

Mathematical Modeling of Eddy Current Non-Destructive Testing

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Abstract—This paper proposes analytical and numerical models for the measurement process of Eddy-Current (EC) non-destructive testing. EC inspection represents an essential method for the electromagnetic nondestructive evaluation (NDE) of cracks in conductive materials, with its main applications being found in the examination of aircraft, particle accelerators, and other engineering constructions. The method is based on the detection of the magnetic field produced by eddy currents induced in the specimen being tested. The presence of a crack disturbs the flow of the eddy currents, thus producing a magnetic field perturbation dependent on the position and shape of the defect itself. Variations in the electrical conductivity and magnetic permeability of the test object material, and the presence of defects in the object causes a change in eddy current and a corresponding change in phase and amplitude that can be detected by measuring the impedance changes in the magnetic field generating coil, which is a telltale sign of the presence of defects. The nature of the method is complex and there is therefore a need for deeper understanding that may be gained from mathematical models. Such models can have several objectives as for example procedure and equipment optimization or understanding of the method capability and reliability.

Keywords—eddy current testing, mathematical modeling, analytical model, numerical model

I. INTRODUCTION

EC non-destructive testing is widely used in metal industry and science in order to evaluate the properties of materials without causing damage. This testing method is used in the maintenance of aircrafts, of particle accelerators etc. for: crack detection, conductivity measurements, coating evaluations, material thickness [1]. The phenomenon behind the eddy testing consists in an alternating current flowing through a coil at a chosen frequency, current that generates a time varying magnetic field around the coil as in Fig. 1. When the coil is placed close to an electrically conductive material, eddy currents are induced in the material. If there is a defect in the conductive material, the eddy currents circulation is disturbed and the magnetic coupling between the coil and the tested material is modified and a defect signal can be read by measuring the coil impedance variation [2], [1].

Mathematical models [3], [4] of the physical mechanism of EC inspection are necessary not only for a deeper understanding of the process but also for good results regarding equipments design [5].

This paper proposes a numerical model of the measurement process of EC non-destructive testing which will be validated by an analytical solution.

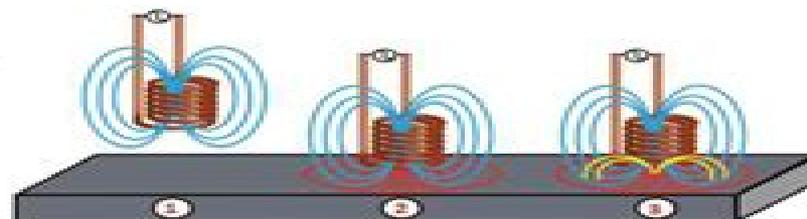


Fig. 1: EC non-destructive testing [6]

II. ANALYTICAL MODEL

The geometry of the analytical model is the one presented in Fig. 2. The geometrical model consists of one copper winding placed above a conductive plate at a distance l . This winding is circulated by an alternating current [2].

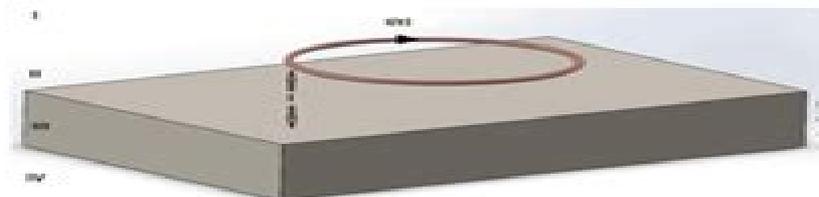


Fig. 2: Single turn coil

The analytical model starts from the Maxwell equations from which the diffusion equation is obtained for the magnetic

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