Damage detection and classification utilizing Lamb waves and artificial neural networks

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Introduction

Reliable damage detection in the aeronautical field is becoming crucial with the application of new materials [1,2].

This work presents a novel method for identifying the existence of damage and its extent in a aluminum sheet employing Lamb waves (LW) in conjunction with artificial neural networks.

Experimental Methodology

As a base for the large volume of testes required by the machine learning algorithm, a Finite Element model was created. It consists on an aluminum sheet with 300 x 300 x 2 mm, where the mesh size is 1.5 mm. The actuator/sensors were placed in a square configuration at a distance of 90 mm form the edge, as can be seen in Fig. 1. The LW, which are a form of guided waves, were generated using a Hanning window pulse with a frequency of 100 kHz and applied to the horizontal surface of the plate.

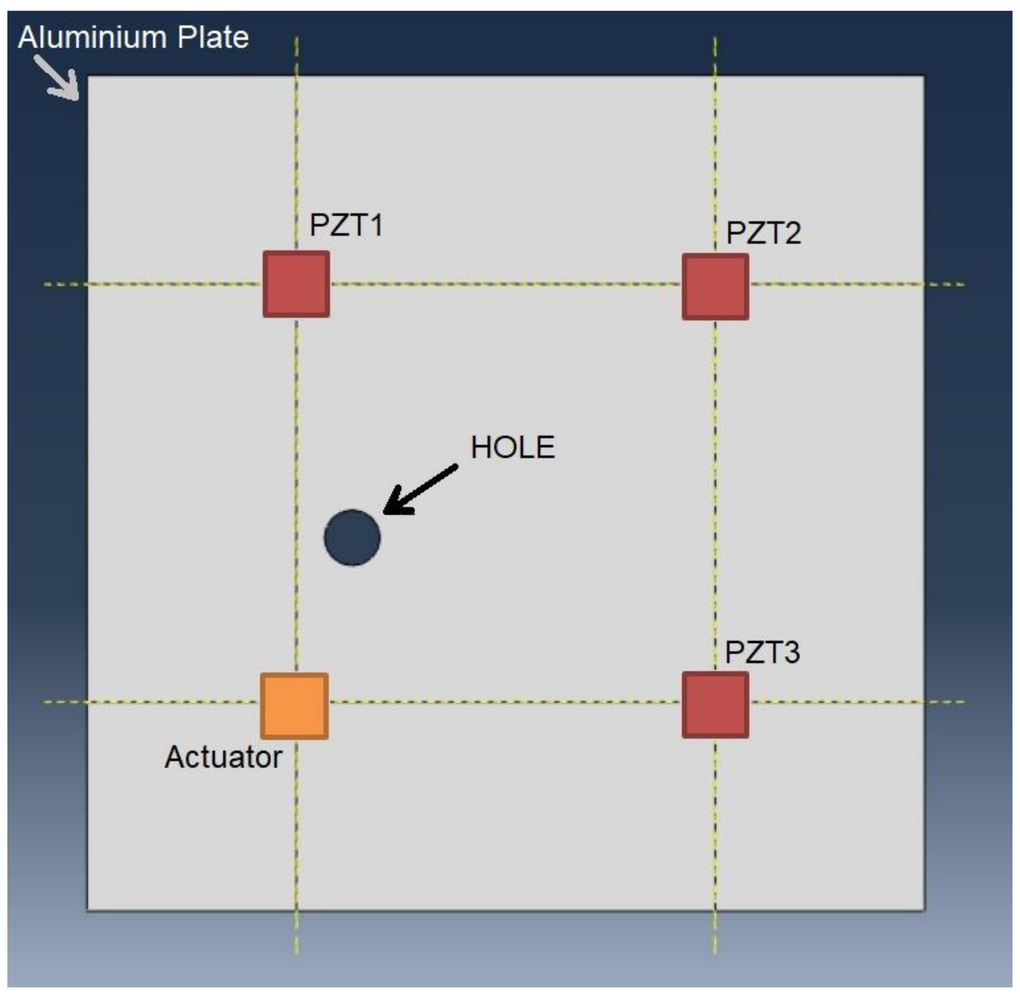

Figure 1 – Simulation of LW passing though an aluminum plate and the actuator/sensors positioning.

