Validation of a finite element impact wave propagation model

Structural Health Monitoring (SHM) has become an important topic in aircraft industry to reduce the maintenance costs and increase the availability of an aircraft fleet through additional sensor networks. In this work, a finite element model, simulating wave propagation in a structure due to an impact, was successfully validated by comparing the computed sensor responses with the measured sensor responses caused by an impact on a flat aluminium plate. These tests were performed at NLR, using piezoelectric (PZT) and optic fibre Bragg grating (FBG) sensors.

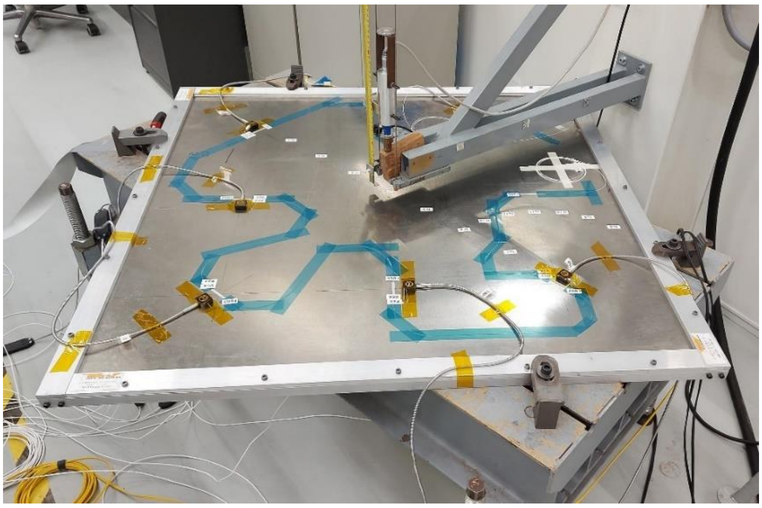

Figure 1: Experimental test setup

Introduction

A finite element model for wave propagation due to an impact is very desirable, to enable the design of optimal sensor networks for SHM applications and to obtain a better understanding of wave propagation, especially in composite structures, and also to generate simulated (virtual) test data for SHM algorithm development. Therefore, an Abaqus explicit finite element (FE) model was developed for wave propagation due to impacts. To validate such a model, a series of impact tests were performed with a drop tower on an aluminium and composite clamped square panel, see Figure 1, at different impact energy levels and different impact locations. On both panels, six piezoelectric (PZT) and eight optic fibre Bragg grating (FBG) sensors were installed. The experimental results were used to validate the FE model, in which the impacts were simulated. The computed PZT and FBG sensor responses were compared against the experimental sensor responses.

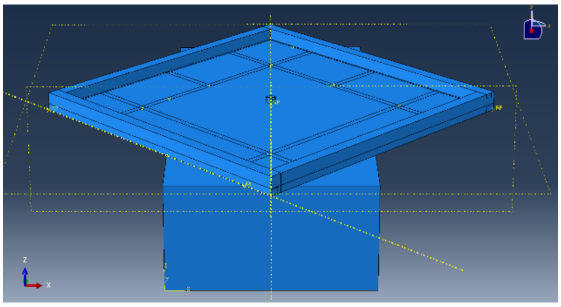

Figure 2: 3D model in Abaqus CAE

Methods and approach

The objective was to develop an accurate (Abaqus) finite element model, while keeping computational costs as low as possible to allow simulations on more complex structures. The whole test setup depicted in Figure 1 was modelled, consisting of the plate, the support frame, the impact table and the impactor, see Figure 2.

With this baseline model, sensitivity analyses were performed for the various model parameters, in which the strain time responses were computed at the PZT and FBG sensor locations due to an impact on the plate. From these results the model parameters were determined that have a large influence on the wave propagation in the plate, such as for instance the boundary conditions and the impactor model.

The computed PZT and FBG strain time responses were subsequently compared with the experimentally obtained sensor responses for different locations and energy levels.

Results and observations

With the correct geometries for the different parts, material properties, element types, mesh density and the correct impactor model, the strain for first milliseconds matches the experimental data well.

The main difficulty was to correctly model the boundary conditions, even for the rigid support frame. This significantly affects the strain after the first few milli seconds. After this, the boundary conditions play an important role and since they can't be modelled perfectly the strain start to differ from the experimental data.

This is highlighted in Figure 3, were we can see that the strain extracted from Abaqus (in blue) fit the experimental data (in red) for the first 3ms and then it starts to differ.

Figure 4 depicts the comparison of the numerical and experimental impact force over time, which also shows a good accuracy.

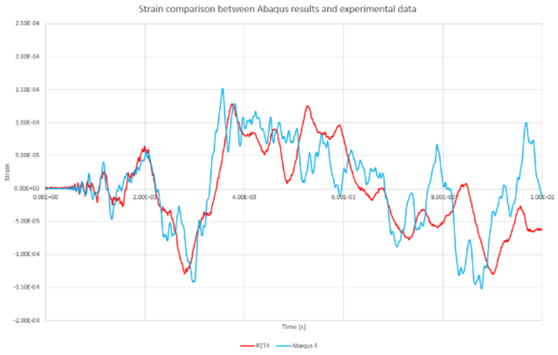

Figure 3: Strain comparison between Abaqus result and experimental data

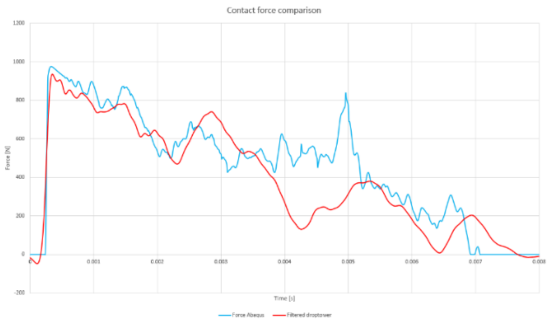

Figure 4: Impact force comparison between Abaqus result and experimental data

Conclusion

To conclude, the current finite element model of the impact tests is providing good results.

The sensitivity analyses revealed the model parameters that have a large influence on the wave propagation and the strain response at the sensor locations, of which the boundary condition is most uncertain.

In near future work, the model will be validated for the (thermoplastic) composite panel, for which experimental results already have been collected.

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