Bessel Time Frequency Distribution and ART2 Network approach in Non Destructive Evaluation

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Abstract: The use of ultrasonic Non-Destructive Evaluation presents a suitable scanning procedure for different materials. This sort of strategy is known as B-scan display. The goal of this paper is to detect flaws using ART2A networks with time frequency distribution approaches. In order to process this information the use of pattern recognition for signal processing presents a novel approach to determine temporal distance based on echoes analysis, without using classical signal processing techniques. The use of model building instead of data acquisition is a significant step.

1. Introduction

The use of ultrasonic Non-Destructive Evaluation presents a suitable scanning procedure for different materials. This technique consists of a pulse echo system integrated in a single transducer. This transducer is moved along a linear scan path where the temporal distance of a particular flaw, the bottom part of the material as well as the inherent grain thickness are monitored. This sort of strategy is known as B-scan display.

The goal of this paper is to detect flaws using ART2A networks and time frequency distribution approaches.

In order to process this information the use of pattern recognition for signal processing presents a novel approach to determine temporal distance based upon echoes analysis, without using classical signal processing techniques.

Moreover, this study classifies the echo signal with respect to a type of time-frequency distribution under the evaluation of a sample of aluminium material.

The approach followed in this paper is oriented on pattern recognition on-line using cluster classification techniques (Solis et al., 2001) which is enhanced by the use of Time Frequency Distribution (TFD) as pre processing module of pulse echo signal.

Following this brief description, this paper is divided in five sections. Second section presents the Bessel Time-Frequency Distribution using in this work. Third section describes the ART2 network approach. Fourth section, presents current approach based upon Bessel TFD with ART2 networks. Preliminary results are presented in fifth section. Finally concluding remarks are presented in sixth section.

2. Time Frequency Distribution

There is a group of time frequency distributions from Cohen proposal (Cohen, 1989) such as Wigner-Ville, Choi-Williams, Born Jordan or Bessel. In this work the later TFD is used.

The Bessel time frequency distribution in a discrete form is expressed as eqn. 1.

$$DBD(n,k) = 2\sum_{\tau=-N+1}^{N-1} H(\tau)H^*(-\tau)e^{-\frac{j2\pi k\tau}{N}} \bullet \bullet \sum_{\mu=-2\alpha|\tau|}^{2\alpha|\tau|} \frac{1}{\pi\alpha|\tau|}\sqrt{1-\left(\frac{\mu}{2\alpha\tau}\right)^2}\, x(\mu+n+\tau)\, x^*(\mu+n-\tau) \quad (1)$$

where the index $-N+1 \le n \le N-1$ represents the discrete time; the index $0 \le k \le N-1$ represents frequency vector; vector $H(n)$ with the related index $-N+1 \le n \le N-1$ is a sampled time window (Hanning) and vector $x(n)$ with index $-N+1 \le n \le N-1$ is the analytical signal of the measured signal.

3. ART2 Neural Network

The objective of this technique is to define certain groups (from actual data) around specific data points named as cluster centres. When a new group appear its centre is identified in order to be defined as cluster.

The ART2 network has been implemented following the approach presented by Frank et al., (1998). This scheme is shown in Fig. 1.

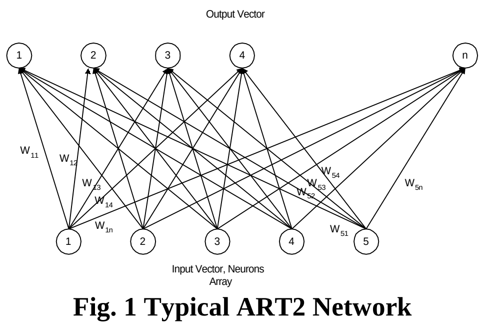

Fig. 1 Typical ART2 Network

This technique has been used in a similar fashion presenting stable results (Solis et al., 2001 and Solis et al., 2002).

4. Current Approach

The approach proposed in this work will be described by means of a case study. It concerns with the evaluation of an aluminium sample material. The schematic diagram in order to evaluate materials is shown in Fig. 2 (Solis et al., 2002). Fig. 3 (Solis et al., 2002) shows the block diagram of the set up experiment. The proposed strategy has been developed under MATLAB using time frequency distribution and ART2 network using this approach MATLAB processes the pulse-echo signal. The result of this process is a matrix whose elements are the energy associated to a specific time and frequency pair. This matrix is processed by a ART2 network in order to classify a finite number of patterns.

