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ADAPTATION OF SIGNAL PROCESSING ALGORITHMS WHILE AUTOMATIC DETECTION OF DEFECTS SIGNALS IN MFL NONDESTRUCTIVE TESTING

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1. INTRODUCTION

Relevance of automatic defect detection in MFL (Magnetic Flux Leakage) nondestructive testing is caused by several advantages of this method of non-destructive testing – high productivity of inspection comparing with ultrasonic or roentgen methods, week influence of subjective factors, good prerequisites for data processing automation. MFL flow detection is widely used for example in pipeline inspection, oil/gas tank bottom inspection, inspection of steel ropes. At the same time high required reliability of inspection results assumes high reliability of data processing algorithms. Typical value of defect detection reliability is about 95% at acceptable level of false detections of 20-30%. So there are very strict conditions of signal detection.

2. DESCRIPTION OF SIGNAL MODEL

For MFL nondestructive testing is specific that in applied magnetic field signals of defects given type have typical shapes, which can differ in magnitude and scale [1]. Typical defects detected by MFL-instruments are pitting and common corrosion, cracks, notches. Fig. 1 depicts model signal of pitting corrosion. Characteristics of the signal can vary depending on linear size and depth of the defect, but the general shape leaves. This signals can be calculated with help of FEM models. Analyzing signals from different defects in spectral space we can determine frequency range for axial and azimuth spatial frequencies.

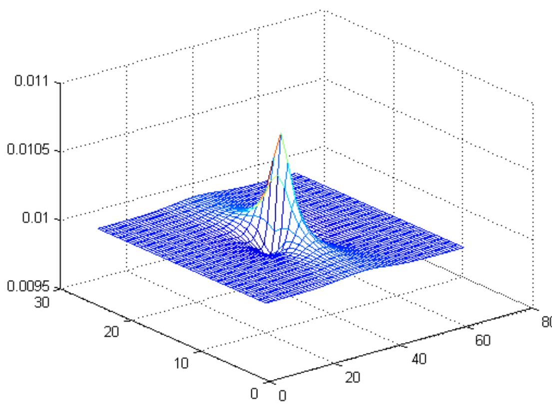

Fig.1 Model signal of pitting corrosion

Real diagnostic signals are affected by different influences. This complicates automatic defects detections and estimation of its parameters significantly. Main influence factors are: inhomogeneity of material structure (of pipe/tank wall or rope wires), variation of air gap between sensors and object surface, some arbitrary external disturbances on measurement system. For example, Fig. 2 depicts MFL intelligent pig signal from corrosion on longitudinal welded pipe and Fig. 3 – signal from corrosion on seamless pipe. One can see obvious structural disturbances in the second case, which should be suppressed. Characteristics of this disturbance can change from one pipe to another dramatically. In the first case welding seam makes also some kind of disturbance.

