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

Naasson Pereira de Alcantara Jr.; Luiz Gonçalves Jr.

São Paulo State University – Unesp/Bauru

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Reinforced Concrete: The main building material in many countries, including Brasil.

- Origem histórica do Concreto: Roma antiga (Cal hidráulica e cimento pozolânico)
- Cimento Portland: inventado no ano de 1824.
- Concreto armado: surgiu na segunda metade do século XIX, especialmente na França e Estados Unidos.

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Corrosion: One of the main causes of deterioration of reinforced concrete structures

It is estimated that **3%** of the Brazilian GDP is consumed by corrosion annually.
(Source: abraco.com.br)

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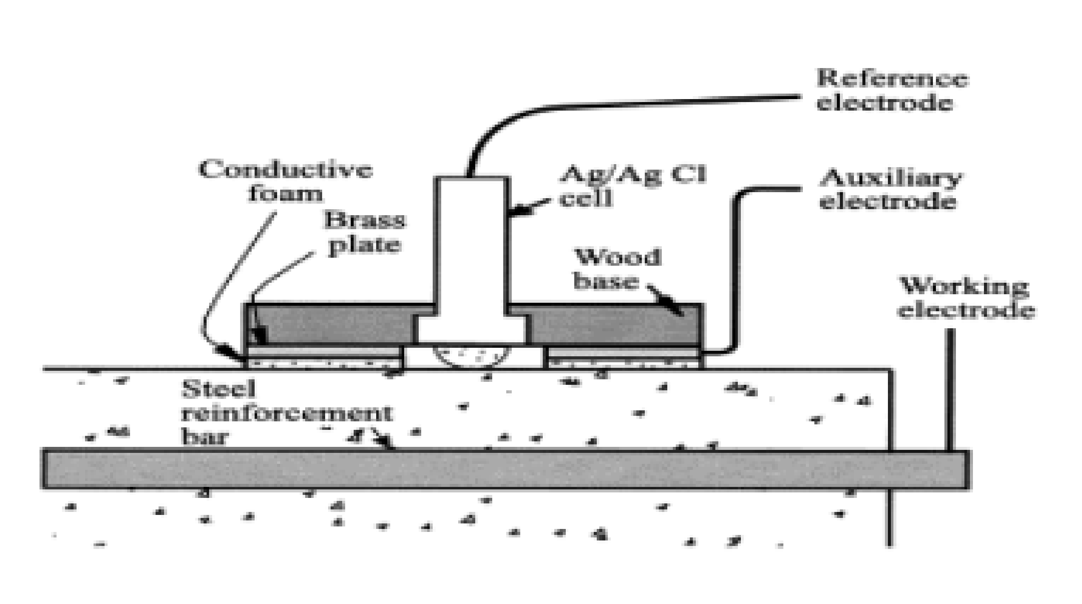
Detection by electrochemical techniques



Ha-Won Song, Velu Saraswathy, Corrosion Monitoring of Reinforced Concrete Structures - A Review. Int. J. Electrochem. Sci., 2 (2007) 1- 28

