17th Symposium IMEKO TC 4, 3rd Symposium IMEKO TC 19 and 15th IWADC Workshop
Instrumentation for the ICT Era
Sept. 8-10, 2010, Kosice, Slovakia

Chirp and Multi-frequency Eddy Current Non-destructive Evaluation

Radislav Šmíd, Jakub Král, Martin Mrázek[1]

[1] *Czech Technical University in Prague, Faculty of Electrical Engineering, Department of Measurement, Technicka 2, 166 27 Prague 6, Czech Republic, phone 224 352 131, fax 233 339 929, smid@fel.cvut.cz*

Abstract- This paper describes an eddy current (EC) based non-destructive testing system used for experimental verification of optimized chirp signal. The time-frequency content of the EC driving signal is synthesized with respect to material properties. We are expecting an improvement in sensitivity of crack and corrosion detection.

I. Introduction

The Eddy Current (EC) method is a well established technique for flaw and corrosion detection in many application areas of non-destructive testing (NDT), e.g. in aircraft maintenance. Eddy currents induced in a tested object by a changing magnetic field from a coil inside a probe concentrate near the surface of the object adjacent to the coil. Because eddy currents produce their own magnetic field that opposes the primary field, the strength of the eddy currents decays with depth because. The eddy currents are formed first at the surface, weaken the magnetic field that induces the deeper layer of eddy currents.

With increasing depth into the material the magnetic field and the resulting eddy currents are weaker. It is widely understood [2] that the penetration depth δ of an eddy current depends on the excitation frequency ω

$$\delta = \frac{1}{\xi} = \sqrt{\frac{2}{\gamma\mu\omega}} \tag{1}$$

γ and μ are material properties. Phase lag is an useful parameter of the eddy current signal describing the shift in time between the eddy current response from a flaw on the surface and a flaw at some distance below the surface. Phase lag θ in radians can be calculated as

$$\theta = \frac{x}{\delta} \tag{2}$$

where x is a distance below surface and δ is the penetration depth. When the frequency of driving current is sweeping through a frequency range, the influence of eddy current from different depths is changing. This principle is useful for obtaining information about flaws in different depths, about conductivity changes, about layered structure of the object etc.

We propose to generate the driving signal through a range of frequencies for obtaining information from range of depths. This can be accomplished by common technique - linear sweeping of frequency (linear chirp) [3].

We compute another prescription for frequency changing to linearise the relation between depth and time during one measurement cycle. Is it also possible to optimize the chirp for minimization of lift-off. In the case of homogenous object is possible to estimate the conductivity of the material.

II. Realization

The overall scheme of the experimental EC system developed for evaluation of proposed methods is shown in Fig. 1.

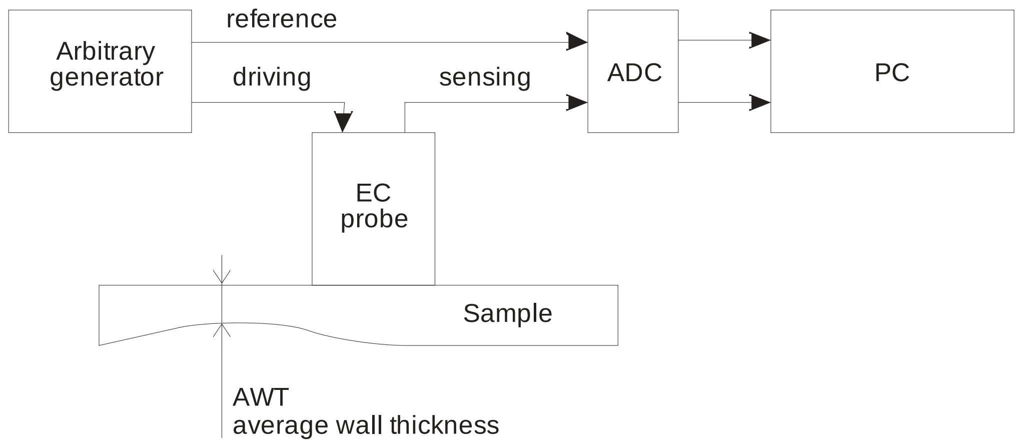

Figure 1. Experimental EC system

The system consists from arbitrary generator programmable from PC using USB interface, driving and sensing low-noise amplifiers, an EC probe, a multichannel analog-to-digital converter and PC. The chirp signal is synthesized using Matlab and loaded to the generator. Both driving and sensing signal are digitized and synchronously detected using numerical processing in Matlab. The proposed system can be also implemented using digital signal processor (DSP).

