Development of Automatic Neural Network Classifier of Defects Detected by Ultrasonic Means

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Abstract. The possibility of applying artificial neural network to the multistage processing of defect signals detected by ultrasonic means was analyzed in this paper. Two networks were used for that purpose: the first was the neural network for feature extraction and the second one was used for defect class estimation. Two major defect types were considered – plane and volumetric defects. Developed technique was used to process signals from artificial defects of specially made steel bars and real pipes as well. Classification results were fine in both cases.

Introduction

It is very important to know the type of defect (is it plane or volumetric) during ultrasonic testing of products and materials [1]. There is certain amount of main defect types for various products. But commonly there are only two main defect types that are characterized by their shape. The first type is presented by defects caused by improper production process. They have mostly volumetric shape and are not stress concentrators and therefore they can't grow in metal. Defects caused by improper production process are not as dangerous as fatigue cracks are. Fatigue cracks are stress concentrators and they are the result of tested product exploitation. These defects can grow and cause equipment failure.

1 Theoretical Aspects

Capabilities of acoustical method of non-destructive testing enable defects detection and estimation of their geometrical dimensions as well. In most cases it is very difficult to estimate defects' type by analyzing measurements that were made during ultrasonic testing procedure. This is because of complex waveform of echo-signals reflected from defects. The amplitude of echo-signal depends on piezoelectric transducer frequency, wave incident angle, depth and orientation of defect etc. In other hand, defects of different size and shape can have the same equivalent area and reflect echo-signals with the same amplitude [2].

It is known that the shape form of defect is very determinative for evaluation of numerous structures, products etc. Nowadays to estimate the type of defect the analysis of single frequency echo-signals spatial distribution in selected directions within vertical and horizontal planes is mainly used [3]. Therefore it's considered to be unreliable to estimate the defect type (plane or volumetric) by analyzing amplitudes of echo-signals from one transducer which emits acoustic waves in one direction (e.g. only in horizontal or vertical plane).

Due to these reasons the development of automatic NDT systems is provided worldwide. These systems should not only detect the defect but also to identify its type by waveform of reflected echo-signal.

A lot of scientific researches have been done for the development of methods and techniques of defect classification in NDT world community [2-4]. Usually realization of the results of such researches is difficult because of high software and hardware requirements.

In this paper we propose to use artificial neural networks for solving problem of automatic defects classification using A-scan images.

2 Ultrasonic Experimental Tests

Realization of the proposed method should be carried out in following steps:

1) collection of a certain number of A-scans different type defects and their digitalization
2) feature extraction procedure
3) artificial neural network (ANN) training for classification 2 or 3 defect types
4) trained ANN test with new A-scans.

Proposed method is based on the analysis of echo-signal waveform based on A-scan. Capability and expediency of such analysis are described in [3-5].

Experiments were done in two stages to check this. At the first stage of experiments steel specimen of bar shape was made (dimensions 160x80x20 mm). Two types of artificial defects were made in this specimen: holes with diameter of 2 mm at depths of 3, 5, 7, 12 and 20 mm and flat reflectors with width of 3, 7 and 12 mm at one depth (20 mm).

Equipment used for contact ultrasonic testing echo-impulse was digital defectoscope UD2-70 with piezoelectric transducers with nominal frequency 2.5 and 5 MHz. During this experiment stage 20 A-scan images of each type of defects were collected using both samples (all together 160 A-scan images).

The second stage of experiments was carried out using specimen made of part of lifting pipe (diameter 89 mm and wall thickness 6.5 mm) with 3 artificial defects (2 lateral plane defects and 1 hole). Equipment used for immersion ultrasonic testing was echo-impulse digital defectoscope UD2-70 with piezoelectric transducer with incident angle 70° and with nominal frequency 2.5 MHz. 20 A-scan images were collected from each defect.
All A-scan images were transferred to PC using specialized software for defectoscope UD2-70.

3 Feature Extraction Technique

Classification of certain number of defects types obviously need to be done by considering some amount of common characteristics of echo-signals reflected from defects. This is the essence of feature extraction problem. Images of echo-signals from different types of defects (plane and volumetric) are shown in fig.1. Stability of their wave form gives us the opportunity to propose new approaches for defect classification.

To solve this problem we didn't use classical feature extraction approach [4, 5] which include estimation of rise time, fall time, pulse duration, peak level etc. Instead of this we used neural network based approach.

The main point of the proposed feature extraction technique is neural network based compression of digitized A-scan images. Extracted features are taken as outputs of hidden layer when network deals with its training data set (signals to be compressed). Information losses are no more than 5-7%.

