Magnetic In-Line Inspection of Pipelines: Some Problems of Defect Detection, Identification and Measurement

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Abstract. Automatic identification and estimation of pipeline defects natural and artificial art MFL in-line pipeline inspection by “intelligent pigs” have proved to be an actual and complex problem. Additional complications are caused by a difference between pipe types and by the defects clusters. Solution of this problem presumes some special properties of the applied software, either to its general architecture, as to the specific algorithms. It also supposes fine matching of algorithms and magnetic measurement system. These questions as well as some results of a real in-line inspection system will be discussed in the report. Special attention will be paid to the algorithms of defect identification and its classification, defects detection and measurement for defects clusters.

Introduction

Intensification of energy crisis of late years leads to the increasing of the pace of pipeline development and its importance. In this connection the problem of inline pipeline diagnostic takes especially meaning. Herewith amount of necessary yearly inspection is very high – thousands of kilometers. Such task can be fulfilled only at high level of analysis process automation, which increases analysis productivity on the one hand and its reliability on another. We will discuss some problems of automatic data processing by MFL inline diagnostics.

Problem of diagnostic data processing

Registration of magnetic flux leakage from pipeline defects underlies MFL inline pipeline inspection. Field topology above the defect empowers to identify defects type and estimate its geometrical size [1]. To make estimation more accurate two components of magnetic field are used – axial and azimuth. Defect identification and estimation is based on the results of numerical modeling of MFL-distribution for some defects types. Generally reconstruction of defects geometry belongs to inverse problem, which can be solved in some different ways. Analysis of defects field topology shows, that no directly connection between defects geometrical parameters and some signal features can be found. So one should consider some combination of features of both field components.

Thereby solution of defects geometry estimation problem includes:

1.Defect detection and localization

2.Defect classification

3.Estimation of defects geometry.

Quality of signal localization influence significantly correctness of defect classification and accuracy of geometry estimation. Correct defect classification presume that its frame covers the whole signal of this defect but without signals of nearby ones. Validity of classification affects the accuracy of geometry estimation. For example one can find two defects of different type (metal-loss and scrape) and geometrical sizes with very similar MFL-distribution. These main steps of defect geometry estimation determine the structure of software complex that realises solution of this problem.

Structure of the data processing programm.

Within the framework of cooperation between Co. “Intron plus” and technical diagnostics center “Diascan” MFL inspection pig and and program complex for its data interpretation were developed. Up till now thousands kilometers of pipelines were inspected with this tool in Russian Federation. It ensures detection and geometry estimation of such defects as metal-loss, cracks and dents as well as defects of transverse and spiral welds [2].
Structure of program complex agrees the data flow diagram on the Fig. 1.