Discussion

The data set was created with a total of over 2000 cases. These cases were divided into equal number for each given hole size, i.e., 0,2,6 and 10 mm, with randomly positioned inside the square that has the sensors and actuator as vertices. This allowed the machine learning model to have one class for each hole size, independently of their positions. The chosen features ware the amplitude and time of the peaks present in the LW signals (Fig. 2). This data where then applied to a conventional feed forward neural network (ANN) and a convolutional neural network (CNN).

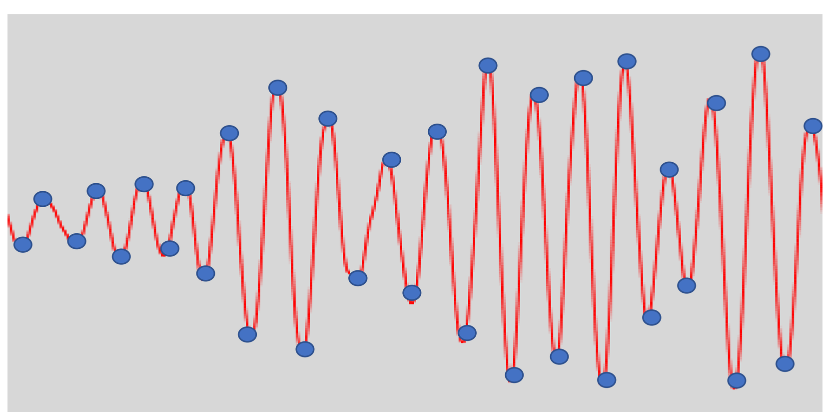

Figure 2 – Features extracted from raw LW signals, marked in blue.

Results

Both the ANN and CNN used 3 classes "of different damage sizes" and presented an accuracy of over 97% and a loss under 0.1 for testing samples. It is also possible to see results with a low number of epochs (Figs. 3 - 5).