Polarization resistance method

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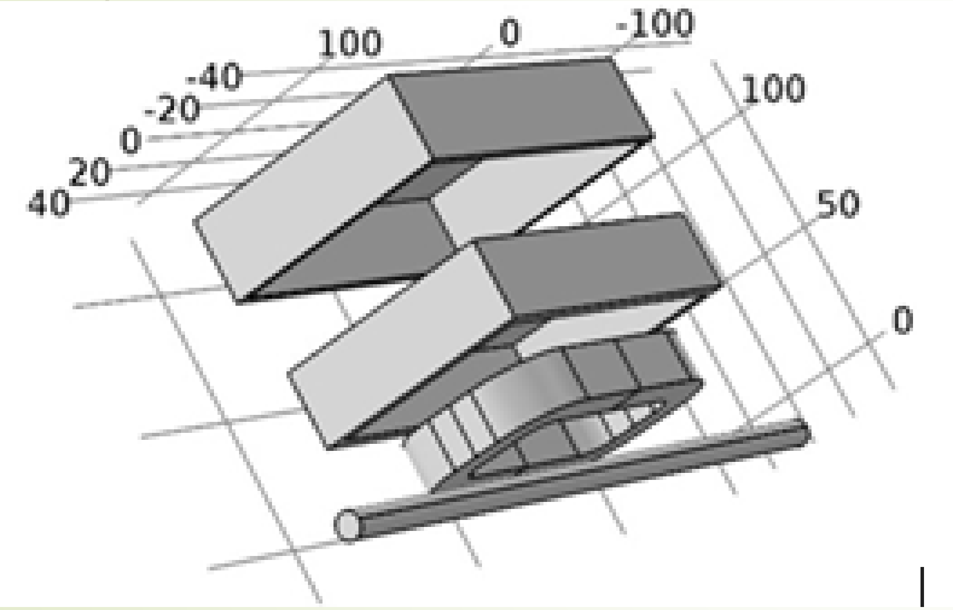
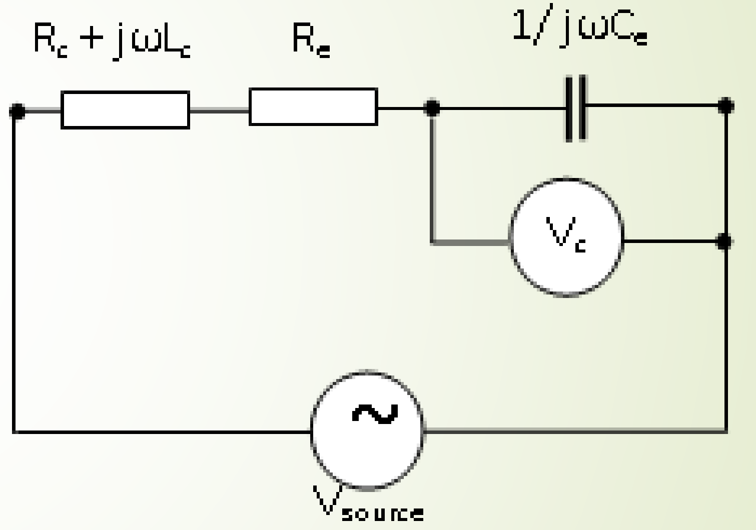
An electromagnetic sensor, based on Eddy Current Testing (ECT) method.





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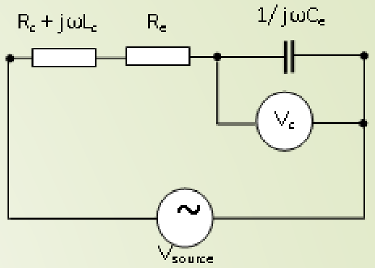

$$V_{source} = (R_c + R_e) i_{sensor} + j\left(\omega L_c - \frac{1}{\omega C_e}\right) i_{sensor}$$

$$i_{sensor} = \frac{V_{source}}{(R_c + R_e) + j\left(\omega L_c - \frac{1}{\omega C_e}\right)}$$

$$\boldsymbol{i_{sensor} = \frac{V_{source}}{R}}$$

$$f = \frac{1}{2\pi\sqrt{L_c C_e}}$$

$$\boldsymbol{V_{cap} = -j\frac{V_{source}}{\omega R C_e}}$$

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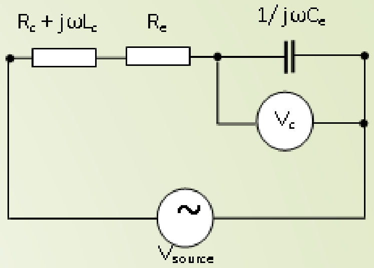

$$L_{ef} = L_c + \Delta L_r$$

$$V_{source} = (R_c + R_e)i + j\left(\omega L_c - \frac{1}{\omega C_e}\right)i + j\omega \Delta L_r i$$