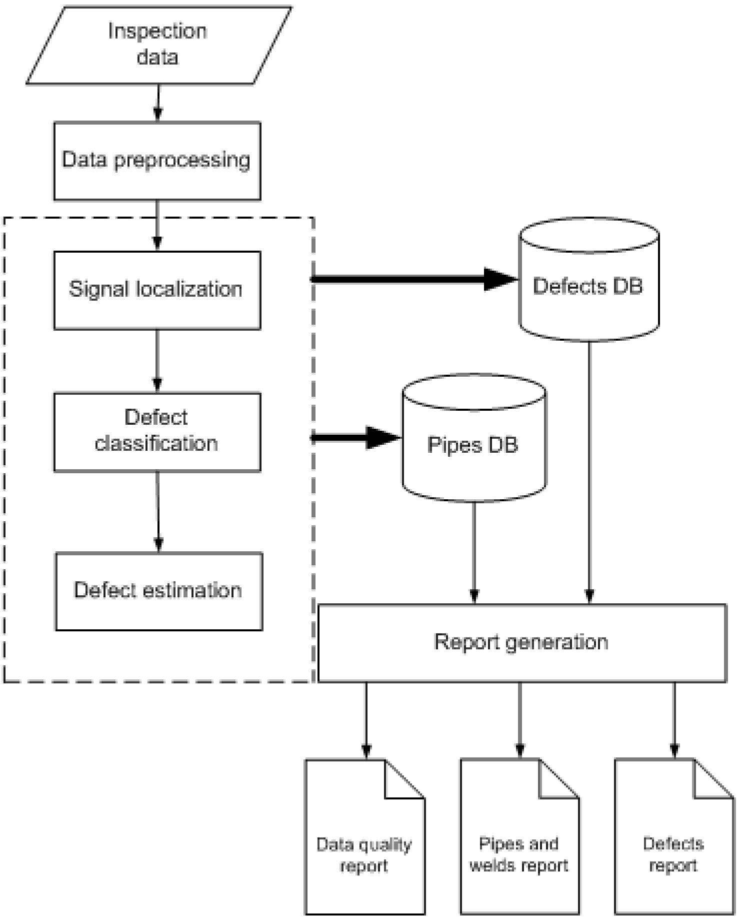

Fig. 1. Simplified data flow of analysis software

Data pre-processing includes data checking and possible correcting of failures, recalculation of signals with respect of calibration of measuring system and preliminary noise suppression. Signal localisation stage ensures defects detection and correct signal localization. Selected signal areas (frames) pass through classification stage, which purpose is to identify defects and pipes fitments. Geometrical sizes of defects are calculated at the stage of defect estimation on the base of appropriate MFL-signals. Defect location should be also specified at this stage. To increase reliability of the estimation different calculation algorithms can be applied: neural networks, statistical and genetical. The type of algorithm can be chosen automatically or assigned by an operator. All the information about defects and pipes is stored in a special database, which is used for report generation. So far the system is designed for processing of big amounts of data it should run on the segment local computer network (parallel data processing).

Defect detection on different types of pipes

Quality of defect detection depends significantly on the noise level and its influence on the useful signal. In this connection inspection of seamless pipes presents especially serious problem. Signals from this kind of pipes have an intensive structural noise. Fig. 2 shows example of MFL-signal of some seamless pipe with this noise caused by the pipe knurl. This intensive structural noise decrease significantly sensitivity to defects signals. Magnitude of the knurl signal can respect signals of the metal-loss of 0.3 – 0.35 wall thickness. For reliable defect detection one should increase detection level up to 2 times in comparison with noise, which corresponds metal-loss of 0.5 – 0.6 wall thickness. Thereby to keep sensitivity we should suppress noise effect.

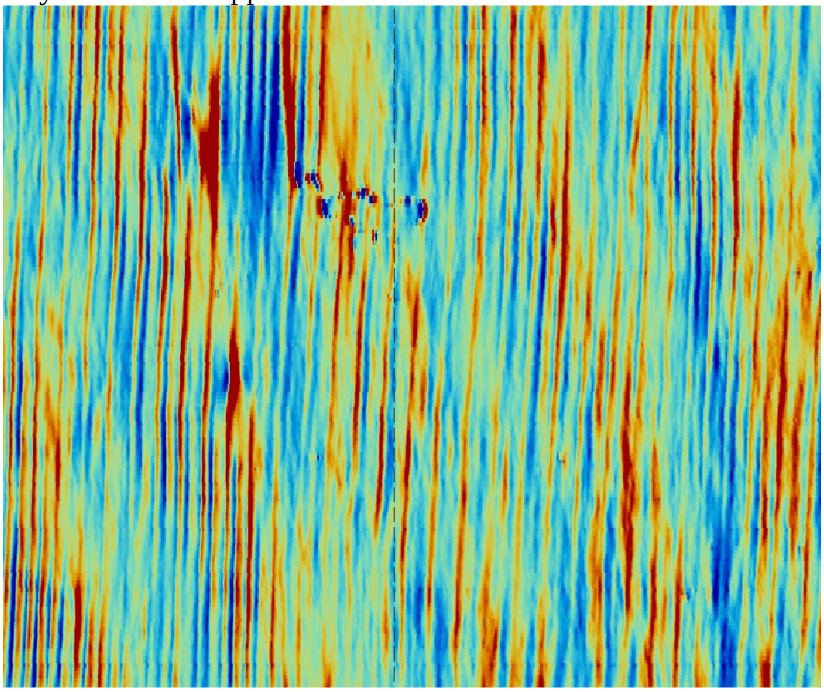

Fig. 2. Seamless pipe with some defects

Our investigations have shown that the most effective way of structural noise suppression are adaptive algorithms, which enable consideration of local noise features of special pipe section. In particular such an algorithm includes adaptive filtering and adjustment of defect detection level. Developed adaptive algorithm ensures reliable defect detection at the signal-to-noise ratio about 1. Fig. 3 shows the result of defect detection on the seamless pipe with helps of developed algorithm. Amount of false frames for adaptive algorithm is 100 - 200 time lower than for the traditional one with fixed filter parameters and detection levels. Sensitivity for metal-loss is about 0.3 wall thicknesses. Correct design of the algorithm ensures a calculation slow-down not more than 1.5-2 times.

