Non-destructive Evaluation of Conductive Materials by Eddy Current Swept Frequency Technique

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Novel approach in continuous non-destructive evaluation of conductive materials is concerned in the paper. Swept frequency excitation is employed to drive eddy currents in a conductive object. A conductive plate made of austenitic steel with artificial electro discharge machined notches is inspected in this study. The notches differ in depth. Various eddy current probes are employed for the inspection in order to evaluate their resolution characteristics concerning the depth of a detected defect. An eddy current probe is fixed at a certain position during the inspection, while the frequency of harmonic exciting current is changed in a wide range. Induced voltage in a pick-up coil of a probe is sensed. Frequency characteristics of the induced voltage for different notches are evaluated in order to assess the resolution capabilities. Numerical model of inspection is created in LTspice and COMSOL Multiphysics softwares and it connects a model of high frequency coil with a measurement chain. Experimental measurements are carried out as well and the results are compared and discussed. It is shown that novel eddy current swept frequency technique can be employed in continuous non-destructive monitoring of conductive structures.

***Index Terms*—eddy currents, frequency response, non-destructive testing, numerical simulation**

I. Introduction

New approaches such as System Health Monitoring and Condition Based Maintenance are nowadays employed for assessment of structural integrity of various components and structures. They follow three consecutive phases – detection of non-homogeneities, their diagnosis and prognosis of their further development. The first two phases are inherently associated with Non-Destructive Evaluation (NDE) of materials. NDE techniques are based on numerous physical principles and phenomena. Eddy current testing (ECT) is one of the widely utilized electromagnetic NDE methods. ECT works based on an interaction of time-varying electromagnetic field with a conductive body according to the Faraday's electromagnetic induction law [1]. The method is widely employed mainly in nuclear, petrochemical and aviation industries. ECT is a relative method and standard procedures evaluate relative change of an output signal during movement of an ECT probe. However, new approached in maintenance require continuous monitoring with fixed sensors. This is challenging issue concerning employment of ECT in such applications. The authors propose a new driving technique to tackle the challenge [2].

The swept frequency technique is not very explored yet in a field of the non-destructive testing and a crack evaluation by eddy currents. However, this technique may be perspective because it allows fixed location of a sensor and continuous monitoring of an investigated object. The monitoring demands a long-term evaluation of structures for a better assessment of their structural integrity.

The swept frequency eddy current technique connect the eddy current method, which is successful in the detection and the evaluation of conductive materials with the swept frequency excitation where the frequency of driving signal is changed in a wide range [3], [4].

The aim of this work is to detect and to evaluate defects in a conductive material by various types of eddy current probes in fixed positions. The frequency of the driving signal is changed in a wide range. Frequency characteristics of an output signal are acquired. Resolution characteristics of probes are evaluated by numerical means and experimental measurements as well.

II. Numerical and Experimental Investigations

An eddy current probe with air core is employed for the inspection at first. The probe consists of two multi turn coils. The exciting coil "Tx" is supplied with a time-varying electrical current and the receiving coil "Rx" senses the induced voltage. These coils have the same outer diameter d_{out} = 2.8 mm and their height is v = 2 mm. They differ in the number of turns, Tx = 140 and Rx = 80, therefore an inside diameter of the coils is different, d_{Txin} = 1.8 mm and d_{Rxin} = 1.4 mm. The configuration of air probe is shown in Fig. 1.

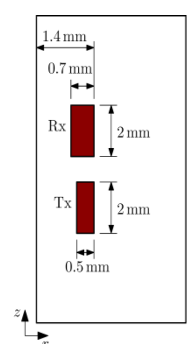

Fig. 1. The configuration of the eddy current air probe

In order to create precise numerical model of the probe for wide frequency range, the probe is positioned in air without any conductive object in proximity, at first. This model connects the high frequency representation of coil with the measurement chain due to a large impact on the resulting signal. The circuit model of the eddy current air probe is an important component. LTspice software is used for its creation. Subsequently it is verified in COMSOL Multiphysics and compared with the experiment. The results are compared in Fig. 2. Frequency characteristic of ratio of the input and the output induced voltage are displayed.

