Machine Learning-Based Methods for Quantification of Weak Adhesion

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Introduction

The use of adhesive joints has become increasingly popular in various industries due to their many benefits, such as low weight and good mechanical performance. However, adhesive joints can suffer from defects, one of them being weak adhesion. This defect poses a significant risk to structural integrity and can lead to premature failure, but is hard to detect by existing non-destructive testing methods [1,2]. Therefore, there is a need for an effective technique that can detect weak adhesion in single-lap joints (SLJ) to prevent failure and assist maintenance, namely in the framework of structural health monitoring. This work presents a numerical model of SLJs with different levels of weak adhesion and validate it with data from real samples, so that reliable LWs data can, in the future, be easily generated to train and test any adopted machine learning data-driven algorithms. The study shows that using simulated data increases up to 26 % the detection capability when compared to only considering experimental data. Therefore it is possible to determine the validity of using simulated cases to replicating damage.

Experimental Methodology

As a base for the large volume of testes required by the machine learning algorithm, a Finite Element model was used. The model was created with two aluminium sheets with 25 x 120 x 2 mm where the mesh size chosen was 1.5mm. The sensor/actuator were placed in a centred line at a distance of 10 mm form the edge as can be seen in Figure 1. The LW, which are a form of guided waves, were generated using a Hann window pulse with a frequency of 100 kHz and applied to the horizontal surface of the Plate. Over 70 cases were created by varying the young's modulus between 100 and 700 kPa.

