FACTORS AFFECTING EDDY CURRENT TESTING

Vijay Upreti[1], Akash Vijay Singh[2]

[1,2]*Department of Mechanical Engineering,*

Rajshree Institute of Management and Technology, Bareilly (India)

ABSTRACT

Eddy current testing is classified as an electromagnetic non-destructive testing method having several attractive characteristics like fast inspection speed and high sensitivity against surface defects.

Non-destructive techniques are used widely in the metal industry in order to control the quality of materials. Eddy current testing is one of the most extensively used non-destructive techniques for inspecting electrically conductive materials at very high speeds that does not require any contact between the test piece and the sensor. This paper includes an overview of the fundamentals and main variables of eddy current testing.

This paper includes an overview of the fundamentals and main variables of eddy current testing

Keywords: Cause effect diagram Eddy current testing, Factors affecting eddy current testing,, Non-destructive testing .

I. INTRODUCTION

Eddy current (EC) non-destructive evaluation (NDE) techniques are the most used methods for in-service inspection in industrial practice. EC NDE works on the principle of electromagnetic induction through the use of energy coupling between an EC sensor excited by an alternating source and the evaluated conducting materials.

It is based on detection of the interaction between the magnetic field inducting the EC in the tested specimen and the magnetic field created by such a specimen. In most cases this involves measurement of the impedance. The presence of the defect modifies the distribution of ECs, which generate alteration in the magnetic flux closely related to the position and shape of the defects. The distribution of EC in the probe depends on various parameters, such as excitation frequency, conductivity, permeability of the material, and also presence of defects. EC inspection is normally carried out with probes that offer higher inspection speed compared with most other NDE techniques [1–3].

Quantitative NDE techniques are needed for evaluating sizes, shapes, and locations of defects and cracks; the well-known methods available include the finite difference method (FDM), the boundary-element method (BEM), and the finite element method (FEM). The FEM is more general, numerically superior, primarily used for its versatility modelling of material properties, simulations of boundary conditions, modelling arbitrary domain space, and reduces substantially the experimental work. If a coil carrying an alternating current is placed close to the surface of a conductive sample, ECs will be induced in the sample close to this surface. These currents, in turn, affect the current in the exciting coil by mutual induction. EC testing is based on correlation between electromagnetic properties and physical/structural properties of a test specimen.

International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No. (03), January 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

Different parameters affect the outcome of non-destructive test (NDT) in different ways, those parameters that determine the result of an inspection are defined as *essential parameters (EP)*.

Essential parameters related to any particular inspection can be associated to different parts of the inspection and divided into three groups: input parameters, procedure parameters and equipment parameters.

Essential parameters have received considerable attention recently, especially in the nuclear field, due to the growing demands on the reliability, repeatability and accuracy of non-destructive testing. NDT that has been an independent field for many years starts using, such tools as, measurement error, probability of detection (POD), or receiver operating characteristic (ROC), the tools that have been already established in measuring engineering and communications for a long time. In this situation it becomes important defining eddy current (EC) instrument and specify its essential parameters in a way similar to that used for any other measurement instrument or communication receiver.

In this preliminary study we will focus on such issues related to the EC equipment and the employed procedure as, probe handling, influence of lift-off and scanning speed on defect sizing.

The goal of this study is qualitative analysis of the influence of the above mentioned factors on the ability to detect and size flaws using mechanized ET. The influence of different variables will be investigated by means of physical reasoning employing theoretical models, and demonstrated using simulated and real EC signals. The study will not include simulations of electromagnetic fields related to various defect parameters and coil configurations. The study should result in a number of practical recommendations for the users of ET and should indicate the areas that are to be further analyzed.

II. PRINCIPLE OF EDDY CURRENT TESTING

Eddy-current testing uses electromagnetic induction to detect flaws in conductive materials. In this method eddy currents are produced in the test-piece by bringing it in proximity of alternating current carrying coil. **(Almeida *et al.* 2013)** The changing magnetic field of the coil (due to alternating current) is modified by the eddy currents' magnetic fields. This modification depends on the condition of the nearby part of the coil, it is a measure of any discontinuities, cracks, impurities in the materials, flatness etc.

