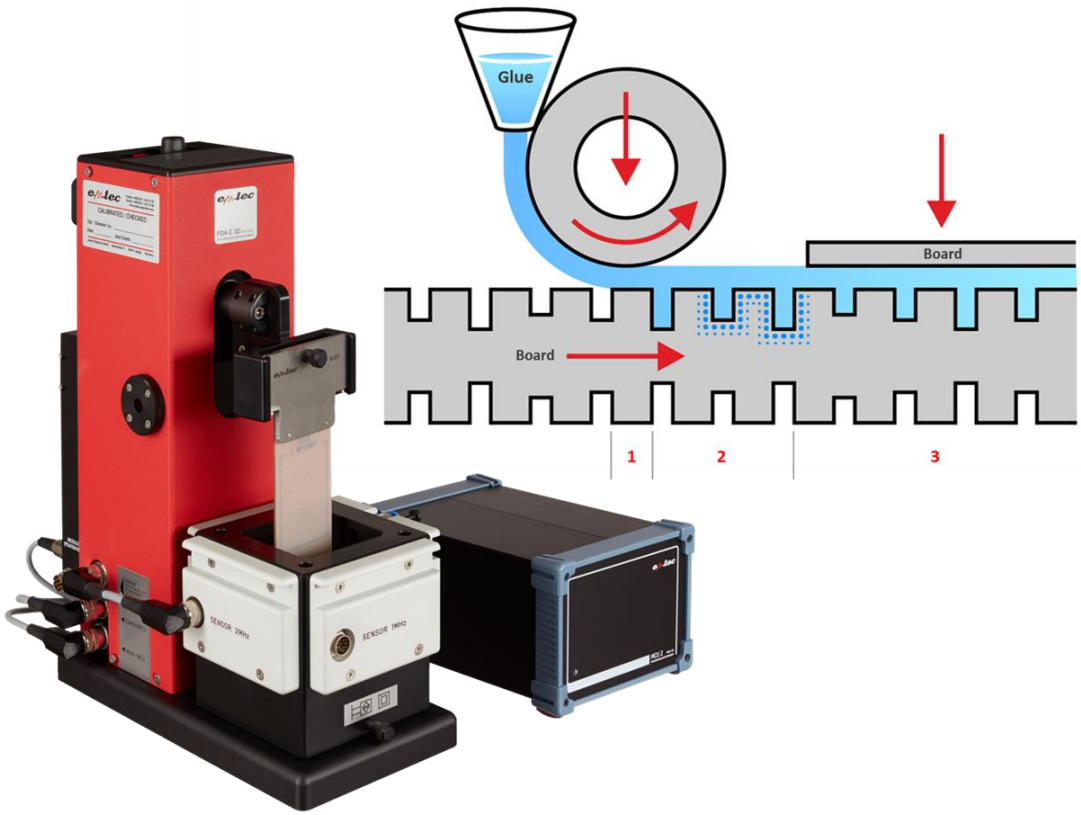


emtec PDA Penetration Dynamics Analyzer

Module Standard (MST)

Cost and material saving by measurement of converting process-relevant surface parameters of paper and board with an innovative measuring system to predict the gluability, printability and coatingabilty.

by Dipl.-Phys. Giselher Grüner (emtec General Manager)

Agenda

1. General Statement
2. What are the main problems in converting processes of paper and board?
3. What can be the reasons for problems in converting processes

   3.1 Gluing Process

   3.2 Coating Process

   3.3 Sheet Offset Printing Process
4. Application of the PDA to characterize CaCO3 coated paper
5. Why can Standard Porosimeter and Cobb Tester not help to solve the problems?
6. Why can the PDA help to solve converting problems?
7. Application areas
8. Application example

