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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 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.

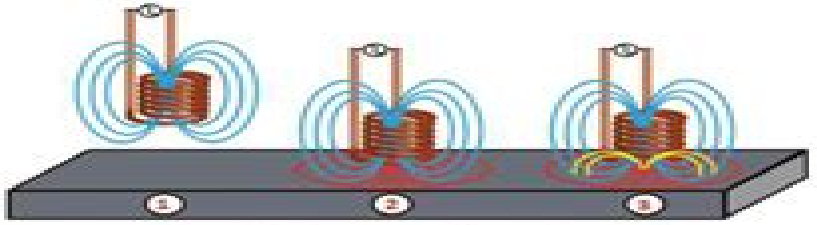

Fig. 1: EC non-destructive testing [6]

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].

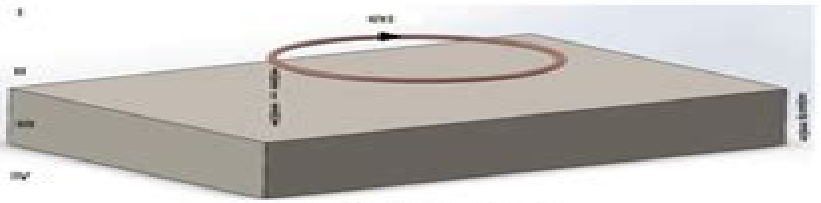

Fig. 2: Single turn coil

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

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Mathematical Modelling In Non Destructive Testing

Huangqi Zhang

Mathematical Modelling In Non Destructive Testing:

Mathematical Modelling in Non-destructive Testing Michael Blakemore,George A. Georgiou,1988 Very Good No Highlights or Markup all pages are intact **Mathematical Models, Methods and Applications** Abul Hasan Siddiqi,Pammy Manchanda,Rashmi Bhardwaj,2015-12-14 The present volume contains invited talks of 11th biennial conference on Emerging Mathematical Methods Models and Algorithms for Science and Technology The main message of the book is that mathematics has a great potential to analyse and understand the challenging problems of nanotechnology biotechnology medical science oil industry and financial technology The book highlights all the features and main theme discussed in the conference All contributing authors are eminent academicians scientists researchers and scholars in their respective fields hailing from around the world Improving the Effectiveness and Reliability of Non-Destructive Testing W.E. Gardner,2013-10-22 This book is concerned with the two most important aspects of the use of non destructive testing Firstly the effectiveness of procedures to detect and size the defects present irrespective of the geometry materials involved or environment Secondly the reliability of instrumentation and personnel to perform the specified procedures Validation and certification techniques required for the justification of safe operation of a plant are also discussed Experts in industries where safety and defect detection are of paramount importance have made valuable contributions drawn from their experience to make this book essential reading for anyone responsible for safety of plant operation Illustrated throughout the book is also of interest to mechanical and structural engineers researchers and inspectors as well as being a useful reference tool for graduate students British Journal of Non-destructive Testing ,1994 **Non-Destructive Testing of Fibre-Reinforced Plastics Composites** J. Summerscales,1990-09-30 **Nondestructive Testing of Materials** Roy Collins,1995 This book reviews the current state of all types of electromagnetic testing techniques and considers the implications of innovations for future inspection practice both in Europe and Japan This volume provides researchers with an overview of exchanges on the subjects of ACPD and ACFM from both Japanese and continental perspectives For instance the Japanese project of applied electromagnetic theory to inspect nuclear power plants and the theory of signal inversion for flaw identification Topics covered are Inversion imaging and flaw reconstruction Advanced signal processing Artificial intelligence and neural networks Modelling simulation and benchmark problems Reliability of inspections new techniques and novel sensors Automation of data acquisition and processing The work covers a wide range of disciplines and will therefore serve a large number of researchers of electromagnetic theory for the next millenium **Barkhausen Noise for Non-destructive Testing and Materials Characterization in Low Carbon Steels** Tu Le Manh,Jose Alberto Perez Benitez,Jose Hiram Espina Hernandez,Jose Manuel Hallen,2020-06-11 Barkhausen Noise for Nondestructive Testing and Materials Characterization in Low Carbon Steels presents a balanced approach reviewing the disadvantages and advantages of using this technique and its comparison over other magnetic testing techniques In addition the book looks towards future