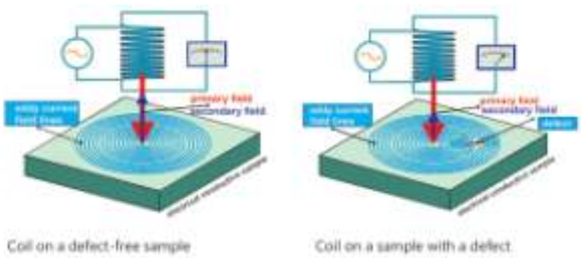


Figure 1.3: Principle of eddy current testing

III. FACTORS AFFECTING EDDY CURRENT TESTING

Large numbers of factors are responsible which significantly affect the efficiency and effectiveness of eddy current testing. **(Kumar and Mahto 2013)** Following are some of the factors which affect eddy current testing:

1. Resistivity of workpiece material ρ (ro)
2. Permeability of workpiece material μ (mu)

3. Current Frequency f
4. Depth of penetration δ (depth of penetration)
5. Proximity (Lift off / fill factor) i.e. distance between workpiece and probe or coil
6. Geometry of workpiece
7. Specification of coil
8. Probe Handling
9. Discontinuities in workpiece (Defects)

IV. ANALYSIS OF FACTORS AFFECTING EDDY CURRENT TESTING

Repeatability, reproducibility and the conditions at which the process can be used is the measure of its effectiveness and sensitivity, for this purpose the analysis of some factors which affect eddy current testing is done. Following formula of depth of penetration is used for above said analysis-

$$\delta = \sqrt{\frac{\rho}{\pi . f . \mu}}$$

In this formula **δ** is depth of penetration

ρ is resistivity of the workpiece material i.e. inverse of conductivity,

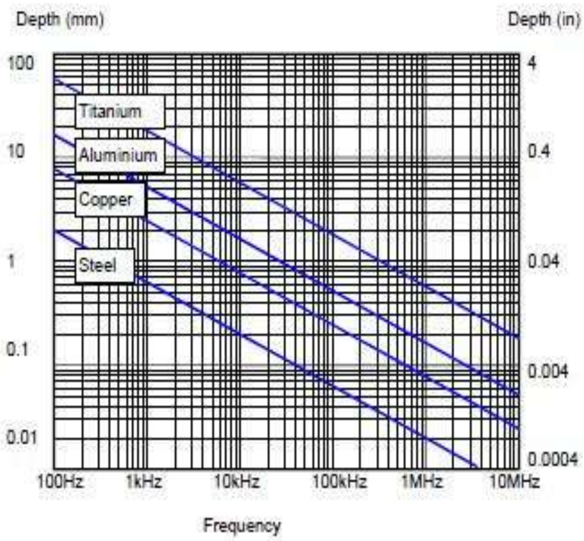
f is frequency of alternating current,

µ is permeability of workpiece material.

For the particular material, value of resistivity and permeability remains constant, there is only one variable i.e. frequency present in this equation. As it can be seen from the equation that decrease in frequency will increase the depth of penetration but it should also be kept in mind that at very low frequency the sensitivity of ECT falls rapidly. Therefore, there has to be some trade-off between frequency and depth of penetration for efficient working of ECT.

Following table provides the information about applicability i.e. information about materials which can be used and evaluation of depth penetration in different materials at different frequencies. This given table can also elucidate that for a particular material which frequency is suitable for working and detecting defects.

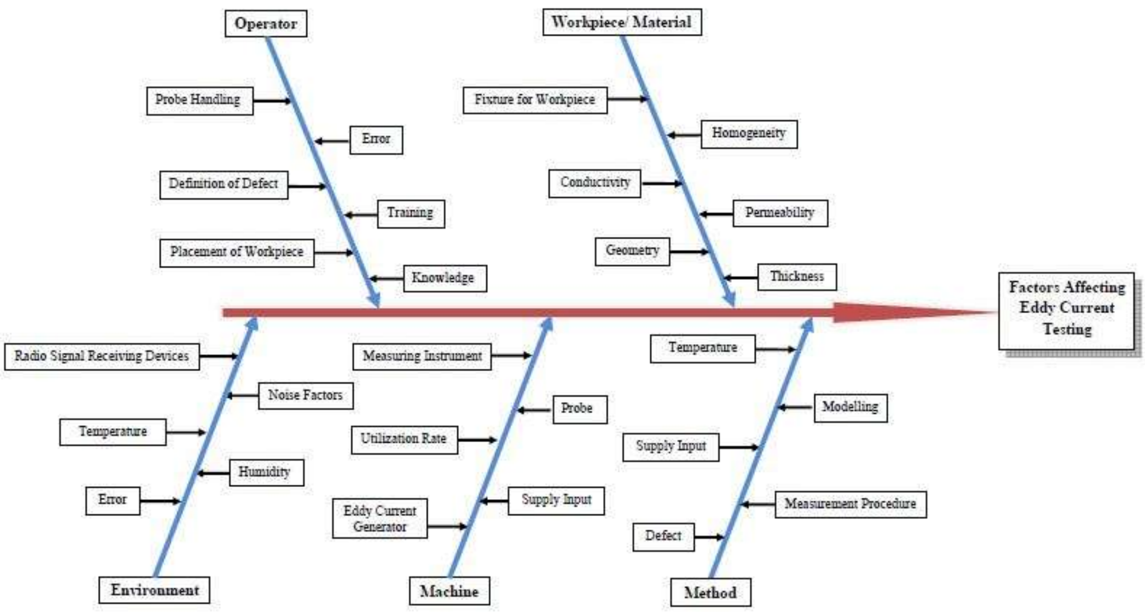
Material →	**Titanium**	**Chromium steel**	**Tin**	**Tungsten**	**Aluminium**
Resistivity (Ω·m) ρ →	$43x10^{-8}$	$29.3x10^{-8}$	$11x10^{-8}$	$5.65x10^{-8}$	$2.8x10^{-8}$
Permeability (N·A^{-2}) µ →	$0.34x10^{-5}$	$5.03x10^{-5}$	$2.27x10^{-5}$	$6.81x10^{-5}$	$2.2233x10^{-5}$
Frequency ↓	**δ (mm)**				
50 Hz	28.37	3.44	5.55	0.129	2.83
100 Hz	20.06	2.43	3.93	0.096	2.00
500 Hz	8.97	1.09	1.76	0.041	0.896
1 K Hz	6.34	0.768	1.24	0.029	0.634
5 k Hz	2.84	0.344	0.55	0.013	0.283



