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A CO-SIMULATION APPROACH FOR CRASH ANALYSIS

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In this paper, co-simulation between a concept beam and a flexible body is studied, with the purpose to increase computational efficiency for crash simulations. The behaviour of a simple beam during a longitudinal impact with a wall is presented. The simple beam is modelled by two parts: a 1D model created with LMS Imagine.Lab AMESim and a 3D model created with LMS Virtual.Lab Motion. In order to obtain reference results, the impact behaviour of both a finite element simple beam using LSTC LS-Dyna and a concept beam modelled in LMS Imagine.Lab AMESim are considered. The co-simulation-based results validate well with the two reference results.

Keywords: crash, concept model, co-simulation, simple beam, impact behaviour.

1. Introduction

Automotive manufacturers increasingly employ computer simulation, because physical vehicle crash-testing is highly expensive. In early design process steps during the computer simulation, it is necessary to create and evaluate many different design variants, such as new materials or new geometry, but the detailed 3D models require more computation time. Long analysis times can be an impediment for achieving results and may limit the ability of the engineer to efficiently improve a model.

To resolve the problem of the long time to perform a crash analysis, [5] investigated the possibility of performing practical analysis by highly parallel computing. It was concluded that a possible method to raise the speed of large-scale calculation is parallelization that requires the development of the necessary hardware and software update.

Another way to improve the computational efficiency is to increase the mesh element size, but coarsening the mesh may lead to artificial stiffening of the model [6]. In the same reference, the mass scaling technique for computation time reduction is analysed. This technique enables an increased efficiency by the application of a larger time step in the analysis process.

A full-vehicle crash analysis process successfully compressed from weeks to a day is presented in [7]. Even so, the tests should be repeated many times in the case the results are not good enough from the beginning, which require many simulation days.

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In this paper, the possibility of coupling two different simulation environments for crash analysis is studied: coupling of a 1D model with a 3D model.

In the initial design stages, the concept model can be used by the designers through a co-simulation. This allows the analysis in shorter time of the impact behaviour of new design iterations for automotive structure elements, such as rails, bumper beams, poles etc.

The proposed concept model [3] is created in LMS Imagine.Lab AMESim and the 3D model in LMS Virtual.Lab Motion. The combination of these two software packages is introduced for crash analysis. In this co-simulation study, the impact behaviour of a simple beam is presented. The application of co-simulation for the beam application has led to large efficiency increase in terms of simulation time. This demonstrates the added value of the proposed co-simulation methodology. The reference results are generated by a 3D model analyzed in LSTC LS-Dyna. The co-simulation model is presented in the first part of the paper and the 1D concept model is presented in the second part. It will be shown that comparable results are obtained.

2. Co-simulation model

The crash behaviour of a beam is simulated with two different software products: 1D concept modelling was done in LMS Imagine.Lab AMESim, while 3D detailed dynamic modelling was done in LMS Virtual.Lab Motion. The idea is to reduce the computation time during a crash simulation for new design concepts. In order to reduce the computation time, the concept model is used to replace the part that the designer wants to change. For this purpose, a simplified component (the concept model), is integrated in a complex structure (Fig. 1).

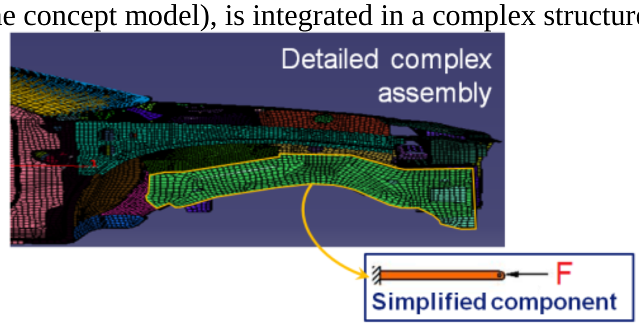

Fig. 1. Integration of a simplified component in a complex structure

The objective is to analyse the behaviour of the rail using the integrated simplified component in the full structure (Fig. 1). The analysis of the full model requires high computational time (390 s to simulate 0.02 s of an impact for a simple beam with 2510 shell elements). The computation time can be reduced using a simplified component for a part of the full model, modelled in LMS

Imagine.Lab AMESim as a concept model. Another reason to use a concept model is that changing the properties of the beam is simpler, using auxiliary files. Therefore, finding and fixing a wrong behaviour is less complex in a concept model than in a full model.