$$V_{source} = Ri + j\omega \Delta L_r i$$

$$V_{cap} = -j\frac{V_{source}}{[R + j\omega \Delta L_r]}\frac{1}{\omega C_e}$$

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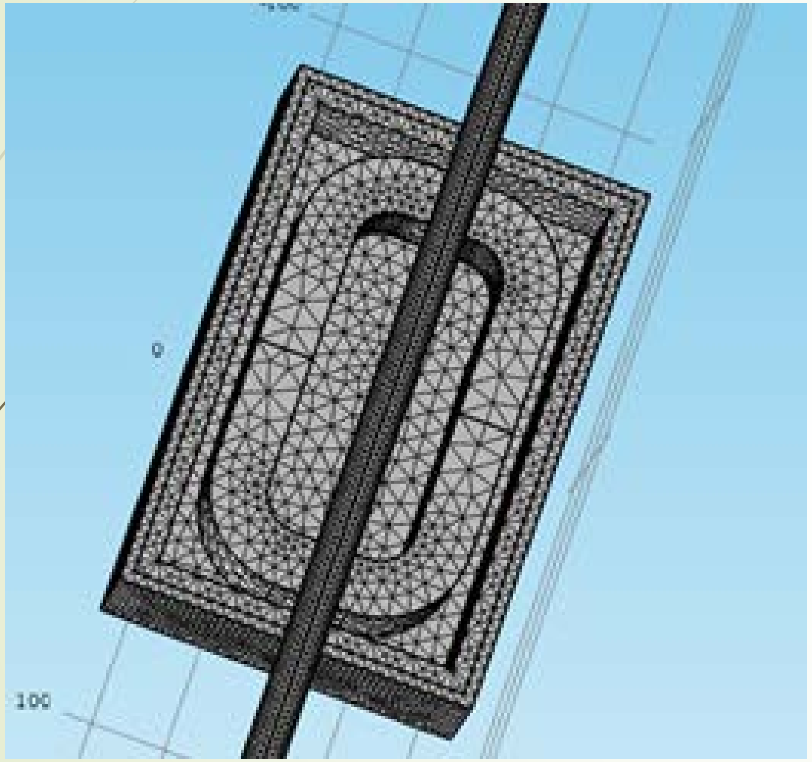
Use of COMSOL Multiphysics



Meshing was chosen according to the regions of interest, using predefined size options.
Coarse to the air up to extra fine, to the shielding.
Free tetrahedral elements were used. No special features, like sweep and boundary layers were necessary.

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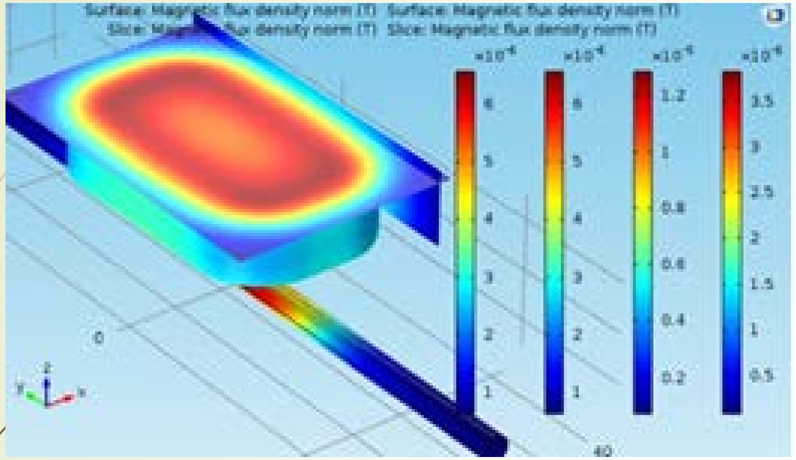
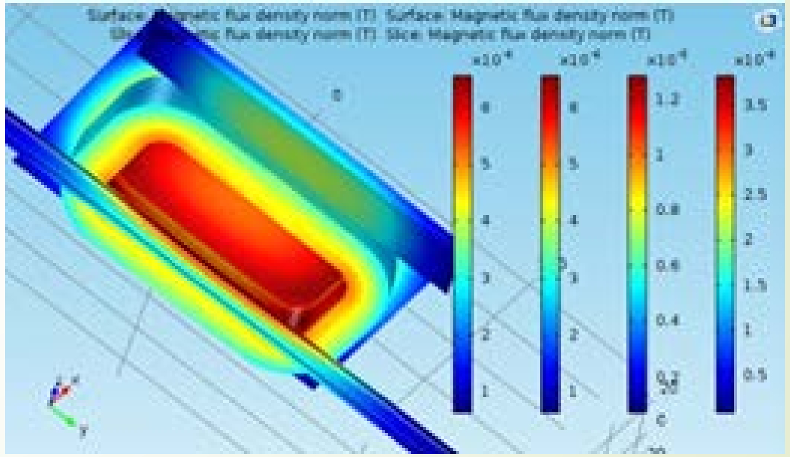


Magnetic flux density at the coil and steel bar surfaces, and within regions that would be occupied by the surrounding ferrite box (top perspective)



Magnetic flux density at the coil and steel bar surfaces and within regions that would be occupied by the surrounding ferrite box (bottom perspective).