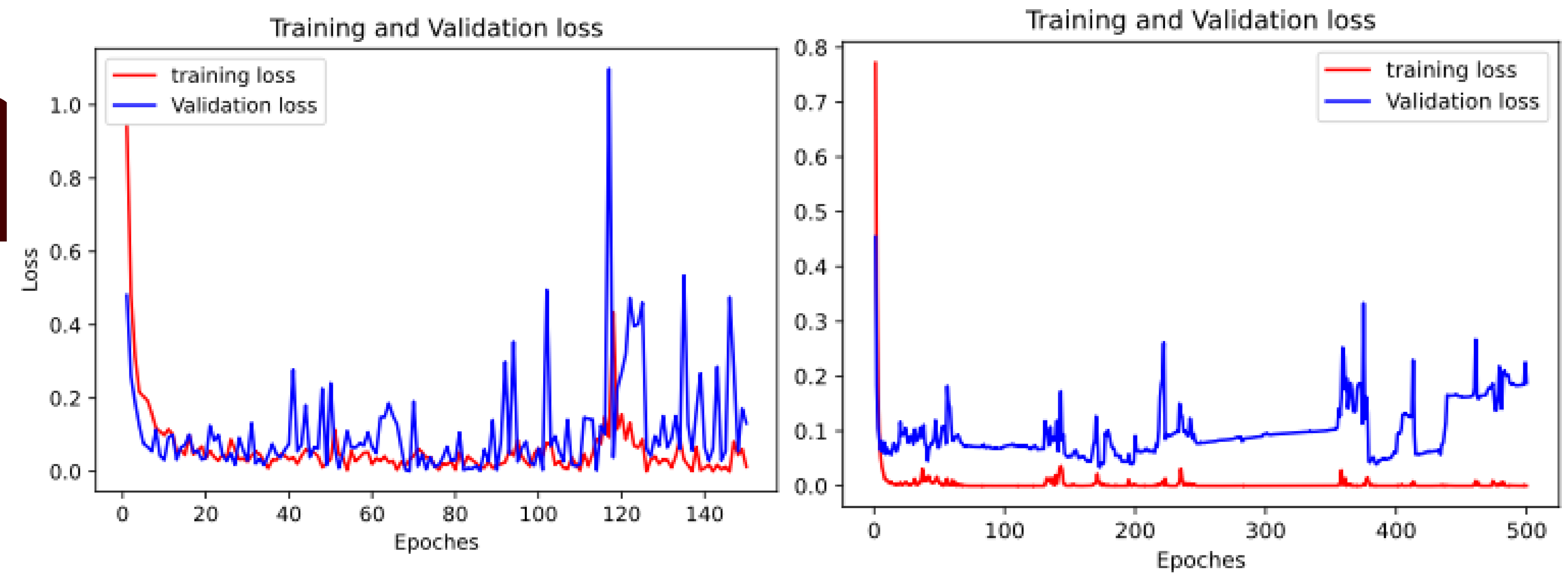

Figure 3 – (Right) ANN, (Left) CNN – Accuracy in each epoch.

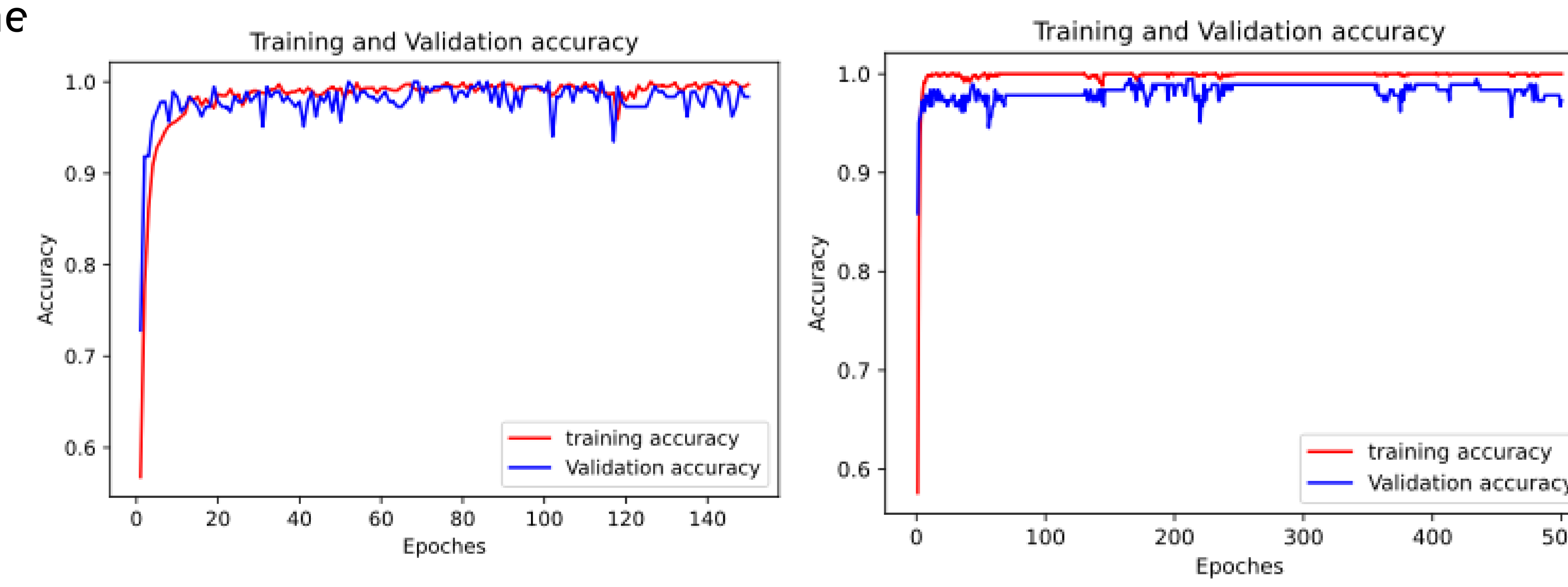

Figure 4 –(Right) ANN, (Left) CNN – Loss in each epoch.

