

1.1.18. STATISTICAL DIAGNOSTIC MODEL FOR DEFECT PARAMETERS RECONSTRUCTION IN MFL NON-DESTRUCTIVE TESTING

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Inverse problem of magnetic inspection consists in defect linear dimensions and defect depth determination by magnetic field leakage topography. To solve conventional inverse problem one shall establish analytical dependence between magnetic induction measured values and estimated defect parameters. However, existing analytical dependences, simulating uniformity defect as “magnetic dipole” or capacitor “charged magnetically” are applicable only for magnetic field of artificial defects description.

Unlike analytical model finite elements simulation allows to consider actual defect shape features and also imperfections of magnetizing and measuring system. Still due to great amount of estimated parameters numerical diagnostic model built in such a way loses compactness property. To achieve proper parameterization accuracy several dozens of thousand models shall be calculated. As a result, instead of analytical expression we obtain data base as diagnostic model that includes approximately 10,000 magnetic signals. In this case, special methods, allowing large bulk of data analysis, are appropriate for inverse problem solution. These include statistical analysis methods, genetic algorithms, neural networks.

Each method has its peculiarities, but all of them are implemented in practice. Nevertheless, statistical estimation provides a range of extra advantages, such as possibility of developed model adequacy determination, obtained results reliability assessment, factor analysis and influencing factors significance determination.

In reference [1] method of multiple linear regression application for magnetic inspection inverse problem solution is described. Linear predictors were applicable for defect parameters estimation, corresponding to three different models – “corrosion”, “notch”, “crack”. Estimation model choice was made by means of statistical Bayesian classifier as well. Above mentioned estimation scheme predetermined acceptable results in the large.

It shall be noted that similar to neural-network and genetic approaches given estimation algorithm is rather general and formal, it does not take into account considered task specific character adequately. Present study is aimed at building statistical method of non-destructive inspection inverse problem solution wherein estimation model is developed with regard to physical regularities.

Defect parameterization method was developed concerning in-tube longitudinal magnetization defectoscope readings. Two components of magnetic induction were analyzed – axial and azimuthal. Magnetic field leakage topography not relating to any specific physical model was analyzed as result of some defect faces fields overlapping. In this connection, instead of defects grouping by “corrosion”, “notch”, “crack” principle regression equations were introduced for parameterization of defects with almost equal linear dimensions. Such approach allowed to carry out piecewise linearization of correspondence between magnetic induction axial component amplitude and defect depth.

Figure 1 shows correlation coefficient between defect depth and maximum value of magnetic induction axial component as a function of defect length and its eccentricity, characterizing defect elongation in azimuthal direction. Correlation score between depth and magnetic signal magnitude changes in the range from 0.97 to 0.7. High correlation

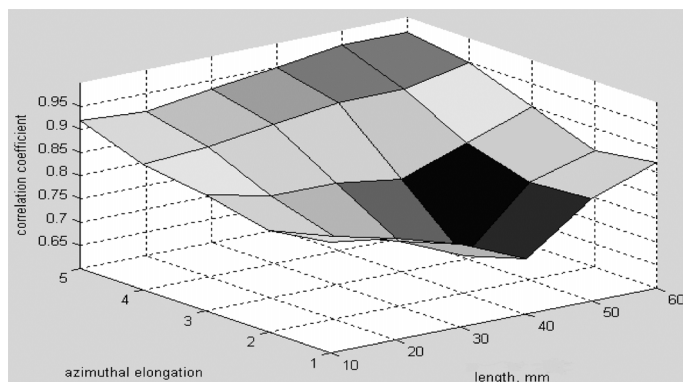


Fig. 1. Correlation coefficient between defect depth and maximum B_z value as a function of defect length and its eccentricity

score (more than 0.9) provide defect depth high accuracy estimation based only on one amplitude parameter using simple linear regression.

Graph region, showing low correlation score between magnetic signal amplitude and defects depth (less than 0.85), is of special interest. Low correlation score can be explained by the fact that at object longitudinal magnetization similar-waveform signals may correspond to some of different defects. However, even in this case depth determination error can be minimized due to application a special parameterization scheme.

We use rated features, characterizing ratio of magnetic magnitude to the signals length, width and area. It is carried out comparison of magnetic induction axial and azimuthal components topography is analyzed.

Developed method was thoroughly tested using several thousands artificial and natural defects sample. Defects depth determination error does not exceed 19% of tube wall thickness (average error equals to 9%), linear dimensions determination error is about 1 cm.

References:

1. **Barat V., Lunin V., Seidel H.-U., Bock A.** "Signal Processing of Magnetic flux Leakage Data Obtained from Pipeline Inspection", 48th International Scientific Colloquium: Proceedings Ilmenau, Germany, 2003. – P. 131–132.