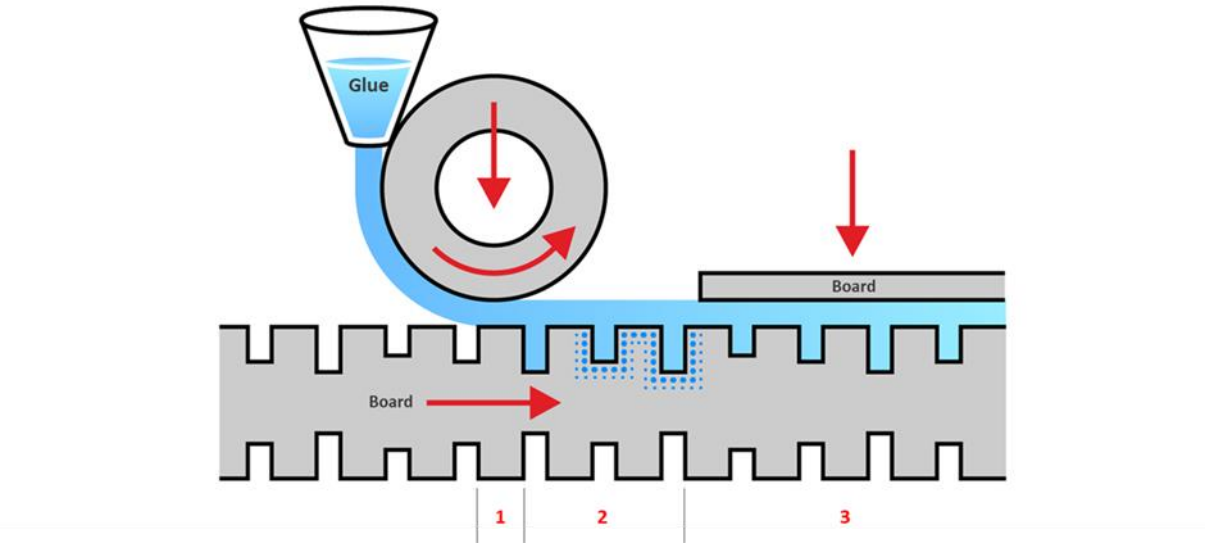
General statement

Paper and board are usually produced for a converting process (coating, printing, production of corrugated board, folded boxes) respectively used by the end customer. Each produced paper/board is finished and/or converted further in one or the other way to assure the required final quality. This is done, for instance, in the coating machine, the printing machine or in a gluing machine during production of corrugated board/packaging material. A certain specification of the paper/board is required to achieve an optimum run-ability during finishing or converting processes and by that an optimal result. Usually, these specifications are based on standard measurement methods (like Cobb test, Hercules Sizing Test HST, Bendtsen porosimeter, Gurley porosimeter, Smoothness Beck). Usually, the produced paper and board meets these standard specifications. However, often processing problems occur, but nobody knows the reasons. A frequently occurring problem is that standard measurement devices do not characterize the substantial converting relevant paper parameters. For solving this problem one should know what to measure for being able to predict processing problems reliably. For that, the process has to be analyzed and understood. What happens during main converting processes? With rough models on the following pages, we try to identify and specify the basic processes and the relevant phases, which determine the final quality.

What are the main problems in converting processes of paper and board?

The three main converting process in the paper and board production

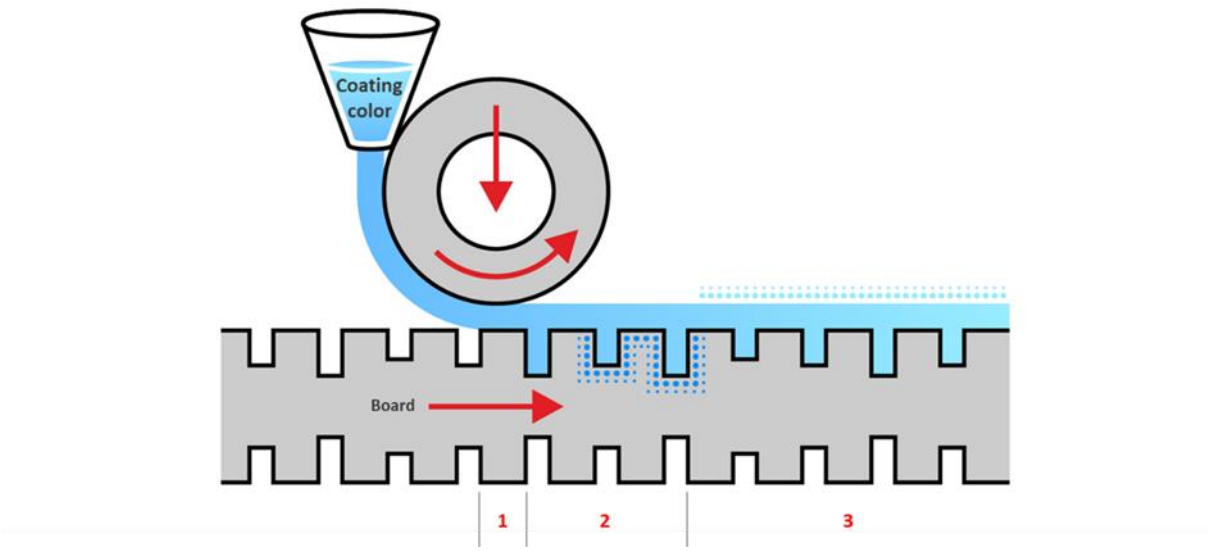
The gluing process



Schematic representation of the bonding process/application of adhesive onto paper/board surfaces

The gluing process can be split into three phases. In phase no. I, the pressure impulse controls the glue penetration into the paper/board surface affected by the surface pore structure and liquid rheology. In phase II, the applied glue film dewaters, controlled by the surface sizing / hydrophobia, which leads to an increasing viscosity and water retention of the glue. Phase III is characterized by the drying and fixing of the glue layer by further penetration/ evaporation/hardening reaction.

