



A MODERN ON-LINE POROSITY ANALYZER FOR PAPER AND BOARD MACHINES

Heikki Mustalahti*, Jaakko Rintamaki*, Urpo Launonen **

*ACA Systems Oy, Sotkuma, Polvijärvi, Finland

** UJL Pty Ltd, 59 Bellevue Avenue, Doncaster East, Australia

ABSTRACT

The on-line porosity analyzers have in recent years, become a practical tool for papermakers to maximize paper quality and production profitability. The best on-line porosity analyzers have been developed to a new standard of measurement accuracy, speed and reliability to satisfy the requirements of on-line sensor technology.

The PERMI, being a fast and reliable on-line porosity analyzer from ACA Systems Oy, helps papermakers to rapidly adjust all grades to specification and carry out fast paper grade changes. The monitoring of several paper grades can accurately and reliably be measured with only one single calibration. The very fast machine direction measurement enables a new kind of control of paper and paperboard processes.

The effects of process adjustments can be monitored immediately after changes because it is not necessary to wait for laboratory results. Responses to test runs can be confirmed directly. In addition, the on-line analyzer measures the process 24 hours every day and 7 days a week and actual readings can be graphed and backed up for long periods.

Paper quality variations in the machine direction can be reduced with greater ease when a fast real paper quality measurement is available. It is easier to track the root causes of faster variations (recipes, dosing of chemicals, screen cleanings, variation in deaerator vacuum and air content etc.) Naturally, this leads to better paper uniformity, not only in porosity but also in most of the other important quality characteristics.

The refining of chemical pulp as well as the post-refining of mechanical pulp can be optimized for each paper grade in spite of quality changes in the incoming pulp. The process automation system (DCS) can be equipped with a closed loop control circuit to maintain the required porosity level. The potential to save energy and increase production is remarkable and the uniformity of paper quality improves noticeably.

The dosing of paper chemicals (fixatives, retention aids, and defoamers) can be monitored and optimized so that a good combination of retention, formation and drainage, as well as better runnability on the machine, can be achieved. Overdosing and the costs of the chemicals can be reduced without any risks to the process operation.

The vacuum levels in the wire section (foils, vacuum rolls, vacuum boxes) can be quickly adjusted in the grade changes and therefore a good formation and dewatering with lower energy costs can be achieved.

When monitoring the operation and usability of paper machine wires and felts, the annual costs of machine clothing can be decreased. The operation of test wires and felts can be quickly observed and therefore the development time of clothing is shorter.

The draw difference between the press and drying sections can be minimized with the help of the PERMI. Depending on the paper grade, the final porosity may considerably increase when the draw difference grows.

This paper presents the key features of the modern on-line porosity analyzer and the real on-line porosity measurement results from some European paper machines.

INTRODUCTION

Porosity of paper can be defined as follows:

$$\text{Porosity} = (\text{open space volume})/(\text{total volume}).$$

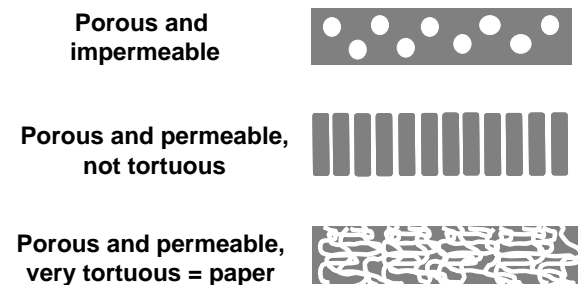


Figure 1. Porosity, permeability and tortuosity.

In the following presentation porosity will be understood to be the same as air permeability (permeance), which is the measured flow of air through the paper sheet with a specified pressure and measurement area. Common dimension is $\mu\text{m}^3/\text{Pa s}$.



Porosity grows when the value of this dimension increases.

Some well-known laboratory porosity measurements and devices are: Bendtsen, Sheffield, Parker Print Surf (PPS) and Borgwaldt (ml/min).

Other types of instruments, called densometers, measure the time needed from a standard volume of air to flow through a standard area of paper with a certain pressure. Here the measured value increases with air resistance i.e. higher number means lower porosity. Some well-known measurements and devices are: Gurley, Bekk, Oken and Coresta (s).