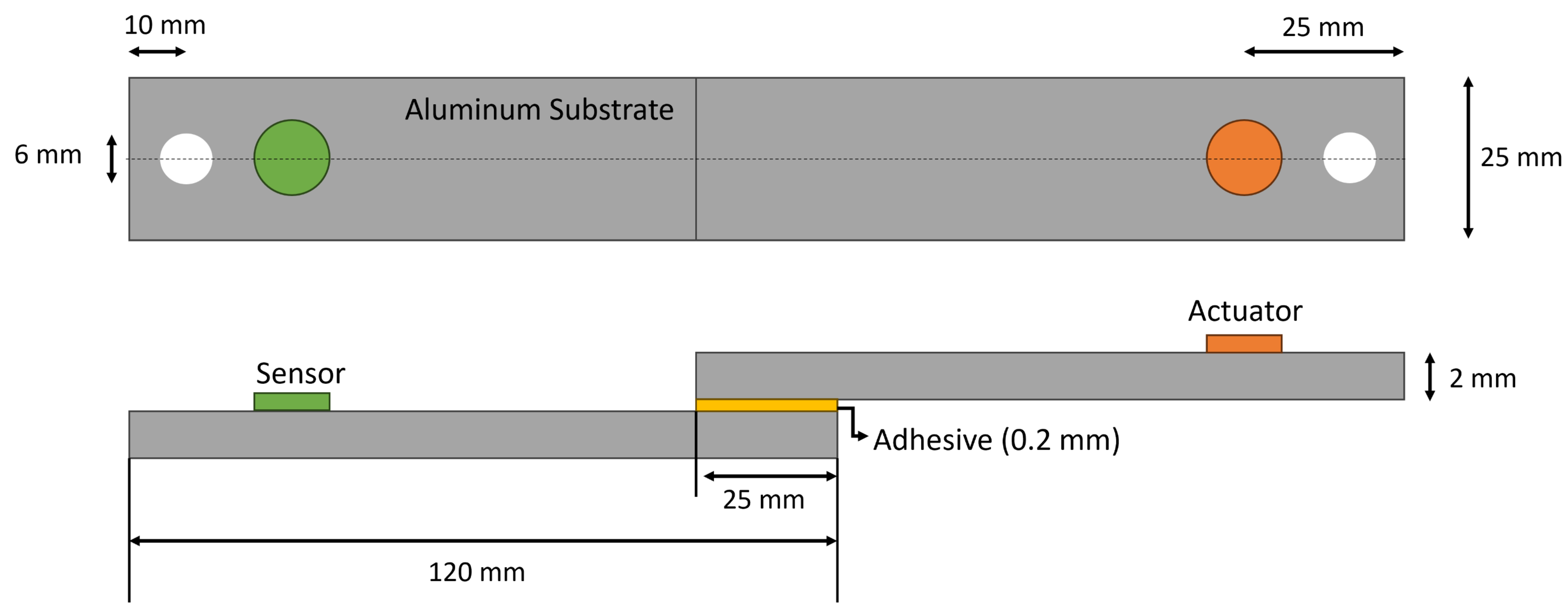

Figure 1 – Simulation of LW passing though a aluminium Plate and the actuator/sensor positioning.

Together with this numerical model, 11 test samples were made with different levels of weak adhesion. This was done by changing the quantity of release agent that was applied to the surface that was going to be adhered. These parts then had the sensors and actuators attached and data acquired and this setup can be seen in Figure 2. Finally these sensors were removed and the part was subjected to a tensile test to determine their level of weak adhesion and correlate them to the vibrational data, again seen in Figure 2.

