Finite Element Modeling of Remote Field Eddy Current Phenomenon

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Abstract

Remote field eddy current (RFEC) technique is a nondestructive testing (NDT) technique for detection of defects in ferromagnetic tubes. This is based on low frequency eddy current, which employs an exciter coil and a receiver coil separated by a characteristic distance. The exciter is fed with a low frequency sinusoidal current and the receiver coil senses the perturbation of the magnetic fields caused by the eddy currents in the tube. The separation distance is fixed such that the receiver coil is insensitive to the direct magnetic field coupling from the exciter (inside the tube) and sensitive to the indirect (eddy current) fields (through the tube wall). The amplitude and phase of the induced voltage in the receiver coil is measured and correlated to the presence of defects or anomalies in the tube wall. It is important to study this phenomenon in details to design and develop a RFEC sensor. The spacing between the exciter and receiver coils and the operating frequency are the most important parameters of RFEC testing for detection of defects in the tubes. Finite element modeling is beneficial in this context, to study the phenomenon and to optimize the parameters of interest. The governing partial differential equation (PDE) was derived from the Maxwell's curl equations and the magnetic vector potential formalism was used.

2D-Axisymmetric modeling of the RFEC phenomenon in ferromagnetic steam generator (SG) tubes made of modified 9Cr-1Mo steel was carried out using COMSOL Multiphysics®. The solution domain consisted of an excitation coil, SG tube and the air box. The boundary and the mesh were initially optimized such that there is no variation in the predicted vector potential values inside the tube region. A uniform mesh consisting of 64,000 triangular elements was chosen and the direct UMFPACK solver was used to obtain the solution. The model was solved at different excitation frequencies. The predicted vector potential values were used to calculate the induced voltage in a fictitious receiver coil unit positioned at different axial locations. Detailed analysis have been carried out to optimize the frequency and intercoil spacing based on the RFEC zones, to probe configuration, and to predict the RFECT signals from reference defects in SG tube. This paper gives details of the finite element modeling of the RFEC phenomenon and the results obtained.