CONVENTIONAL DESIGNS

During the last few decades, the on-line porosity gauges have become a reality in the paper and board making lines. There have been different methods and trials to get reliable and accurate porosity readings. The first generation instruments work very much like a Gurley densometer as it measures the time required for a fixed volume of air to pass through the moving web. Unlike the Gurley, these instruments are accomplished with vacuum rather than with positive pressure so that the instrument only needs to contact the sheet on one side. Air has been sucked through the paper web using bellows located a long distance away from the measuring point. This principle is good enough for the laboratory, where the measurement may take longer, but it is not well suited for on-line measurement to detect fast changes in the machine direction.

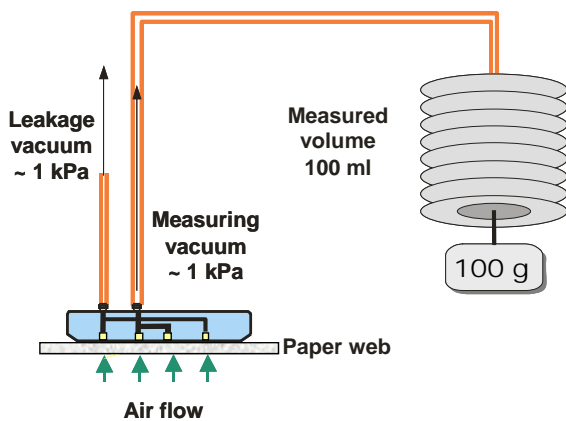


Figure 2. The basic principle of the old style porosity gauge where the flow time of air is measured.

This old fashion measurement principle has several limitations when used in the on-line gauges. An inherent limitation of the Gurley principle is, that the

measurement is not continuous, and there is a dead time, when the bellows are moving back. Secondly, all measurements having a long distance between the measuring head and air flow measurement are inaccurate due to the change of air temperature, the condensation of humidity and volume changes of piping from the measuring head to the measurement point of the air-flow rate.

PERMI – THE NEW GENERATION POROSITY ANALYZER

When the new porosity analyzer was developed, it was decided that the principle must be the same as with most modern laboratory instruments i.e. the measurement and control of pressure and the air-flow rate must be as close to the paper sheet as possible (Fig. 3). No flexible pipes like in old type Bendtsen instruments should be allowed. Other design criteria of the PERMI analyzers were reliability, accuracy, fast measuring over the complete paper grade range, automatic cleaning and a durable sensing head.

When the first trial runs with the new unique operational principle were made, it was immediately noted that Darcy's law was valid and the measured flow of air correlated linearly with the web porosity.

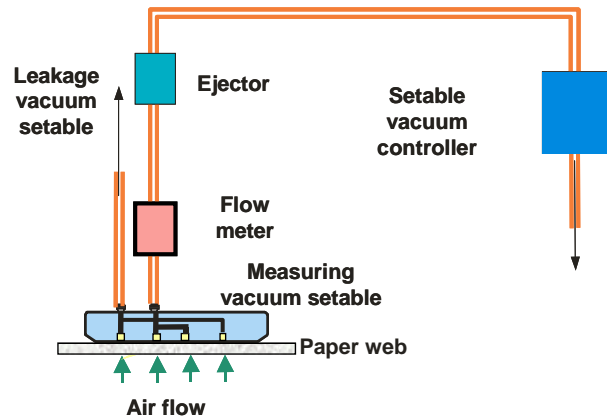


Figure 3. The principle of the PERMI analyzer is to measure the flow rate instead of time.



Figure 4. An example of sensor head with measuring slots and tightening ring for sucking of leakage air.

The sensor head (Fig. 4) has a durable and low friction coating to contact the paper web. The sensor head has an outer vacuum ring, which has separate vacuum control preventing leaks or errors caused by the air traveling with the moving web. Using the optimized sensor geometry, the PERMI can recalculate several porosity values according to different standards. This is crucial for paper machines producing many grades, which require different porosity standards. An important benefit is the grade independency. This brings the papermaker more reliable and accurate on-line readings, which help optimize machine setting, furnish mix and especially get faster grade changes with minimum broke.

