Use of Artificial Intelligence to Identify Adhesive Joints Defects by Using Ultrasonic

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ABSTRACT

Defects in adhesive joints are an important issue in the construction of space structures. In this paper, using lamp waves, suitable properties have been obtained to identify the size and position of the defects of the adhesive joints. Using finite element simulations, the effect of the defect on the propagation of the lamp waves has been investigated. Simulations have been performed for three different adhesive thicknesses, three different sizes of circular defects in 9 different positions, and the effect of each of them on the wave passing through the joint has been investigated. The signals obtained from the faulty connections were compared with the signal obtained from the healthy connection and the desired area was isolated from the total received signal for further analysis. Proper and correct separation of defects requires finding suitable characteristics for it. Therefore, 34 features were examined to differentiate and separate defects. Then, the neural network was used to provide the basis for creating appropriate patterns for the separation of defects. The percentage of correct detection of neural network for adhesive thickness separation was 93.8%, for defect area separation in terms of size 100% and for defect position separation in X and Y axes were 96.1 and 95.1%, respectively. The obtained results show the efficiency of the improved distance evolution method and the features selected to distinguish the defects of such connections.

KEYWORDS

Non-destructive evaluation, limb wave, adhesive bonding, status monitoring, neural network

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1. Introduction

Vertical diffusion inspection method is a simple and very widespread method in inspections. The converter is usually placed at the desired level. Volumetric waves are normally propagated perpendicular to the surface to inspect conditions along this direction. The discontinuity in the direction of propagation affects the reflection and creates an additional wave packet in the signal. Because the adhesive layer is usually very thin, a high-resolution transducer is needed to differentiate between the joints within the adhesive area[1]. In this regard, Pilarski and Rose[2] have propagated volumetric waves diagonally instead of volumetric longitudinal waves in normal propagation to investigate the state of adhesion. Rose showed that the sensitivity of the limb waves to detect defects is higher than that of ordinary ultrasound waves. They also reported that testing with lamp waves was faster and cost much less than conventional ultrasound techniques and other inspection methods.

In their research, Lou et al. Examined the sensitivity of the lamp waves to defects. They also tried to relate different wave defects with different dimensions in this study to associate wave modes with defect sizes and wave reflectance.

The purpose of this study was to investigate the effect of adhesive connection defects on the lamp waves when passing through this connection. In other words, the goal is to find a suitable indicator of the received signal by using only one sensor so that with the help of this indicator, the characteristics of the defects in the adhesive can be extracted. For this purpose, first numerical modeling will be done in three dimensions and changes in parameters such as adhesive thickness size, position and circular defect size will be investigated.

2. Methodology

For stimulation, an appropriate signal should be used that has the appropriate excitation time and the desired bandwidth to prevent adverse effects related to dispersion. In this paper, to achieve the desired signal to activate the sheet waves, the valve tone signal was used. The relationship used to generate the signal in the software environment is:

$$A(t) = \frac{1}{2} \times \sin(2\pi ft) \times \left(1 - \cos\left(\frac{2\pi f}{N}t\right)\right) \quad (1)$$

In Equation (1), the median excitation frequency is expressed in Hertz and the number of tonal signal cycles. In addition to the intermediate frequency of the excitation, which is determined based on the excitation frequency, the number of cycles of tone burst is also an adjustable parameter that directly affects the signal length and bandwidth. As the number of cycles of the tone burst increases, the bandwidth decreases but the duration of the signal increases. In this case, a 5-cycle excitation signal like Figure 1 is used to generate sheet waves. Although the reduction in bandwidth due to the increase in the number of tone burst cycles is a positive feature for wave propagation and prevention of dispersion, increasing the signal generation time causes the excitation signal to be recorded by other sensors when it is not yet produced as a complete packet. And this leads to complexity in the intuitive analysis of wave propagation; Therefore, the optimal selection of excitation signal parameters is based on a compromise between design criteria.

