Finite Element Model for Simulating the Inspection of Stainless Steel Tubes Using Electromagnetic Acoustic Transducers

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Abstract

Stainless steel tubes are widely used in industries. In order to ensure the safety and reliability of industrial processes, electromagnetic acoustic transducers (EMATs) based guided wave technology has been developed for inspecting stainless steel tubes regularly. Theoretical models and finite element modes were built to investigate the EMAT technology. However, existing models mainly focused on studying the transmitting process of the EMAT. In this paper, we present a finite element model, using the COMSOL Multiphysics® software, to simulate the whole process of inspecting stainless steel tubes using EMATs, including both the transmitting and receiving processes.

As shown in Figure 1, the inspection process is a coupling process between the magnetic field and the acoustic field, the constitutive relationships occurred in the process are analyzed firstly. Four steps of the finite element model are organized based on the relationships. Firstly, the static magnetic fields produced by the EMATs are calculated by a static magnetic field analysis. Secondly, a transient electromagnetic analysis is performed to obtain the eddy current density excited by excitation currents. Based on the Lorentz law, the Lorentz forces generated by the eddy current and the static magnetic field are loaded on the tube wall. Elastic waves excited by the Lorentz force are simulated in a solid mechanics interface. In the final step, the induced eddy current density, contributed by the static magnetic field and the particle displacement, are used as an input in another transient electromagnetic analysis. The induced voltage in the receiver coil are obtained based on the Faraday's law in a magnetic field interface.

Furthermore, the voltages induced by EMATs with different parameters are calculated through the mulitiphysics model. Simulation results are used to optimize the structure of the EMAT for increasing its detectability. The work presented in this paper will extend the use of mulitiphysics simulations in the area of electromagnetic nondestructive testing.

Figures used in the abstract

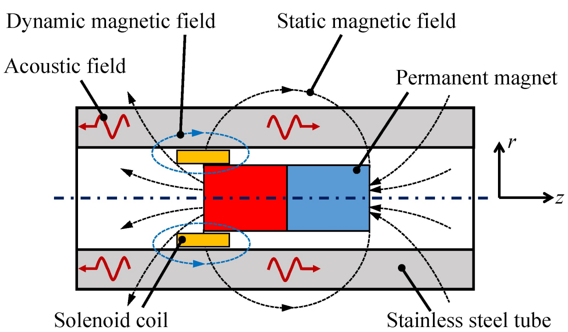

Figure 1: Schematic diagram of the coupling process between the acoustic field and the electromagnetic field for inspecting the stainless steel tube using the EMAT in a cylindrical coordinate system.