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The Charge Sensing Device Approach – Sensor for non-conductive materials using the native electrostatic Charge

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Complete manuscript:

Non-conductors such as paper, foil, and textile materials, have the property of becoming charged electrostatic by friction. Although this charge interferes in industrial processes in general, it can not be completely eliminated. This fact is one of the starting points of the measuring principle.

However, it is about much more than the detection of the charge itself, which can be handled "by the way". It turns out that this stochastically distributed charge on the non-conductor is highly related to other physical properties that are technically very interesting.
The aim of the innovation was to gain this information contact-less (e.g. length, speed, size of the test material) and furthermore make it available for a wide variety of applications.

Starting with basic signal theory research, this problem was solved gradually. For special applications, new sensors were developed and lead to mass production readiness. The full breadth of applications of this completely new measurement approach is currently being explored but not yet rudimentary.

Physical quantities such as speed, acceleration, and length are already measured contact-less easily - without the usual restrictions of optical methods. In fact, the effect of antistatic agents, or the degree of friction between different objects can be determined online also. The list is far from complete since new questions and possible applications are added frequently.

Basic Principle:

The innovation is based on the physical effect of a charge separation caused by the influence of the stochastic distribution of the charge moving past the sensor material in the measuring electrode. This charge is measured as electrical potential or as voltage to a neutral ground. The analysis is done using a mathematical convolution operation.

The measuring electrode can be tailored for each application. By a special design as a structured electrode array the voltage profile can specifically influenced. Like this, waveforms can be generated, or modified in various ways. However, this is not done the common time-related way, but is determined by the local arrangement of parts of the sensor-element relative to the target.

This is called spatial filtering. The principle of spatial filtering is usually known from optics but was adapted for the innovation of an electrostatic signal extraction method in industrial processes.

The frequency response of the measuring electrode was optimized using the theory of wavelets. There is still a lot of potential in this area. Further research can lead to an even higher yield.

Using these sensors, many problems can be solved on an industrial scale today, that where only manageable with expensive laboratory procedures before.

Application areas:

The first major application area was found in the textile industry.
There, the current basic requirements had to be considered in a special way since the environmental conditions are harsh. The sensor has to be resistant to dirt and chemicals, while high mechanical loads must not lead to malfunctions or failures.

The speed and the running length of textile fabric are basic technological parameters that need to be

identified for process safety and quality in many segments of the textile processing chain.
Inaccurate measurements of thread-lengths in each of the production steps sum up over the course of the textile production chain and cause significant economic losses.
In industry, the speed of textile structures is primarily measured on rollers (measuring wheel), using mechanically-coupled speed sensors or indirectly by determining the driving speed of components.
Most of the available measurement-methods such as the measuring wheel, Laser Doppler velocimetry, laser interference, the optical spatial filter, and the correlation method are of limited applicability because they are either too vague, too expensive or impractical; especially when the textile process may be influenced mechanically by the sensor itself.
In these situations, only contact-free methods are useful.
It was therefore necessary to bring a simple, inexpensive, contact-free measurement method for the determination of yarn speed and thread-length to an application stage.
The Institute of Textile Machinery and High Performance Material Technology at the Technical University Dresden (Germany) made the necessary research of sensor prototypes for functionality, to assess the accuracy and to assess the breadth of use in the laboratory and at the institute's textile machinery.
In a cooperative project with “Neumann Elektrotechnik GmbH Chemnitz” (Germany), the basic research results were transformed into a technical project and patent grant.

Regular development of these sensor-types and further analysis are conducted in the laboratory and under practical conditions by “Sentex Chemnitz GmbH” - a spin-off of “Neumann Elektrotechnik GmbH Chemnitz”.

RLS sensor FS 08

It was therefore a huge challenge for the developers to implement the technical task but achieve an acceptable price for the customer, also. Hereby, the developers broke new technological ground as all past attempts by competitors in this area had failed. The period between the start of basic research with promising test results in 1995 and the first production-ready product (yarn sensor for winding process) was 13 years.

The actual sensor element, the comb, was put together with the processing electronics on a printed circuit board. The comb provides a periodic, but still highly distorted signal, which is processed in the subsequent electronics (amplifiers, various filters, etc.) depending on the tasks. For example, the output signal can be a voltage that allows a statement about the charge and the correlating material properties. It can also be a pulse sequence that provides a highly accurate indication of the speed of the test material.

Standard solutions were not leading to a suitable solution, so new signal theory algorithms had to be developed, which could be not found in any textbooks so far.

The first family of sensors was implemented almost completely in analogue technology. This was due to the early beginning of development in 1995 and the available options at the time. The end result is a sensor that can fulfil the task in their entirety at an acceptable price as a mass product.

Of course, modifications in analogue technology are difficult, as more hardware changes are required. Therefore, the transition to digital solutions takes place at present (now FPGA, possibly ASIC later). This is also made possible by the evolution in the components market.
By digitizing, significantly improved signal processing algorithms can be implemented which will in turn lead to new applications.

Comparable contact-free measurement methods are based on optical principles so far. They use the roughness of the surface and detect a value out of this the variable signal. Thus, plain materials are not detectable. In optical processes the test material has to be guided through the light beam in a fixed, defined way. Unlike in our working principle, a fluttering thread is not measurable using optics.