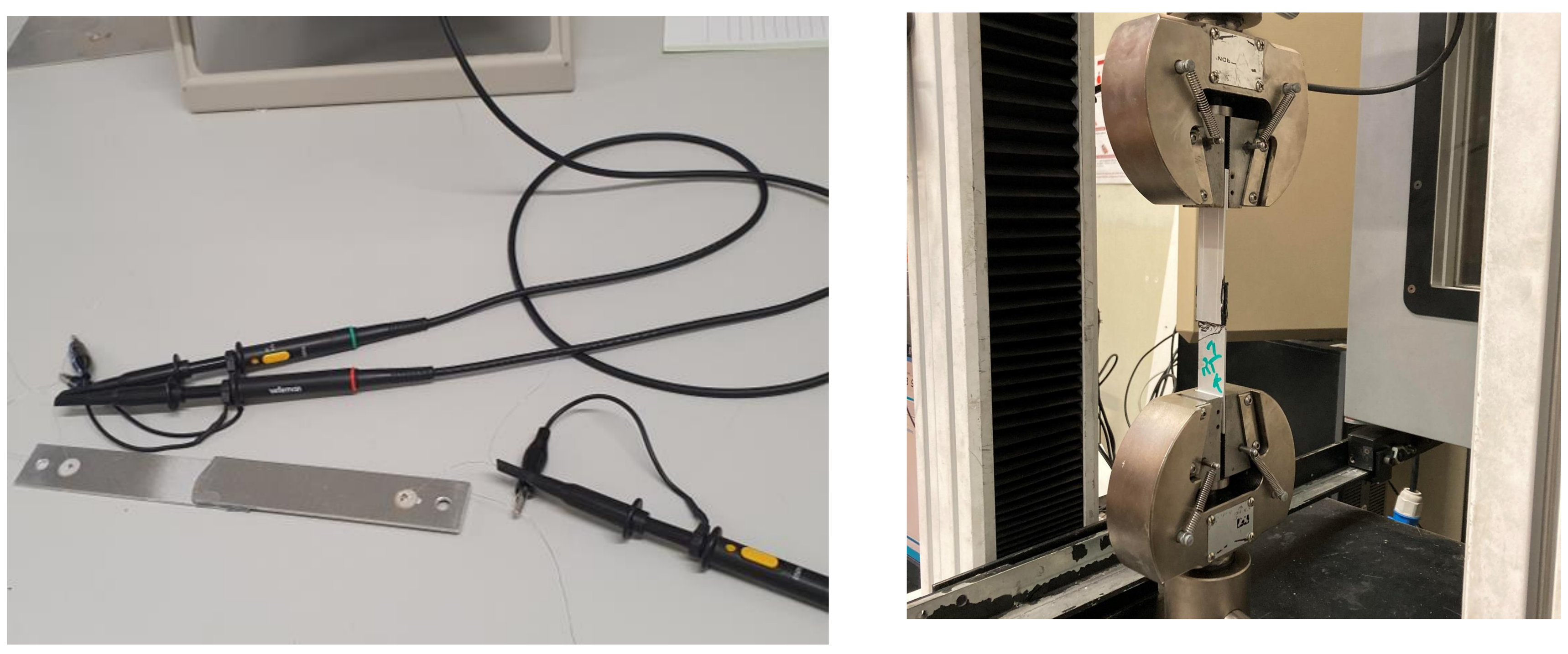

Figure 2 – Experimental setup for the vibrational data (Left) and Experimental setup for the tensile test of the 11 experimental samples (Right).

Results

Alone the experimental data had no correlation between them as can be seen in Figure 3 where there is no underling correlation that can be seen easily.

