Simulation of a Thin Walled Aluminum Tube Subjected to Base Acceleration Using LS-DYNA®'s Vibro-Acoustic Solver

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Abstract

A shaker table test, where a simple thin walled aluminum tube was base accelerated at two geometrical locations, was simulated using the vibro-acoustic solver of LS-DYNA. It was shown that the method of modeling the fixture of the tube to the shaker table's moving plate had a great impact on the simulation result. Three modeling methods of the fixture were tested, and acceleration PSD results at various points along the tube were compared to test data. A simple, numerically low-cost method, of modeling the fixture was found which gave very good agreements with the experimental data.

Introduction

LS-DYNA is a widely used finite element code, intended to solve complex mechanical problems. While initially the code was based on explicit calculations schemes, during the last decade implicit capabilities were added to the code, which now enable users to solve even more complex mechanical problems. One of the recent developments of the code is the addition of an implicit vibro-acoustic solver, which enables users to perform a variety of vibro-acoustic simulations in the frequency range. This paper presents a series of simulations which were used to validate the vibro-acoustic solver capability, to accurately predict a simple shaker table test performed on a thin aluminum tube being base accelerated simultaneously at two locations. The simulations were performed using a number of fixture methods (where the term "fixture" is used to describe the method in which the tube is being connected to the shaker table). The goal of the work was to find a fixture simulating method that will be computationally low cost on one hand, while still give reasonably accurate results on the other hand. The fixture methods being tested will be described, and the results obtained by each method will be compared to the experimental data.

Problem's Description

A thin walled aluminum tube, whose geometry is shown in Figure 1, was base accelerated at the laboratory using two shaker tables, with a PSD of acceleration as an input, as described in Figure 3. The tube external diameter is D = 50.9 [mm], and it has a wall thickness of 3.3 [mm].

All of the materials involved have material density $\rho = 2.7\times10^{-6}\ {}^{kg}\!/\!_{mm^3}$, Young's modulus $E = 70Gpa$ and Poisson’s ratio 0.3.

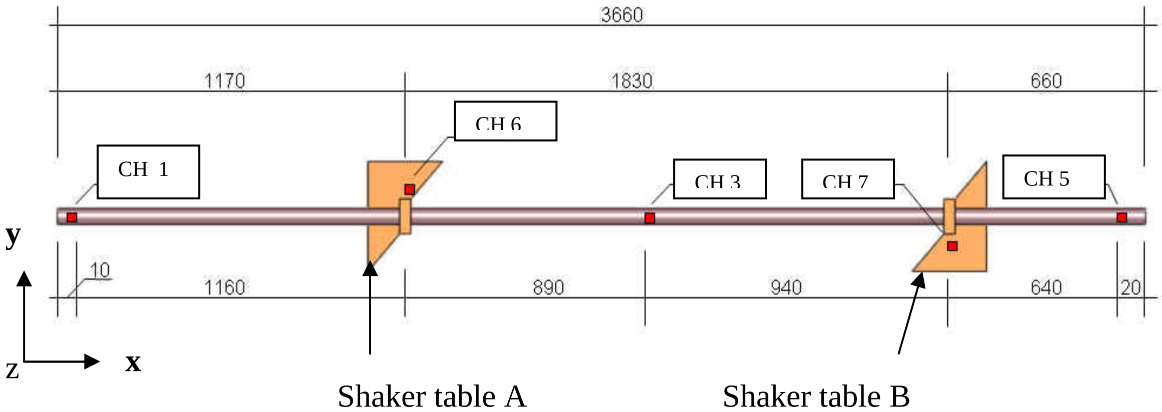
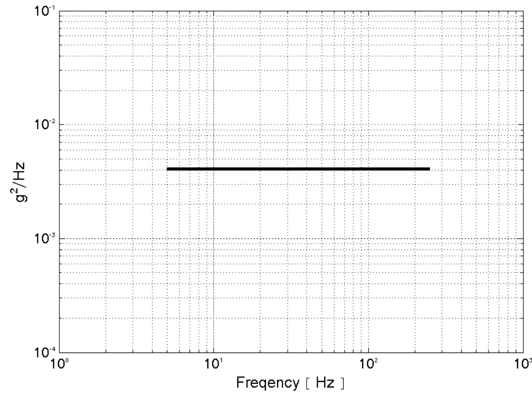


Figure 1 – Tube dimensions and experiment setup. All dimensions are in [mm]

The tube was fixed to the shaker tables using aluminum blocks which surrounded the tube and were tightened using screws, as shown in Figure 2.