For synchronous detection, it is necessary to use reference and 90-degree shifted reference signals. We reconstruct the reference signal from digitized samples using chirp-fitting algorithm with the help of apriori determined frequency content of the reference. To synchronize the measurement runs at the beginning of the synthesized chirp is a starting tag embedded (see Fig.2).

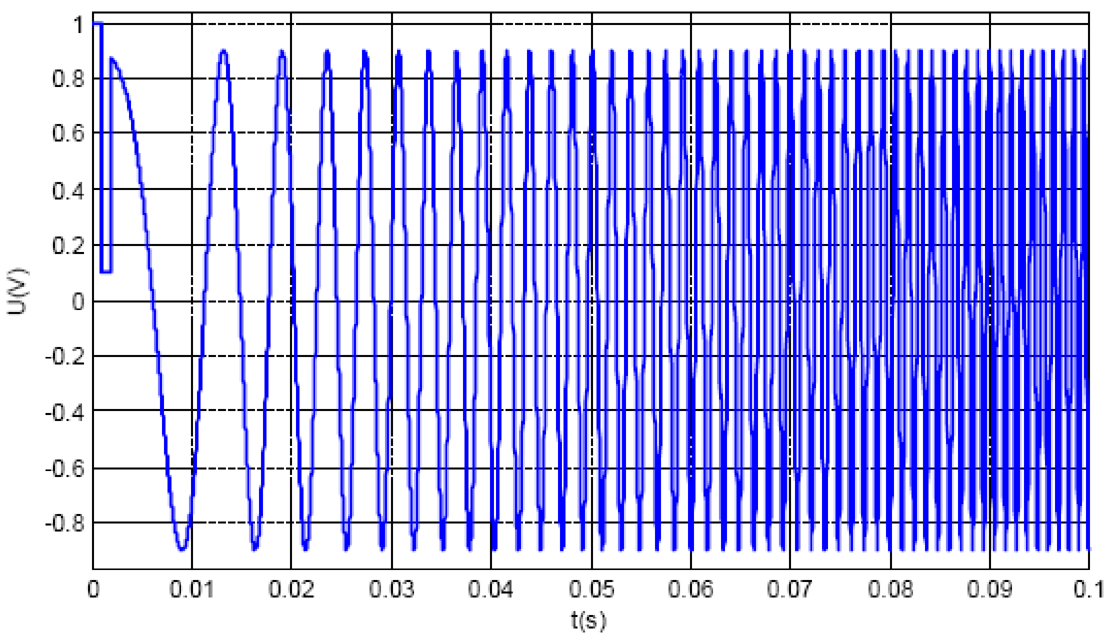

Figure 2. Chirp signal with embedded starting tag

From the acquired waveform, the in-phase and quadrature component is reconstructed and used for synchronous detection to obtain complex plane signal visualization.

