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On-line measurement of paperboard air permeability using aerostatic bearings

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Abstract

On-line measurement of paperboard air permeability during the manufacturing process allows process control with a shorter feedback loop than measuring off-line in the lab after the process. Measuring the permeability with airflow-based instruments has been only possible with stationary sample pieces, as the sample needs to be clamped against the instrument to create a seal between the instrument and the sample.

The proposed method is based on creating a pressure difference across the paperboard and measuring the air flow rate through the web. The control volumes of the developed device are sealed against the paperboard with porous aerostatic bearings, in contrast to conventional solutions utilizing contact seals such as O-rings. Using aerostatic non-contact seals, paperboard web can travel through the measurement device at a high speed. The accurate measurement of the flow through the paperboard requires measurement of the seal leakage flowrate and the chamber inlet and exhaust flow rates. Thus, the air feeds are instrumented with flow meters, and the seal is designed so that it divides the flow to the volume and the ambient in a deterministic way.

The present study focuses on stationary performance of the proposed method and does not consider the effects originating from the web traveling through the device. The device is validated in stationary conditions against a reference measurement, that uses a device based on O-rings to seal against the paperboard. Presented comparison of the studied non-contact seal to the reference contact seal allows determining the accuracy of the air permeability measurement method, including the methods to mitigate the effects of the added air flow from the aerostatic bearings.

aerostatic bearing, aerostatic seal, paperboard permeability

1. Introduction

Measurement of paperboard permeability is vital for quality control of the product. There are both on-line and off-line measurement methods that are used. Various off-line methods are outlined in the ISO 5636-3:2013 standard [1].

The methods are based on measuring the flow through a certain area of paper and have contacting seals that are pressed against the measured paper sheet [2,3]. In some methods, the sample is supported by a mesh or a porous surface [4,5].

The developed method is based on aerostatic seals that are contactless. The contactless seals allow for the paper sheet to travel through the measurement device at high speed, allowing disturbance-free on-line measurement. In the present study, the measurement method with aerostatic seals was validated against a reference measurement with O-ring seals.

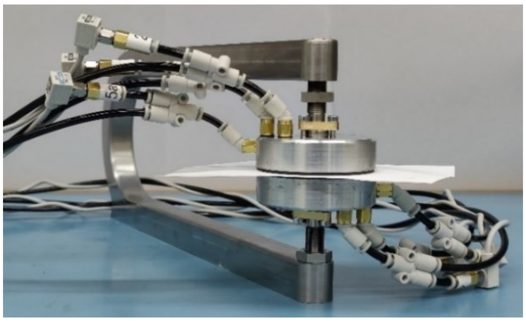

Figure 1. The measurement setup with aerostatic seals. The aerostatic seals had individual air feeds for inside and outside edges. The inlet to the paper chamber is from the top half, and the exhaust is from the bottom half. Each supply and exhaust line are equipped with pressure and flow sensors.

2. Methods

The measurement setup consists of a pair of chamber halves, that are positioned on both sides of the sample sheet (Figure 1). The seal bodies were made from aluminum. The O-rings in the reference seals were SMS 1149 standard square profile EPDM seals with 25mm internal diameter. In contrast, the aerostatic seals feature a graphite restrictor with a 25mm internal diameter. The external diameter of the seal is 58mm and the thickness of the graphite is 4mm. The graphite restrictor was attached to the body with epoxy, and the seal surface was lapped planar. In addition, there are two independent feed grooves behind the restrictor in order to separate the flow to the inside and outside edges (Figure 2).

The measurement setup is instrumented with pressure and flow sensors in the chamber inlet and exhaust lines and in each seal feed. The individual sensors allow to separate the seal leakage from the flow through the paper sheet. The specifications of the sensors are presented in Table 1.

The measurement data was acquired with a NI 9220 module in a CDAQ-9174 chassis. At each measurement point, 10 000 samples were measured at 1 kHz sampling rate. In processing of the measurement data, values at each measurement point were averaged. In the reference measurement with O-rings seals, the flow through the sample was calculated as the average of chamber inlet and exhaust flows. However, in the measurement with aerostatic seals, the seal leaks air into the inlet and exhaust chambers. Therefore, the flow through the sample was calculated by subtracting the seal leakage flow from the exhaust flow. The seal leakage into the exhaust chamber was measured from the inner feed groove of the seal. The flows at the exhaust chamber were used as its pressure is closer to the ambient pressure than the high-pressure inlet chamber. The closer to ambient pressure results in cleaner division of the seal flow between the chamber and the ambient.

The same paper sample was measured with the aerostatic seals and the O-ring seals. The measurement procedure for the reference and the aerostatic seal measurements was the following:

1. Place the sample into the measurement setup.
2. Set the seal feed pressure regulator to 0.5MPa in the aerostatic seal measurements.
3. Increase the chamber inlet pressure by roughly 10 kPa and measure.
4. Repeat steps 3. until the measured flow is out of the measurement scale of the sensor.

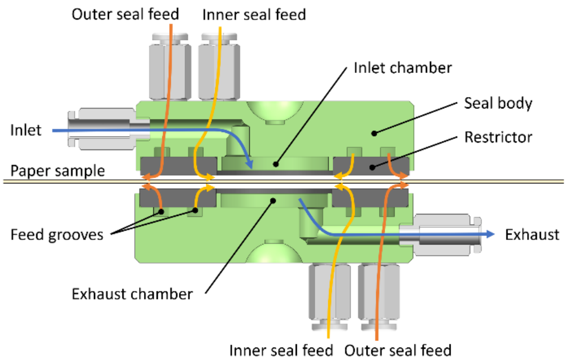

Figure 2. The measurement setup with aerostatic seals. Flow and pressure were measured at inlet, exhaust, and each seal feed. The color-coded arrows describe the flow paths through the device.

