MODELING AND SOLVING PROBLEMS ON ELECTROMAGNETIC NON-DESTRUCTIVE TESTING OF STEEL PIPES

JAVIER I. ETCHEVERRY

Abstract. Quality control of the production and rigorous in service testing are two main ingredients of modern damage tolerant / retirement for cause approach to engineering structures integrity assessment. With an aging world infrastructure this is a hugely significant social and economic problem.

In the particular case of the energy sector, the oil and gas extraction, conduction, refinement, and distribution infrastructures are of enormous importance. Key tools for their inspection are the electromagnetic techniques [1]: magnetic flux leakage (MFL), magnetic particle inspection (MPI), eddy currents (EC), etc. These are relatively low frequency applications (below 1MHz).

Mathematical modeling serves many purposes in this context. On the one hand, it allows to understand capabilities and limitations of the techniques, determine optimum operation practices, assist in the analysis of the probability of detection for different kinds of defects, etc. On the other hand, it is a valuable tool in the design of inspection equipment. However, due to the complexity of the underlying physics [2], the choice of suitable models is not always clear.

Being low frequency applications, these techniques are usually modeled under the so called eddy currents approximation of Maxwell's equations. The main difficulties come from the constitutive relations, which are nonlinear and hysteretic [3,4] and difficult to measure and characterize, and also from the diversity of scales of interest (submillimeter details in thousands of times bigger structures), and the relative motion between different parts of the structure of interest.

The value of making efforts on the material characterization and the importance of making the right choice of the mathematical model in order to obtain meaningful results will be discussed for particular examples: MFL, EC, etc. Mention will be made also to the role of benchmark problems [5], in order to assess not only the quality of the numerical solutions, but also the adequacy of different mathematical models to the case under study. Finally, some numerical solutions will be presented (most of them obtained using a commercial multiphysics package, COMSOL), and the difficulties encountered will be discussed.

Keywords: Electromagnetism, Numerical Methods, Maxwell Equations, Nondestructive testing.

Mathematics Subject Classifications (2010): 78A30, 78A55, 78M10, 35Q61

References

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E-mail address: jetcheverry@tenaris.com