In this co-simulation a part of the simple beam is modelled as a flexible beam in LMS Virtual.Lab Motion and the other part is modelled with LMS Imagine.Lab AMESim.

The LMS Virtual.Lab Motion interface block from LMS Imagine.Lab AMESim allows the user to connect a 3D mechanism model with a 1D model (Fig. 2).

Motion model becomes a "sub-component" of LMS Imagine.Lab AMESim. This interface is useful when studying the interaction between complex mechanism models and simple concept systems.

The solvers of both subsystems are synchronously running and the transfers of displacement, velocity and force data of the control nodes from the common section of the beam are deployed at discrete communication time steps.

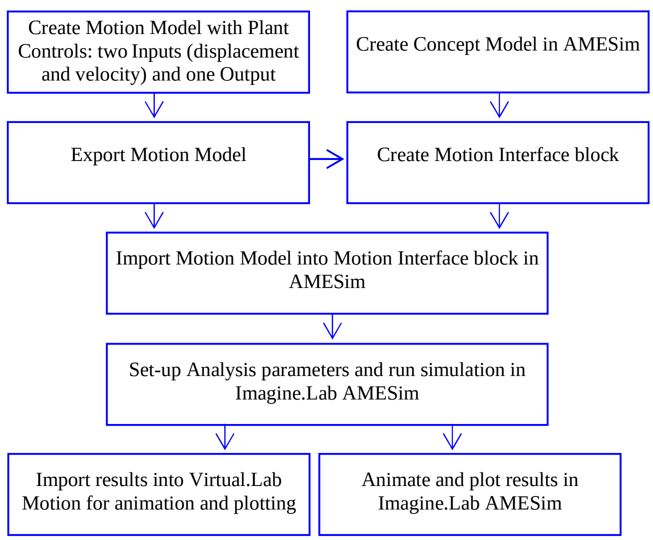

Fig. 2. Integration of the concept model through the import of LMS Virtual.Lab Motion Model into LMS Imagine.Lab AMESim Model

The full model in LSTC LS-Dyna is used to determine the boundary between the plastic and the elastic zones of the beam. The elastic zone is modelled with LMS Virtual.Lab Motion and the plastic one with LMS Imagine.Lab AMESim (Fig. 3).

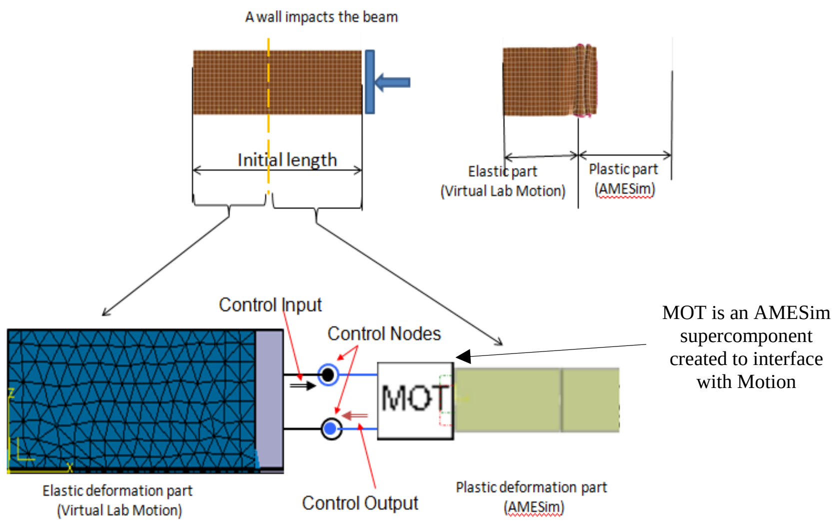

Fig. 3. Co-simulation modelling

LMS Virtual.Lab Motion can provide capabilities for modelling flexible bodies in complex mechanical systems. The LMS Imagine.Lab AMESim models are combined with other flexible or rigid bodies by joints and force elements to create a fidelity simulation. The flexible bodies experience linear elastic deformation in addition to nonlinear large displacement motion.

The co-simulation model used in this work for a simple beam is presented in Fig. 4. The simple beam is an assembly of two parts: “Motion Part” and “Amesim Part” through the two control nodes.