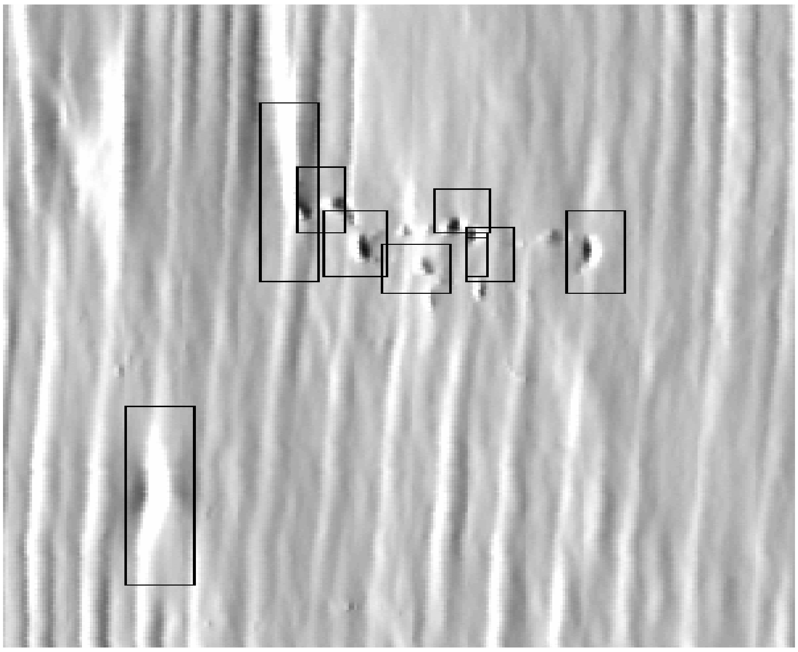

Fig. 3. Defect detection with adaptive algorithm

Processing of defects agglomeration

Another problem, which complicates automatic data interpretation, is bound with defects agglomeration. Fig. 4 shows an example of such agglomeration.

