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Evaluation of numerical simulation when solving the problem of eddy current thickness measurement of non-magnetic conductive pipes

Computer simulation and numerical methods are of great importance for the process of creation, research, optimization and resource efficiency. Comsol Multiphysics is a powerful simulation environment using the finite element method (FEM) to model and solve scientific and engineering problems based on partial differential equations (PDEs). This software platform enables conversion of standard models for one type of physics into multiphysics models that solve different physics phenomena and perform this simultaneously. Any number of modules can be seamlessly combined to handle challenging multiphysics applications. Accessing this power does not require in-depth knowledge of mathematics or numerical analysis. The product features are geometry modeling, meshing, finite elements, equation-based modeling, solvers, materials, physics-based modeling, results, import/export and other discretization schemes. Thanks to the built-in physics modes it is possible to build models by defining the relevant physical quantities such as material properties, loads, constraints, sources, and fluxes rather than by defining the underlying equations. Comsol Multiphysics automatically compiles a set of PDEs representing the entire model. Comsol Multiphysics is a user-friendly platform, and it has links for Matlab and some CAD programs.

Some opportunities of Comsol Multiyphysics when solving the problem of eddy current thickness measurement are described below. The effect of various influencing parameters in interaction with the eddy current probe surface and non-magnetic conductive pipe are considered in more detail.

The eddy current probe surface is widely used to solve numerous problems in nondestructive testing: thickness measuring of conductive and non-conductive coating objects on a metal base, control of metal and alloy electrical conductivity, inspection of products of different shapes and structuroscopy of nonmagnetic and ferromagnetic alloy parts. The advantages of the eddy current probe surface are its versatility, the ability to control objects of planar, cylindrical, and complex shapes with one-way access to the test object, high resolution and pinpointing the defect area when scanning the surface of the inspection object [1, 2]. One of the important inspection problems which are effectively solved using the eddy current probe surface is the wall thickness measuring of nonmagnetic conductive materials and thickness measuring of dielectric pipe coating or the air gap between the probe and the pipe surface. A practical example where this probe is used is wall thickness measuring of alloy drill pipes made of duralumin D16T. The advantages of these pipes compared to those made of steel are low weight, low flow resistance and non-magnetic properties of the material that are required for directional survey of wells.

Analytical models are also used to calculate the parameters of interaction between the magnetic field of eddy current probe surface and electrically conductive object, and to find the conversion function of the influencing parameters of the object and those of the probe signal with sufficiently high degree of compliance with the theoretical and experimental results [2, 3]. However, these analytical solutions were obtained for a limited class of interactions. They involve a typically axisymmetrical positioning of the probe and test object of a regular geometric shape (planar, spherical, cylindrical, etc.) in contrast to numerical methods. These solutions do not allow study of the impact of real factors on the output signal of the eddy current probe surface. These factors are linear and angular displacements of the symmetry axis of the probe and the symmetry axis of the test object, deviation from the symmetrical shape of the inspection object, local defects such as cracks or local thinning and the end effect.

FEM accuracy is determined mainly by the mesh density in the computational domain. The computing power of modern computers makes the drawback of FEM associated with a large amount of computations at high mesh density insignificant. The mesh density can be enlarged in the areas with small values of the electromagnetic field gradient parameters and the areas of no computation interest.

FEM allows the analysis of the effect of not only the material electrical conductivity, wall thickness and pipe outer diameter, the gap between the probe and the pipe surface on the probe output signal. In contrast to analytic models, it enables the analysis of the effect of linear and angular misalignments of the eddy current probe surface and pipe, non-uniform thickness and the presence of local thinning of the pipe wall and the end effect.

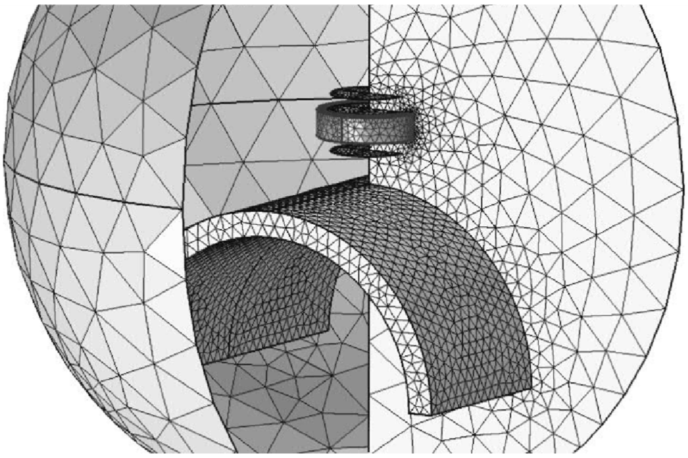

Fig. 1. Partitioning of the calculation model into finite elements in COMSOL

The 3D model was created in COMSOL Multiphysics, version 4.3a, AC/DC module.

The experiment was carried out using the eddy current thickness device BT 15.01 which provides measurement of the wall thicknesses in the range of (6…15) mm with an accuracy of less than ± (0.2…0.5) mm with the gap in the range of (3…12) mm and conductivity of the material deviating from the nominal value by not more than ±10 %. The device was made in the Institute of Non-Destructive Testing, TPU.

The analysis of the results showed that quantitative discrepancy between the real and numerical model within the tested range of changes in the influencing parameters does not exceed 7 %. It is considered to be a good result for further application of numerical methods and COMSOL to solve a wide range of problems in NDT.

References

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