applications of this technique in particular its industrial applications as a method for pipeline inspection current advantages and barriers to implementation The book is suitable for materials scientists researchers and engineers and may be applicable for those working in metallurgical plants Not only does the book discuss fundamentals it reviews recent discoveries such as the correlation between magnetocrystalline energy and Barkhausen noise the modeling of this relationship and the application of this technique in the characterization of magnetic materials Provides detailed explanation for the stochastic and deterministic characteristics of Barkhausen noise Discusses principles of applying Barkhausen noise as a non destructive method and magnetic material characterization method Reviews the advantages and disadvantages of this non destructive testing technique and compares it to other competitive techniques Mathematics in Signal Processing V J. G. McWhirter,I. K. Proudler,Institute of Mathematics and Its Applications,2002 This is a collection of papers from the IMA conference on Mathematics in Signal Processing Signal processing is an important industrial area for the application of mathematical concepts it has recently been fuelled by developments in mobile communications multimedia systems and digital TV This collection of papers presents a good coverage of current activity on this subject worldwide and is of interest to those in industry carrying out research into signal processing for communications sonar radar navigation and biomedical applications and to academic mathematicians identifying new mathematical problems *Remote Techniques for Nuclear Plant* ,1993 This volume covers the practical application of remote technology to all types of nuclear plant both experimental and commercial It concentrates on the remote inspection refurbishment and decommissioning of reactor pressure vehicles reactor internal components primary circuits boiler and steam generators PIE and fuel routes reprocessing plant and radioactive waste storage The emphasis is on equipment currently in use and it also covers equipment under consideration and development Consisting of 44 papers these proceedings draw on the experience of nuclear engineers from around the world to form a substantial reference work on remote techniques for the inspection and refurbishment of nuclear plant

Handbook of Mathematical Models and Algorithms in Computer Vision and Imaging Ke Chen,Carola-Bibiane Schönlieb,Xue-Cheng Tai,Laurent Younes,2023-02-24 This handbook gathers together the state of the art on mathematical models and algorithms for imaging and vision Its emphasis lies on rigorous mathematical methods which represent the optimal solutions to a class of imaging and vision problems and on effective algorithms which are necessary for the methods to be translated to practical use in various applications Viewing discrete images as data sampled from functional surfaces enables the use of advanced tools from calculus functions and calculus of variations and nonlinear optimization and provides the basis of high resolution imaging through geometry and variational models Besides optimization naturally connects traditional model driven approaches to the emerging data driven approaches of machine and deep learning No other framework can provide comparable accuracy and precision to imaging and vision Written by leading researchers in imaging and vision the chapters in this handbook all start with gentle introductions which make this work accessible to graduate

students For newcomers to the field the book provides a comprehensive and fast track introduction to the content to save time and get on with tackling new and emerging challenges For researchers exposure to the state of the art of research works leads to an overall view of the entire field so as to guide new research directions and avoid pitfalls in moving the field forward and looking into the next decades of imaging and information services This work can greatly benefit graduate students researchers and practitioners in imaging and vision applied mathematicians medical imagers engineers and computer scientists NON DESTRUCTIVE TESTING Danny van Hemelrijck,Athanassios Anastassopoulos,1996-01-01 Focusing on visual and optical inspection ultrasonics acoustic emission dynamic techniques X ray radiography material characterization industrial applications and qualification programmes this book is intended for engineers and researchers as well as teachers and graduate students **Non-destructive Testing** J. M. Farley,R. W. Nichols,1988 **U.S. Government Research Reports** ,1964 Proceedings of International Conference on Computational Intelligence Ritu Tiwari,Mukesh Saraswat,Mario Pavone,2024-07-17 The book presents high quality research papers presented at International Conference on Computational Intelligence ICCI 2023 held at Sardar Vallabhbhai National Institute of Technology Surat India during 4 5 November 2023 The topics covered are artificial intelligence neural network deep learning techniques fuzzy theory and systems rough sets self organizing maps machine learning chaotic systems multi agent systems computational optimization ensemble classifiers reinforcement learning decision trees support vector machines hybrid learning statistical learning metaheuristics algorithms machine vision Internet of Things image processing image segmentation data clustering sentiment analysis big data computer networks signal processing supply chain management web and text mining distributed systems bioinformatics embedded systems expert system forecasting pattern recognition planning and scheduling time series analysis human computer interaction web mining natural language processing multimedia systems and quantum computing

