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DEFECTS LOCALIZATION AT MFL PIPELINE INSPECTION BY MEANS OF CLUSTER ANALYSIS

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ABSTRACT

At magnetic inspection of extended object, such as gas and oil pipelines, the MFL signal length is equal to the length of testing distance, about several tens or hundreds kilometres. The manual speed of such signal processing is 1 km per day, whereas the modern processing program works about a hundred times quicker. The first and topmost stage of program analysis is search of "interest areas" – localization of signal fragments which correspond to defects. This paper presents an algorithm of localizing areas of the signal, corresponding to defects, by means of clustering. Clustering is uncontrolled classification, at which objects are merged into one and the same cluster based on measure similarity, which is determined by a certain "degree of proximity". Objects in our case are different parts of signal, characterizing one and the same defect. The "measure of proximity" is geometrical distance between elements.

When using clustering algorithms for localization of signal areas, we obtain an intellectual location, which makes it possible to merge into a location cluster the signals, corresponding to extensive defect of a complex shape.

Index Terms - MFL signal, signal detection, clustering

1. INTRODUCTION

The purpose of nondestructive evaluation methods, including the magnetic one, is to detect defects, determine their parameters and danger level. Magnetic inspection distinctive feature is its high sensitivity. A number of defects, pitting corrosions, total corrosion damages, fatigue cracks, notches, and other defects are detected during magnetic inspection of pipelines.

Diagnostic signal measured as a result of MFL pipeline inspection is a two-dimensional space signal, its size in axial direction may reach several hundreds of kilometers. The signals include fragments of heterogeneities corresponding to magnetic flux leakage of pipeline structural elements, welded connections and defects. Stochastic noise is also present in the signal. Defects detection and location are the first and very important step of diagnostic data processing. Accuracy of defect parameters determination and therefore the inspection result in the whole depend on defect location results.

2. LOCALISATION OF "INTEREST AREAS"

The simplest way of localizing areas corresponding to defects is the threshold method which supposes localization of signals areas, exceeding a certain threshold. Algorithms implementing the threshold method efficiently locate point defects. In case of extensive defects of a complex configuration (solid corrosion, notches of a large width, cracks) such algorithms work incorrectly, detecting several location areas for the given defect.

This work describes defects intelligent location algorithm based on statistic cluster analysis, which works correctly even when it's needed to locate signal of a complex configuration.

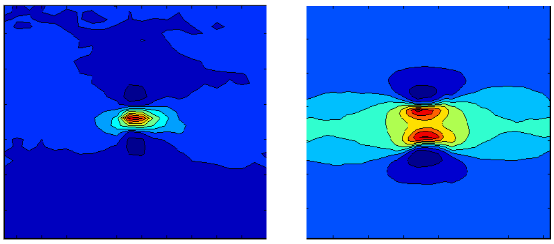

Fig. 1 Magnetic field leakage topography of a) local pitting corrosion b) total corrosion

Fig. 1a shows the magnetic flux leakage topography for a local pitting corrosion and 1b - the corrosion damage of a large area. The both presented signals may be described using quantity, area and mutual location of the extreme (maximum and minimum) domains.

In the case illustrated by Fig. 1b, the threshold algorithm of localization would detect two location areas, one for each positive extreme. Using clustering, we make an initial assumption that the signal area consists of a number of extreme domains, outlining the defect boundaries.

Clustering is objects grouping according to their similarity measure in the space of features. In this case, location clustering is performed, and we choose the geometric distance between parts of diagnostic signals as a measure of similarityIf defects location algorithm works properly, all extreme domains characterizing the same defect shall be united by a location frame which does not contain other details.

Each extreme domain of magnetic signal is shaped by border-line contour, built by a specific level. Extreme domains grouping are carried out in accordance with a distance between two adjacent points of border-line contours.

Clustering is performed according to hierarchical agglomerative algorithm with single link clustering. In single linkage clustering, the distance between two clusters is computed as the distance between the two closest elements in the two clusters. Thus, clusters may be forced together due to single elements being close to each other, even though many of the elements in each cluster may be very distant to each other.

The algorithm results in formation of clusters, which are set by the rectangle frames defining their borders. In each cluster, the extreme domains corresponding to the same defect are located.

3. LOCATION CLUSTER TYPE DETERMINATION

After the clustering stage the MFL signal transforms to a number of cluster frames, corresponding to various defects. Signals in the location frames are analyzed in order to determine the sizes of the corresponding defects and the degree of their danger. In order to obtain a reliable assessment of defect parameters, it is necessary to determine the cluster frame type, since for each type of cluster, an individual set of diagnostic features is distinguished, that is used for the subsequent parameterization of detected defects.

Each cluster may be conventionally referred to one of three following types: "pitting corrosion cluster" (fig.2), "total corrosion cluster" (fig.3), "crack-type cluster" (fig.4).

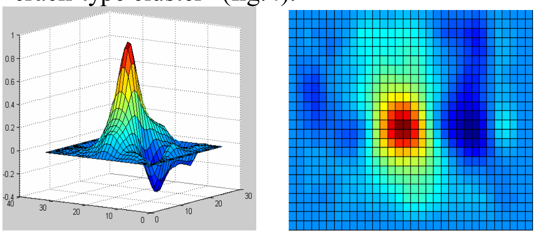

Fig.2 Pitting corrosion cluster (one extreem)

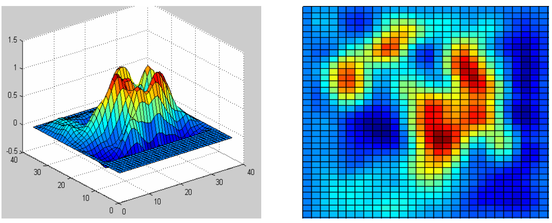

Fig.3 Total corrosion cluster (a chain of extremums outlining the defect boundaries)

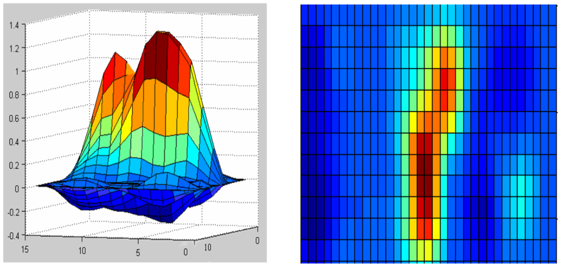

Fig.4 Crack-type cluster (a chain of extremums, formed due to sensor block deviation)

The signal relating to the type "pitting corrosion cluster" is shown in Fig.2. It’s characterized by one positive extreme located above the defect center. For parametrization of the point defect, the maximum signal value shall be estimated, as well as the length of extremal domain in axial and azimuthal direction.

The signal corresponding to total corrosion (Fig. 2) consists of several near extremal domains, outlining the defect contour. In the case “total corrosion cluster” the length and width of separate extremal domains is non-informative, and the total signal length in axial and azimuthal direction is estimated.

Crack-type cluster corresponds to long defects - notches or cracks. The signal shown in Fig.4 consists of a chain of extremums formed due to sensor blocks displacement. Based on the magnetic signal, in addition to amplitude, the length of signals is estimated as the sum of lengths of separate extremes, and width of signal as average extremes width.

4. CONCLUSION

Application of defect localization algorithm based on clustering analysis, instead of standard amplitude location, made it possible to reduce the error of defect parametrization to a small extent (about 5%). At that, the confidence interval of error estimation, the confidence factor being p=0.95, reduced due to the exclusion of “rough emissions” caused by incorrect determination of boundaries of the signal corresponding to the defect.

The addition of location cluster type determination function to the clustering procedure allowed to increase data processing capacity.

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