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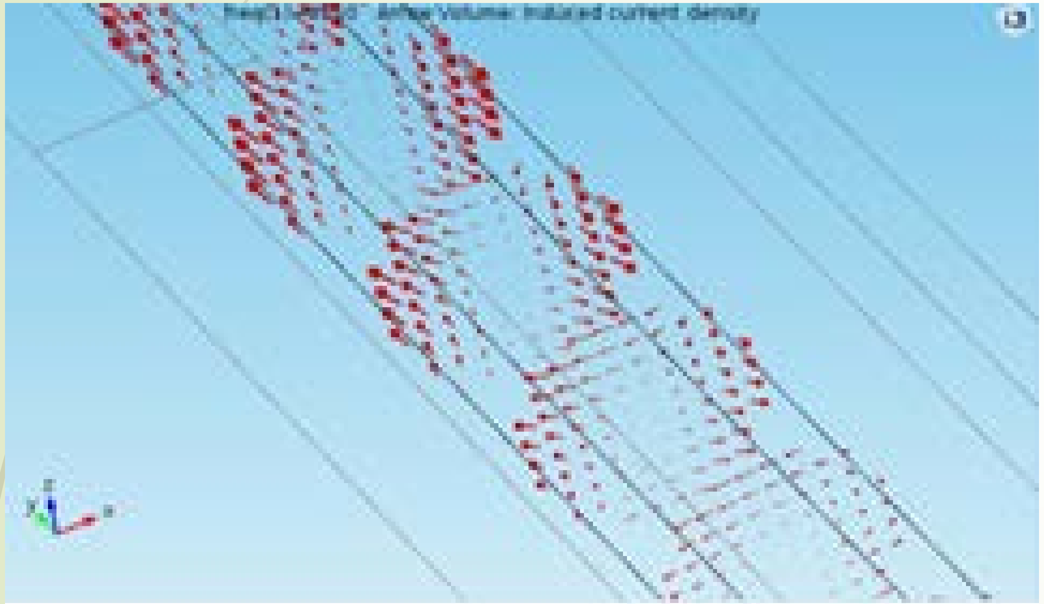
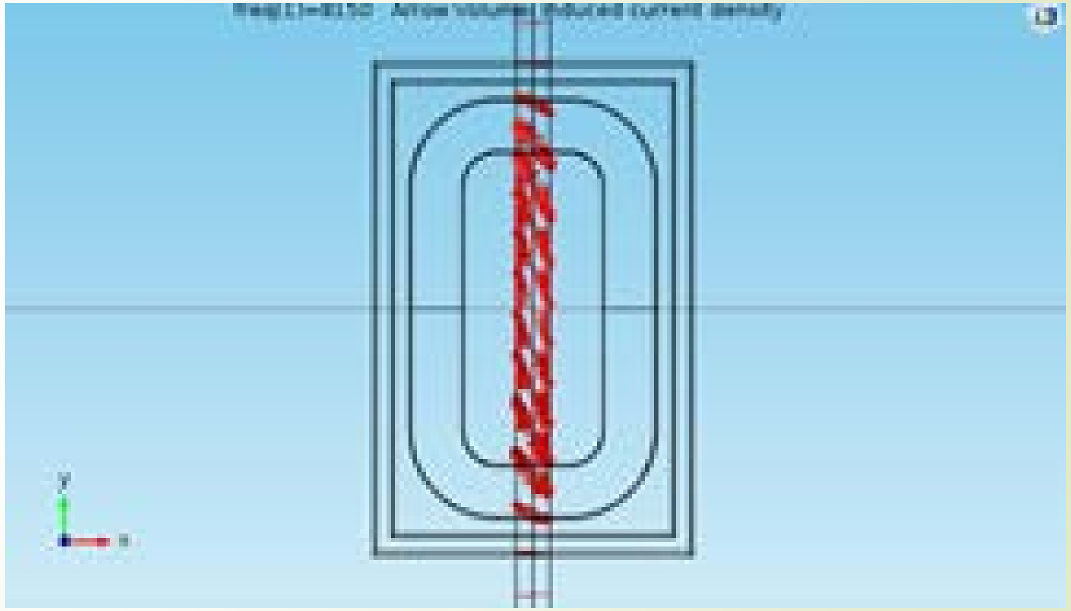
Eddy current induced within the steel bar.





