PROBLEMS OF DATA ANALYSIS AUTOMATION IN MFL NONDESTRUCTIVE TESTING

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Automation of data processing in MFL nondestructive testing corresponds to one of the main trends of NDT development of last years. It ensures increasing of efficiency and reliability of defect detection and evaluation. So far automatic data processing supports regularly and objective technical condition monitoring, it serves as necessary prerequisite for prediction of technical condition of inspected equipment and systems components. This is essential for safety and security of industrial objects.

In the broad sense automation of NDT includes automation of measuring system calibration procedure, automatic preliminary and general processing of measurement signals, automation of tested objects condition classification and proposal of further actions. In this report we consider questions of data analysis automation in MFL nondestructive testing.

Typical phases of diagnostic MFL-data processing are shown on the Figure 1.

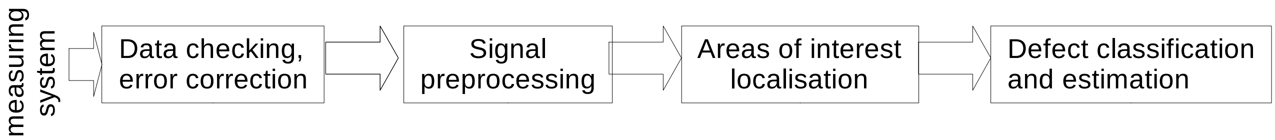

Fig. 1

Automation of data processing includes automatic detection and correction of measuring systems errors (coursed, for example, by distortion of measuring system path), automatic localization of areas of interest (defects and constructs), automatic defect detection/classification and estimation of defects parameters.

General automation problem can be solved only on the base of comprehensive approach with consideration of interconnection between different phases of data processing. One should consider the influence of signal preprocessing parameters on the result of defect localization and classification. Results of datachecking should be concerned while defect classification and estimation of defects parameters. Malfunctions of measuring system should be at least detected, that means registration of faulty sensors and the corresponding distance of malfunction. As a maximum data errors should be corrected. This is possible with consideration of signals from neighboring sensors and a general model of useful signal. For example separate loss data scans (occurs frequently while irregular movement of measuring system) can be restored with help of conventional linear interpolation. Information about location of incorrect data should be considered while defect detection and localization, as far as while estimation of their parameters.

Key role in automation of data analysis in NDT application plays automatic defect detection and classification. Finally it defines number of missed defects and false detection. Application of adaptive algorithms gives an opportunity for significant improvement of defect detection [1]. These algorithms are base on the consideration of typical defect model and distribution of its parameters as well as on the consideration of local noise characteristics.

As an example let’s take adaptive detection of pitting corrosion at MFL-signal of seamless pipe [2]. This type of pipes distinguishes themselves with a high value of disturbances at MFL-signal. For axial magnetization signal of pitting corrosion have a typical form, shown on the Figure 2 (it is a result of magnetic field simulation without noise).

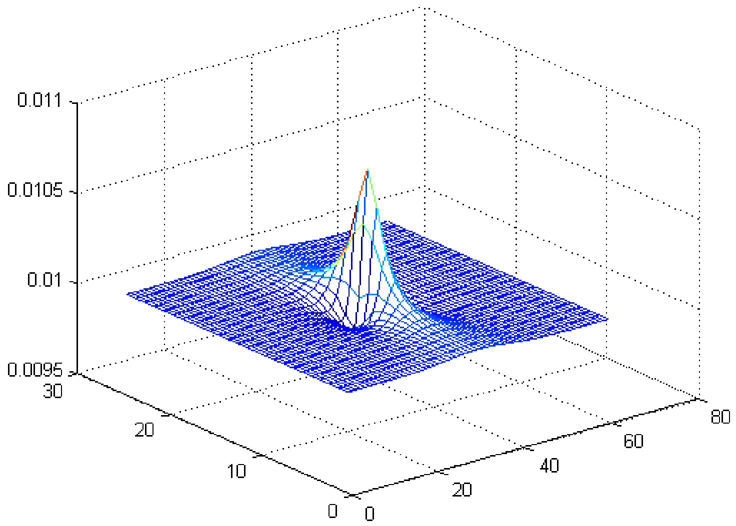

Fig. 2.

Depending on defects linear size and depth the signal differs in its length and magnitude. At the same time sizes of typical corrosions lie in some limited range. So we can limit also spectrum of spatial frequencies, characterizing useful signal. It makes possible use optimal filter to suppress noise and disturbances:

$$H(\omega_1,\omega_2)=\frac{W_{sig}(\omega_1,\omega_2)}{W_{sig}(\omega_1,\omega_2)+W_{noise}(\omega_1,\omega_2)}.$$

$W_{sig}(\omega_1,\omega_2)$ - power spectrum of useful signal, $W_{noise}(\omega_1,\omega_2)$ - power spectrum of noise (and/or disturbance).

Usually disturbance spectrum is not known a priori, moreover it possess only local stationarity, that means this spectrum depends on the distance – different parts of defectogram are characterized by different disturbance spectrum. To overcome this obstacle adaptive optimal signal filtration can be applied. It consists in estimation of disturbance spectrum at some long enough part of defectogram, for example, along several pipes of pipeline. In this case we get statistically robust estimation. Nevertheless key role plays here a priori information in the form of disturbance classification. For example, a type of pipes at the pipeline section under processing. As a result it enables increasing of signal/noise ratio up to 2-2.5 times, this allows to reduce number of false defect detection up to 6-8 times.

Such an approach is realized in several software applications, in particular in the software for steel rope defectogram analysis, in the software for analysis of defectograms of oil/gas tank's steel plates, in data processing complex for Inline Pipeline Inspection.

Another important aspect of data processing automation consists in optimized defect classification. Main goal of classification consists in the choice of correct defect model to estimate defects size on the base of corresponding MFL-signal's parameters. So far minimization of estimation error serves as classification efficiency criterion. This criterion should be considered while dividing of the defects multitude into specific classes. One usually distinguishes pitting metal loss, extensive metal loss, pitting at extensive metal loss, notches and cracks. Correct discrimination of these classes allows remarkably reducing of size estimation error. Results of our work [3] has shown, that such approach of classes construction, for example in inline pipeline inspection provides possibility to reduce depth estimation error up to 30 % at given estimation reliability. Defects parameters are estimated on the base of regression equation, which coefficients β_i are chosen with consideration of classifications results

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

d_i – defects size (depth or length), f_i – signal parameter.

In conclusion it is important to note, that automation of signal processing in MFL nondestructive testing presumes interconsistency of different data processing stages, and as the first of datachecking, defect detection/localization and defect classification. Adjustment of some stages with each other can be carried out by means of iterative approach.

References

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