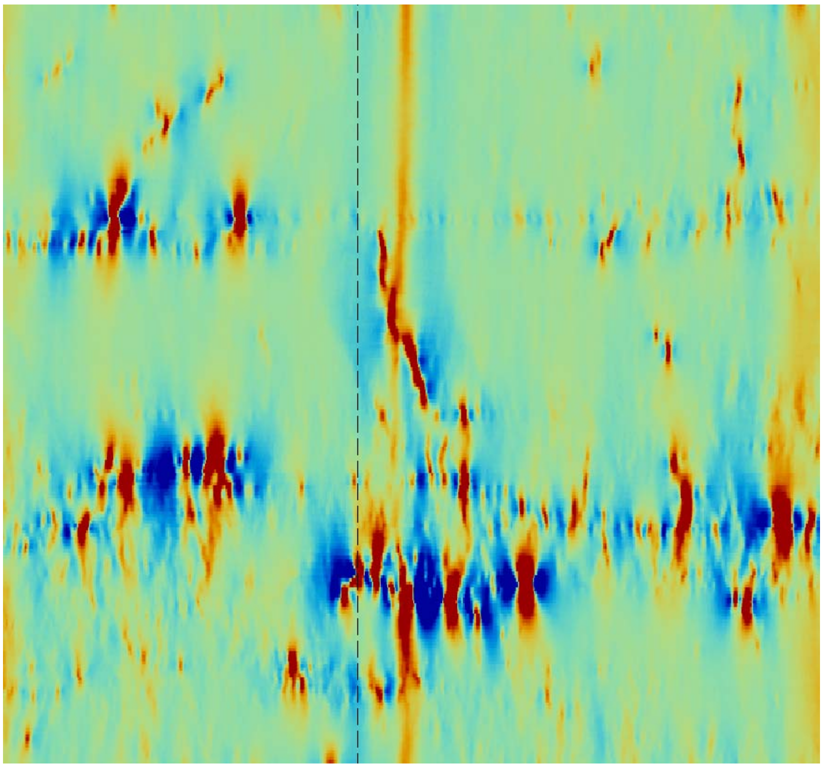

Fig. 4. Defects agglomeration

Correct defect geometry estimation presume separation of distinct defect signals. At the same time this signals should contain possibly the whole MFL-distribution of appropriate defect. Multipass defect detection procedure can solve this problem. Hereby borders of each frame are elaborated with respect of nearby frames and features of the defect. The procedure can be especially tuned for metal-loss defects. Fig. 5 shows result of defect detection in a metal-loss agglomeration with helps of multipass procedure.

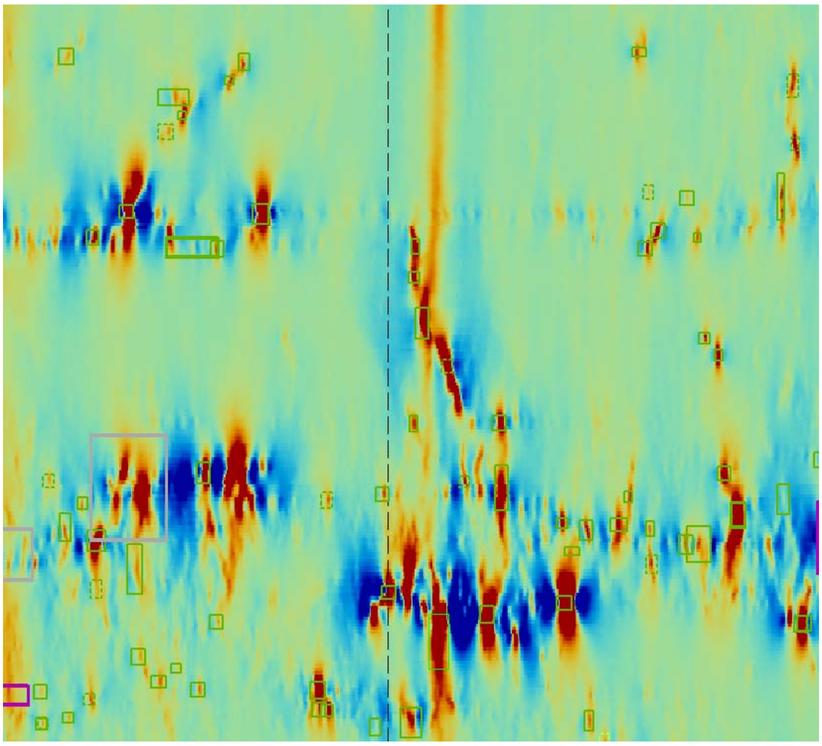

Fig. 5. Detection of defects in agglomeration

After that some separate defects can be consolidated in clusters, which parameters should be defined on the base of parameters of the defects from this cluster. Such an approach enables increasing of defect geometry estimation in metal-loss agglomerations.

Achived results

Described algorithms are applied in the developed software system for automatic processing of diagnostical MFL-data. General marks of the system are:

- Metal-loss sensitivity by automatic processing about 10% – 20% of wall thicknesses
- Reliability of defect identification at 80-90%.
- Accuracy of depth estimation under 20% of wall thicknesses by reliability of 95%.

References

[1] A.V. Gaivoronsky, V.P. Lunin, D.A. Gomonov: "Inversion of magnetic flux leakage on surface for defect reconstruction", International Conference "Computer methods and inverse problems in Nondestructive testing and diagnostics", Minsk, Belarus, 1995, pp.87-90

[2] Defect identification and parameter estimation by MFL inline pipeline inspection with helps of MDScan pig, Slessarev D., Belitsky S., Vasin E., Stepanov N., Shipakov M. – 17th Russian-International Scientific-Technological Conference “Non-Destructive Testing and Diagnostics”, Ekaterinburg, 2005