Data Fusion of Matrix Transducer’s Signals for Evaluation of Train Hollow Axles

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***Abstract*— In this paper results of data fusion algorithms of magnetic flux leakage signals measured by matrix type transducer for evaluation of train hollow axles are presented. First the transducer’s geometry analysis were carried out and the sensors’ array misalignment were estimated. Then the data registration process was proceeded. Finally, signal level data fusion algorithms were carried out.**

***Keywords*—multisensor data fusion, remanent magnetic flux leakage, hollow axles inspection**

I. Introduction

Nowadays observed significant development in high-speed trains industry encourages an increase in efforts for the improvement of the existing safety inspections procedures or development of new ones. One of the greatest attentions is being paid to destruction evaluation of train axles, which are the crucial structural component for the maintaining of adequate safety level of the high-speed trains. For the minimization of risk of the danger failures of the wheelsets a number of inspections have to be carried out during the exploitation of rolling stock. The most popular inspection systems utilize ultrasound technique, however it is insensitive for surface breaking defects [1]. Therefore, recently a new electromagnetic system was introduced [2]. The system uses remanent flux leakage technique and multisensor transducer, which allows evaluation of the near surface regions of the hollow axles.

Depending on the scanning type, the matrix transducer can be utilized to increase: the speed of inspection or the probability of proper evaluation of the axles’ destruction level. In this paper, in order to increase the level of proper evaluation, the signals acquired by the matrix transducer are used to carry out the data fusion procedures. The pixel level signals integration algorithms are applied and the results presented and discussed.

II. Measuring System and Results

The transducer consists of a permanent magnet, which magnetizes the hollow axle. Then the remanent flux leakage field is measured by matrix of eight Honeywell’s HMC 5883 AMR (Anisotropic Magneto Resistive) sensors [3]. In order to obtain similar sensitivity for defects having a different orientation the 3-axis transducers were applied to monitor three components of the magnetic field. The sensors were fitted in the plastic supporting element in equally spaced positions located every 45 degrees on the circumference of the transducer. The detailed description of the system can be found in [2].

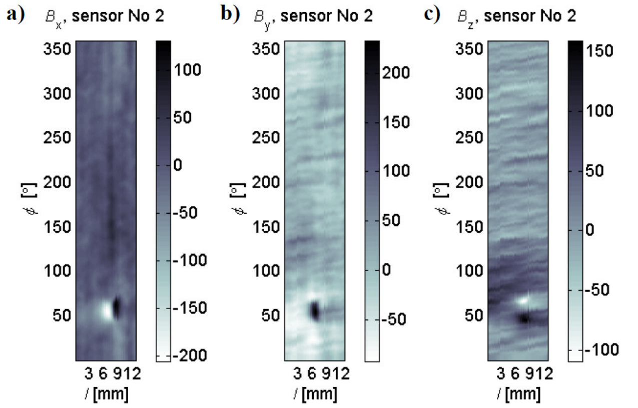

Figure 1. Selected results of all three field componnents obtained for flaw having 2mm depth during 2-D scanning (l, ϕ); unit: 100 equals to 0.4 G.

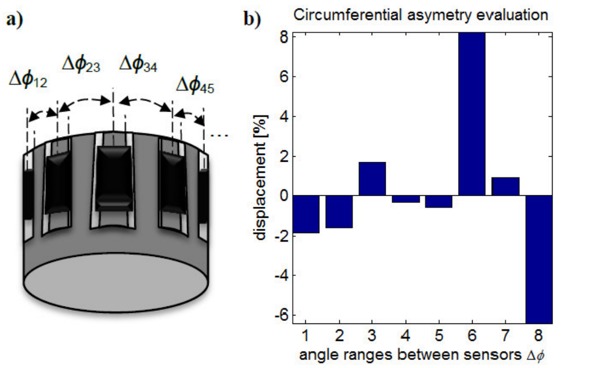

Figure 2. Spatial alignment evaluation of the transdcuer’s sensors: a) view of the plastic component with AMR sensors, b) results of the sensors angular misalignment estimation.

All measurements were made for hollow axle sample with EDM notches having different depths (Electro Discharged Machined). During the data acquisition, the transducer was first moved by linear step and then rotated by 360 degrees. The selected results of measurements of all three components measured by one sensor obtained for flaw having 2 mm depth is presented in Fig. 1. Each measured field component allows to achieve different information about the defect, such as: length, width and depth [2].