Figure 2 – Close view of the expeimental fixture

Five accelerometers were located at various points along the tube as shown in Figure 1.
A PSD of acceleration, as shown in Figure 3, was input to the tube using the two shaker tables.



Total : 1.00 [Grms]

No.	Freq.	g^2/Hz
1	5	0.004082
2	250	0.004082

Figure 3 - PSD of acceleration used as an input for both shaker tables

LS-DYNA simulation using simple fixture

A simple FEM model was built and is shown in Figure 4. The tube was modeled using shell elements, where the fixture was defined using one node set with constrained movement along all directions except the Z direction. This enabled the base acceleration input to move the fixture in only one direction.

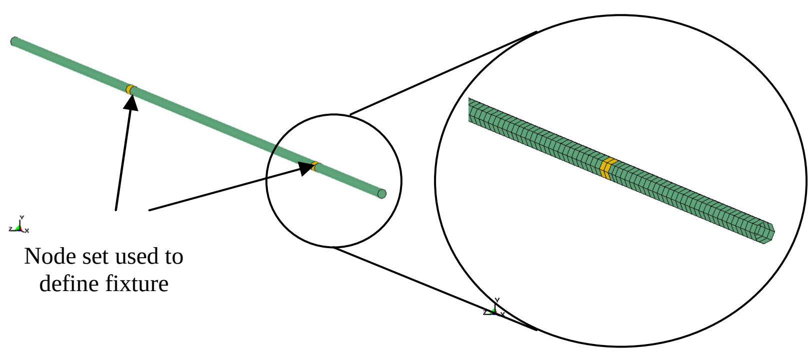


Figure 4 – Initial numerical model using constrained node sets at shaker table inputs

An implicit vibro-acoustic run was performed using LS-DYNA. A typical comparison between the experiment and the simulation is brought in Figure 5 and Figure 6:

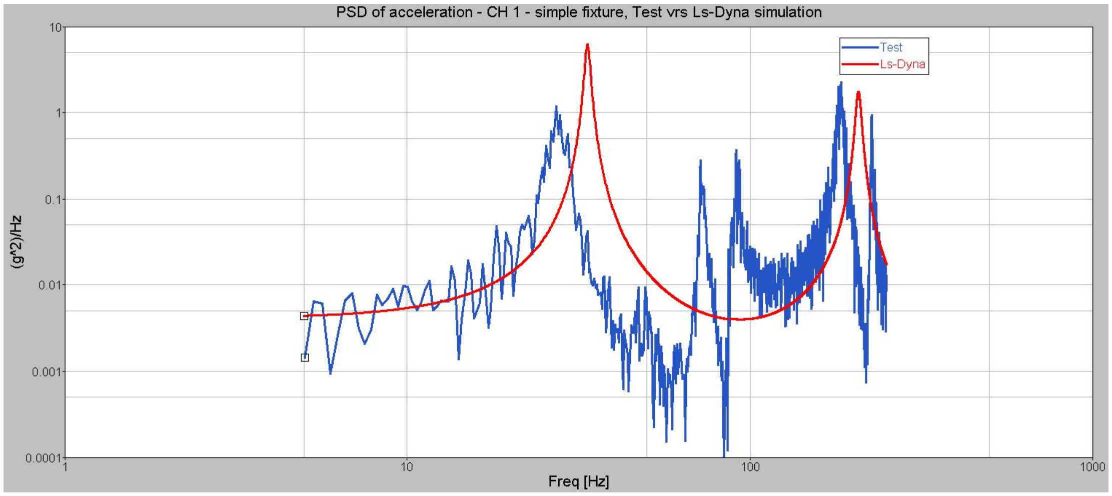


Figure 5 – PSD of acceleration at channel 1, Test vs. Simulation, simple fixture

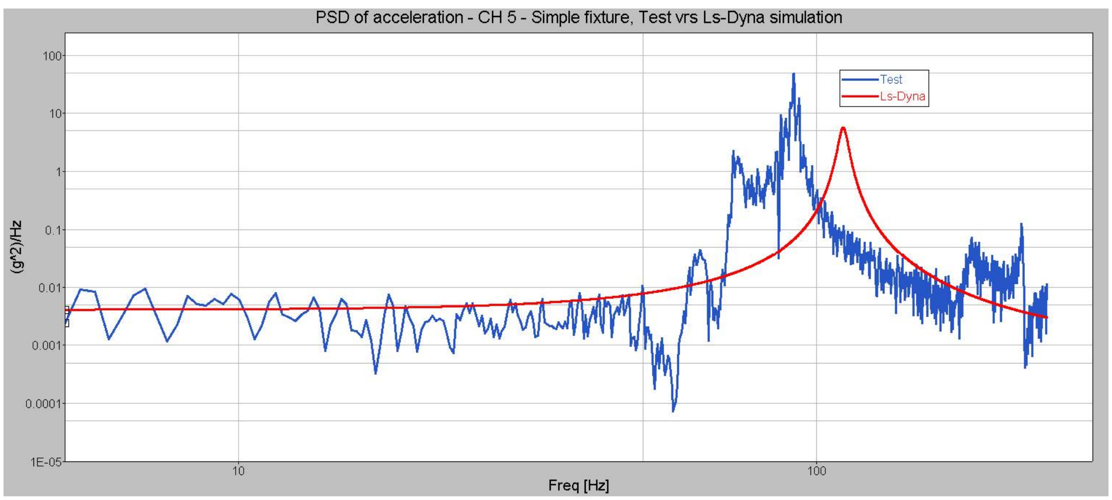


Figure 6 – PSD of acceleration at channel 5, Test vs. Simulation, simple fixture

It can be seen that while the simulation is close to the experimental result in some values of the frequency range, yet there is a major difference between the two at other ranges, and it seems as if some modes are not obtained by the numerical model. A close look at the eigenmodes (Figure 7) will reveal why. The fixture method being used was too stiff and did not enable the tube to vibrate freely as one continuous body. It must be stated that while the PSD input to the LS-DYNA simulation was a perfectly flat line, the actual experimental input was quite noisy due to the limitation of the experimental equipment. This is the main reason for the noise in the experimental results.

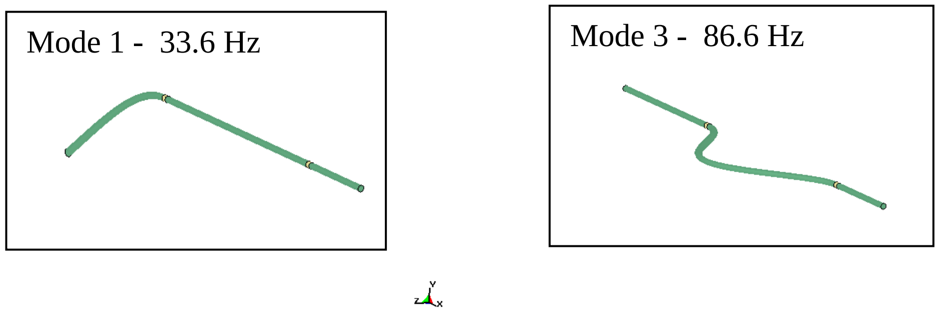


Figure 7 – A view of typical eigenmodes shapes 1 and 3, simple fixture

LS-DYNA simulation using improved, low cost fixture

An improvement to the fixture was introduced by adding an external support for the tube at the locations where the shaker table vibrates the tube (Figure 8). The base acceleration was applied to this new support, instead of the nodal sets previously used, and a contact algorithm was added in order to transfer the support's movement to the tube.

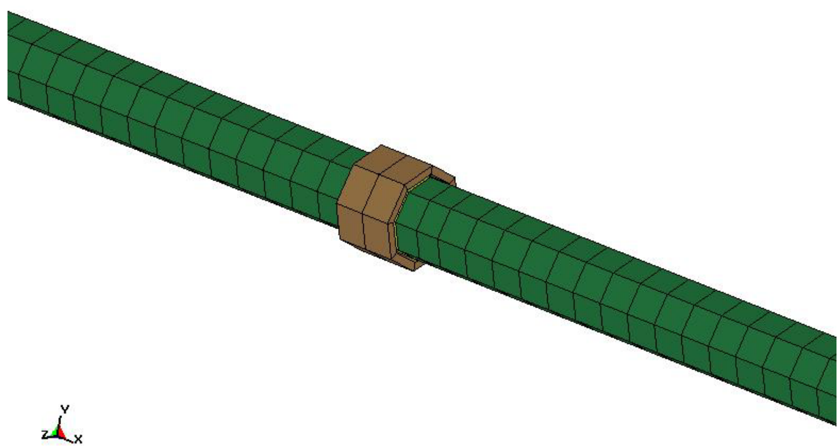


Figure 8 - close view of the improved fixture

Figure 9 shows a typical eigenmode of the improved fixture model. It can be clearly seen that in opposed to the first model, where the fixture limited the movement of the tube, the improved fixture enabled the tube to vibrate as a continuous body, and movement at one end of the tube is affecting every point along the axis of the tube.

