Mechatronic design approaches for innovative displacement sensor applications

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In the field of non-contact displacement measurement, capacitive, inductive and eddy current measurement principles are well known technologies. Being introduced way before optical measurent principles like laser based or confocal chromatic principles, they still offer advantages in diverse application settings and environmental conditions. These principles are especially relevant under certain application conditions e.g. when there is limited space to mount the sensor. An advantage of capacitive measurement is the possible linearity and high resolution which can reach the sub-nanometer domain under controlled environments. On the other hand, eddy current displacement measurement can be applied in harsh environments with dirt, humidity and high temperature ranges.

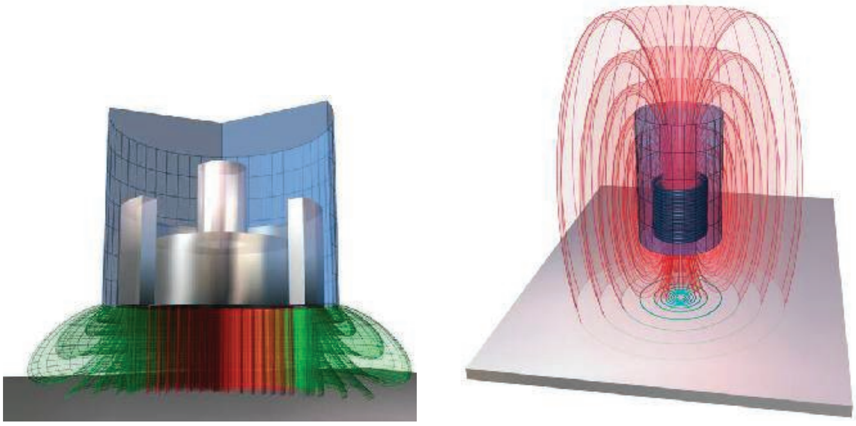

Fig. 1: Illustration of capacitive (left) and eddy current (right) principles

Besides these properties, new applications often require a high grade of system miniaturization, higher overall precision, system performance and immunity to environmental influence, a high level of sensor integration as well as combination of multiple sensors to achieve higher dimensional measurements or to add redundancy. Combined with demands in intelligent and efficient sensor data processing and interfacing the challenges in the domain are quite high.

A design approach to address these challenges requires the interplay of multiple disciplines like integrated electronics/sensor co-design, new packaging technologies, high precision manufacturing processes, simulation, multi-sensor integration, sensor-actuator combination and smart sensing techniques.

An example for the outcome of following such approach is the newly developed Embedded Coil Technology (ECT) by Micro-Epsilon. ECT is a patented new way of building sensors with a high degree of long-term and temperature stability, for extreme environmental requirements like resistance to abrasion and chemical substances, vacuum compatibility or allowing for operating temperatures up to 350°C. In this case, the sensor is completely embedded and in an anorganic material which allows for the mentioned above properties.

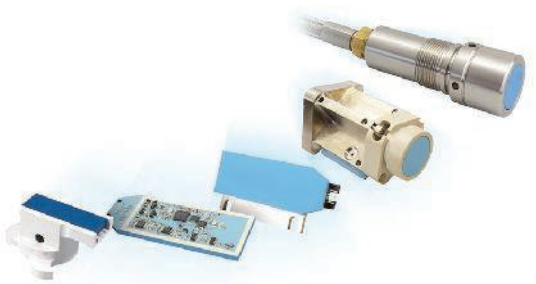

Fig. 2: Sensors in Embedded Coil Technology (ECT)

Another example for a new emerging technology is the development of a new magnetic displacement sensor: The mainSENSOR (Magneto-Inductive Sensor). The measuring principle combines the advantages of different existing principles and offers very high sensitivity and dynamics. The sensor measures up to 60mm using a small magnet on the target object and can be used as an alternative to Hall-sensors especially when a large measuring range and a high dynamics is needed. The measuring range can be easily scaled by use of different magnets.