Dynamic Methods for Damage Detection in Structures Antonino Morassi,Fabrizio Vestroni,2008-12-11 Non destructive testing aimed at monitoring structural identification and di nostics is of strategic importance in many branches of civil and mechanical gineering This type of tests is widely practiced and directly affects topical issues regarding the design of new buildings and the repair and monitoring of existing ones The load bearing capacity of a structure can now be evaluated using well established mechanical modelling methods aided by computing facilities of great capability However to ensure reliable results models must be calibrated with curate information on the characteristics of materials and structural components To this end non destructive techniques are a useful tool from several points of view Particularly by measuring structural response they provide guidance on the validation of structural descriptions or of the mathematical models of material behaviour Diagnostic engineering is a crucial area for the application of non destructive testing methods Repeated tests over time can indicate the emergence of p sible damage occurring during the structure s lifetime and provide quantitative estimates of the level of residual safety **MATERIALS SCIENCE AND ENGINEERING -Volume III** Rees D.

Rawlings,2009-12-05 Materials Science and Engineering theme is a component of Encyclopedia of Physical Sciences Engineering and Technology Resources in the global Encyclopedia of Life Support Systems EOLSS which is an integrated compendium of twenty one Encyclopedias Materials Science and Engineering is concerned with the development and selection of the best possible material for a particular engineering task and the determination of the most effective method of producing the materials and the component The Theme with contributions from distinguished experts in the field discusses Materials Science and Engineering In this theme the history of materials is traced and the concept of structure atomic structure microstructure and defect structure and its relationship to properties developed The theme is structured in five main topics Materials Science and Engineering Optimization of Materials Properties Structural and Functional Materials Materials Processing and Manufacturing Technologies Detection of Defects and Assessment of Serviceability Materials of the Future which are then expanded into multiple subtopics each as a chapter These three volumes are aimed at the following five major target audiences University and College students Educators Professional practitioners Research personnel and Policy analysts managers and decision makers and NGOs *Innovations in Wave Processes Modelling and Decision Making* Alena V. Favorskaya,Igor B. Petrov,2018-02-16 This book presents methods for full wave computer simulation that can be used in various applications and contexts e g seismic prospecting earthquake stability global seismic patterns on Earth and Mars medicine traumatology ultrasound investigation of the human body ultrasound and laser operations ultrasonic non destructive railway testing modelling aircraft composites modelling composite material delamination etc The key innovation of this approach is the ability to study spatial dynamical wave processes which is made possible by cutting edge numerical finite difference grid characteristic methods The book will benefit all students researchers practitioners and professors interested in numerical mathematics computer science computer simulation high performance computer systems unstructured meshes interpolation seismic prospecting geophysics medicine non destructive testing and composite materials **Applied Mechanics Reviews** ,1989 **Demand Bibliography** ,1989 *Electromagnetic Non-Destructive Evaluation (XXIII)* G.Y. Tian,B. Gao,2020-11-03 Electromagnetic Non destructive Evaluation ENDE is an invaluable non invasive diagnostic tool for the inspection testing evaluation and characterization of materials and structures It has now become indispensible in a number of diverse fields ranging from biomedics to many branches of industry and engineering This book presents the proceedings of the 24th International Workshop on Electromagnetic Nondestructive Evaluation held in Chengdu China from 11 14 September 2019 The 38 peer reviewed and extended contributions included here were selected from 45 original submissions and are divided into 7 sections eddy current testing and evaluation advanced sensors analytical and numerical modeling material characterization inverse problem and signal processing artificial intelligence in ENDE and industrial applications of ENDE The papers cover recent studies concerning the progress and application of electromagnetic EM fields in the non destructive examination of materials and structures and topics covered include evaluations at a micro

structural level such as correlating the magnetic properties of a material with its grain structure and a macroscopic level such as techniques and applications for EM NDT E Recent developments and emerging materials such as advanced EM sensors multi physics NDT E intelligent data management and maintaining the integrity of structures are also explored The book provides a current overview of developments in ENDE and will be of interest to all those working in the field

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