Figure 9 – Typical eigenmode shape for the improved fixture model

A typical comparison between the experiment and the simulation using the improved fixture is brought in Figure 10 and Figure 11:

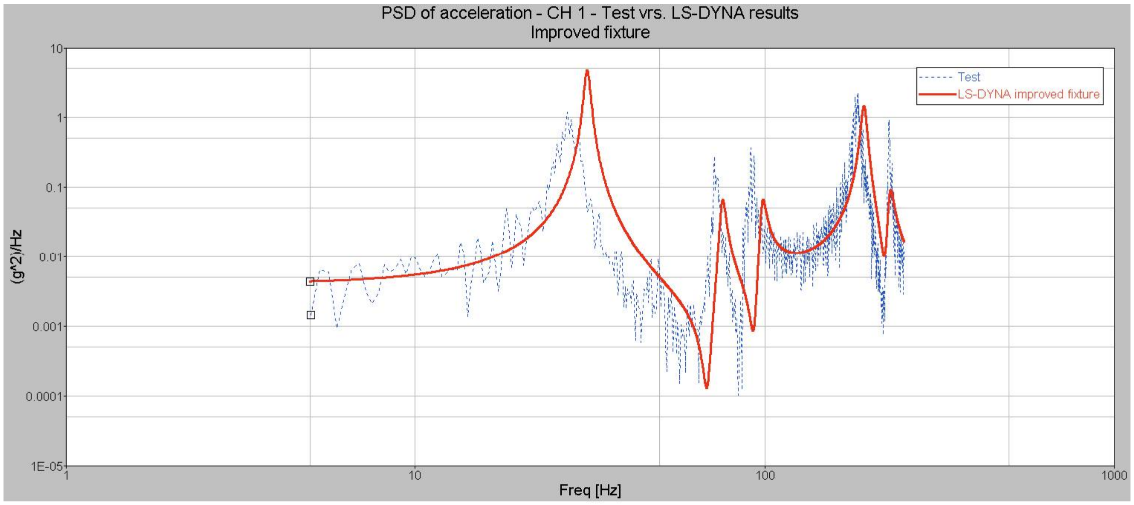


Figure 10 – PSD of acceleration at channel 1, Test vs. Simulation, improved fixture

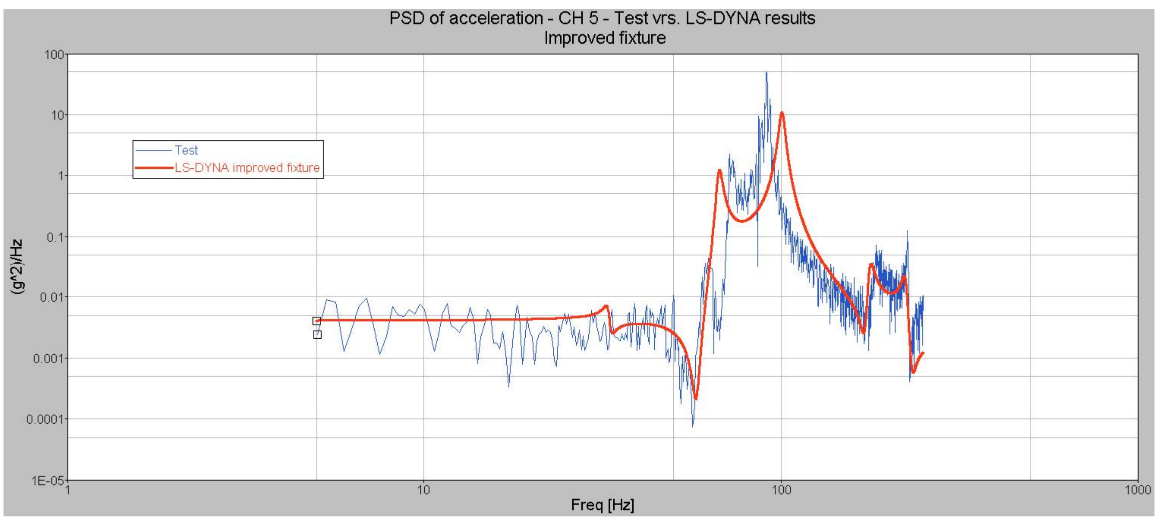


Figure 11 – PSD of acceleration at channel 5, Test vs. Simulation, improved fixture

It can be clearly seen that the simulation results were much more accurate when using the improved fixture. Although there was a slight shift in the eigenfrequency, overall behavior between the test and the simulation was close.

