STATISTICAL DIAGNOSTIC MODEL FOR DEFECT PARAMETERS RECONSTRUCTION IN MFL NONDESTRUCTIVE TESTING

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Inverse problem of MFL nondestructive testing consists in reconstruction of defect's depth, width and length on the base of 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 dependencies, simulating uniformity defect as "magnetic dipole" or capacitor "charged magnetically" are applicable only for description of artificial defect's magnetic field.

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. Fig. 1 depicts result of finite element simulation of metal loss. In this case solution of inverse problem should be based on methods, appropriate for analyzes of large amount of numerical data. These include statistical analysis methods, genetic algorithms, and artificial neural networks.

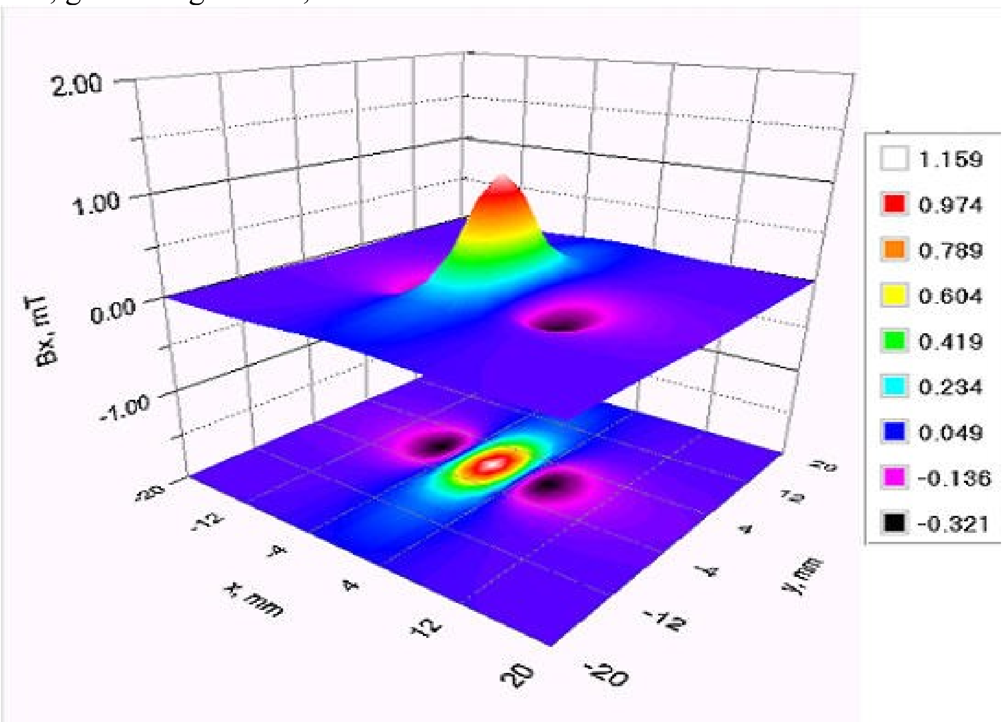

Fig. 1 Finite element simulation of metal loss

Each method has its peculiarities, but all of them are implemented in practice. Nevertheless, statistical estimation provides a range of extra advantages. On one hand it is possible to determine adequacy of developed model and consider influence of most significant factors, on the other hand it supplies reliability assessment of obtained results.

In reference [1, 2] method of multiple linear regression application for magnetic inspection inverse problem solution is described. Defects parameters d_i such as depth, length, width are to be estimated according to linear regression model:

$$d_i = \beta_0 + \beta_1 f_{1i} + \ldots + \beta_p f_{pi}$$

f_i – features, extracted from magnetic diagnostic signal, β_i – regression coefficients.

To estimate defect's parameters linear predictors were applied, which correspond to three different models – "corrosion", "notch", "crack". Choice of estimation model was made by means of statistical Bayesian classifier as well. Such estimation scheme predetermined acceptable results in the large, but there is some subset of defects, which parameters can be estimated with appreciably higher error only [3]. Such defects lie somewhere between corrosions and notches.