V. CAUSE EFFECT DIAGRAM OF FACTORS AFFECTING EDDY CURRENT TESTING

Here factors affecting eddy current testing are also elaborated with the help of cause-effect diagram. In this study the cause-effect diagram or fish-bone diagram is used to describe the factors affecting eddy current testing these factors are divided in following five categories.

1. Workpiece/Material
2. Method
3. Material
4. Operator
5. Environment



Cause-effect diagram for factors affecting ECT

VI. CONCLUSIONS

From the above study it can be concluded that due to the large number of variables in eddy current testing, in order to correctly interpret the results of ECT, all of the above factors must be considered. This is also one of the reasons of inconsistency in ECT.

Analysis of different factors like depth of penetration, sensitivity and frequency of the testing is also done in this study, which gives an idea about the suitable frequency range for different materials.

By drawing and studying the cause-effect diagram factors affecting eddy current testing and the explored difficulties with ECT are found as varying conductivity within workpiece, homogeneity of workpiece material, flatness, porosity, surface roughness, orientation of defects, location of defects, measurement error, probe handling etc.

Most of the manufacturing operations do not take care of these factors and difficulties as these are not very significant for most of the products. Therefore, it can be concluded that ECT can suitably be applied where the process of manufacturing takes care of the above mentioned factors and the causes of associated difficulties itself.

REFERENCES

[1] S. M. Metev and V. P. Veiko, “Laser Assisted Microtechnology”, 2nd ed., R. M. Osgood, Jr., Ed. Berlin, Germany: Springer-Verlag, 1998.

[2] J. Breckling, Ed., “The Analysis of Directional Time Series: Applications to Wind Speed and Direction, ser. Lecture Notes in Statistics. Berlin, Germany: Springer, 1989, vol. 61.

[3] S. Zhang, C. Zhu, J. K. O. Sin, and P. K. T. Mok, “A novel ultrathin elevated channel low-temperature poly-Si TFT,” IEEE Electron Device Lett., vol. 20, pp. 569–571, Nov. 1999.

[4] M. Wegmuller, J. P. von der Weid, P. Oberson, and N. Gisin, “High resolution fiber distributed measurements with coherent OFDR,” in Proc. ECOC’00, 2000, paper 11.3.4, p. 109.

[5] R. E. Sorace, V. S. Reinhardt, and S. A. Vaughn, “High-speed digitalto-RF converter,” U.S. Patent 5 668 842, Sept. 16, 1997.

[6] (2002) The IEEE website. [Online]. Available: http://www.ieee.org/

[7] M. Shell. IEEE tran homepage on CTAN. [Online]. Available: http://www.ctan.org/texarchive/macros/latex/contrib/supported/IEEEtran/

[8] FLEX Chip Signal Processor (MC68175/D), Motorola, 1996.

[9] “PDCA12-70 data sheet,” Opto Speed SA, Mezzovico, Switzerland. Karnik, “Performance of TCP congestion control with rate feedback: TCP/ABR and rate adaptive TCP/IP,” M. Eng. thesis, Indian Institute of Science, Bangalore, India, Jan. 1999.

[10] J. Padhye, V. Firoiu, and D. Towsley, “A stochastic model of TCP Reno congestion avoidance and control,” Univ. of Massachusetts, Amherst, MA, CMPSCI Tech. Rep. 99-02, 1999.

[11] Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification, IEEE Std. 802.11, 1997.