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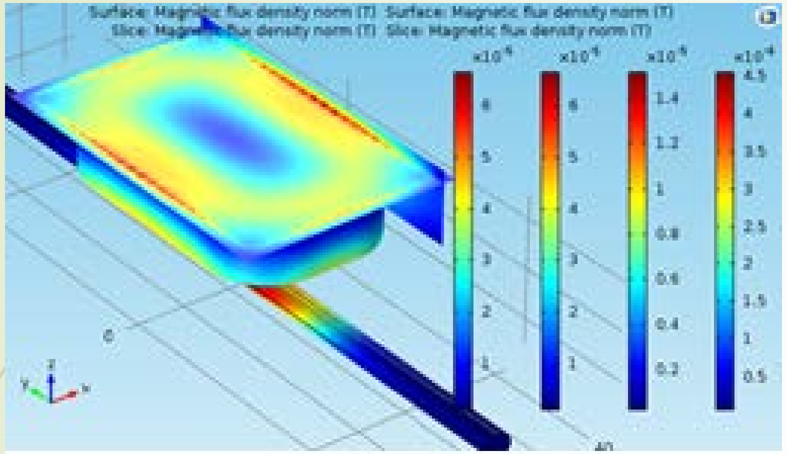
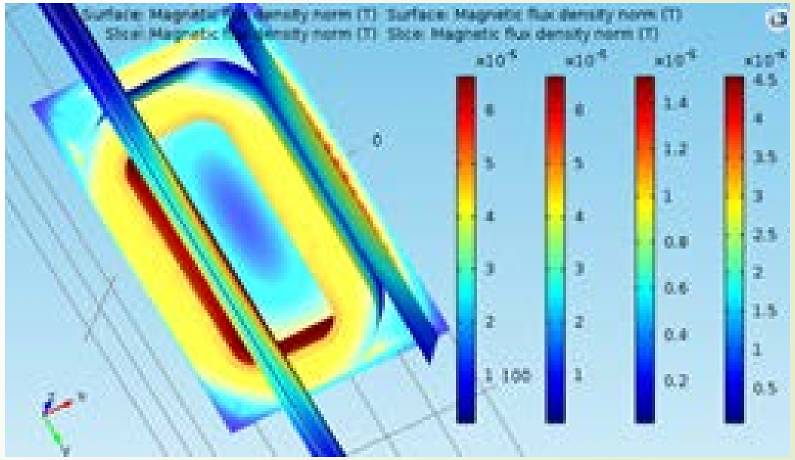


Magnetic flux density at the coil and steel bar surfaces, and within the walls of the ferrite box (perspective from the top).



Magnetic flux density at the coil and steel bar surfaces, and within the walls of the ferrite box (perspective from the bottom).

