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Thin Crack Detection in Cylindrical Structures Using Eddy Current Nondestructive Evaluation Theory

Eddy current nondestructive evaluation (EC NDE) is widely used in the aerospace, petroleum, nuclear, and manufacturing industries for material characterization of the conductor and flaw detection in the metallic structure. The modeling of EC NDE is not only helpful for the probe design and the interpretation of measurement data, but also essential to the corresponding inverse problems in which the flaw geometry and size are estimated. Due to high conductivity and low operating frequency, the traditional pure numerical methods require large memory and long CPU time to model EC NDE problems accurately. The issue of computational cost is especially critical in the inverse problems. In order to overcome above difficulties, semi-analytical approaches are chosen to efficiently solve a series of eddy current problems in our research work.

By applying the semi-analytical approach, the solution can be expanded into simple series form if the geometry is not complicated, as in the case of a uniform infinite plate or an infinitely-long tube. However, in practice, flaws often occur around the corners or edges of conductors under the stress. Therefore, in our semi-analytical approach, we have to further deal with edge structures in the cylindrical polar coordinate. Truncated region eigenfunction expansion method is used to satisfy boundary conditions on two intersecting surfaces when an edge structure is excited by an inductive probe. Furthermore, this method has also been extended to derive the dyadic Green's function involving a singular source in the same configurations. A volume integral method, which is developed based on the dyadic Green's function and the equivalent electric dipole model, provides an efficient and accurate way to predict the probe signal. Special numerical implementations are also proposed to ensure the performance of our code and the convergence of the expansion series calculation. Prediction of the probe signal shows a good agreement with experimental measurement.