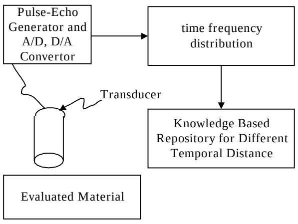

Fig. 2 TFD-ART2A Approach

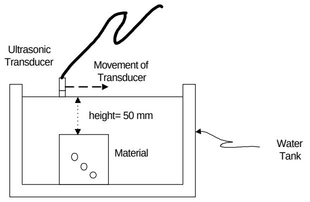

Fig. 3 Schematic Diagram of Setup Experiment

Afterwards, a new pattern is declared by the ART2 network as soon as this is processed using the decomposed matrix. The information presented as input of this approach is the normalized sample of the signal obtained from pulse echo generator (Fig. 2). The flow chart shown in Fig. 4 depicts two stages. First, the training procedure based upon time frequency distribution and neural network processes. Second stage named as classification procedure without using time frequency distribution process.

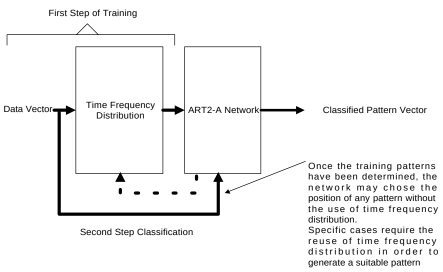

Fig. 4 Training and Classification Processes

Following training and classification strategies, it is possible to determine which temporal distance (out of the knowledge database) is the most suitable and represents the evaluated section of the material without using time frequency distribution process. As the reader may realize, the temporal distance is represented by the patterns database.

Having defined this approach, it is used to B-Scan an aluminium material in order to make a pattern database. This database consists of different characteristics with several flaws and borders of the material named as scenarios. These scenarios are formed by a number of samples. Each sample is captured and discretized by the oscilloscope. This information is passed to MATLAB environment in order to be processed. Each sample depends on the linear movement of the transducer named as step. Each step has a distance of 0.635 mm.

This material is composed of 90% aluminium and it has (Fig. 5.a) three determined flaws of 2cm deep with a diameter of 0.5 cm (flaw1, flaw 2 and flaw 3). Positions of these flaws are shown in Fig. 5.b.

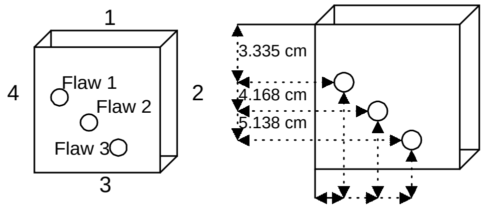

Fig. 5.a Fig. 5.b

Fig. 5 Sampled Material with Flaws

5. Preliminary Results

Next group of results show how this approach has been performed. Firstly, the Bessel TFD of the processed signals (Figs., 6, 7, 8 and 9) and, secondly, final results processed by Bessel-ART2A algorithm (Figs., 10 and 11) in order to generate a B-scan pattern database.

In order evaluate this material, it is necessary to normalize each sample from a range of values between 0 and 1. Furthermore, the length of each vector consists of 1000 points. Moreover, neural network learning and vigilance parameters are set to 0.92 and 0.3 respectively.

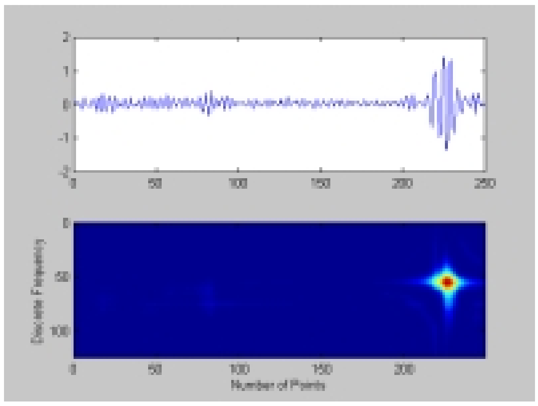

Fig. 6 Echo-Pulse Signal Processed by using TFD without Flaw

Fig. 6, shows the result of an echo-pulse signal been processed by Bessel TFD. Y axis shows the frequencies. X axis represents the temporal distance. This graphic corresponds to the bottom part of the element. It is essential to mention that this distribution is centred with respect to main frequency from transducer. This whole matrix is processed by the neural network in order to generate a number of representative patterns.

