Finite element modelling, numerical simulation and sensitivity analysis of a bogie

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January 2016

1 Extended Abstract

The bogie of a rail vehicle is the structure responsible of its movement and supporting the weight of the carbody. It is also responsible of the opposition forces needed to keep the train stable and helps avoiding non desired movements. It usually carries an electric engine.

This project was focused on vibroacoustic transmission coming from the rail – wheel interaction. This transmission happens through the bogie and the bogie structure. This is the only vibroacoustic transmission that has been taken into account in this project, and only between the carbody and the rail – wheel interaction.

The bogie of a real vehicle of the company was fully modelled using the software Altair Hyperworks so the behaviour of as a result of the transmission of structural noise could be characterized and predicted with more accuracy (Figure 1). This model was simulated, analysed and compared with the real-life tests and results, with the objective of obtaining a better representation of it.

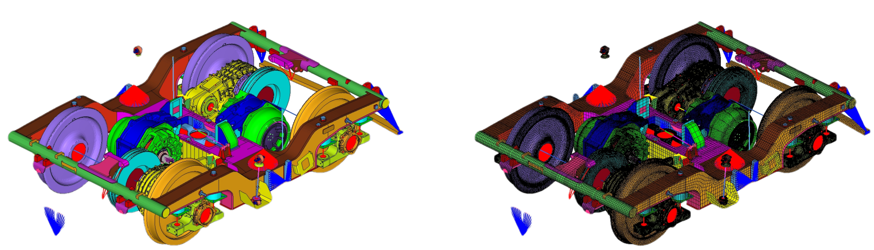

Figure 1: CAD and FEM models for the full bogie

This presentation, though, is going to focus only in one of the components of the bogie, so the attendants can understand how does all the process work and all its complexity. The component chosen is the vertical damper, which is the one that connects the bogie frame with the car body.

Figure 2: Real damper and internal representation

The first step of the procedure is to work on the model to transform it from CATIA or any other CAD software to the meshed component, so we can work directly on it. In this step, company standards on how to model each one of the parts are followed so the representation of the physical components is the more accurate possible. These standards are obviously based on previous modelling and experience from the experts and provide the best initial approximation. Once we have this initial model, the first thing we need to check is mass and inertia. The values for them come from real tests and the magnitudes in both real and model must be the same or, at least, very similar. They have to be consistent with the approximation.

After these initial checks, modal analysis and tranfer function analysis based on these ones are carried. The main objective is again to match the results from the test analysis and the simulation ones. This is the hardest part, as usually the simplifications carried to simulate make the models behave different than expected. They must be corrected then and this implies changing modelling, meshes,etc. becoming an iterative process.

As test analysis, there are two different methodologies: Free-Free and Clamped. These two try to obtain results for our components in different ways. For the F-F subcase, without added stiffness. In the clamped subcase, with infinite stiffness. This second subcase is the one that haves more similarities to the real one, but both of them are useful when characterizing our model behaviour.

Two methodologies are used frequently at this step. MAC (Modal Assurance Criterion) and FRF (Transfer functions). MAC compares the modal shapes from two different sources. In our study, the two sources are mainly described as "TEST results" coming from the real bogie analysis and "SIMULATION results" coming from our software. Modal shapes obtained from these two sources are compared numerically, obtained a comparison table. The main objective is to achieve the maximum number of modes with a maximum level of similarity (value 1) and to have them ordered in the same way (table mainly diagonal) (Figure 3)

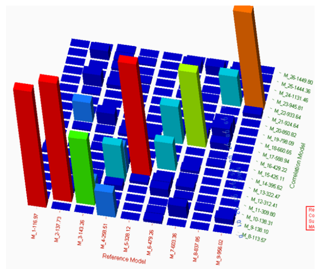

Figure 3: MAC table: test (red) vs simulation (green)

On the other side we have transfer functions. They compare the excitation transfer from one point to another one in our component. This procedure is done also in real life using excitation hammers and accelerometers to capture the amplitude of this excitation on several points. Same paths are compared from test to simulation to try to obtain curves with the more similarity possible (Figure 4)

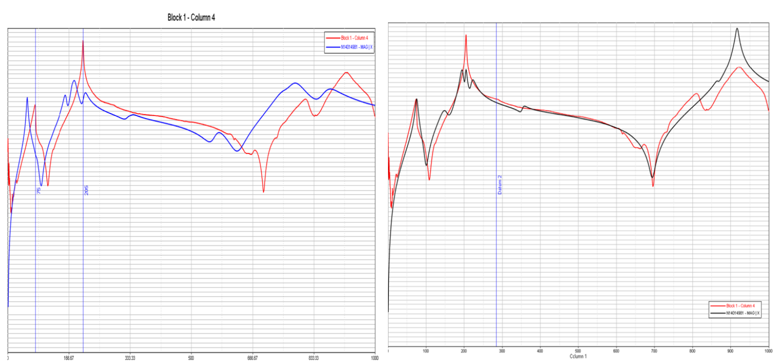

Figure 4: Comparison between Transfer Functions x-axis: frequency ; y-axis: accelerance (amplitude) red: Test blue: Simulation (amplitude). Higher correlation can be seen in the second graph, as peaks coincide better

Finally, once all this has been done, we get a component model that behaves aproximately as the real one. In this step we are able to modify some variables that make the behaviour change in order to reduce noise in our full bogie. This way trams and trains are improved so every time they produce less vibrations and less noise, both interior and exterior.

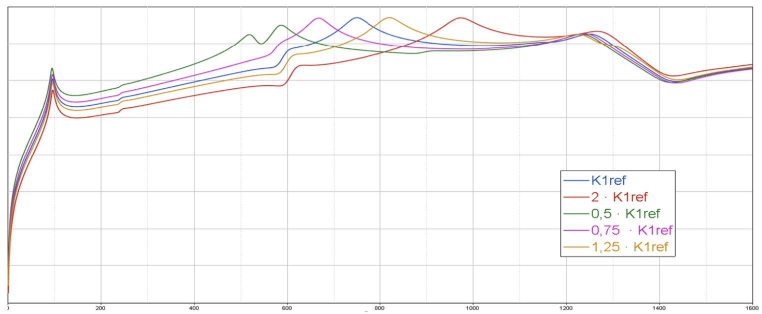

Figure 5: Sensitivity to the changes to one stiffness of the model

The described procedure can take some days or weeks to be completed and in this case the damper was a really small model. When we have to work with bigger components or bigger meshes everything becomes slower as simulations take longer to finish. Finally analysis of full - bogie have to be carried also, taking several hours to simulate. This is remarked to understand the time that a project like this can take.

The development of this project has led to a higher knowledge in terms of structural noise, finite element modelling and has allowed the designers and simulation software experts to introduce several improvements in the rail material design and its features. It has also helped a lot in terms of finite element modelling in the company, introducing also several new methodologies to obtain better results in less time. Environmental, economic and other issues have been omitted due to the prescribed duration of the presentation and the abstract, but were also considered during the realization of the project and its report.