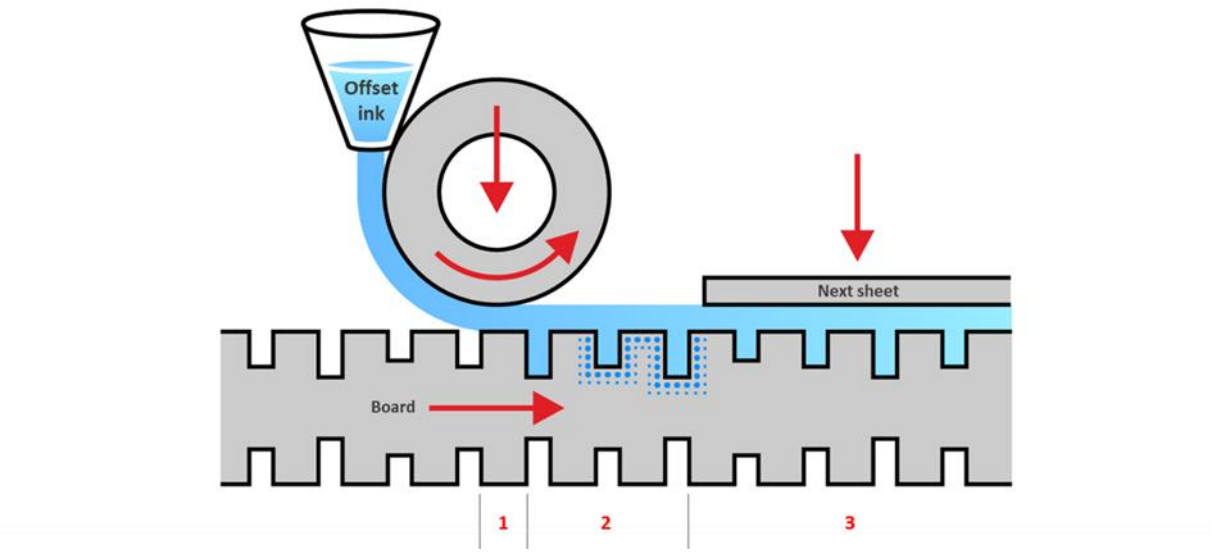
The coating process



Schematic representation of the coating process/application of coating color onto paper/board surfaces.

The coating process can be split into three phases. In phase no. I, the pressure impulse controls the coating color penetration into the paper/board surface affected by the surface pore structure and liquid rheology. In phase II, the applied coating color layer, controlled by the surface sizing / hydrophobia, which leads to an increased solid content/immobilization and water retention of the coating color. Phase III can be characterized by the drying of the coating layer by further penetration/evaporation.

Sheet offset printing process



Schematic representation of the sheet offset printing process/application of offset ink onto paper/board surfaces.

The printing process can be split into three phases. In phase no. I, the pressure impulse controls the ink/fountain solution penetration into the paper/board surface affected by the surface pore structure and liquid rheology. In phase II, the mineral oil/fountain solution is transported from the applied ink, ink emulsion, fountain solution layer, which is controlled by the surface pore structure and partly surface sizing/hydrophobia. This leads to an increased viscosity/fixing of the ink film and/or reject of fountain solution from the surface. Phase III is characterized by the drying and final fixing of the ink layer by hardening reaction (drying or ink oxidation).

In-depth information phase I to III

In Phase I a liquid (adhesive, coating color, printing ink/fountain solution) is applied to the surface of a paper/board. In the offset printing process, the paper surface can be already wetted with fountain solution from the previous printing press! During that, parts of the applied liquid are pushed more or less deeply into the surface due to the arising extremely short (milliseconds or even microseconds!) pressure pulse. The penetration depth depends exclusively on the pressure pulse value (configuration of the application unit, machine speed), the surface porosity of the paper/board as well as the rheological characteristics of the applied liquid.

In Phase II, water (or ink/fountain solution from the emulsion in offset printing process) is transferred from the applied layer into the deeper lying surface areas of the paper/board (within milliseconds or seconds). This increases the viscosity within the liquid layer. This increase of viscosity makes sure that, after leaving the bonding machine, the counterparts bond immediately and the bonded parts do not come loose (in sheet offset process it avoids

"ink set off"). This process is only dependent on surface sizing/hydrophobia, if water-based liquids are used.