III. Spatial Alignment Evaluation and Data Registration

Before the data fusion algorithms were applied the data registration procedure was proceeded. First, in order to transform acquired signals into common coordinate system, the estimation of angular and linear misalignment of each

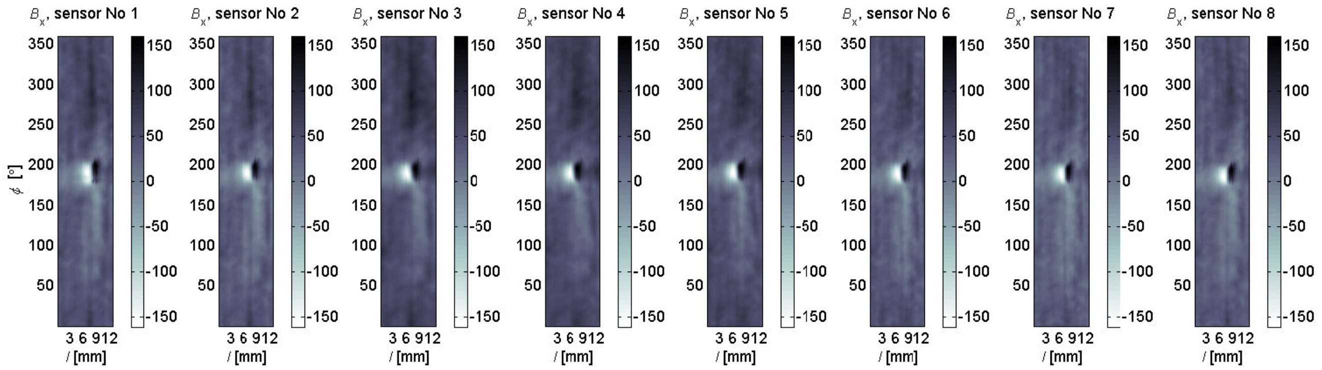

Figure 3. Results of the data registration process obtained for B_x componenet.

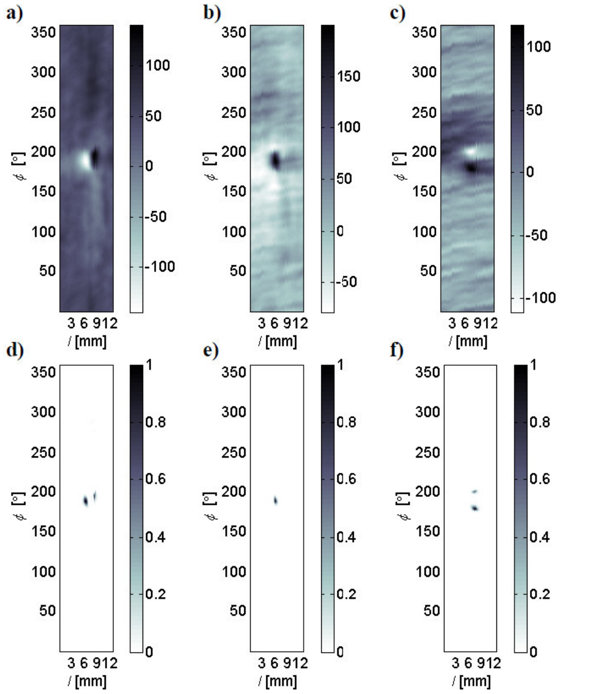

Figure 4. The results of data fusion algorithms obtained for image processing (a,b and c) and statistical algorithms (d, e and f); results for component: B_x (a and d), B_y (b and e), B_z (c and f).

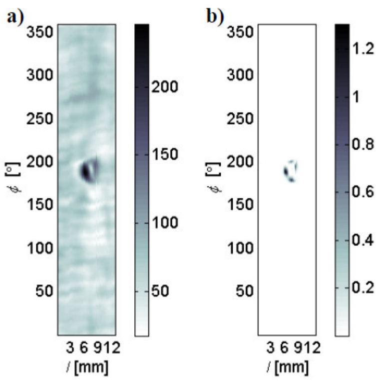

Figure 5. Final results of data fuson algorithms: a) image processing algorithm, b) statistical algorithm.

sensor in matrix was carried out. The results of the angular misalignment evaluation are presented in Figure 2. From the results it can be noticed that the asymmetry of the transducer cannot be neglected. The highest misalignment is around 8% which corresponds to 3.6°. During the validation of the symmetry of the transducer, the misalignment was also calculated in mm scale. It was less than 0.2 mm, which is fairly acceptable in industrial applications. In the second step, the sensitivity rage of sensors in matrix was estimated. During this stage, not only the gain and the offset but also difference in distance between each sensor and the surface of the axle should be taken into account. Considering the gain tolerance and linearity ranges of the sensors [3] and the experimental results, the calibration coefficient were computed. Finally, the data registration process was carried out. The selected results for all sensors obtained for B_x component were presented in Fig. 3. It can be seen that similar sensitivity was achieved for each sensor.

IV. Data Fusion Results

In order to enhance the performance of the system, pixel level data fusion algorithms were applied. The selected results obtained during the integration process carried out using image information processing and statistical algorithms are presented in Fig. 4. Taking into account that each measured field component provides different information about the defect, the final fusion (Fig. 5) is obtained using all three results (Fig. 4 a, b, c and Fig. 4 d, e, f) by computing the norm value. It can be noticed that clear indication of the EDM notch area was achieved. Further analysis of the fused data allows to proceed the defects identification process. The details of the processing and data fusion algorithms with performance evaluation as well as the full set of results will be presented in final version of the paper.

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