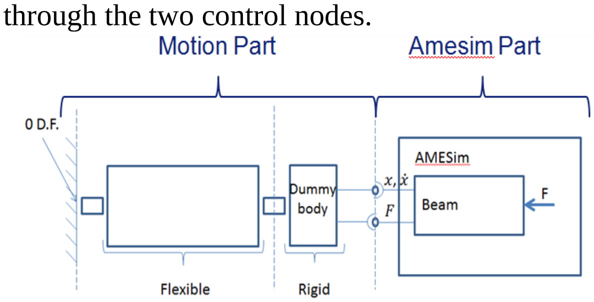

Fig. 4. Co-simulation model for a simple beam

In Fig. 4 the Motion Part (3D Part) is clamped on the left-hand side and connected with the Amesim Part (1D Part) in the right-hand side part. The displacement and velocity parameters transfer from one part of the Motion Part to the other one is possible by a model made of three bodies: a global fixed to ground body (with 0 D.F. = 0 degrees of freedom), a flexible body and a dummy rigid body. These three bodies are connected through two bracket joints: one on each side of the flexible body.

The 1D Part is connected in the left-hand side with the 3D Part and in the right-hand side part it is impacted by a wall, inducing a displacement and a velocity. With this values, the force is computed through LMS Imagine.Lab AMESim interface. In this way, the value of the force from the common section is sent to LMS Virtual.Lab Motion through a control node. With this value, in the 3D Part the displacement and velocity values are computed and sent back to 1D Part through the second control node. Those data transfers are applied to every communication time step.

3. LMS Imagine.Lab AMESim Concept Model

The model in LMS Imagine.Lab AMESim is using a new library created and presented in [3]. Its name is: "concept car body for crash".

The objectives [3] of developing a concept modelling method for crash were:

- take less time to perform the simulations with respect to the detailed FEM simulation;
- accurate compared to the detailed reference case;
- can be used in concept phase to assess design alternatives;

The "supercomponents" created (Fig. 5.) for the "concept car body for crash" library represent the behaviour of the elements of car structures such as beams, joints, wall or clamp.

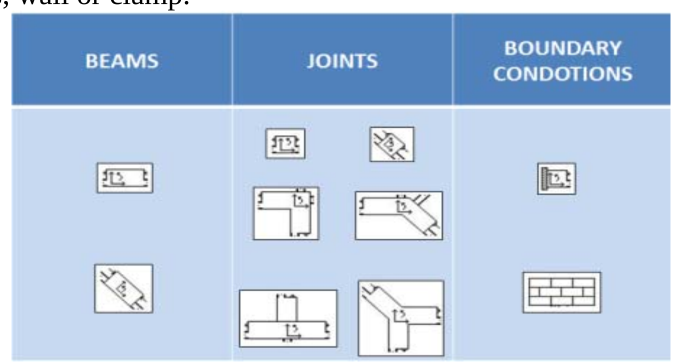

Fig. 5. "Supercomponents" of the new library: Concept car body crash

These elements are using rigid masses connected through prismatic and revolute joints (non-linear springs).

The concept model is clamped on the left-hand and it is composed by two pairs of a beam and a joint supercomponents. The rigid wall supercomponent impacting the tested beam is represented in the right-hand side of Fig. 6.

Fig. 6. The beam concept

The beam supercomponent's behaviour is established by three parts which define the relations between two rigid bodies: two revolute parts and a prismatic one (Fig. 7).

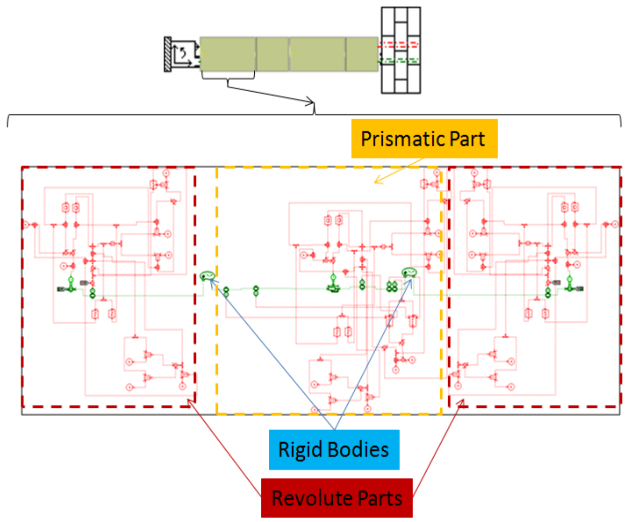

Fig. 7. The Beam supercomponent

Displacement sensors are used inside of the supercomponents to compute the right function for compression or tension and positive or negative rotation.

