Impact of probe configuration on cracks' resolution in pulsed eddy current non-destructive evaluation

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Abstract **Pulsed eddy current non-destructive evaluation is concerned in the paper. Impact of eddy-current probe's configuration on response signals, especially on crack's depth resolution from the signals is numerically investigated. Orientation of an exciting coil of the probe regarding surface of a tested material is changed while the coil's dimensions are varied at the same time to evaluate influence of the parameters on induction coupling between the probe and the material. The induction coupling affects information transfer between the probe and the material and consequently it influences the resolution of detected defects. Numerical simulations with various diameters of the coil are then performed and evaluated to investigate impact of this parameter on resolution of defects with different depths.**

Keywords **Non-destructive evaluation, pulsed eddy currents, response signal, depth of defect, resolution**

I. INTRODUCTION

Different physical principles are utilised for the non-destructive evaluation (NDE) of materials. Eddy current testing (ECT) is one of the widely utilized electromagnetic methods [1]. It originates from the electromagnetic induction phenomena and its principle underlies in the interaction of induced eddy currents with structure of an examined body.

Conventional eddy current technique employs harmonic continuous-wave excitation under only one or a few discrete frequencies. On the other hand, pulsed eddy current (PEC) instruments apply a broad-band pulse, or step excitation to a coil to generate a magnetic field pulse. This magnetic field pulse propagates into a conductive material, generating pulsed eddy currents that according to the Lenz's theorem oppose the exciting field. The net field which is the superposition of the exciting field and the field "reflected" by the induced eddy currents in the specimen can be detected by a coil.

The pulsed driving produces an inherently wideband frequency spectrum, permitting extraction of more selective information that cannot be obtained by performing the inspection using a single frequency [2]. This provides an opportunity for better resolution of defect signals from interfering signals and also more complex information about specimen under inspection can be obtained. In view of further enhancing of PEC an optimal excitation system has to be designed. In PEC a test piece is coupled to an exciting coil through the electromagnetic induction. The induction coupling affects the information transfer and it relates especially to a lift-off (the distance between the coil and the surface of material under inspection), to dimensions of the coil as well as the coil's orientation. One should understand these relations in order to design high performance PEC probes.

Parametric study is carried out in the paper through numerical means. So called pancake eddy-current probe is used for the inspection. The probe is composed of only one circular coil that drives eddy currents in a specimen and pick-ups a response signal. Impact of selected parameters of the probe on the induction coupling between the probe and the specimen is investigated. The investigation is done indirectly through evaluation of the time constant of the coil coupled to the specimen. Influence of the coil diameter on the resolution of cracks with different depths is then evaluated.

II. NUMERICAL SIMULATION

A plate specimen having the electromagnetic parameters of a stainless steel INCONEL 600 with a conductivity of $\sigma = 1\ \mathrm{MS\cdot m^{-1}}$ and a relative permeability of $\mu_r = 1$ is used in this study. The dimensions of the material are 150x150x10 $\mathrm{mm^3}$. A circular coil drives the eddy currents in the specimen and pick-ups a signal. The coil is driven from a voltage source, while the voltage is changed in step from 0 to 10 V. The coil's current is considered as the response signal. Clearance between the coil and the plate surface, so called lift-off, is kept constant at 1 mm during the investigations.

A. Coil orientation and dimensions

At first the influence of the exciting coil orientation regarding the plate surface on the induction coupling is investigated. Two particular orientations of the coil are considered here: a) normal position – the coil axis is perpendicular to the plate surface, b) tangential position – the coil axis is parallel to the plate surface. Particular results of time evolution of the coil current for the two orientations of the coil are shown in Fig. 1. The current waveform for the coil in free space is displayed in the figure as well. Dimensions of the coil for this case are as follows: diameter $d_c = 50$ mm, width of winding $w_c = 1$ mm and height of winding $h_c = 1$ mm. It is clear from the presented results that the time constant of the coil coupled to the plate are different for the two orientations of the coil over the plate comparing to the self time constant of the coil (coil in free space). It means that the induction coupling is different for different orientation of the coil over the plate surface, while it is the strongest in the coil's normal position.

The investigations for the two orientations of the coil are also done for other coil's dimensions. All the three coil's dimensions are varied in wide ranges to study their impacts on the induction coupling. Figure 2 presents time dependences of the current for two values of the coil diameter d_c: 3 and 50 mm while the coil is in the normal position regarding the plate surface and the winding cross section is 1 mm^2.

