# Simulation of an ECT Sensor to Inspect the Reinforcement of Concrete Structures

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## Abstract

INTRODUCTION: Reinforced concrete structures are widely used around the world, and non-destructive testing (NDT) methods to assess the status of their components is a very important subject [1]. Among various types of methods, techniques based on electromagnetic principles occupy a special position [2]. This paper describes the use of COMSOL Multiphysics to simulate an ECT (Eddy Current Testing) sensor, designed to inspect the elements of the armature of reinforced concrete structures. It represents advances to previous work of the main author [3]. The electromagnetic parts of the sensor constitute a RLC series circuit, where L is the inductance of a multi-turn coil, R is the total resistance, (the coil resistance and an external one), and C is an external capacitance. Figure 1 shows the main elements of the sensor, in an exploded view.

The operating principle of the sensor is as follows. The sensor is fed by a voltage source, near to the resonance frequency. In the absence of metallic bodies under the sensor, the capacitive and inductive reactances are almost the same and the electrical current in the circuit has a maximum value. When steel bars are under the coil, the inductance is slightly disturbed. However, there will be a significant difference between the capacitive and inductive reactances, and the current in the circuit will decrease. Changes can be detected on the voltage at the capacitor, and can be related with the gauge and position of the steel bar under the sensor.

USE OF COMSOL MULTIPHYSICS®: A 3D model was developed. Magnetic Fields and Electrical Circuit physics were used, and the solutions were carried out in the frequency domain. The default parameters for the solver were not changed. Five domains were used: air, coil, steel bar, ferrite box and shielding. Meshing were chosen according to the regions of interest, using predefined size options. Coarse for the air, up to extra finer the shielding. Multi-turn coil feature was used to model the sensor winding and magnetic insulation was applied to the air block.

RESULTS: Three situations were considered: Case 1: only the steel bar and the coil (without the ferrite box and the shielding), case 2: without the shielding and case 3: the complete sensor. As illustration, figures 2 and 3 show the magnetic flux density for cases 1 and 2, respectively.
The details and results of the simulations will be presented in the definitive paper. Figures 2 and 3 give examples for the magnetic flux density for cases 1 and 2, figure 4 shows the obtained results in terms of voltage variation at the sensor terminal.

CONCLUSION: This paper described the use of COMSOL Multiphysics to model the

electromagnetic parts of an ECT sensor, designed to inspect the armature elements of reinforced concrete structures. All the three models simulated here presented good results. COMSOL Multiphysics proved to be very useful in the three-dimensional modeling of electromagnetic components of this type of application, and the results are encouraging for future works.

## Reference


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[2] M. de Magistris, M. Morozov, G. Rubinacci, A. Tamburrino and S. Ventre, “Electromagnetic inspection of concrete rebars”, The International Journal for Computation and Mathematics in Electrical and Electronic Engineering, vol 26, (2007), 389-398.

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## Figures used in the abstract

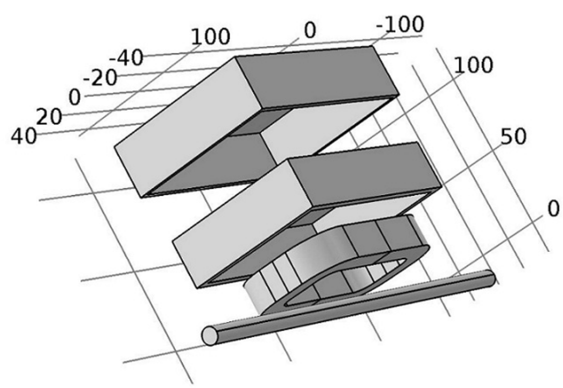


**Figure 1**: The components of the sensor. From top to bottom: Alluminum Shielding, ferrite box, coil and the steel bar.

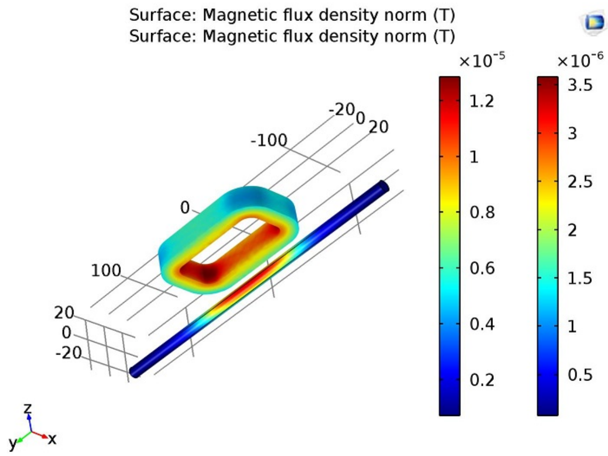


**Figure 2**: Magnetic flux density on the coil (left legend) and the steel bar surfaces (right legend).

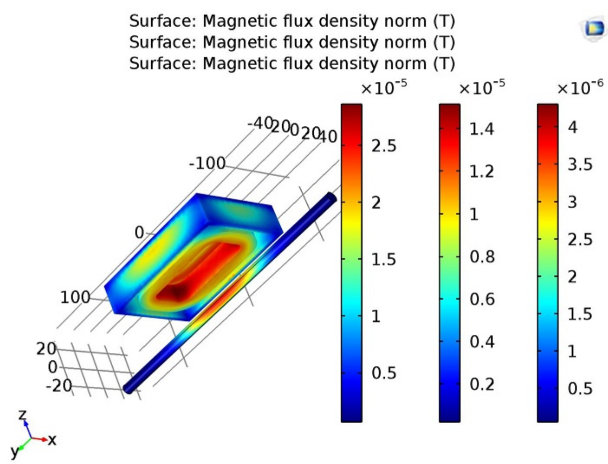


**Figure 3**: Magnetic flux density on the coil (left legend), steel bar (central) and ferrite box surfaces (right legend).

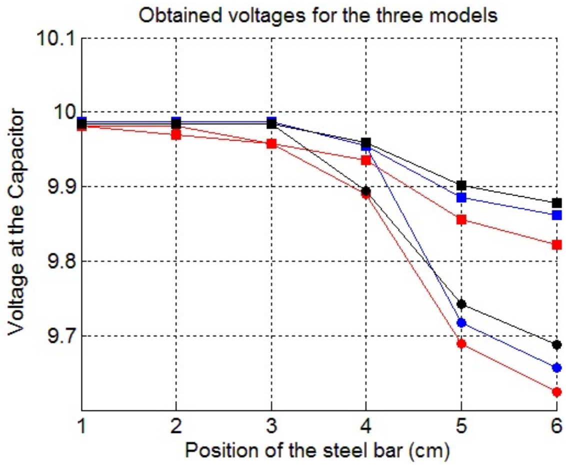


**Figure 4**: Obtained results for the voltage at the capacitor. Square marks: steel bar placed 2 cm under the sensor. Circle marks: bar placed 1 cm under the sensor.