

Mathematical Modeling of Eddy Current Non-Destructive Testing

E.S. APOSTOL¹, Adrian NEDELICU¹, Dan V. DANIEL², Ionel CHIRIȚĂ¹, Nicolae TĂNASE^{1,2}

¹ INCDIE ICPE-CA, ECCE Department, Splaiul Unirii, Nr. 313, District 3, 030138, Bucharest, Romania,

² University POLITEHNICA of Bucharest, Splaiul Independentei nr. 313, District 6, RO-060042, Bucharest, Romania
 dan@lmm.pub.ro, nicolae.tanase@icpe-ca.ro, simona.apostol@icpe-ca.ro, ionel.chirita@icpe-ca.ro, cristinel.ilie@icpe-ca.ro

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 specimens 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 modelling, 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.

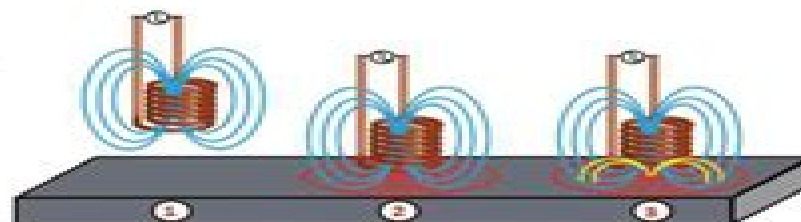


Fig. 1: EC non-destructive testing [6]

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].

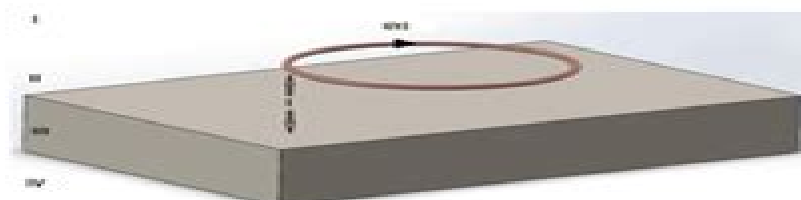


Fig. 2: Single turn coil

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

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Table of Contents Mathematical Modelling In Non Destructive Testing

1. Understanding the eBook Mathematical Modelling In Non Destructive Testing
 - The Rise of Digital Reading Mathematical Modelling In Non Destructive Testing
 - Advantages of eBooks Over Traditional Books
2. Identifying Mathematical Modelling In Non Destructive Testing
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Mathematical Modelling In Non Destructive Testing
 - User-Friendly Interface
4. Exploring eBook Recommendations from Mathematical Modelling In Non Destructive Testing
 - Personalized Recommendations
 - Mathematical Modelling In Non Destructive Testing User Reviews and Ratings
 - Mathematical Modelling In Non Destructive Testing and Bestseller Lists
5. Accessing Mathematical Modelling In Non Destructive Testing Free and Paid eBooks
 - Mathematical Modelling In Non Destructive Testing Public Domain eBooks
 - Mathematical Modelling In Non Destructive Testing eBook Subscription Services
 - Mathematical Modelling In Non Destructive Testing Budget-Friendly Options
6. Navigating Mathematical Modelling In Non Destructive Testing eBook Formats

- ePub, PDF, MOBI, and More
 - Mathematical Modelling In Non Destructive Testing Compatibility with Devices
 - Mathematical Modelling In Non Destructive Testing Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Mathematical Modelling In Non Destructive Testing
 - Highlighting and Note-Taking Mathematical Modelling In Non Destructive Testing
 - Interactive Elements Mathematical Modelling In Non Destructive Testing
 8. Staying Engaged with Mathematical Modelling In Non Destructive Testing
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Mathematical Modelling In Non Destructive Testing
 9. Balancing eBooks and Physical Books Mathematical Modelling In Non Destructive Testing
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Mathematical Modelling In Non Destructive Testing
 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
 11. Cultivating a Reading Routine Mathematical Modelling In Non Destructive Testing
 - Setting Reading Goals Mathematical Modelling In Non Destructive Testing
 - Carving Out Dedicated Reading Time
 12. Sourcing Reliable Information of Mathematical Modelling In Non Destructive Testing
 - Fact-Checking eBook Content of Mathematical Modelling In Non Destructive Testing
 - Distinguishing Credible Sources
 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
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 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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