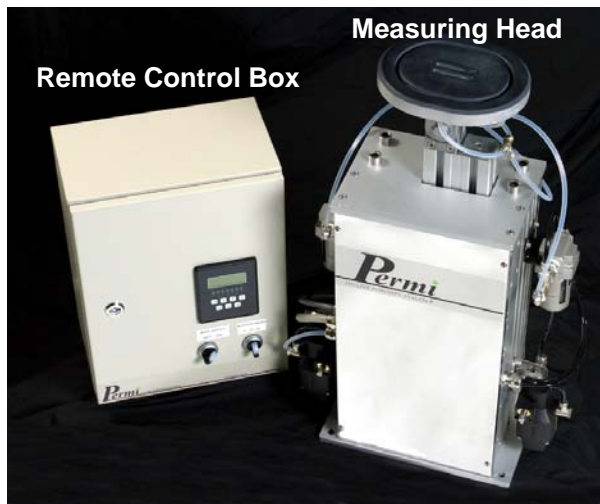


Figure 5. Remote control box and measuring head

The critical electronics are integrated to the measuring head (Fig. 5). The remote control box is only electrically linked to the measuring head.

Correlation with laboratory measurements has been excellent. In Fig. 6 is a typical comparison between PERMI measurements of the surface of machine reel compared to the laboratory measurement of the same CD position samples.

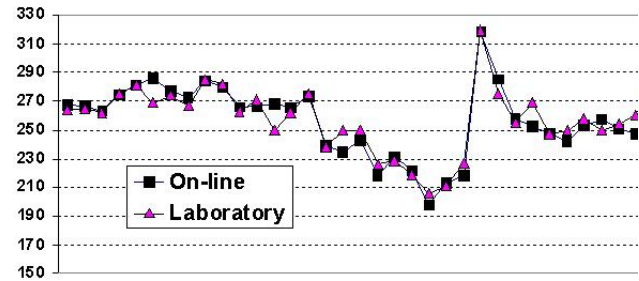


Figure 6. Correlation between the measurement readings of PERMI and laboratory is excellent.

With this new method it is possible to measure very fast variations in the machine direction and get reliable average values for the process and quality control. If needed, sampling frequency can be over 500 readings per second (if speed is 1200 m/min this is one measurement for every 40 mm in the machine direction).

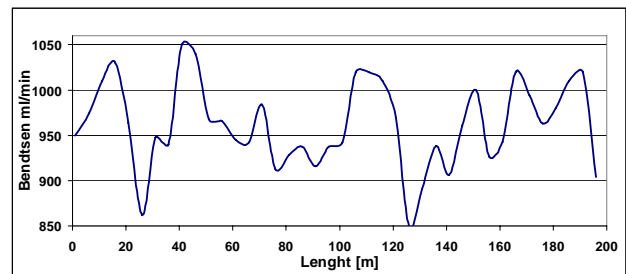


Figure 7 Example of a fast variation ($\pm 10\%$) in the machine direction

In Figure 7 a typical PERMI measurement of woodfree paper is presented. Variation of the porosity is $\pm 10\%$ during 10 s (or inside 200 m, with 20 m/s). With manual laboratory samples, taken from the top of a machine reel, the value can be 850 ml/min or

1050 ml/min or anything between those values. In this situation it is quite impossible to make some relevant corrections to the process.

ABOUT APPLICATIONS

Fibre Quality and Refining

Normally, a higher content of long and thick fibres increases porosity. Especially in wood-containing papers, a higher content of long and thick softwood chemical pulp increases porosity. Porosity also increases when fibres are stiff and have thick cell walls and lumens are not collapsed. Fibre refining and addition of wet-end starch decrease porosity and increase fibre bonding and tensile strength.

Fibre refining is normally controlled with net specific energy consumption by measuring mass flow and motor power. This would be quite a good system if the raw material (fibre) had no variation. However, in practice there can be great variations depending on the wood and fibre source and fluctuations in the pulping process. To reduce this variation, some mills have installed on-line freeness measurement and control. However, measuring freeness of one fibre component is not a measure of paper quality. In many cases it would be important to change the freeness according to the changes in other papermaking parameters like quality and content of other fibre components, broke and filler. Also some other process variables must be considered for refining like dewatering on wire, press draw, solids content after presses etc.

