Analysis of an Inductive Proximity Sensor

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Abstract

Today, 90 percent of automation sensors are binary proximity detectors. Besides capacitive and optical types, inductive proximity sensors are essential for industrial applications. Compared to their mechanical counterparts, they offer almost ideal properties as contact-free and wear-free working principle as well as high switching frequency and precision [1,2]. Inductive sensors cover a detection range of 0.8 mm to 60 mm, typically [3].

Centerpiece of the sensor is a LC-resonator circuit. The sensor provides a high frequency magnetic field, which interacts with the object to be sensed. In principle, two effects are suitable for detection. First, there is a shift in frequency of the LC-resonator. Second, the oscillation amplitude changes. Both effects are used for technical applications. In this work model-based insight is provided to the effects. In particular, it is analyzed why exploiting the amplitude effect for industrial inductive sensors is suitable. The modeling is preformed regarding the particular sensor shown in Figure 1.

The model is setup with the Magnetic Fields and the Electrical Circuit interface. For numeric efficiency, a 2D Axial Symmetry and Infinite Element Domains are used. The following Magnetic Fields boundary conditions are configured (cf. Figure 2): Ampère's Laws for the Air, Object and Coil-Core domains separately, Multi-Turn Coils for a frequency and a time study separately. To investigate the transient behavior of the LC-resonator a Capacitor and an External I Vs. U node are inserted to the Electrical Circuit interface. The chosen model configurations including meshing sequence and used material data [4,5,6,7] are reported in the paper.

Figure 3 displays examples of calculated magnetic fields for varied sensor-object distances in case of the exemplary resonator frequency fres = 1 MHz [8]. The field magnitudes within the region of the object and the coil core are significantly higher than in the rest of the model domains. This relates to the respective values of the permeability's. The skin effect is observed for the measurement object. Figure 4 shows the real and imaginary part of the normalized sensor impedance (with respect to the 10 mm value) over distance [8]. These results provide direct insight to the sensor sensitivity. For very small distance, the imaginary part of the impedance (impact on resonance frequency) provides a detection effect. For larger distance, only the real part of the impedance (impact on oscillation amplitude) provides a reasonable sensitivity. More details and applicatory aspects, for example regarding the selection of the sensor capacitance [9], will be discussed in the paper.

Using the Magnetic Fields and the Electrical Circuit interface a model was setup to analyze an inductive proximity sensor. The obtained results provide insight on how the sensor should be operated to maximize sensitivity.

Reference

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Figures used in the abstract

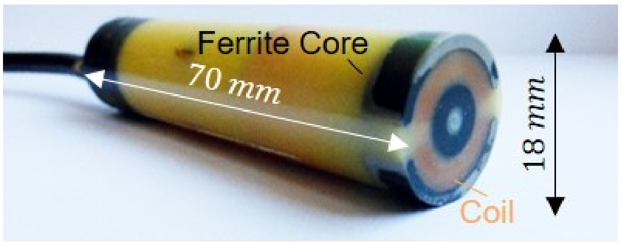

Figure 1: Analyzed inductive proximity sensor.

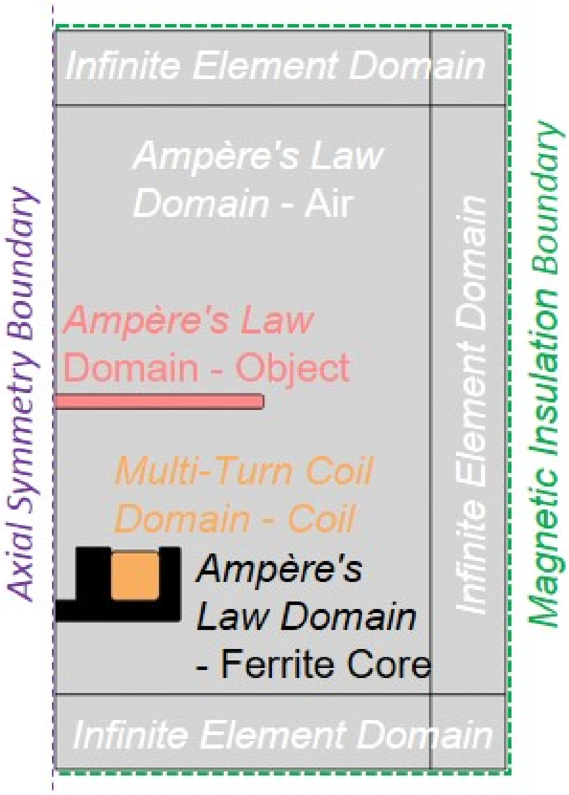

Figure 2: 2D model setup.

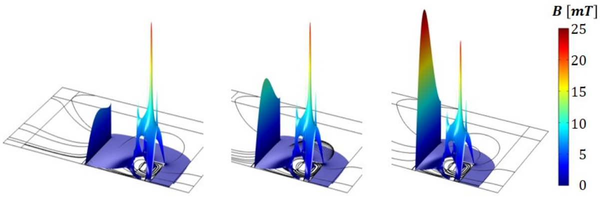

Figure 3: Magnetic field for fres = 1 MHz and sensor-object distances: 13 mm., 10 mm., 7 mm.

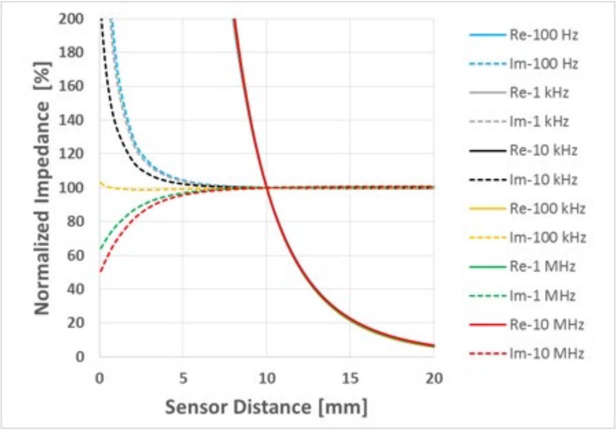

Figure 4: Real and imaginary part of normalized sensor impedance (with respect to the 10 mm value) over distance.