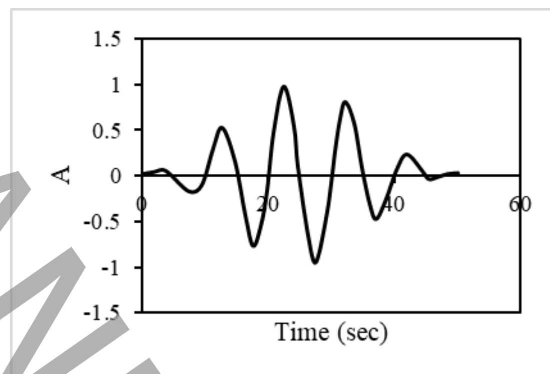

Figure1. Signal amplitude in the time domain

3. Finite element modeling of adhesive bonding

In this modeling, two aluminum sheets and the adhesive between them that form the edge-to-edge connection have been investigated. In this simulation $b \times a \times s = 200mm \times 50mm \times 0.2mm$ is considered.

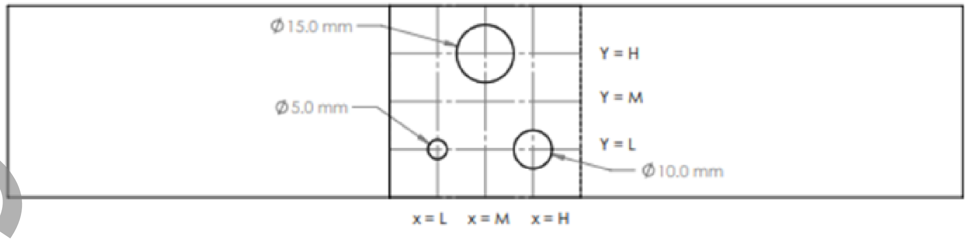

Figure2. Schematic of defects created in the adhesive

4. Finite element analysis of healthy and defective samples

In this research, a complete adhesive with dimensions $50*50mm$ and in three different thicknesses has been modeled. Also, defects were created in three different sizes in nine situations, in which three healthy samples and 81 defective samples were modeled.

The values and number of variables in this simulation are arbitrary and only to show the sensitivity of the received signal to changes in the thickness of the adhesive and the presence of defects in different positions of the adhesive. These defects are schematically shown in Figure (4).

5. Results and Discussion

Figure (5) shows three examples of received signals in three different areas. As can be seen, the signals received by the sensor change as the defect area changes.

Using the IDE method, the score of the introduced features is extracted and is shown in Table (1).

Table1. Normal rating of properties in simulation mode

Property	Normalized score
Average*	0.992
Average square root *	0.961
Elongation	0.986
Criterion deviation *	0.972
Crest Invoice *	0.961

6. Conclusion

The best neural network structure in this study consists of an input layer of 5 input neurons, a middle layer with 7 middle neurons and an output layer with 3 output neurons. In this process, the mean power of the second error (MSE) with the value of 0.0206 is obtained.

As shown in Figure (6), as the 27 specimens in each group, diameters of 5, 10, and 15 mm, all of them are correctly classified.

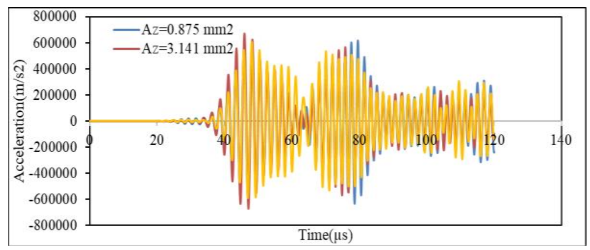

Figure3. Acceleration diagram in terms of time in a piece with defects in three different areas

Figure4. The accuracy of the network in correctly diagnosing the defect area

7. References

[1] Z. Tang, A. Cheng, J.D. Achenbach, An ultrasonic technique to detect nonlinear behavior related to degradation of adhesive bonds, in: Review of Progress in Quantitative Nondestructive Evaluation, Springer, 1998, pp. 1347-1354.

[2] A. Pilarski, J.L. Rose, A transverse-wave ultrasonic oblique-incidence technique for interfacial weakness detection in adhesive bonds, Journal of Applied Physics, 63(2) (1988) 300-307.