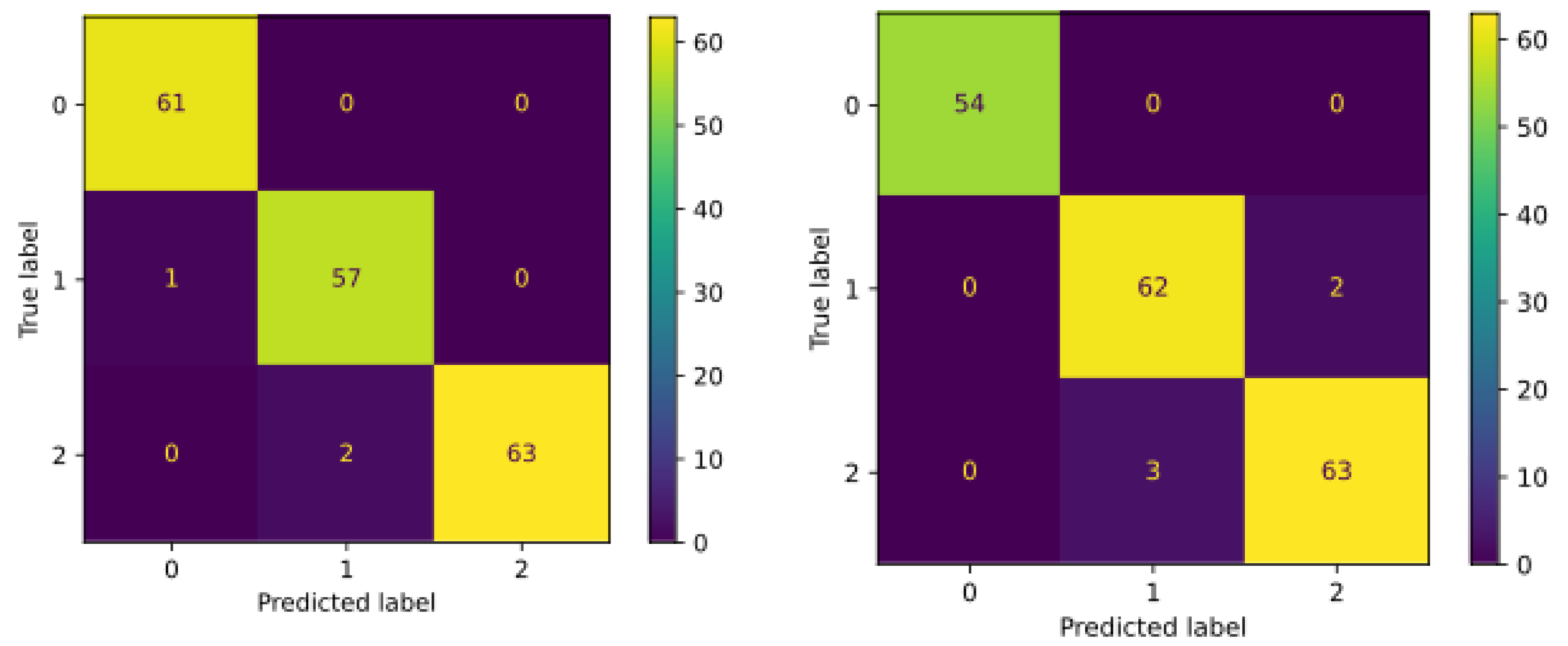

Figure 5 –(Right) ANN, (Left) CNN – Confusion Matrix of best epoch.

Conclusions

This work presented a novel approach using ANN and CNN to determine, with relevant accuracy of over 97% in the test batch, the level of damage in an aluminum plate. These results will allow for further developments in various high-end industries for the detection of different types of defects in structures.

References

[1] Karachalios EF, Adams RD and da Silva LF (2013) Strength of single lap joints with artificial defects. International Journal of Adhesion and Adhesives 45: 69–76. DOI:10.1016/j.ijadhadh.2013.04.009.

[2] da Silva, LF, Öchsner, A, Adams RD (2011) Handbook of Adhesion Technology. 1st edition. Springer-Verlag Berlin Heidelberg. DOI:10.1007/978-3-642-01169-6-1.

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