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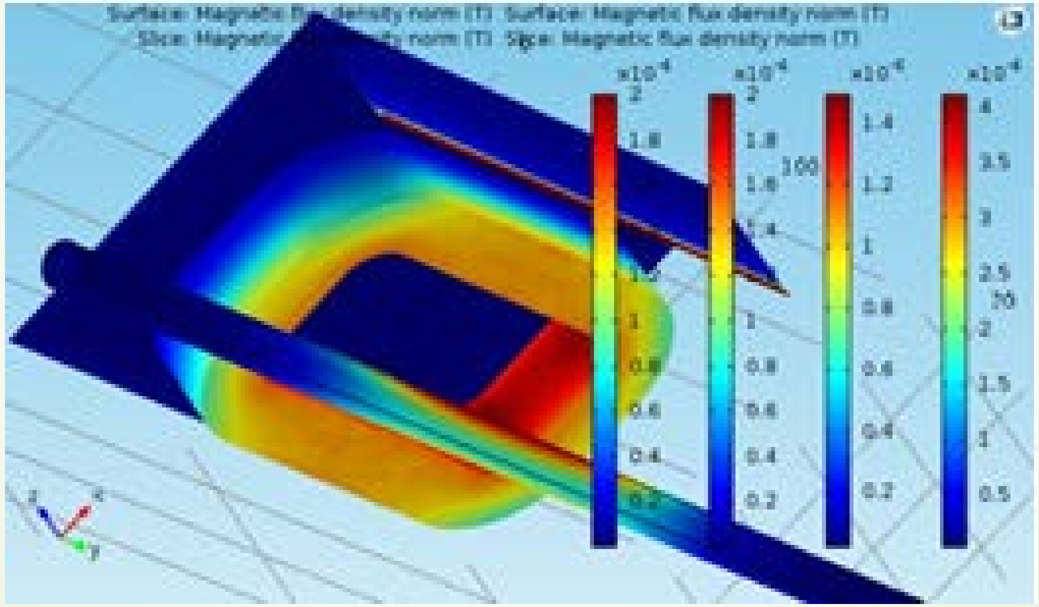
Magnetic flux density at the coil and steel bar surfaces, and within the walls of the aluminum box (perspective from the bottom).



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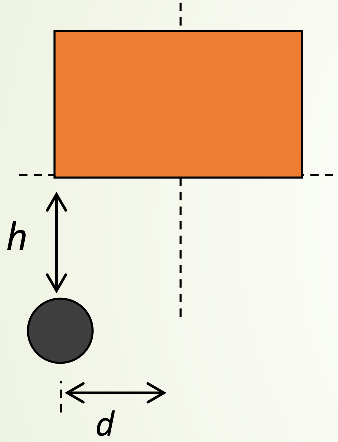
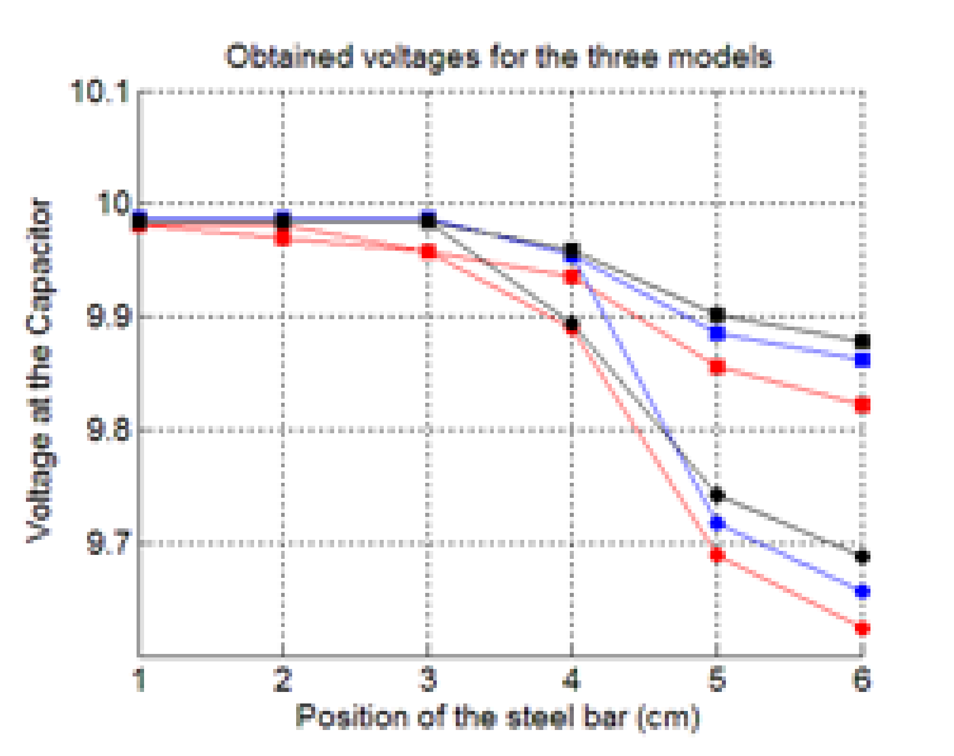
Simulation of the movement of the sensor