In revolute part, a driven revolute pair submodel is used, which computes explicitly x and y constraint forces, using linear spring stiffness and damping coefficient.

A detailed simulation of a reference beam is needed to obtain the behaviour (Reaction Force / Axial Displacement and Moment / Rotation) that has to be given to the revolute and prismatic parts. Defining a curve with the behaviour, the joints mimic the behaviour of the detailed model. The concept model development is presented in Fig. 8.

To distinguish the elastic behaviour from the plastic one, a control on the angle displacement is used. When the angle displacement gets greater than the limit value of the elastic angle, the reaction moment switches from elastic to plastic.

In order to obtain the reaction moment needed to compute the behaviour of the next rigid body of the concept beam, two tables are introduced for the plastic deformation: one for the positive and one for the negative moment. For reaction force, which depends on the axial displacement, there are introduced a stiffness for the elastic deformation and two tables for the plastic deformation: one for the compression and one for the tension.

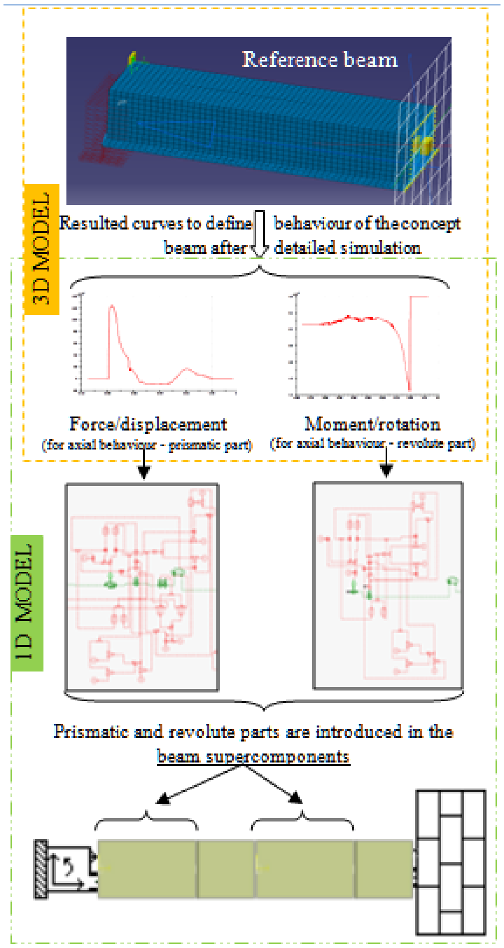

Fig. 8. Concept model development

When the displacement value for one of the rigid bodies gets greater than the limit of the elastic value, the reaction force switches from elastic to plastic behaviour.

During the co-simulation of the concept beam model the elastic part is replaced with the 3D model in LMS Virtual.Lab Motion through an ”Interface block”. The ”Interface block” is inserted into the supercomponent called ”MOT” (Fig. 9).

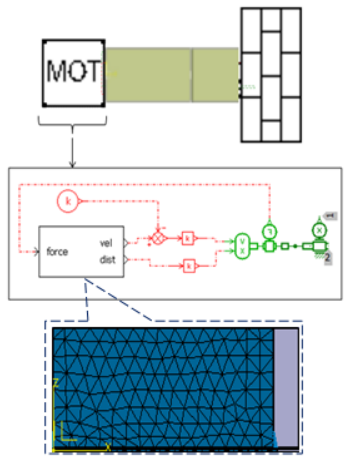

Fig. 9. Motion interface block inserted in "MOT" supercomponent

4. Results

The computation time to simulate 0.02 s of an impact in AMESim for the concept model was smaller than 10 seconds, while the full 3D model with LS-Dyna was computed in 390 seconds.

The thin-walled beam models had a rectangular section of 40x50 mm, length of 200 mm, and an empty fill. The material proprieties of LS-Dyna material Johnson-Cook Steel Material [4] were used for define the behaviour of the beam.

