

Optimization of the eddy current transducer using COMSOL Multiphysics® and MATLAB® software

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Abstract. The article presents a method of optimizing the eddy current transducer. The transducer is made of three toroidal air cored coils: one excitation coil and two receiver coils. The transducer is used for eddy current nondestructive testing (NDT).

1 Introduction

The article presents the capabilities gained by interoperation of the COMSOL Multiphysics® and MATLAB® software. The COMSOL module allows, among other things, to use the Finite Element Method (FEM) for simulation of the electromagnetic phenomena occurring in the NDT [1] transducer model. The MATLAB software utilizes the genetic algorithm method (GA) found in the *Optimization Toolbox* for optimization and post-processing.

Interoperability of both software allows for effective optimization of transducer's dimensions.

2 Optimization solution

Interoperability of different types of calculation software requires an efficient data transfer. Automatic data transfer between COMSOL and MATLAB software is possible thanks to "LiveLink™ for MATLAB®" within the COMSOL software. The LiveLink module is based on the Java environment and works as a client-server model. The COMSOL server provide the computation tools (solvers) for the MATLAB software. The interoperation model is visible in Figure 1.

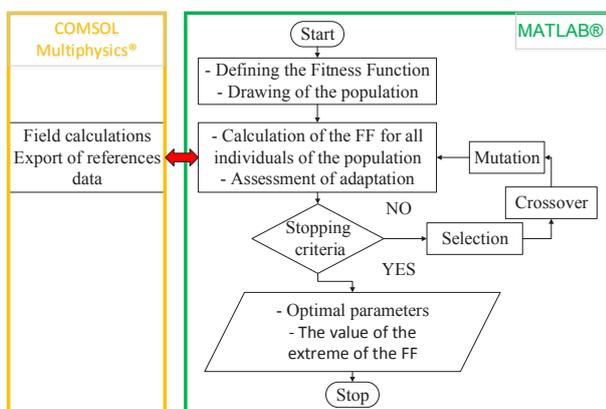


Fig. 1. Optimization with COMSOL and MATLAB software.

The genetic algorithm [2] used in this study is a stochastic method of optimization. It utilizes the mechanisms taken among other from environmental sciences, including natural selection and inheritance. Included genetic operators such as selection, crossover and mutation, allow to produce more successful offspring that will pass the data to further generations.

3 Transducer optimization

The simulations included the optimization of the dimensions of a transducer (Fig.2) used for determination of the material characteristics of given object [3]. The transducer designed as 2D axisymmetric is made of excitation coil (air cored coil) powered by alternating current with frequency of 200 Hz that generates magnetic field. Two differentially connected receiver coils are placed in a certain distance from the excitation coil [4-5]. The distance between the coils is determined by the maximum thickness of the object.

Following parameters were put to optimization:

a_2, h_2 – width and height of the receiver coil 1,

a_3, h_3 – width and height of the receiver coil 2.

Based on those parameters it is possible to determine remaining characteristics:

n_2 and n_3 – number of turns in receiver coil 1 and coil 2:

$$n_2 = k \cdot a_2 \cdot h_2 / S \quad (1)$$

$$n_3 = k \cdot a_3 \cdot h_3 / S \quad (2)$$

where: $k=0.86$ is the fill factor of the coil, S - cross-section of a turn

r_3 – radius of the receiver coil 2:

$$r_3 = r_2 + \frac{a_2}{2} + \frac{a_3}{2} \quad (3)$$

z_3 – location on the z axis of the receiver coil 2:

$$z_3 = \frac{h_1}{2} + \frac{h_3}{2} + h_2 + h_0 + z_1 \quad (4)$$

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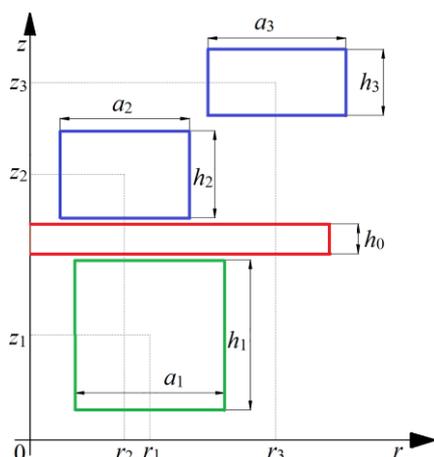


Fig. 2. Eddy current transducer model.

