Caliper Sensor for Moving Wet Fabrics

1. Company information

Feltest (Feltest Equipment BV) (www.feltest.com) is specialized in trouble shooting equipment for use in the paper industry. The small company, Feltest currently employs 4 people, is rapidly expanding and expects to reach a 1.75 million euro turnover in 2019 with sales to 70+ countries. Every year 10% of the revenue is invested in R&D.
Feltest has participated in PwI before, in 2014 and in 2018. All cases concerned innovative new sensor technology that will be incorporated into a new range of products. Feltest's measuring instruments give papermakers all over the globe new information on their paper machine and the paper making process, which will enable them to produce more efficiently and reduce their carbon footprint.
Founder and CEO **ing Marcel Lensvelt** has a background in mechanical engineering and industrial marketing. When it comes to R&D, he is a generalist who understands the demands of the market and it is his task to find the specialists that can transfer these demands into actual products.

2. Problem

Goal for the PwI workshop is to select the optimal sensing technology for the purpose of Feltest (see Background and urgency below), and preferably to test this technology so that it is certain it will be the right direction for further development.
Feltest wants to investigate if it is possible to develop a **handheld**, battery operated device that can measure the thickness/caliper of a porous textile fabric ("belt")...

i. in the range of 0.5 to 3 mm thick...
ii. that contains an **unknown** quantity of **process water** (e.g. 200 to 500 g/m² water in a fabric of 1200 g/m²) of unknown quality and...
iii. is several meters **wide** (and the full width must be measured);
iv. and can have a temperature variance of up to 10°C on an average temperature of 30-50°C;
v. is **moving** at speeds of 10 to 40 m/s;
vi. and is **only** accessible from the topside.

The backside is not accessible and no tools or parts can be positioned here. Behind the belt is only air (usually at least up to 300 mm distance) and further back are unknown machine parts. The environment can contain a light mist of process water.
An absolute measurement is definitely preferred with an accuracy of +/- 0.01 mm in the range of 1.00 to 3.00 mm fabric thickness. If an absolute measurement is not feasible, a relative measurement will be acceptable too as this as this will at least give a caliper profile over the full width of the belt.

Background and urgency of the problem

The production of paper is a continuous process. At the end of the paper making machine big rolls of paper come out. These rolls can be up to 4 m in diameter and up to 11 m wide and contain kilometers of paper. These big rolls require the paper to have very even properties in all directions. For example: a slightly higher sheet dryness on one edge would immediately result in conically shaped rolls and problems with ink absorption at a print house.
Please note that Feltest is not measuring the paper web itself, but textile belts that support the paper web through a number of rotating presses. Both the belt and the paper are pressed, in order to remove water from the paper and temporarily store it in the belt. Due to the pressing and wear, the belt's caliper decreases over time and becomes more irregular. This has the consequence that the transfer of the press load onto the wet paper sheet becomes irregular and hence the paper profile. So by measuring the caliper profile of the belt, one will get a good indication of how the paper profile looks like.
With a good belt caliper sensor the papermaker will gain more control of his production process. If his machine contains crown-controlled press rolls, he can immediately adjust the press load distribution over the width of the machine. It will also help to decide whether he needs to replace the belt, or if other machine parts need to checked or replaced. In other words: a belt caliper sensor will reduce productions losses and premature belt exchanges.

Possible solutions or directions toward solutions to the problem

Currently Feltest offers a mechanical device that touches both top and backside of the belt. This measuring method can only be applied at the edges of the belt and is not suitable for full width measurements. A setup with two optical triangular distance measurements (from both sides) is not possible because the backside of the belt is not accessible over the full width.

The belt is actually a woven fabric with a batt needled into this mesh. The void volume inside the fabric is filled with mostly water and some air. As the fabric is running through a press, it is a quite dense mixture of mostly polyamide and process water. If one could send out a "signal" from one side of the fabric and detect the distance to the fabric/air interface on the other side of the fabric, one would know the caliper.

Two principles come to mind. Ultrasonic measurements could be an easy and affordable way. However, the ultrasonic measurement uses the speed of sound in the medium for its calculation. With a porous textile filled with an unknown amount of water of an unknown quality (conductivity) and variable temperature, it might be virtually impossible to get a reliable, reproduceable test result.
The second principle was discovered during the PwI 2014 project: we worked on a 4-point conductivity measurement to measure the amount of water inside the fabric. It was then suspected that with a very small sensor (4 electrodes relatively close to each other) that such a caliper measurement could be possible. Feltest still has numerous sensors for testing purposes available.

Why we need help from the physics community
We are not able to solve these questions ourselves. We don't have the knowledge, nor the network, to truly understand the possibilities and impossibilities of the suggested measuring principles, being ultrasound or conductivity.
We expect electromagnetism and electronics (conductivity), ultrasound and maybe optics to be the relevant physics disciplines to solve this problem.

Above, an impression of a running belt in a paper making machine. On this picture Marcel Lensvelt (owner of Feltest) is holding a prototype of the Aequo moisture sensor, from the 2014 PwI project. The to be developed sensor will likewise be held by hand, either touching or not touching the belt surface. In the picture Marcel is standing behind the moving belt, which is potentially unsafe (if the 400 kg heavy belt would rip with 40 m/s he would get seriously hurt).

Basic information on ultrasound measurements: https://www.olympus-ims.com/en/applications-and-solutions/introductory-ultrasonics/introduction-thickness-gaging/ and https://www.olympus-ims.com/en/ndt-theory/thickness-gage/factors/
Findings of the tests with a 4-point conductivity measurement (for moisture measurements) will be made available in a later stage.

Boundary conditions (e.g. technical, organizational, or budgetary requirements).
In the final product, the sensor must be installed into a handheld, battery operated device. To keep the further development costs and cost price of the end product within limits, commonly available parts and knowledge are preferred.