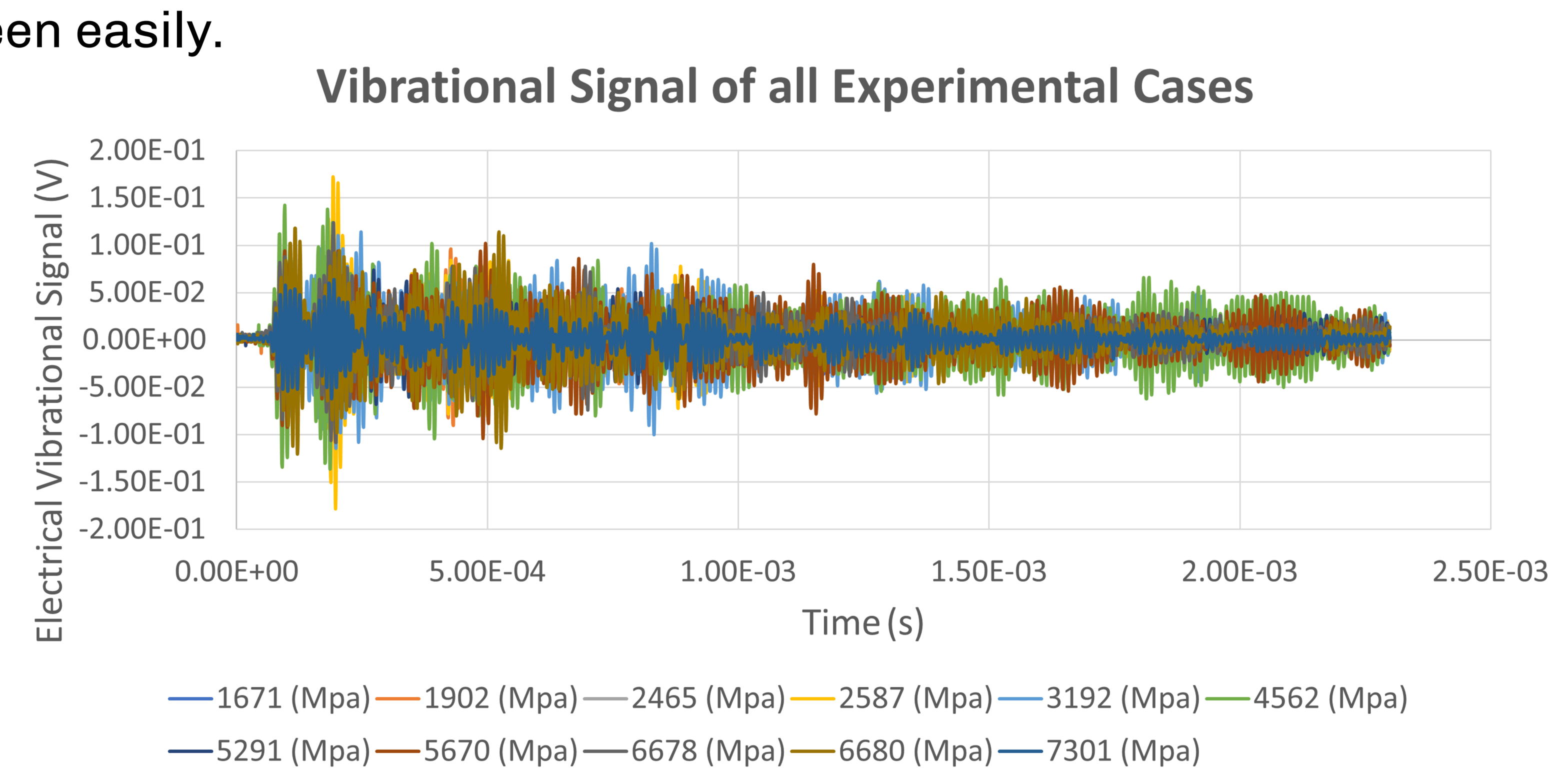

Figure 3 – Vibration acquired from the sensor of the 11 experimental samples showing no trend of data or direct correlation that can be obtained easily.

Therefore it is necessary to utilize these data together with the simulated data. As there are numerous hyper parameters, a few were altered to compare the values. It can be seen (Table 1) that tests that use experimental and simulated data have an increase of up to 26% in detecting the cross validation of the experimental data in comparison to only experimental data.

	77 Exp , 15 % Noise		22 Exp, 15 % Noise	
	Simu+ Exp	Only Exp	Sim + Exp	Only Exp
Case 1671 Mpa	288.55	465.21	470.03	462.85
Case 1902 Mpa	205.49	144.32	235.25	288.79
Case 2465 Mpa	42.36	134.20	94.32	256.30
Case 2587 Mpa	215.26	154.72	177.65	288.94
Case 3192 Mpa	24.98	146.67	134.74	283.93
Case 4562 Mpa	197.76	211.83	176.24	31.31
Case 5291 Mpa	350.89	161.06	299.51	187.14
Case 5670 Mpa	253.86	253.12	163.33	99.13
Case 6678 Mpa	427.01	420.28	321.30	188.97
Case 6680 Mpa	195.47	417.37	203.08	188.55
Case 7301 Mpa	313.67	328.48	500.26	326.14
Avarage	228.66	257.93	252.34	236.55

	22 Expe, 5% Noise		49 Exp, 5% Noise	
	Sim + Exp	Only Exp	Sim + Exp	Only Exp
Case 1671 Mpa	415.68	450.98	470.37	468.55
Case 1902 Mpa	272.91	306.89	228.67	169.93
Case 2465 Mpa	100.43	259.00	82.08	140.73
Case 2587 Mpa	214.51	276.59	224.79	200.49
Case 3192 Mpa	76.65	266.28	136.70	241.11
Case 4562 Mpa	209.71	127.53	185.02	141.18
Case 5291 Mpa	279.33	195.98	232.13	162.68
Case 5670 Mpa	65.04	292.53	163.12	247.91
Case 6678 Mpa	312.77	184.34	373.95	427.91
Case 6680 Mpa	181.89	284.62	185.23	355.86
Case 7301 Mpa	163.00	333.27	355.90	357.95
Avarage	208.36	270.73	239.81	264.93

Table 1 – Results of cases with and without simulated data applied

Conclusions

This work presented a comparison between experimental and simulated single lap joints subjected to weak adhesion and determined the validity of the simulated data along with methods to approach the problem of evaluating the level of weak adhesion on a part. In this study it was seen that combining both simulated and experimental data can have an increase of accuracy of 26%

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, Lucas F M, O¨ chsner, Andreas, Adams RD (2011) Handbook of Adhesion Technology. 1 edition. Springer-Verlag Berlin Heidelberg. DOI:10.1007/978-3-642-01169-6-1