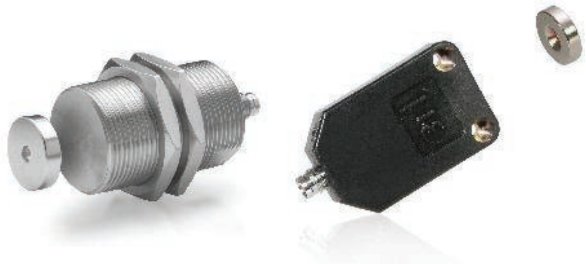

Fig. 3: Magneto-inductive Sensors (MainSENSOR)

Fig. 4 shows a comparison of the output signal of a hall probe and a mainSENSOR. Especially at ranges greater that 25 mm, the mainSENSOR shows advantages over the hall probe as its sensitivity significantly higher.

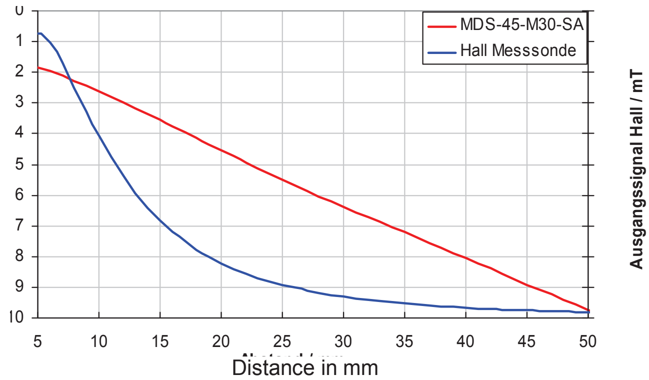

Fig. 4: Comparison of mainSENSOR and hall probe output signal

New applications often require a combination of different measurement principles. For the application of thickness measurement the ECT combiSENSOR combines a capacitive and an eddy current sensor in one housing. It is especially suitable for layer thickness measurement of plastics. The eddy current sensor penetrates the plastic layer and measures the distance to a metal layer underneath it. The capacitive sensor precisely measures the distance to the plastic layer. The difference between both signals forms the thickness information of the plastic layer.

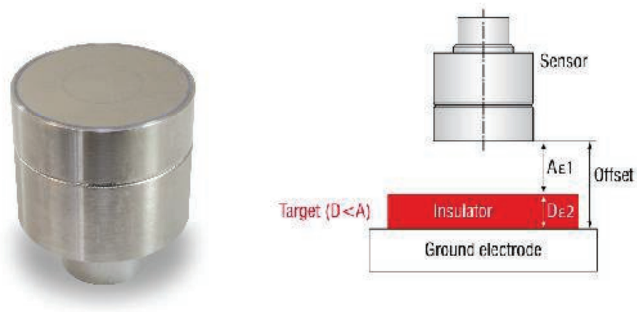

Fig. 5: The combiSENSOR for thickness measurement

A similar example for combining two different measuring principles for thickness measurement consists of a laser triangulator and an eddy current sensor. Fig. 6 illustrates how the laserbeam travels through holes in the eddy current sensor measuring the distance to the surface of a paint layer. The eddy current sensor measures the distance to a ferromagnetic target layer below. Subtracting the two distance values results in the thickness of the paint layer.

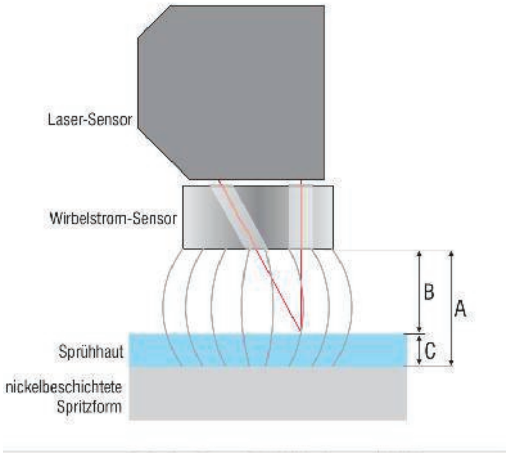

Fig. 6: Configuration for thickness measurement using laser and eddy current principles