Objective function (fitness function) taken for the optimization assumes minimization of the differential voltage (V_{diff}) induced in the receiver coils (V_1, V_2) in the case when the object is not present.

Performed study was limited by the range of values assumed for optimized geometrical parameters.

3.1 Results of the optimization

Results of the optimization are shown in the Table 1. The numbers in the head show the optimization range. The table contains only partial results of conducted simulations. To find the minimum value of objective function and shorten the computation time, the process was performed with different genetic algorithm settings. Chosen variables were: population size (P) (from 200 to 5), number of generations (G) (from 100 to 5), selection method (Roulette) and other GA elements. Best results (in millimeters) and minimal fitness function (FF) values (in volts) shown in Table 1 were obtained for following combination: population size and number of generations equaled to 15 and 15.

Table 1. Optimization results.

| P | G | a_2 | h_2 | a_3 | h_3 | FF value |
|----|----|-------|-------|--------|--------|----------|
| | | 10-35 | 10-40 | 35-120 | 35-120 | |
| 10 | 10 | 16.4 | 10.5 | 85.1 | 83.1 | 0.248 |
| 15 | 5 | 10.7 | 16.3 | 73.1 | 108.2 | 0.196 |
| 5 | 15 | 11.9 | 12.7 | 56.3 | 94.1 | 0.188 |
| 15 | 15 | 11.1 | 11.4 | 52.0 | 108.8 | 0.158 |
| 25 | 5 | 11.9 | 14.8 | 50.9 | 90.9 | 0.202 |
| 5 | 25 | 11.4 | 13.2 | 56.3 | 95.1 | 0.185 |

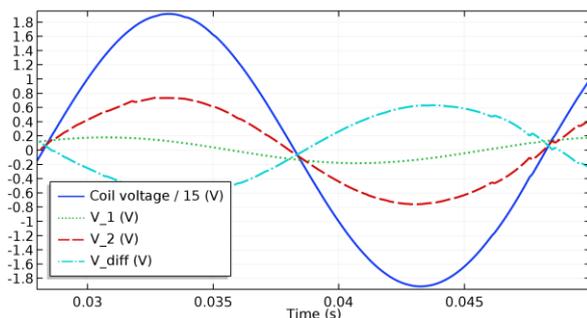


Fig. 3. Voltage values.

The values of the voltage for obtained combination (15 and 15) of optimized parameters are visible in Figure 3. The voltage in excitation coil have been scaled down (divided by 15). Figure 4 presents the magnetic flux density (T) of the excitation and receiver coils in the optimized model (15 and 15 combination).

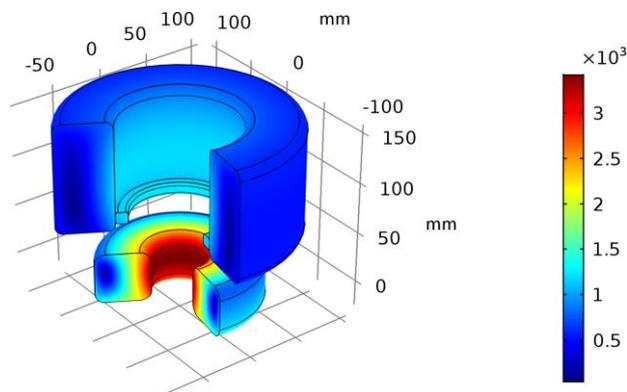


Fig. 4. Optimized model of the eddy current transducer.

4 Conclusions

Optimization of the four chosen dimensions allowed to reduce the output signal for the case when the object is not present. At the same time, it did not allow to nullify the differential voltage. Nullification of the differential voltage requires optimization of additional design characteristic. This includes coil radius, distance between coils and possible other elements of the transducer – ferromagnetic core and conducting screen, which were not taken into account in this work.

Performed study have shown that efficient optimization of the NDT transducer design can be performed with interoperable COMSOL and MATLAB software. The same procedure can be used for similar problems [5-6] by modifying the model.

References

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