In Phase III (minutes or hours, in coating process seconds), the liquid dries or will be hardened by oxidation (sheet offset). During the bonding process this signifies the final fixation of the bonded parts.

This signifies: due to the process specifications virtually only the surface parameters are important for converting (gluing, printing, coating). This means especially surface porosity and surface hydrophobia/sizing.

Source of issues in the converting process

- non-optimal surface porosity, caused for example by too much or too less starch application in the size press or fiber quality/refining
- non-optimal surface sizing, caused for example by too much or too less hydrophobic agent the size press

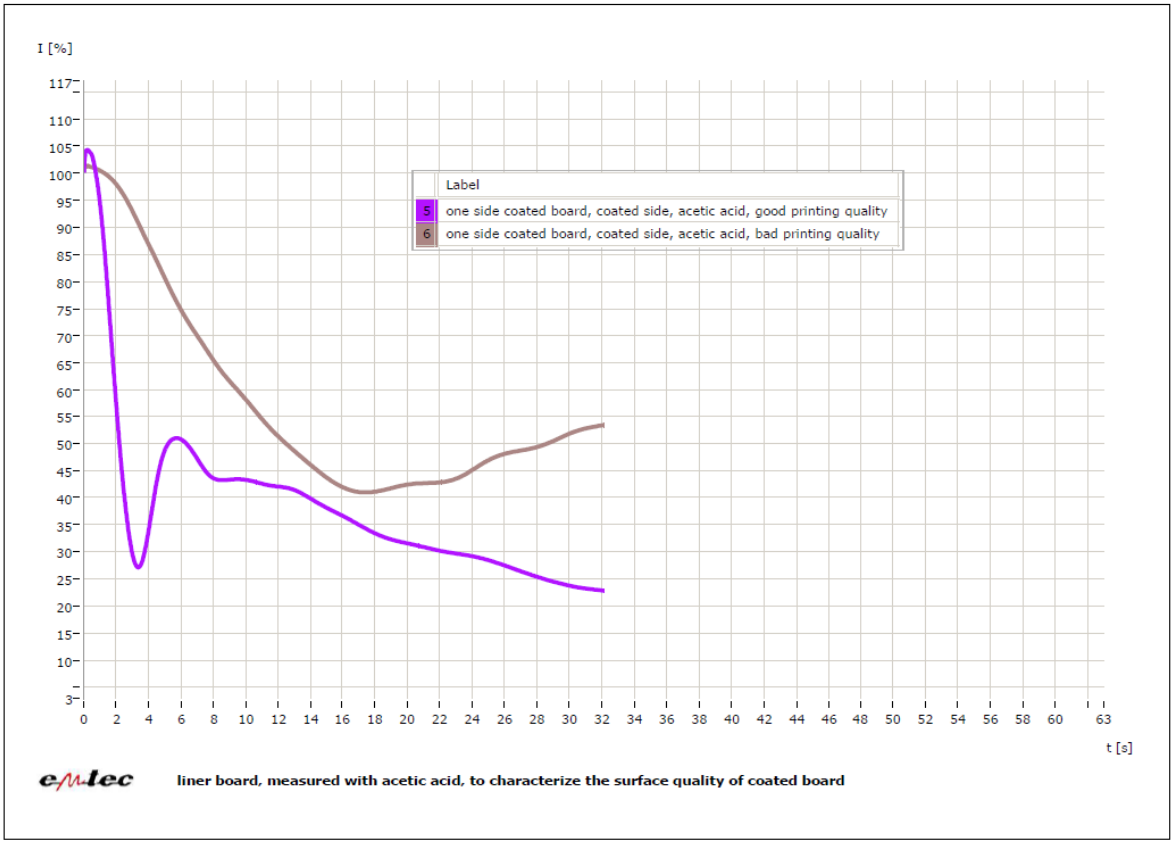
Application of the PDA to characterize CaCO3 coated paper

In the printing process, paper can show a dusting tendency. This means, the filler particles are not sufficiently fixed/covered by binder and can be rejected from the surface by the ink. The binder concentration has also an impact to the surface porosity and therefore to the ink/oil absorption. An easy and efficient but very informative method to determine the surface porosity of calcium carbonate coated paper is the following: using acetic acid as a testing liquid, the acid will dissolve the calcium carbonate particles and generate CO2 gas bubbles. The generation speed of the air bubbles is a measure for the degree of "protection"/covering/fixing of the pigments in the surface structure. The ultrasound transmission is very much affected by gas bubbles in the testing liquid. This means:

- fast reaction between pigments and acid will result in fast CO2 bubble generation and fast decreasing of the transmission (by scattering of ultrasound on the bubbles), and this in turn means lower binder concentration on the surface
- slow reaction/CO2 bubble generation will result in a slow decreasing of transmission, which means high binder concentration

By using the PDA with acetic acid as a testing liquid it is possible to predict the dusting tendency and printability of calcium carbonate coated paper and board.