Optical systems are much more expensive than our solution and thus not suitable as a mass product for online measurement. A production-ready, optical measuring system is not known.

Other competing solutions are based on mechanical measuring components. These solutions do not nearly reach our accuracy and flexibility and are not at all applicable for sensitive materials due to the mechanical load.

With our innovation many measurements are just possible for the first time and we could increase the customer value over existing methods of measurement significantly.

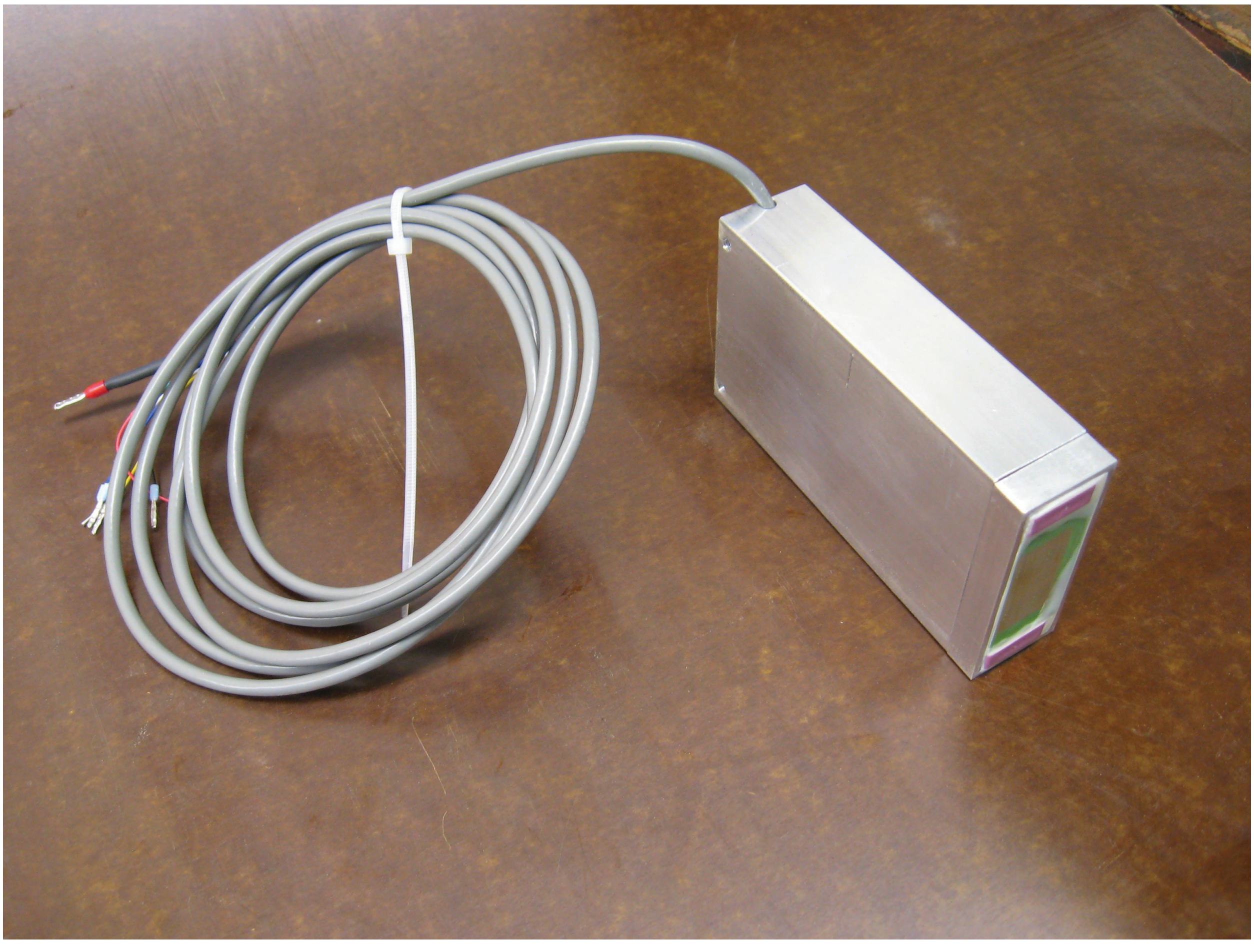
Since May 2010, “Sentex Chemnitz GmbH” took all sensor-related activities from “Neumann Elektrotechnik GmbH Chemnitz”. For Sentex, the sensor technology is the main business pillar. Based on the technology, additional services such as design, assembly of complete measuring systems and process consulting in the textile industry are offered.

Within these activities new ideas for products are constantly being born to enlarge the current program in the next years.

Further possibilities:

The special electronic processing of the sensor signal is used for a wide range of applications. Our core technology is generally open up for further areas:

- Ground flow measurement in industry (At the moment, there are tests running to monitor the grain flow in agricultural machines.)
- Detect gas bubbles in liquids (Research is running to detect and quantify methane gas on the sea bottom.)
- Contact-free measurement of the speed of the weft yarn in weaving (WIL-sensor)
- Contact-free measurement of the electrostatic charge of threads after using preparation (OPU-sensor)
- Perspective: Measurements of the velocity of surfaces



OPU sensor (Oil-Pick-Up)