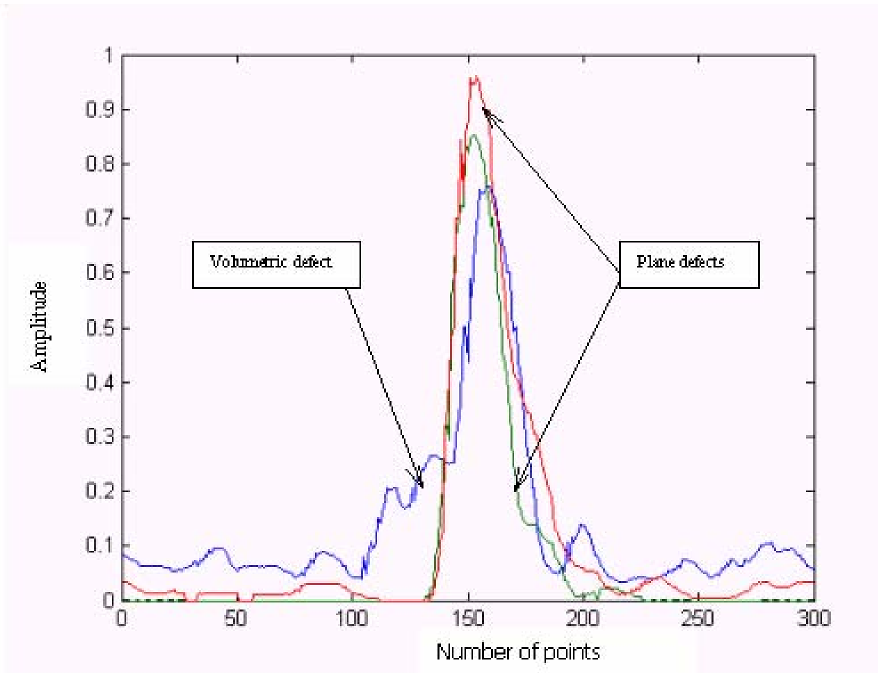

Fig. 1. Echo-signals of two types defects

Extracted features are shown graphically in fig.2. 'Number of points' there means the quantity of extracted features from one input signal. Even without any classifiers it would be very easy to classify these three signals into 2 classes (fig.2). But, however, initial defect signals can be more complicated than those which are shown in fig.1 and problem of pattern recognition is still present. We solve this problem also by using artificial neural networks [6].

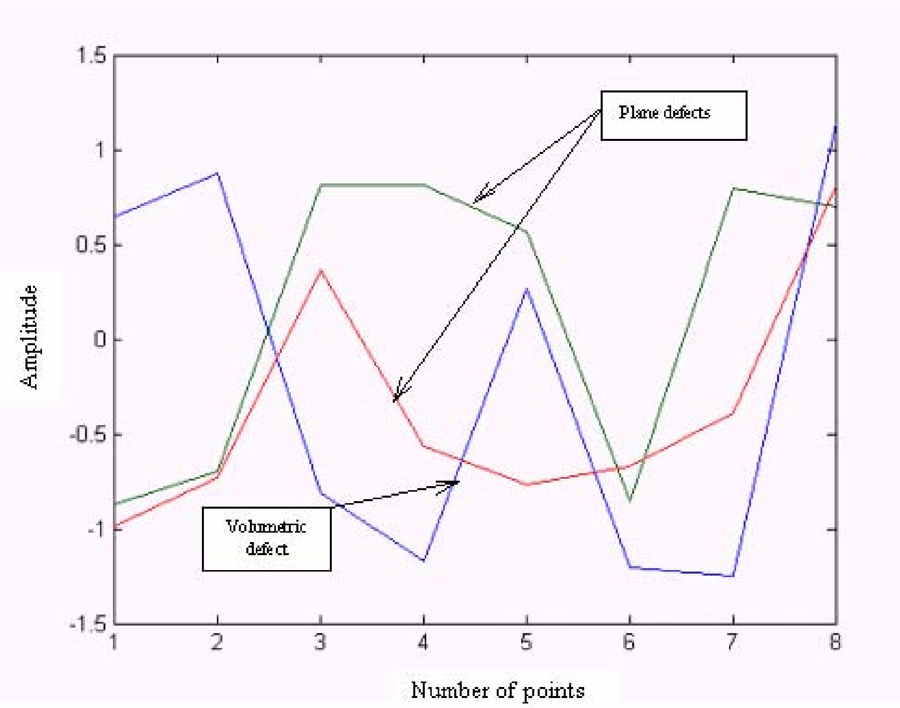

Fig. 2. Extracted features

4 Results

We have developed two neural networks for two stages of experiment correspondingly. Training sets were formed with 17 (of 20) training pairs (input – extracted features, output – defect type) for every class of defects. First two networks were trained to classify artificial defects in steel bar. Second ones were trained to classify defects of three types (2 plane defects of different equivalent area and 1 hole) in pipe.

Both networks were tested using test sets (three pairs for every defect) that were not used during training. Every time the accuracy of classification was near 95-99%. In table 1 you can see the results of the second network tests. The results for 1st and 2nd plane defects show that development of neural networks for defect sizing is possible.

Table 1. Accuracy of defect classification in pipe

Defect class	1st test set	2nd test set	3rd test set
Volumetric	99.7%	96.7 %	95%
1st plane	99.8 %	95.4%	97%
2nd plane	99.5%	99.3%	99.1%

Conclusions

The following main results are obtained in this paper. Proved the possibility of defect classification by analysis of reflected echo-signal waveform. Described experimental procedure of collection of A-scans from artificial defects in bar and in pipe. Proposed new neural network based feature extraction technique for non-destructive testing applications. Proposed and proved neural network based classifier for automatic defects classification with good accuracy (95-99%).

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