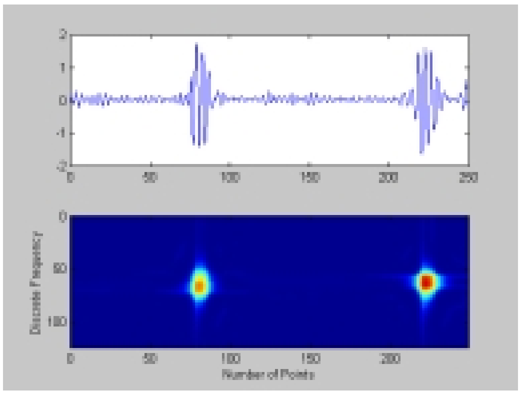

Fig. 7. Echo-Pulse Signal Processed by using TFD with First Flaw

Thereafter, Fig. 7 shows the result of another echo-pulse signal where first flaw is shown. The frequency associated with the transducer presents the location of this flaw. For the case of Figs. 8 and 9, these present similar information with respect to flaw 2 and flaw 3 respectively.

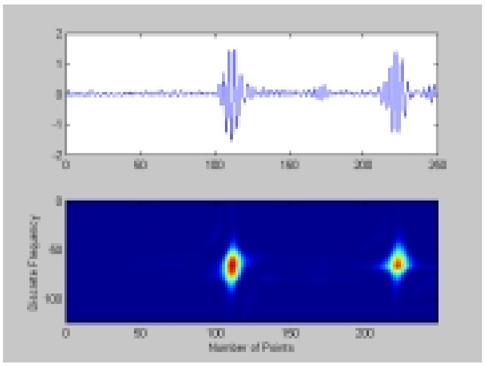

Fig. 8. Echo-Pulse Signal Processed by using TFD with Second Flaw

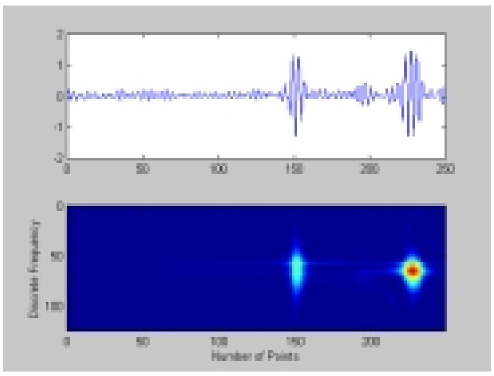

Fig. 9. Echo-Pulse Signal Processed by using TFD with Third Flaw

The Bessel-ART2A algorithm processes B-Scan information, which characterized the sampled material. The neural network has been trained when a new pattern is defined by the use of Bessel TFD. At the end of this procedure, it is accomplished a weight matrix that represents the B-scan of the sampled material.

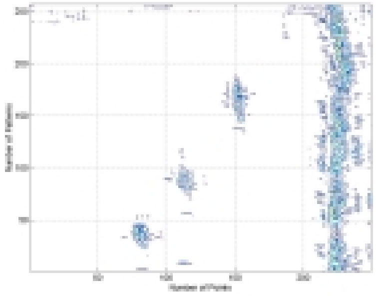

Fig. 10. Transversal view of whole sampled material based upon ART2 Network Approach

Having trained the network with those signals, a transversal view of sampled material is constructed based upon weight matrix of ART2 network. Fig. 10 depicts this information where y-axis presents the number of patterns and x-axis presents the temporal distance in terms of points.
For instance, Fig. 11 shows one signal used to test ART2A network without been processed by the TFD module. In this, one of the patterns (pattern no. 95) has been selected. The number of patterns remains constant (250).

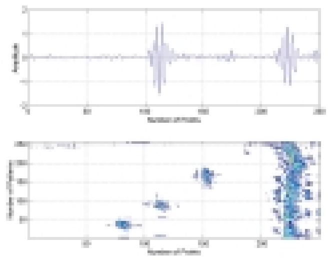

Fig. 11. Evaluated database based upon another pulse echo signal with same flaw at different Scan Position

6. Conclusions

This work has shown the use of a time frequency distribution strategy combined with a neural network for Non-Destructive Evaluation. This strategy has shown an alternative approach for classification of flaws with no physical information from current case study.
Furthermore, patterns database have been constructed based upon several selected echo-signals, which have been obtained off-line. This initial information is basic in order to obtain an accurate model of the inspected material.
A key point of this strategy is, this proposed methodology consists of two algorithms, Bessel TFD and ART2 network. These are not separate algorithm with respect to the whole process.
This approximation enhances the capabilities of the simple use of neural network for pattern classification.
Further work is pursued in order to justify the use one specific Time Frequency Distribution over the rest of current algorithms.
Observe that chosen pattern represents the geometry of the select flaw.

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