Note: this is not an absolute method. It can only be used, when the compared samples have a similar coating formulation (ratio/percentage of CaCO3 and Clay).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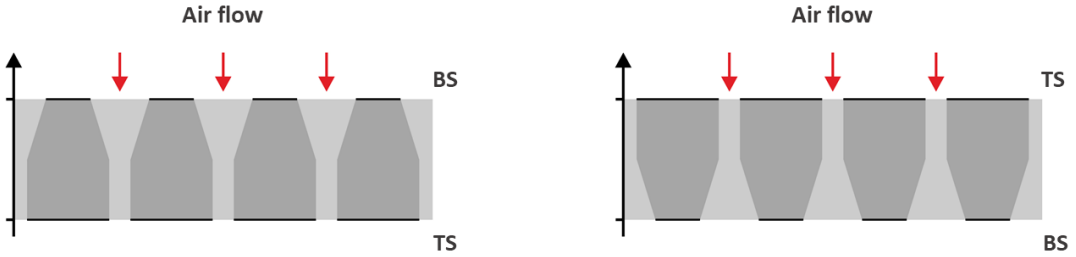
Label
5 one side coated board, coated side, acetic acid, good printing quality
6 one side coated board, coated side, acetic acid, bad printing quality
liner board, measured with acetic acid, to characterize the surface quality of coated board

Why can Standard Porosimeter and Cobb Tester not help to solve the problems?

Why does a standard porosity meter test (Bendtsen porosimeter ISO 5636-3, Gurley porosimeter, Mercury porosimeter) often provide not enough information to predict the behavior of paper/board in the converting process but sometimes even totally wrong information? The below schematic examples show the reason:

Bendtsen porosimeter test

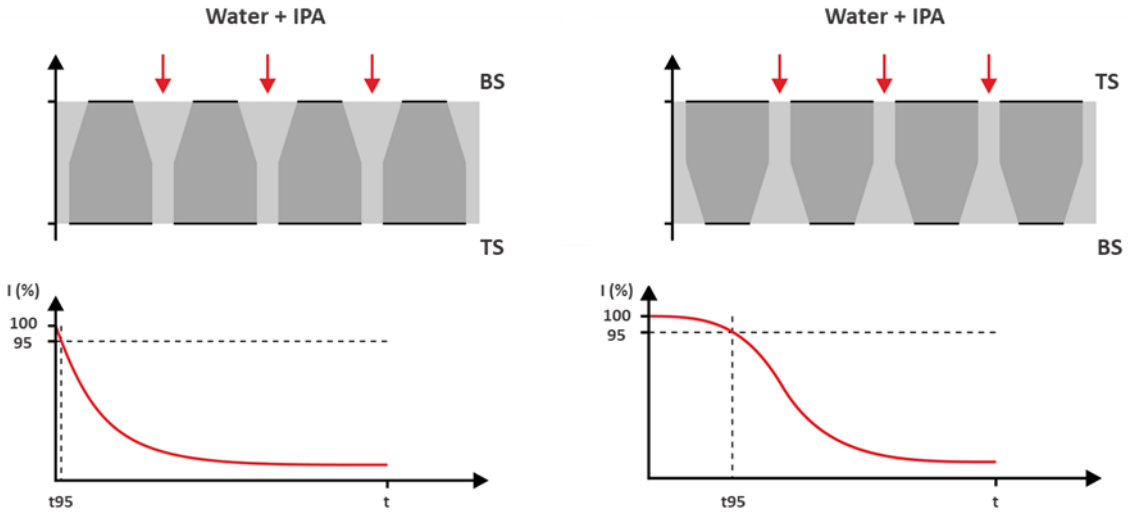


Bendtsen results (BS) = Bendtsen results (TS), this indicates that the surface pore structure of the top side is equal to the surface pore structure on the backside, **this is incorrect!**

Schematic representation of the pore structure distribution of a paper sample in z direction (cross section) and the air flow from Bendtsen porosimeter test, tested both from top side and wire side (example)

The air flow through the paper in z direction is controlled by the sum of the smallest pore diameters. But: because of the two-sidedness and the inhomogeneity of the paper the pore structure/size on one side of the paper can be totally different from the other side, or on the surface it can be different from the internal part! The standard methods do not show this. PDA measurement with water + Isopropyl alcohol can provide information about the real pore structure on the surface of the paper/board:

PDA test

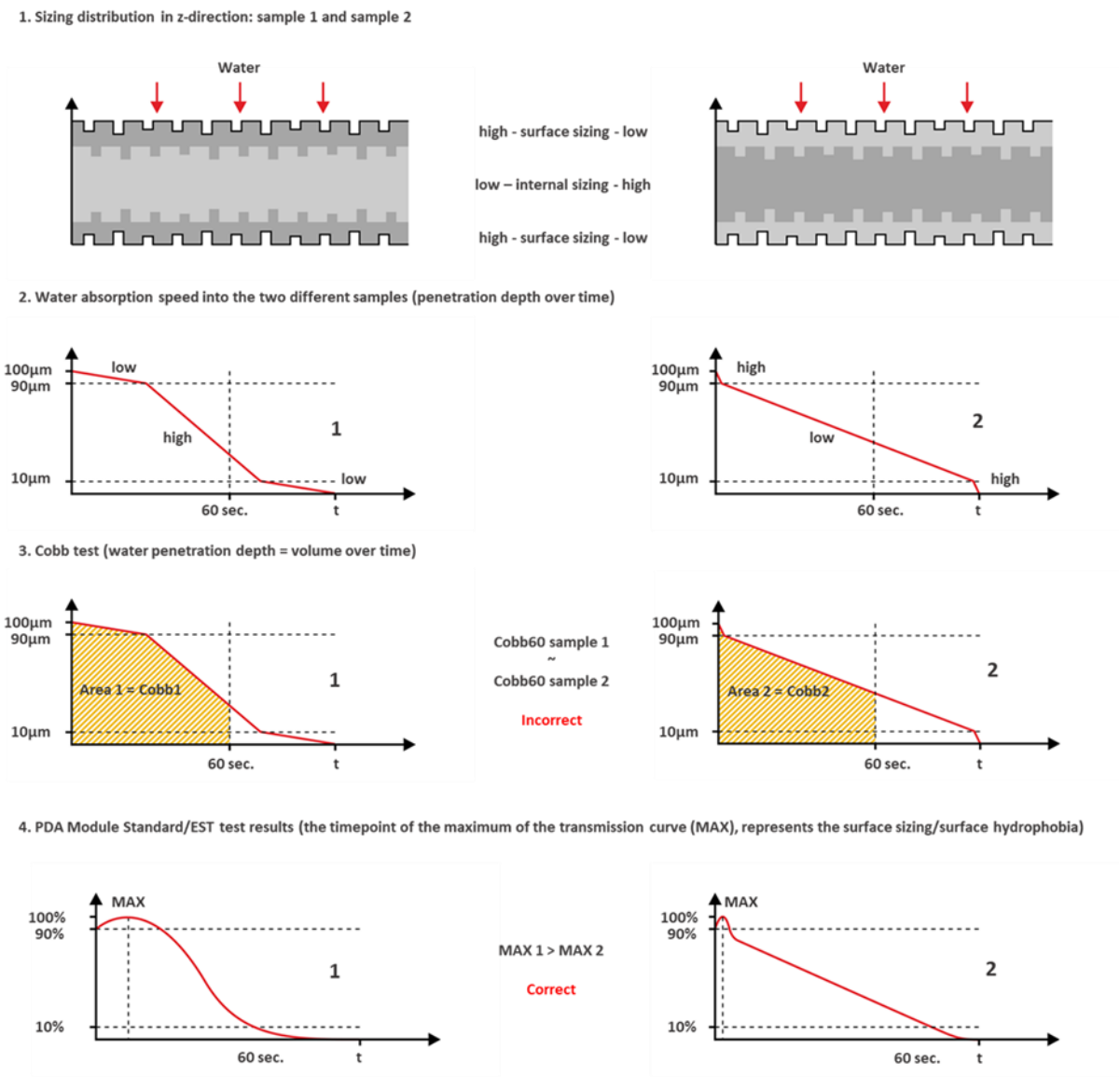


Schematic representation of the characterization of the surface pore structure with the PDA, using water + IPA mixture as a testing liquid

Cobb test

Why does the COBB test (ISO 535:1991(E)) often provide not enough information to predict the behavior of paper/board in the converting process but sometimes even totally wrong information?

The below schematic examples show the reason:



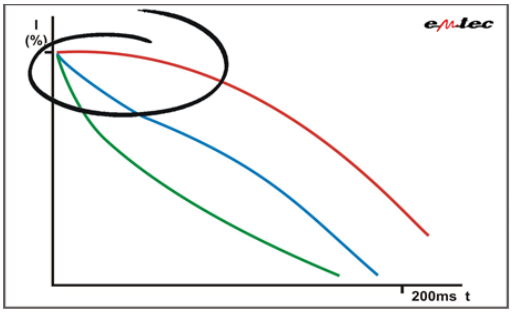
Why you cannot get this information with the Cobb test? The Cobb test gives an average indication about the surface sizing plus internal sizing. No information about surface pore structure or/and surface sizing is possible (the same or even worse with HST test because of the acetic testing ink reaction with CaCO3 filler and long-term measurement).