Old papermakers controlled refining according to couch roll vacuum. This was quite a good system, but also solids content, temperature, basis weight, roll or wire plugging etc. all have effects on the vacuum. With an accurate and fast on-line porosity measurement, it is possible to more greatly optimize the process, when the measurement is made after the drying section and where the moisture of paper is controlled.

Some paper grades, where tensile strength and porosity are the most important characteristics of quality, can gain very fast from the PERMI investment. Payback time can usually be calculated in weeks instead of months. These papers include sack papers, recycled papers, fine papers and cigarette papers.

A good example is a high porosity sack kraft paper, where the optimum window between strength and porosity is very narrow (Fig. 8).

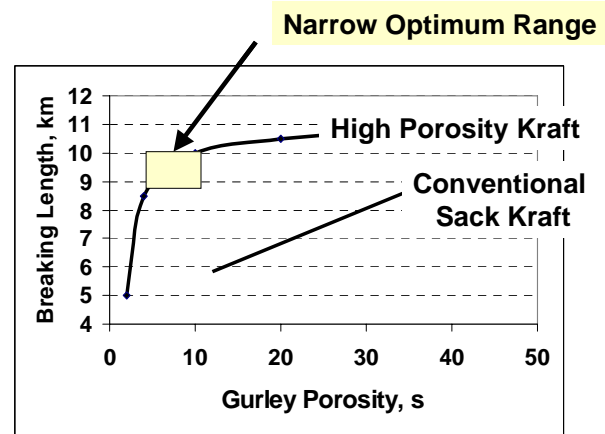


Figure 8. The optimum range of porosity is very narrow. With the on-line PERMI, it is possible to keep the paper quality inside this narrow window.

Medium term variations

Most of the paper machines have scanning measurement and control of basis weight and moisture. The problem with these systems is that they can find and correct stable cross direction variation and long-term variation in the machine direction. The most problematic range for these controls is from 10 to 100 s. If paper machine speed is 20 m/s this is from 200 m to 2000 m in the length of paper.

A single point porosity measurement with PERMI has shown the usability to detect variations in this range, which is difficult to measure in a normal paper mill laboratory. A typical variation source for this range is the approach flow. The following variation sources are most common:

- Variation in consistency control and in furnish mix
- Poor mixing of thick stock, fillers and chemicals
- Deaeration control and air problems
- Cavitation in pumps, valves and pipes
- Washing cycles in screens
- Intermittent dosing of chemicals
- Sedimentation of fines and fillers

Porosity is, unlike basis weight, also a total quality measurement. In the basis weight, only variations before press section can be seen. On the contrary, porosity shows variations also in pressing, drying, surface sizing and calendering.

Control of Wire Section

The control of vacuums and dewatering in a modern gap former can be difficult. Especially a roll and blade gap former with loadable blades can be problematic. Vacuums in the forming roll and forming boxes affect formation but also the porosity and internal bond.

Normally, a better formation originating from fibres, decreases porosity. However, when vacuums are controlled in the wire section, better formation gives a higher porosity as presented in Fig. 9.

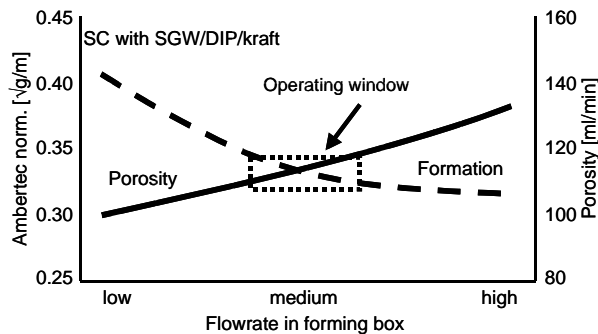


Figure 9. Too much vacuum in the forming boxes of a gap former increases porosity even if formation is better. /1/.