The impactor was a 100 kg rigid wall with dimensions of 200x200 mm, impacting the beam in longitudinal direction with 10 m/s.

Deformation and force values were compared for the following three cases:

1. detailed 3D LSTC LS-Dyna full model (reference model);
2. concept model for crash in LMS Imagine.Lab AMESim;
3. co-simulation model, that combines concept modelling for crash (see section 3) and multi-body modelling in LMS Virual.Lab Motion.

The deformations of the beam for all three cases are presented in Fig. 10. The deformation is measured through the nodes of the impact section displacement for LSTC LS-Dyna, and through the rigid body's displacement of the beam supercomponent from the impact section for concept model and co-simulation model.

It can be noticed that the deformations with respect to the reference model are smaller with 6,3% and respectively 1,6% for the concept model and the co-simulation model, respectively. In the case of modelling the elastic part of the beam with LMS Virtual.Lab Motion and the plastic part with LMS Imagine.Lab AMESim, the deformations are very similar.

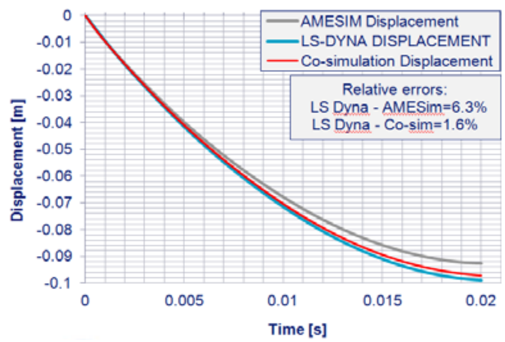

Fig. 10. Displacement in time for all three models: LSTC LS-Dyna, LMS Imagine.Lab AMESim and co-simulation

Force results were measured in the same sections as displacements. The force/time curves are presented in Fig. 11.

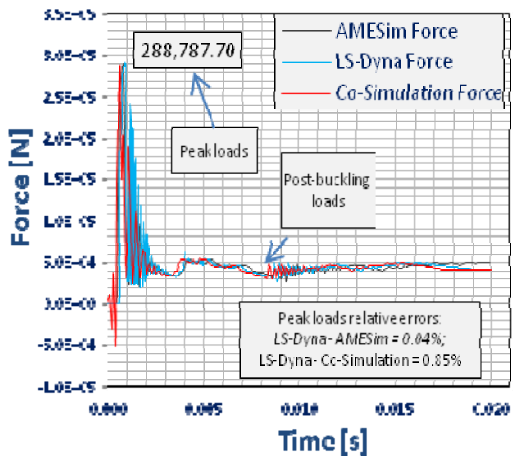

Fig. 11. Force in time for all three models: LSTC LS-Dyna, LMS Imagine.Lab AMESim and co-simulation

The relative errors of the peak loads are less than 1%: for the 1D model the peak load is 0,04% lower and for the co-simulated model it is 0,85% lower with respect to peak force observed on the reference model. The variations of the sectional force at the beginning of the impact in the co-simulation case are due the contact proprieties defined for the impact between the wall and the beam. The rest of the curves are very similar.

5. Conclusions

In this paper, the possibility of coupling two different simulation environments for crash analysis was studied: a 1D model with a 3D model. In the early design stage, the concept model can be used by the designers through a co-simulation to analyze in a shorter time the impact behaviour of new CAD solutions (geometry and material proprieties) for automotive structure elements, such as rails, bumper beams, poles etc. The concept model used was created in LMS Imagine.Lab AMESim and the 3D model in LMS Virtual.Lab Motion. In this article, just the impact behaviour for a simple beam using co-simulation is presented.

The reference results are generated by a 3D model analyzed in LSTC LS-Dyna. The co-simulation model is presented in section 2 of the paper with details on the 1D concept modelling presented in section 3.

Results are similar for all three compared modelling approaches. The simulation time of 0.02 seconds impact in LMS Imagine.Lab AMESim for the concept model was smaller than 10 seconds, while the 3D model representing the same physics with LSTC LS-Dyna was computed in 390 seconds. The co-simulation time of the same duration impact was smaller than 50 seconds.

The obtained results are just a first step for research of co-simulation with concept models for crash applications. Next step is to develop the co-simulation for a complex structure.

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