Why can the PDA help to solve converting problems?

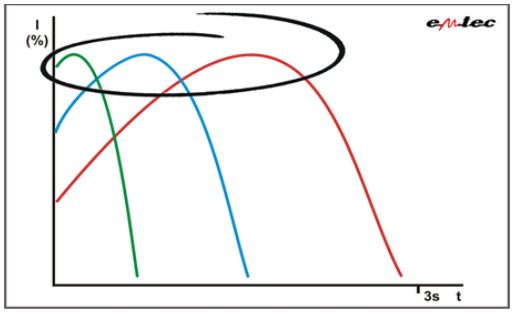
The PDA enables measurement of process relevant surface parameters of paper and board in the laboratory in an extremely easy and efficient manner, using an innovative measuring principle: assessment of the dynamics of ultrasound transparency of paper/board, when contacted with appropriate testing liquids, evaluation of the very first milliseconds or seconds after the initial contact.

Summary

1. Measurement of the interaction between test liquid and sample surface during the first milliseconds (surface porosity) resp. seconds (surface hydrophobia/sizing) after contact:



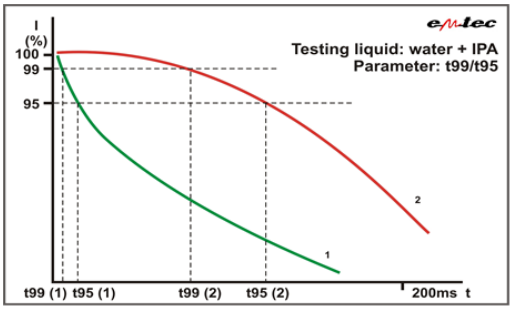
Surface porosity



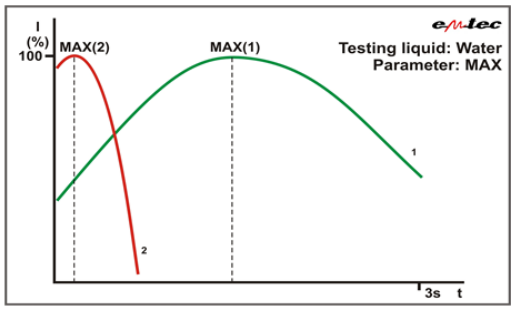
Surface hydrophobia/sizing

2. Use of appropriate test liquids to gain the desired information

   » mixture of water + isopropyl alcohol – characterizes the effective surface porosity as penetration behavior of the liquid is exclusively determined by the pore structure
   » water – characterizes the surface hydrophobia/sizing as the water penetration is exclusively determined by the sizing



Testing liquid "water + IPA" for surface pore structure characterization



Testing liquid water for surface hydrophobia characterization

3. Automatic calculation of the relevant quality parameters:
    - » Characterization of the surface pore structure by the time point, when the curve reaches 95% (or 99%) of the ultrasound transparency after the initial contact time point 0 (using water + IPA mixture as testing liquid)
    - » Characterization of the surface sizing by the time point of the curve maximum (using water as testing liquid)

Application areas

R&D

Process optimization, process controll

Incoming control

Quality assurance

Complaint management, trouble shooting

Application example

An exciting example shall demonstrate the astonishing capabilities of the device system: poor bonding characteristics of uncoated board.

Problem Description

- » The test of the bonding, realized by splitting by hand, does not result in the desired fiber extraction.

Problem solution

- » PDA measurement of samples of good/average/poor quality with the appropriate test liquids (water + IPA mixture, water)
- » Evaluation of measurement outcomes
- » Identification of the reason of the problem
- » Determination of required steps