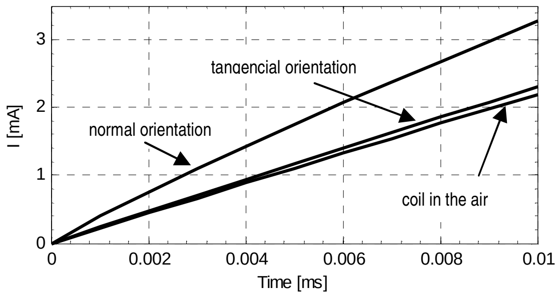

Fig. 1. Time dependences of current for different orientations of the coil

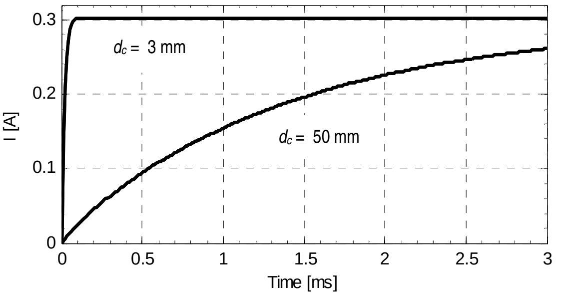

Fig. 2. Time dependences of current for different diameters of the coil

The most important results of the above explained parametric study will be presented in the in the full version of the paper.

B. Resolution of the defect

The resolution of a defect with different depths according to the response signals is then investigated. Influence of the coil diameter on the resolution is studied. The defect has a shape of cuboid with a width of w_d = 0.2 mm, a length of l_d = 10 mm and its depth changes in a range d_d = 1÷10 mm with a step of 1 mm. The defect is situated in the middle of the plate and the coil is situated just over its centre. The width and height of the coil's winding are kept constant each at a value of 1 mm, whilst the diameter of the coil is changed in the range d_c = 3÷50 mm. The coil current is sensed as the response signal (see Fig.1 and Fig.2). However, the changes in signal due to different depths of the defect are relatively small and it is difficult to observe them from the response signals. Therefore, the difference signals obtained by subtraction of the response signals with crack and without crack are evaluated. The example of difference signal for a 2-mm deep crack using a 3-mm-diameter coil is displayed in Fig. 3.

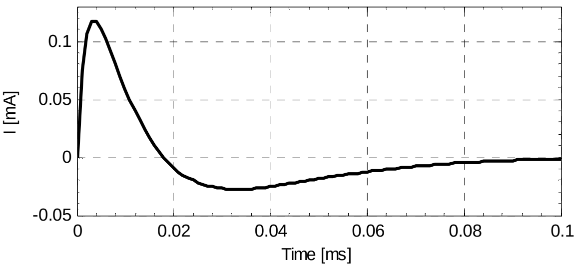

Fig. 3. Difference signal for crack's depth 2 mm using 3-mm-diameter coil

One of the important parameter used for crack's characterization is the maximum value of the difference signal as it strongly depends on the crack depth [3]. Figure 4 shows a dependence of the maximum value of the difference signal on the crack depth gained using 3-mm-diameter coil. The curve determines crack's depth resolution. It can be seen that the saturation occurs on the displayed dependence due to the skin-effect. It means that it is difficult to evaluate defect's depth when it is deeper that approximately 4 mm. However, the saturation point strongly depends on the coil's diameter. The full paper will present gained results in full extent.

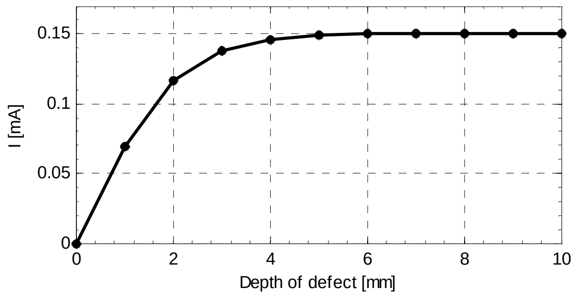

Fig. 4. Dependence of difference signal's maximum values on the crack's depth for 3-mm-diameter coil

III. Conclusion

The paper was focused on impact of exciting coils' configuration on the response signal in pulsed eddy current non-destructive inspection. Especially, resolution of defects with different depths was concerned. It can be concluded from the result that the coil oriented in the normal position with large diameter and small winding cross section provides stronger induction coupling with the plate. The induction coupling has impact on information transfer between a probe and an inspected material and thus it influences the resolution of detected cracks. Cracks with different depths were inspected with coils having different diameters. Using a small-diameter coil the response signals gets saturated faster with increasing the depth of defect while by using a larger-diameter coil the response signal almost does not saturate within an investigated range.

IV. Acknowledgements

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V. References

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