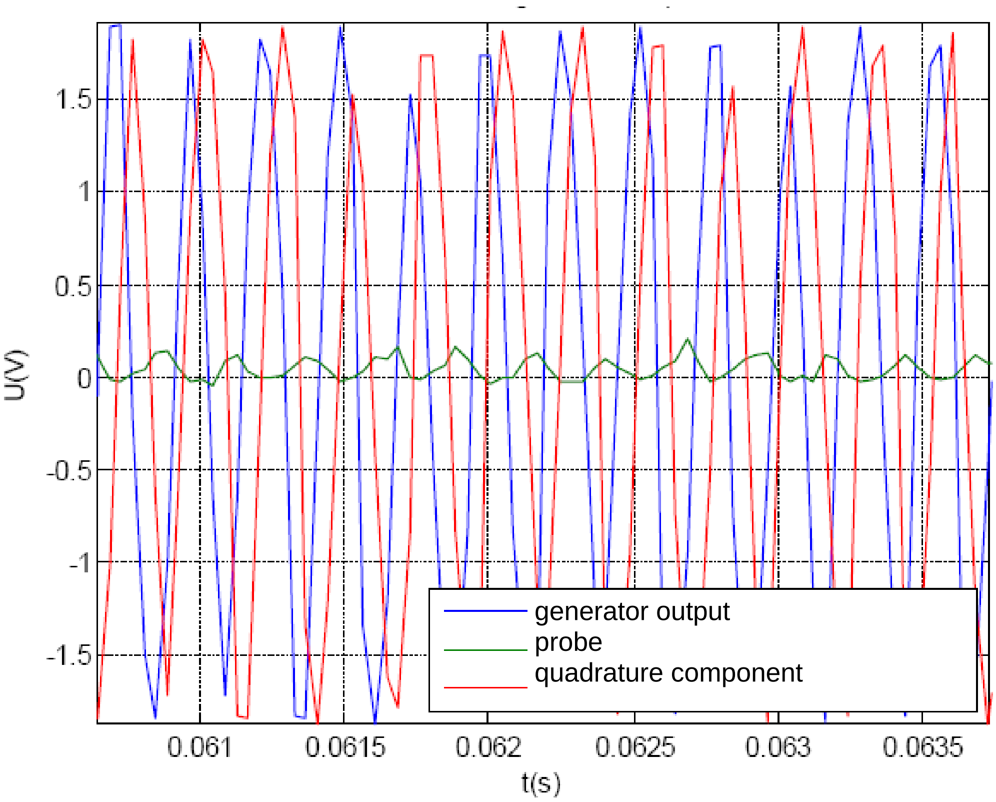

Figure 3. Typical probe output and quadrature components for driving and synchronous detection

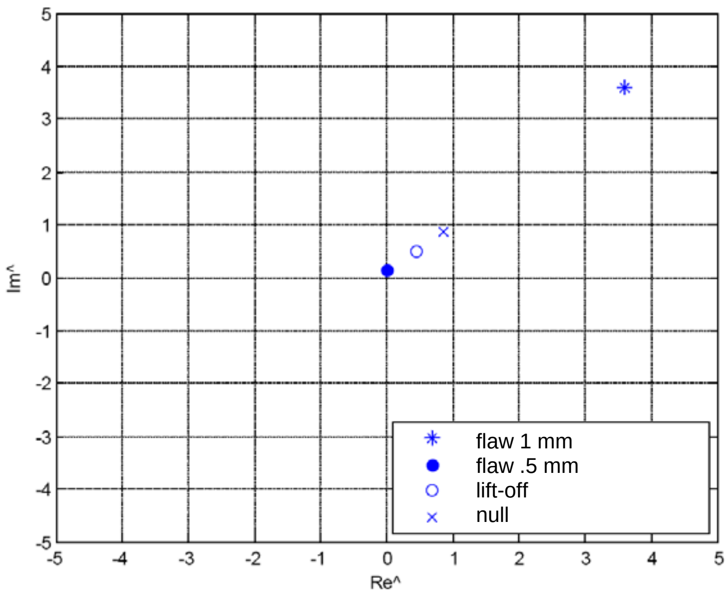

Figure 4. Preliminary results – response to lift-off and flaws of different lengths

Overall sensitivity in the case of single frequency driving signal is depicted on Fig. 4. For the frequency sweep we obtain a curve in complex plane with variable shape resulting from changes of EC for different frequencies (different penetration depths).

III. Conclusion

We propose a system for experiments with arbitrary EC driving signal. Our aim is to optimize and pre-compute the chirp signal with respect to material properties and relation between frequency and penetration depth. We are expecting an improvement both in crack detectability and corrosion mapping performance.

References

[1] John C. Aldrin, Jeremy S. Knopp, "Crack Characterization Method with Invariance to Noise Features for Eddy Current Inspection of Fasterner Sites", *Journal of Nondestructive Evaluation*, Vol. 25, No. 4, December 2006.

[2] Shull, P. J., *Nondestructive Evaluation: Theory, Techniques, and Applications*, CRC Press, 2002.

[3] NDT Resource center, online http://www.ndt-ed.org

[4] Šmíd, R., Dočekal, A., Kreidl, M., „Automated Classification of Eddy Current Signatures during Manual Inspection", *NDT&E International,* Vol. 38, 462-470. 2005.

[5] Dočekal, A. , Kreidl, M., Šmíd, R., System for 3D Visualization of Flaws for Eddy Current Inspection In: *Acta Polytechnica*. vol. 46, no. 2, 36-40, 2006.

[6] C. Mandache, J.H.V. Lefebvre, Transient and harmonic eddy currents: Lift-off point of intersection, *NDT & E International*, Volume 39, Issue 1, Pages 57-60, January 2006.

[7] J.R.S. Giguère, B.A. Lepine and J.M.S. Dubois, Pulsed eddy current technology: characterizing material loss with gap and lift-off variations, *Res Nondestructive Eval* 13 , pp. 119–129, 2001.

[8] M. Morozov, G.Y. Tian and D. Edgar, Comparison of PEC and SFEC NDE techniques, *Nondestructive Testing and Evaluation* 24 (1), pp. 153–164.,2009.