Step 1, application of adhesive, relevant parameter: surface pore structure

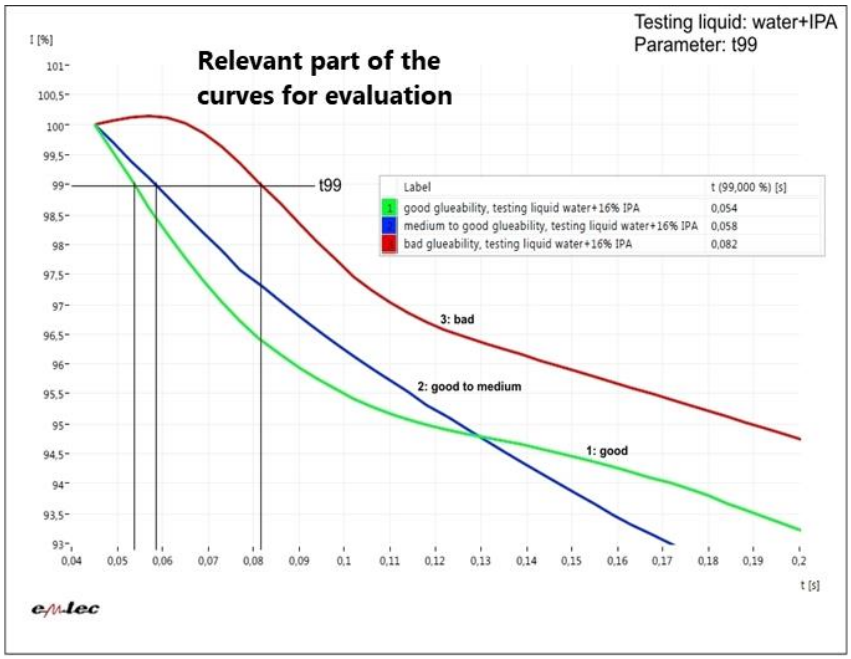


Figure 10: PDA/EST diagram with testing liquid water + IPA - perfect correlation to the gluability

Relevant quality para-meter of paper/board: surface pore structure - measured with water + IPA mixture **in the application unit**, the adhesive is applied to the board surface by a pressure pulse within microseconds. It depends on the surface pore structure how deep the adhesive is pressed into the surface during this process. Surface hydrophobia / sizing does not play any role in this phase. Under extreme magni-fication, the curves measured with the PDA with water + IPA show clear differences between the used samples for the first **70 milliseconds**. For the good-quality sample the curve immediately falls away sharply which points towards a very open surface structure. This open structure results in a good anchoring of the adhesive. For the sample of average quality, the curve falls in a more moderate way which means that the structure of this sample is a little bit more closed. The poor sample with the big bonding problems differs extremely from the other samples. The curve has the shape of a “shoulder” which is caused by a very closed surface pore structure. The reason might be a too high starch concentration at the surface or the use of starch of poor quality in the board production process.

Step 2, Dewatering of the applied adhesive layer in connection with an increase of viscosity within the layer, relevant parameter surface sizing

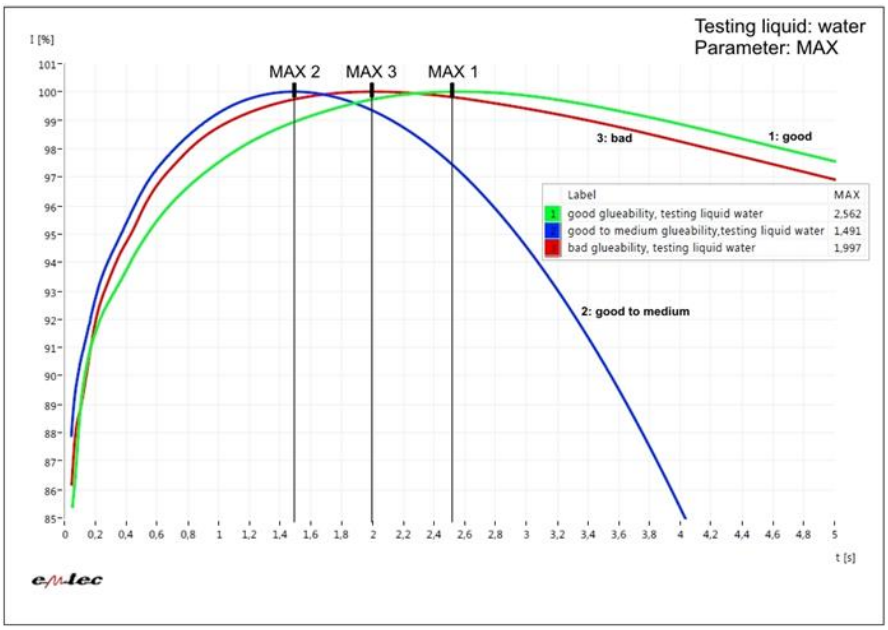


Figure 11: PDA/EST diagram with testing liquid water – no correlation to the gluability

During the milliseconds (or seconds, dependent on process speed) after leaving the adhesive application unit (some microseconds after application) the adhesive begins to dewater. This causes an increase of the viscosity of the adhesive. This results in immediate bonding of the added counterpart in phase III. This dewatering process is controlled by the surface hydrophobia of the board. The PDA determines the surface hydrophobia with water as testing liquid. The device analyses the first milliseconds resp. seconds after the initial water contact.

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