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Multichannel Heterodyning-Based Eddy Current Testing with Magnetoresistive Sensors

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Summary:

High spatial resolution magnetoresistive arrays are utilized for eddy current testing in combination with a single wire excitation and a heterodyne principle to minimize metrology efforts. A discrete frontend with FPGA-based data acquisition makes use of a 128-element eddy current probe to test 440 µm artificial surface defects with an SNR of 24 dB.

Keywords: Eddy Current Testing, Magnetoresistance, Heterodyning, Additive Manufacturing.

Background, Motivation an Objective

The most common question when discussing NDT methods is always: *"What is the smallest defect size that can be detected?"* For eddy current testing (ET) this is not any different. Unfortunately, there is not a simple answer to this question. Since magnetoresistive (MR) sensors based on giant, anisotropic or tunnel magnetoresistive effect (GMR, AMR or TMR) became available, it has not only been shown, that MR-based ET is possible [1][2], but also that MR elements can easily be miniaturized and parallelized while maintaining high sensitivity and, therefore, pushing the limit of smallest detectable defect sizes. Combined with precise excitation of magnetic fields a spatial resolution down to some µm can be achieved [3][4].

In the past, approaches based on integrated or discrete electronics have been made to utilize MR-based high element count ET probes and applying a heterodyne principle to reduce inductive coupling and carrier frequency. [5][6][7][8].

However, utilizing the MR arrays full potential is often not possible due to either ET probes not being widely available or the lack of suitable hardware for amplification and data acquisition. Furthermore, parallelization of the ET probes is often not possible simply because of geometric limitations.

Description of the New Method or System

In this work approaches are made to overcome those limitations. A convenient method is proposed to manufacture MR-based ET probes with 128 single MR elements and a single wire as inducer made from a rigid-flex PCB (see Fig. 1) with a testing width of 16 mm that can be extended to any desired testing width.

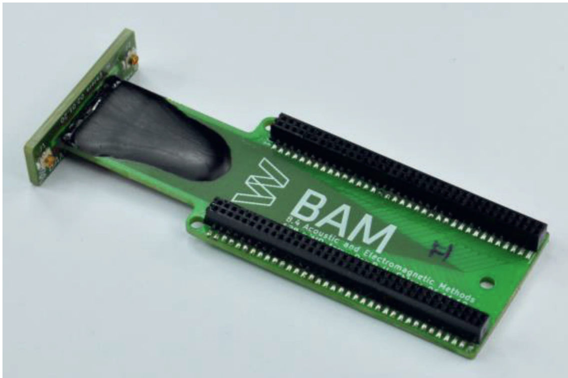

Fig. 1. 128x MR-based ET probe with a single wire on rigid-flex PCB as inducer.

Furthermore, to utilize this ET probes a compact system is set up.

A heterodyning-based frontend with discrete amplification and multiplexing (see Fig. 2) in combination with FPGA-based data acquisition results in a minimum of expensive laboratory scale equipment needed while still being able to achieve similar signal-to-noise ratios (SNR).

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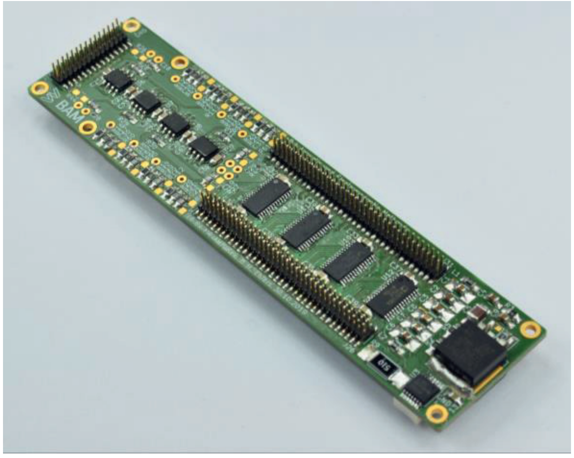

Fig. 2. Heterodyning-based sensor frontend with multiplexing and amplification for 128 MR elements.

Results

The proposed system is used to measure an artificial surface defect of five boreholes each with a diameter of 440 µm. The data of 32 MR Elements are used to create a normalized amplitude image (see Fig. 3) showing the defect information with a SNR of 24 dB. The testing time is 1,7 s

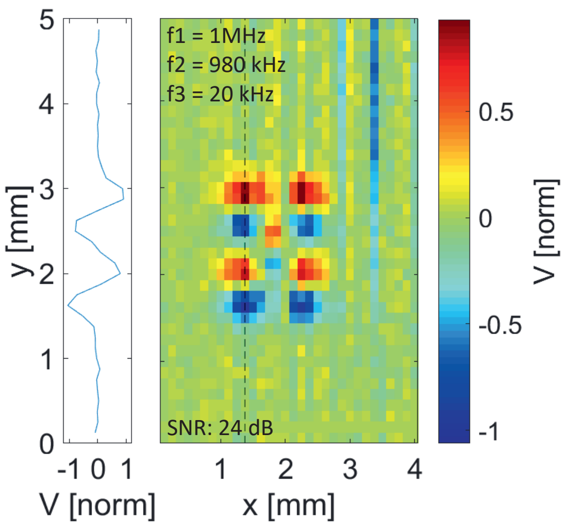

Fig. 3. Amplitude image of 5x Ø 440 µm artificial defect in AL-FN-22 specimen

Outlook

In the future, one of the target applications of this system will be online monitoring of additively manufactured parts. During laser powder bed fusion (LPBF) each manufactured layer will be tested. Helping to understand the LPBF process, the formation of defects and gathering geometric information of the manufactured parts.

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