Table 1. Specifications of sensors in the measurement setup. The accuracy is presented as a percentage of the full-scale value.

Sensor	Type	Scale	Accuracy
Chamber pressure	SMC PSE543A	-100 – 100kPa	1%
Seal pressure	SMC PSE540	0 – 1MPa	2%
Chamber flow	SMC PFM710	0 – 10L/min	3%
Seal flow	SMC PFMV530	0 – 3L/min	5%

3. Results

The air flow through the measured paper sheet in relation to the pressure difference across the sheet is presented in Figure 3. The measured sample was a copy paper with a basis weight of 80 g/m^2. The relative error between the measurement with aerostatic seals and the reference measurement with O-rings is presented in Figure 4. The measurement error was only 0.5% at its minimum and 10.8% at its maximum.

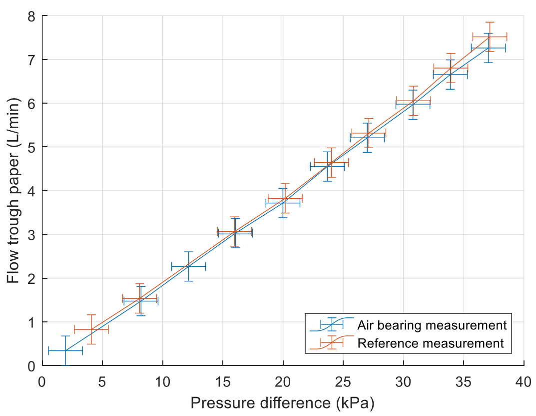

Figure 3. Flow through the paper sample in relation to the pressure difference across the paper sample. The measurement area of the device was a 25mm diameter circle. The error bars represent the type B standard uncertainty of the measurement originating from the sensors.

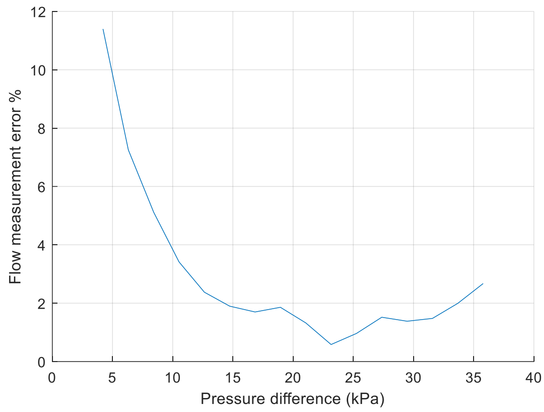

Figure 4. Measurement error between the aerostatic seal and the reference measurements.

4. Discussion

The measurement results show that utilizing aerostatic bearings as seals for a paper permeability measurement device is feasible, even with the simple flow calculation method used in the present study. The flow through the paper sheet for air bearing was calculated by subtracting the seal leakage flow into the bottom chamber from the exhaust flow the bottom chamber. The method could potentially be improved by including the inlet side flows. However, the calculation is not simple due to the high pressure in the inlet chamber diverting more of the seal flow into the ambient.

The accuracy of the measurement depended on the pressure difference across the paper sheet. At low pressure differences, the measurement accuracy suffers due to the low flowrate through the sample. At higher pressure differences, the sheet starts to deform and the higher pressures in the chambers start to affect the seal flows.

The largest contributor to measurement uncertainty was estimated to be the measurement uncertainty of the sensors. Thus, Type B uncertainty was evaluated [6]. Further uncertainties can originate from movement of the sample during measurements. This could be compensated by measuring the speed of the sample and correlating it to the effect on flow measurement. Additionally, manufacturing accuracy of the aerostatic bearings can affect the flow and leakage into the chamber. However, the evaluation of these uncertainties was not included in the present study.

The paper made partial contact with the seals during the measurements, presumably due to deformation of the paper at higher pressure differences. Further studies should focus on how to limit the amount of contact between the aerostatic seals and the paper.

References

[1] ISO 5636-3:2013 Paper and board — Determination of air permeance (medium range) — Part 3: Bendtsen method.
[2] TAPPI test method T 547 om-07, Air permeance of paper and paperboard (Sheffield method), Tappi Press, Atlanta, GA, USA
[3] M. H. Waller, “On-line Papermaking Sensors: An Historical Perspective,” In Sci. Papermak., Trans of the XIIth Fund. Res. Symp. Oxford, 2001. pp. 785–895 doi: 10.15376/frc.2001.2.785.
[4] M. Rasi, “Permeability Properties of Paper,” PhD thesis, Department of Physics, University of Jyväskylä, 2013.
[5] Kano T., A Comparison between Oken Air Resistance-Smoothness Tester and Related Testers in Relation to Measured Values. Japan TAPPI Journal. 2008, 62 (12) p. 84
[6] Joint Committee For Guides In Metrology, “JCGM 100:2008. GUM 1995 with minor corrections. Evaluation of measurement data — Guide to the expression of uncertainty in measurement.” p. 134, 2008.