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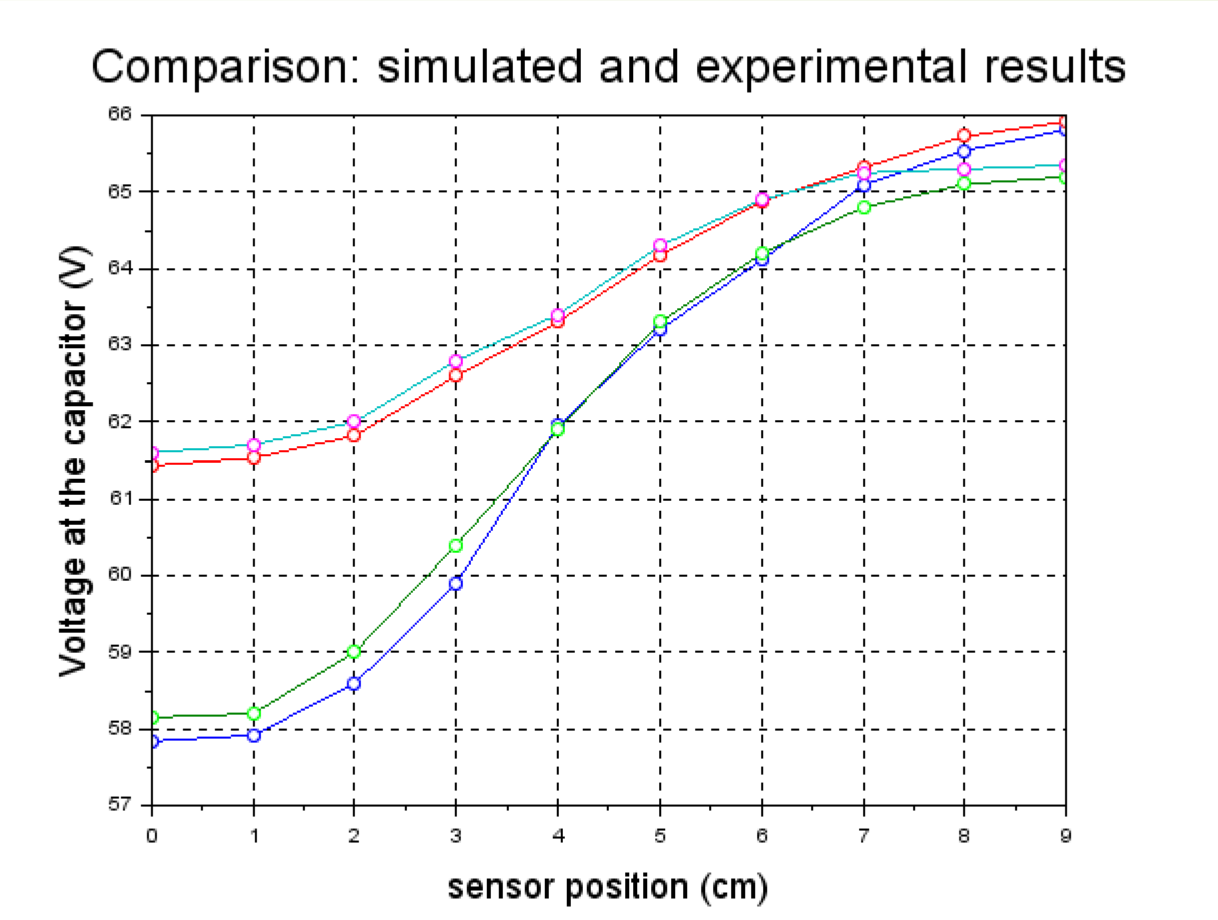
Comparison
Simulation x Experimental Results



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Conclusions

COMSOL Multiphysics proved to be very useful in the three-dimensional modeling of electromagnetic sensors based on Eddy Current Testing. It was possible to have a good perception of the physical phenomena involved. The results obtained from the simulations agree with the results obtained experimentally. COMSOL can, from this point on, be used to optimize the models of sensors, without the need for the construction of many prototypes.

Acknowledgments

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