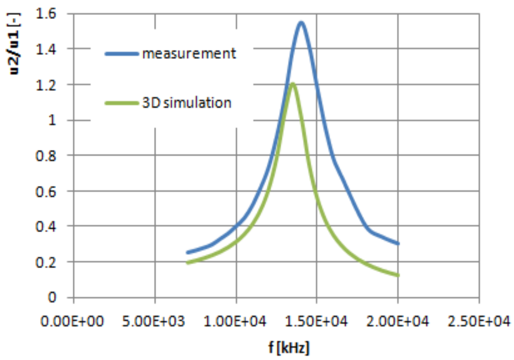

Fig. 2. Frequency characteristic of the voltage transfer of the probe

The main purpose of this work is non-destructive evaluation of a conductive plate using eddy current swept frequency technique. The plate is made of the austenitic steel SUS316L and it is investigated by various types of probes. Three electric discharge machined notches are introduced to the plate. The conductivity of investigated material is $\gamma = 1.4.10^6$ S/m and defects have the zero conductivity. The notches differ only in depth, the other parameters are the same. Configuration of the plate is shown in Fig. 3.

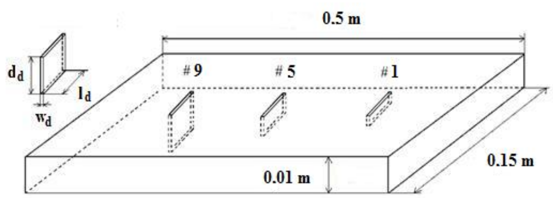

Fig. 3. The dimensions of the plate and the notches

One of the experiments is realized by the eddy current air probe fed from the high frequency generator. The frequency of the driving signal is changed in the range $f \in$ <7.5 kHz, 20 MHz>. The voltage transfer, i.e. the ratio of the output induced voltage to the input voltage, frequency characteristics are evaluated. The experimental results are displayed in Fig. 4.

The numerical simulations are carried out in 3D COMSOL Multiphysics. The parameters of the model are the same as used in the experimental measurements.

The obtained graphs of both the measurements and the numerical simulations provide comparable results. The probe successfully detects all the notches and the results show possibility to resolve between notches of different depths. The resonance frequency is f_R = 14 MHz for the experiments and f_R = 13.5 MHz for the numerical simulations. The difference between the results is due to the number of generated measurements and inaccurate values of the elements of the measurement chain. The resulting signal is affected by the presence of material defect and the highest deflection provide a notch with the depth d = 9 mm.

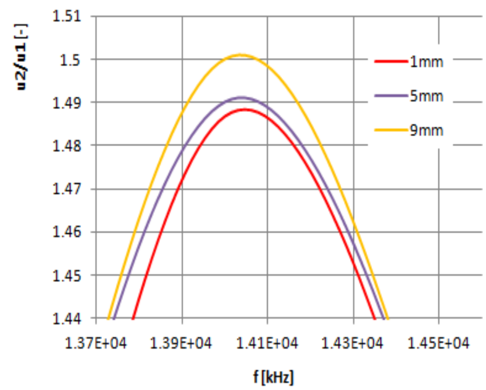

Fig. 4. Results of experiment by the eddy current air probe

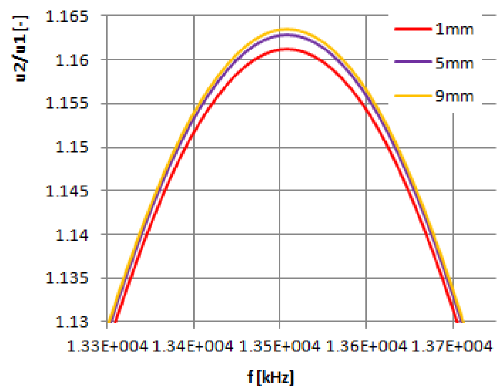

Fig. 5. Results of numerical simulations by the eddy current air probe

The full paper will describe development of numerical models of various types of eddy current probes. The purpose of this work is to prove applicability of the eddy current swept frequency technique in the field of non-destructive evaluation of conductive materials by eddy current. Resolution characteristics of the probes will be compared using numerical simulations and experimental measurements.

III. Acknowledgement

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IV. References

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