Wavelet based approach for detection of material discontinuity in MFL in-line pipeline inspection

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Abstract

At the real pipeline such defects as corrosion have vast variety of forms and size and differ considerably from standard defects on reference pipes used for calibration and verification of inspection gages. Wavelet decomposition offers an efficient solution for detection and evaluation of defects in MFL non-destructive testing, however, it assumes similarity of defects signals to some standard signal. As a result some real detects can be missed. The report shows extension of wavelet based defect detection technique to enable detection of material discontinuities in a broad variety of their size.

1. Introduction

In real NDT practice the most common task is to detect not one specific type of defect but all diversity of defects typical for the object under the test, which can be dangerous for objects integrity or its ability to fulfil given functions. Different kind of defects generates as a rule such a variety of output measuring signals, that can not be described by simple scaling of some basic signal. Good example can be given by signals of pitting corrosion and common corrosion of the pipe wall in MFL in-line pipeline inspection [1]. In this case defect detection should be founded on some subset of basic defect signals. One of the possible approach for it is based on wavelet signal decomposition.

2. Application of wavelet decomposition to MFL signals

Figure 1 a and b shows as an example of signals from pitting corrosion of 10mm x 10 mm with relative depth of 0,4T (a) and common corrosion of 40mm x 40 mm with relative depth of 0,5T (b), where T – wall thickness.

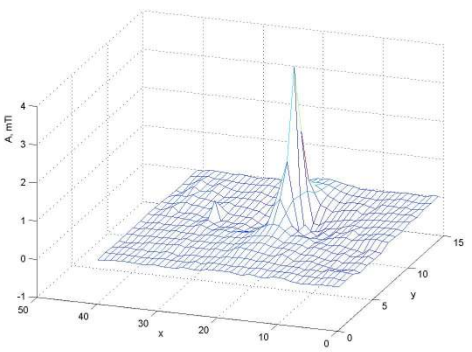

Figure 1a. Signal of pitting corrosion

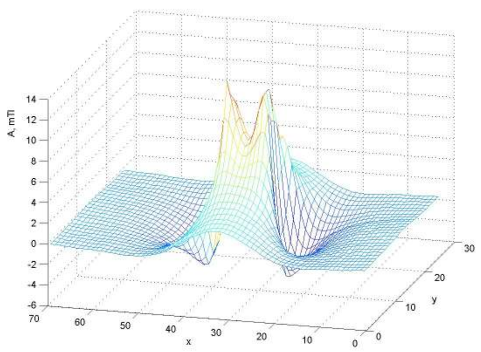

Figure 1b. Signal of common corrosion

Difference in waveform is obvious, consequently different basic wavelets (mother wavelets) should be used for efficient decomposition of these signals. Signal decomposition is based on wavelet packets and includes sets of vectors of approximation and details coefficients [2]. The best signal/noise ratio for each type of defect is achieved at different levels of wavelet decomposition. So signal processing algorithm should include parallel application of several types of basic wavelets. It is practical to choose basic wavelets from most common wavelet families, such as Daubechies or biorthogonal, that gives high computation efficiency and good spatial localization.
Defect detection for input signal $s(x,y)$ can formally be described as:

$$u_j = L_j[\ \psi_j,\ s(x,y)\ ] \text{ and } u_j > \Lambda_j, \qquad (1)$$

where ψ_j – basic wavelet for j type of defects and $L_j[]$ - wavelet decomposition at the given level or signal reconstruction on the base of some set of wavelet coefficient vectors at levels $\{k_j\}$. Threshold value Λ_j should be separately chosen for each basic wavelet used. Λ_j can be defined based on the signal from minimal detectable defect of each type. It should be also taken into consideration that signal magnitude of different types of defects can vary in wide range (up to several times), so some defects may give significant output in decomposition vectors of different applied wavelets. Therefore, general detection algorithm should comprise decision tree with composite conditions, this can increase detection probability (POD) of some types of defects. It enables also preliminary defect classification.
The other aspect to be considered while definition of detection thresholds Λ_j is a probability of false detection P_2. It depends on disturbance in output signal. Tolerance for P_2 value can be used for correct choice of basic wavelet and decomposition level: chosen basic wavelet should keep P_2 under a given limit. Figure 2 shows signal of pitting corrosion (a) and the result of its decomposition with *db2* wavelet (b). Signal/noise ratio has increased more than twice.

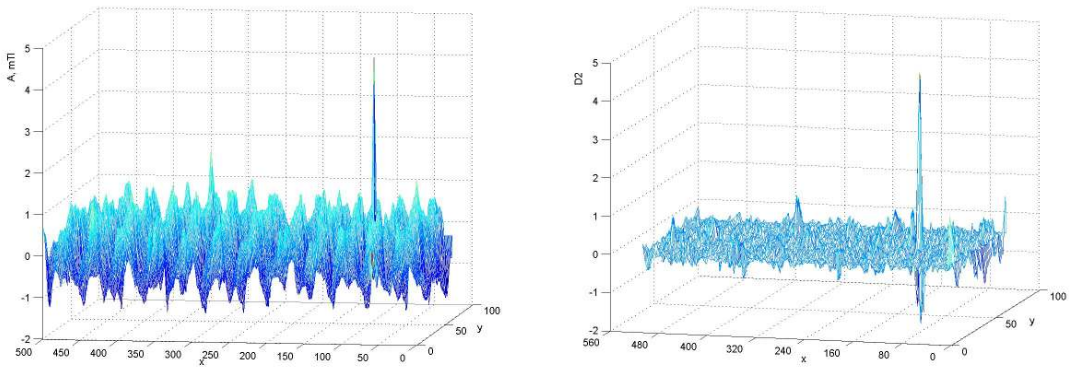

Figure 2a. Signal of pitting corrosion

Figure 2b. Wavelet decomposition of pitting corrosion signal

Application of composite detection conditions with several wavelets at ones allows to reduce threshold value for some defects and, therefore, increase detection probability at the given P_2 value.
The developed detection approach was applied to the testing sample, taken from 3 segments of 8” pipeline of over 20 km total length. Table 1 shows number of different

detected defects, used basic wavelets and efficiency of these wavelets, expressed as increasing of SNR value.

Table 1. Results of wavelet decomposition at the test pipeline segment

Type of defect	Number of defects	Basic wavelet type	Increasing of SNR
pinhole	3	Db2	80%
pitting	13	Bior2.8	50%
grooving	15	Db4	40%

3. Conclusions

This paper demonstrates efficiency of wavelet decomposition in defect detection problems in MFL non-destructive testing. Combination of several basic wavelets allows to increase probability of detection at a given probability of false calls in real applications where several different types of defects appears.

References

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2. S. Mallat, "A wavelet tour of signal processing," Second Edition, Academic Press, 1998.