It shall be noted that similar to neural-network and genetic approaches conventional statistical estimation algorithm is rather general and formal, it does not take into account adequately a specific character considered of task. Present study is devoted to construction of such statistical method of MFL inverse problem solution, which estimation model is developed with regard to physical regularities.

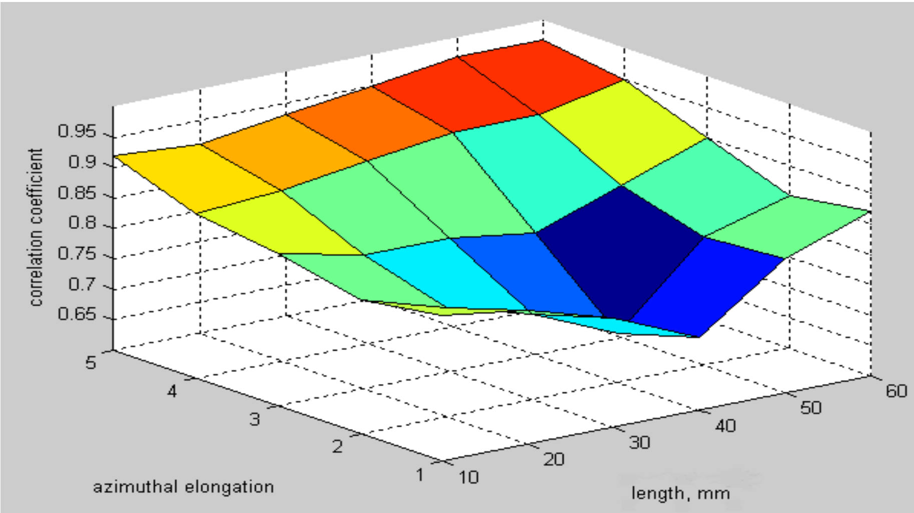

Fig. 2 Correlation coefficient between defect depth and maximum B_z value as a function of defect length and its eccentricity

Developed defect parametrization method concerns in-tube pipeline inspection with longitudinal magnetization. Two components of magnetic induction are to be analyzed – axial and azimuthal. Magnetic field leakage topography was analyzed not relating to any specific physical model but as superposition of defect's faces fields. In this connection principle regression equations were introduced for parametrization of defects with almost equal linear dimensions instead of defects grouping by "corrosion", "notch", "crack". Such approach allowed to carry out piecewise linearization of correspondence between magnetic induction axial component magnitude and defect depth.

Fig. 2 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 score (more than 0.9) provide defect depth high accuracy estimation based only on one magnitude 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 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 parametrization scheme. Example of piecewise linear approximation is shown on the Fig. 3.

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.

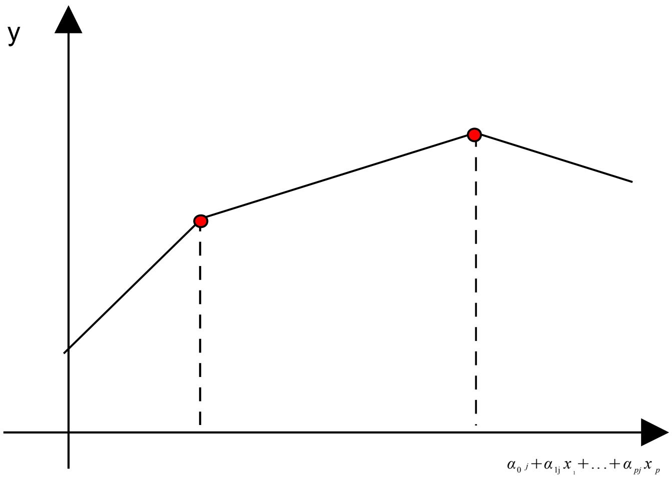

Fig. 3 Piecewise linear approximation

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

References

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