LS-DYNA simulation using fully modeled, high cost fixture

Although very good results were obtained using the low cost fixture method previously described, a new model was built where a complex fixture was modeled, consisting of all parts and screws, in order to examine if further detailing of the fixture would improve the results.

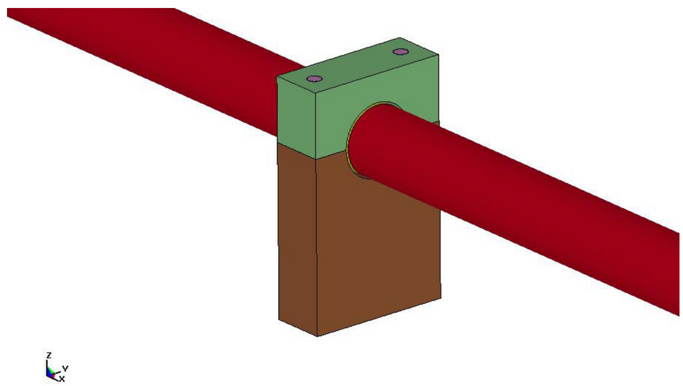


Figure 12 – Fully modeled fixture

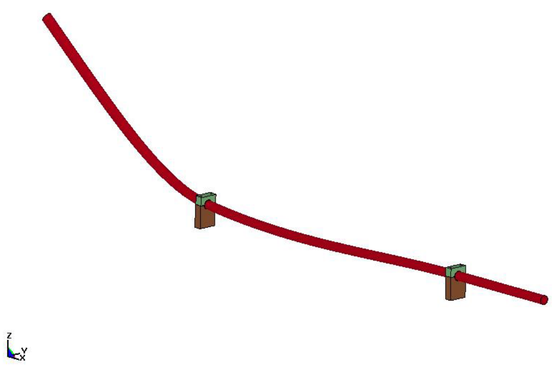


Figure 14 – Typical mode shape whith fully modeled

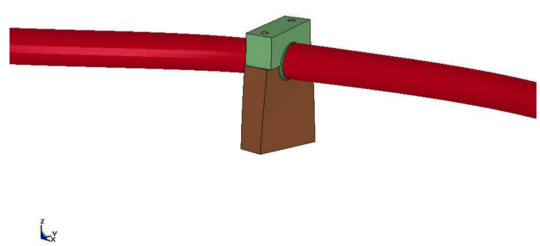


Figure 14 – Close look at fully modeled fixture - typical mode

A typical comparison between the experiment and the simulation using the fully modeled and improved fixtures is brought in Figure 15 and Figure 16:

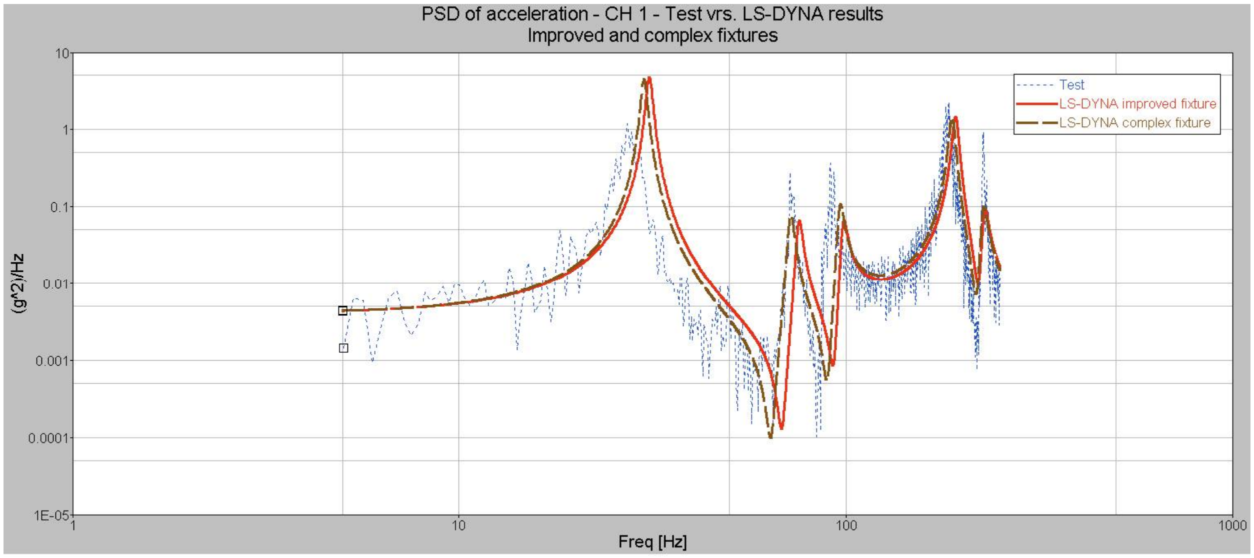


Figure 15 – PSD of acceleration at channel 1, Test vs. Simulation, improved and complex fixtures

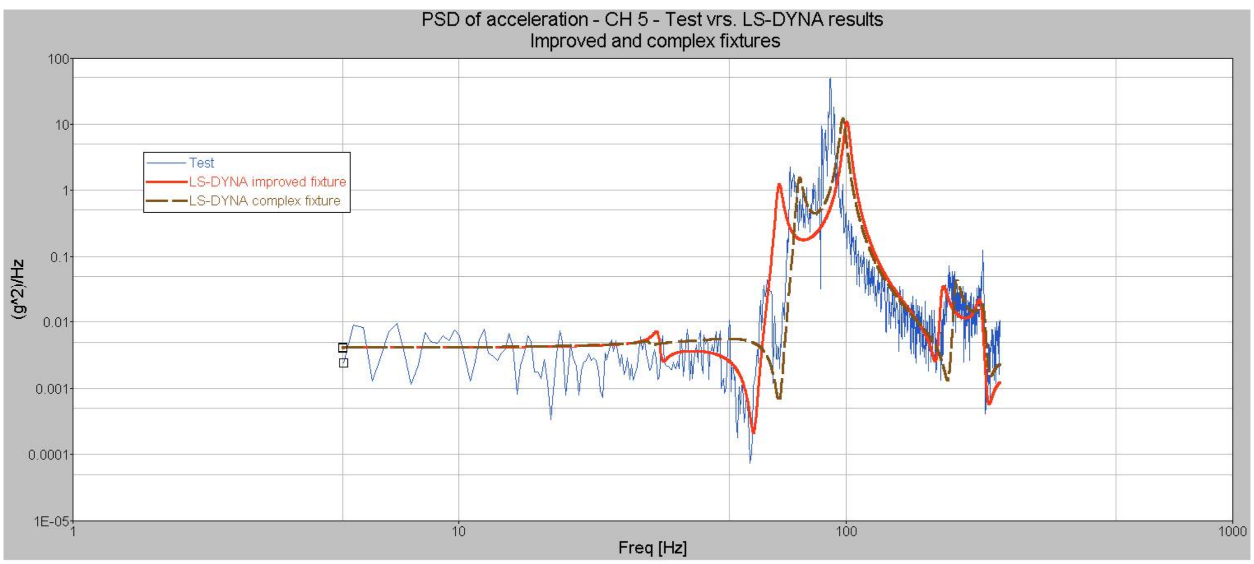


Figure 16 – PSD of acceleration at channel 5, Test vs. Simulation, improved and complex fixtures

It can be seen that the addition of complexity to the model by modeling a full scale fixture did not improve the results drastically, while the computational cost was much higher.

Conclusions

1. The vibro-acoustic solver of LS-DYNA was found to be capable of predicting the results of an experimental test where two shaker tables were used to vibrate a simple structure.
2. It was found that a simple modeling method of a fixture by contact algorithm in LS-DYNA will give reliable results while still be computationally low cost to run.
3. Higher complexity modeling of the fixture (including the modeling of all the parts and screws) did not give a pronounced improvement in the results compared to the improved fixture described in 2, yet it increased the computational time dramatically.

References

1. LS-DYNA® Keyword User's Manual,Version 971, Livermore Software Technology Corporation, 2010.