The PERMI porosity measurement facilitates fast adjustments in the wire section when grade, raw materials, retention or basis weight changes. Together with the new type of advanced formation measurement it is possible to decide, whether a change in porosity is originating from formation or not and what are the root causes of the formation changes.

Press Section and Porosity

The effect of the press section on porosity, bulk and internal bond is very interesting. It is well known that increased wet pressing reduces bulk and porosity and increases internal bond. However, more interesting may be the effect of press draw (speed difference) on paper properties and porosity like in Fig. 10 (2).

When press draw increases, the web break frequency increases. Increasing press draw also increases paper porosity, thickness and bulk and reduces internal bond strength. If a high porosity paper is required, this is a very uneconomical way to increase porosity and bulk due to increased web break frequency.

On-line measurement of press drainage, steam consumption, press draw and porosity can tell several things of wet pressing.

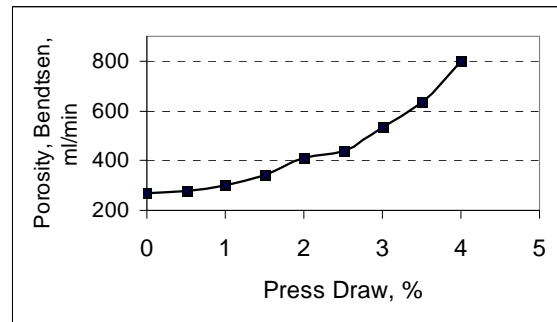


Figure 10. A very common root cause of runnability problems is variation of press draw. Press draw correlates with porosity, which is easy to follow with the PERMI on-line measurement.

Base Paper Applications

The on-line porosity measurement is very beneficial for on-machine coating or surface sizing, where the base paper samples cannot be taken without breaking the paper web. Coating or surface size hold-out or so called coating coverage as well as coated paper gloss and smoothness all depend very much on the base paper porosity. This is evident in the case of film coating where pressure penetration in the roll nip is high, but the latest studies show that porosity is also important for blade coating.

A very interesting special application is minimizing the film forming surface sizes used to close the other side of a glassine release paper. These sizes are very expensive like special starches, PVA and CMC. If the porosity of the base paper varies more expensive surface size must be used, or what is even more critical, silicone consumption increases.



CONCLUSIONS

The on-line porosity measurement is a new power tool for papermakers to better monitor and control the paper quality and to maximize the salable paper tonnage and production profitability. It has brought some new information capabilities like fast trend data from the porosity behavior during such process changes as grade changes, speed changes, furnish changes or other disturbances.

The key question of course is: Why should you measure porosity on-line? The following are good answers:

1. Paper porosity is a good general paper quality indicator, because it depends on so many other paper characteristics. A higher porosity correlates at least to the following properties:
 - Air permeability ↑
 - Tensile strength ↓
 - Size pick-up ↑
 - Coat pick-up ↑
 - Oil absorption ↑
 - Formation ↓ (bad)
 - Pin holes ↑
 - Bulk ↑
 - Opacity and filler content ↓↑
 - Internal bond strength ↓
2. Paper porosity is a universal overall measurement of process stability because so many process variables have an effect on porosity:
 - Fibre furnish
 - Fibre refining
 - Filler content
 - Filler type
 - Wet end starch
 - Retention of fines and fillers
 - Wire drainage and vacuums
 - Air content in the stock
 - Fibre flocculation
 - Wet pressing and press draw
 - Dryer draws and web shrinkage
 - Fibre bonding
 - Calendering
3. It is quite impossible to tune the process or make decisions about paper quality with only laboratory porosity measurements by taking samples from every machine reel in one to two hours interval. The main reason is that the variation of porosity in the machine direction is

about $\pm 10\%$, which is at least ten times as high as the variation of controlled paper properties like basis weight or moisture (normally less than $\pm 1\%$). This high porosity variation can be reduced with the PERMI and a reliable average of the machine reel porosity can be reported to eliminate unnecessary quality rejects.

Literature

1. SC Papers, Voith Paper Machine Days in Salzburg, 2002
2. Metso brochure: Imageneering 12/2004, Paper Machine Dryer Sections