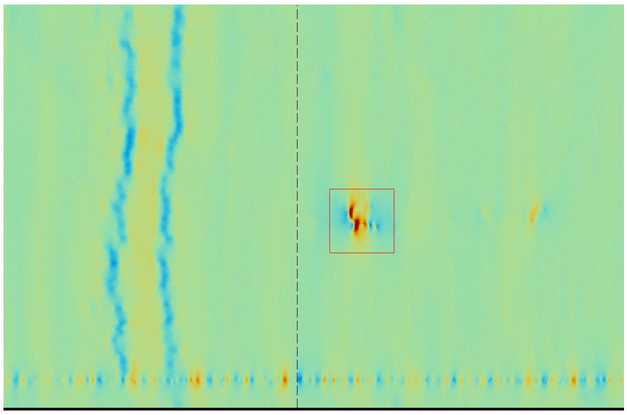

Fig. 2 MFL-signal from corrosion on longitudinal welded pipe

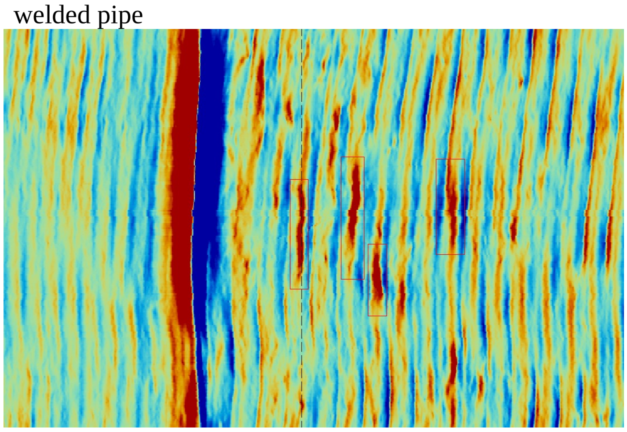

Fig. 3 MFL-signal from corrosion on seamless pipe

Figures 4 and 5 shows corrosion MFL-signal from magnetic tank scanner, got with little air gap (0.5 mm), and with bigger air gap (3 mm). Magnitude of the signals differs nearly 10 times and signal/noise ratio reduces nearly 5 times.

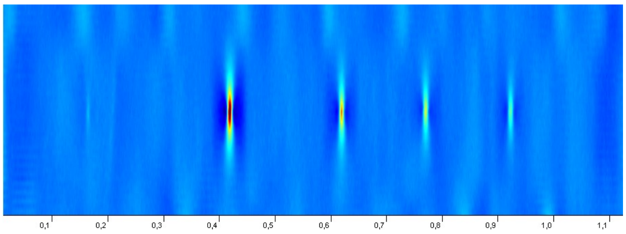

Fig. 4 MFL-signal from corrosions with air gap of 0.5 mm

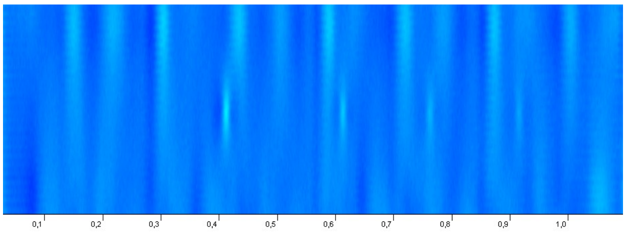

Fig. 4 MFL-signal from corrosions with air gap of 3 mm

Different location of the defect (on the outer or on the inner surface) also influence signal parameters.

3. AUTOMATIC DEFECTS DETECTION PROBLEM

Data processing algorithms, used for automatic detection of defects signals should be capable to filter useful signal varying in magnitude up to 100 times and in its spectral characteristics from 5 to 10 times. Demanded detection reliability should be typically 95 %. Detection problem can be solved conventionally in the case of stationary disturbance characteristics [3]. This solution is based on combination of different spectral signal processing and local energy concentration thresholding. Energy concentration is calculated as:

$$P = \frac{\int_S A^2(x,y)ds}{S},$$

where A – signal magnitude and S – area of signal support.

In reality diagnostic signals do not have stationary disturbance, it differs with distance, especially considering big length of inspection records (one pipeline inspection can be 100-200 km long, one steel rope – several km). Different regions of this objects are exposed different external influence factors, that leads to difference in noise and disturbance characteristics.

This problem can be solved by means of adaptation of signal processing algorithms. Application of signal processing algorithm adaptation proposes in this case follows components:

- fixing of signal characteristic to be used as object of adaptation (in our case – local signal characteristics),
- definition of adaptation quality criteria,
- development of adaptation algorithm.

Adaptation algorithm represents iterative algorithm, which changes on every step some parameters of data processing algorithm. Definition of adaptation quality criteria presumes using some a priori information about signal nature. For example in the case or pipeline we consider local disturbance characteristics (probabilistic and amplitude-frequency characteristics) and its changing through main signal processing algorithm [3]. So on every step we calculate difference of disturbance characteristics and analyze results of defects detection. So far this difference is considerable and results of defects detections are stable we can continue adaptation. On every step we make a decision about adjusting of detection threshold. Estimation of local disturbance characteristics proposes the preliminary segmentation of measurement signal in sections with relatively homogeneous characteristics, for pipeline there are pipe sections.

The similar procedure can be applied for tank bottom inspection to reduce disturbance of surface irregularity. On the base of local disturbance characteristics, calculated for some scanner drive, we can adjust detection threshold and analyze detection results. Adaptation continues till most of detected signals can be classified as defects signals.

This approach provides for a possibility on real data from seamless pipes to reduce amount of false detection from 30-40% to 5%.

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