# SIMULATION OF A CMVSS 215 BUMPER PENDULUM TEST SERIES WITH LS-DYNA


AUTHORS:

Dr. Ing. Armin Huß, Ingenieurbüro Huß & Feickert, Germany

**Dipl. Ing. Heiko Beck, Ingenieurbüro Huß & Feickert, Germany**

CORRESPONDENCE:

Dipl. Ing. Heiko Beck
Ingenieurbüro Huß & Feickert
Im Kohlruß 1-3, 65835 Liederbach, Germany
Tel: +49-6196-6707123
Fax: +49-6196-6707128
h.beck@ihf-ffm.de


## ABSTRACT


In the course of an increasing automotive development for international markets many new loadcases have to be tested. The Canadian bumper pendulum test (CMVSS215) is one of these loadcases that form a special challenge for the simulation with LS-DYNA due to its sequential process. For this test four different bumper pendulums have to impact the vehicle, while with each new test the prior damages have to be taken over. Until now the simulation had to be interrupted after each impact due to the necessity of repositioning the vehicle to the initial state. This demands personal intervention of an engineer after each of the first three impacts costing useful time. In some cases complex scripts are run between the impacts to reposition the car, which has the advantage of being independent of human intervention, but still these are time-consuming methods. Much more practicable and feasible is a solution directly using the possibilities of LS-DYNA which neither cost any script processing time nor affords human intervention. At Ingenieurbüro Huß & Feickert a method was developed which links the motion of the impactors to the movement of the car so that each pendulum can start in the right initial position for the specific loadcase. Thus the test can be performed in one single run saving useful time for development.



KEYWORDS:

CMVSS215, bumper pendulum tests, LS-DYNA, sequential tests, relative barrier movement

## TEST SPECIFICATIONS

According to the regulations of the CMVSS215 the vehicle to be tested is impacted by pendulum-type testing devices twice in the center or outboard area of the bumper-system with a speed of 8 kph and a third time at the corner in an angle of 60 degrees to the longitudinal axis at a speed of 4.8 kph. The geometry of the pendulums is described in the CMVSS215. After the three pendulum impacts the vehicle itself is impacted again by a rigid wall with a speed of 8 kph. After all those impacts all lamps should operate, there must be no leakage at the fuel and exhaust system and the propulsion, suspension, braking and steering system should operate in a normal manner.

## SIMULATION POSSIBILITIES

There are four major modeling variations for the simulation of a CMVSS 215 pendulum test. They mainly differ in time intensity for preparation as well as in accuracy of the obtainable results. In the following these four options shall be described so they can be evaluated regarding their advantages and disadvantages in the further process of this paper.

### SINGLE LOADCASE SIMULATION

The simplest modeling option is the single loadcase simulation. Here each of the pendulum tests is independently simulated with a separate model. While the center pendulum test and the corner pendulum test are relatively independent from each other, the outboard center pendulum results depend on the results and structural pre-loading of the center pendulum. Due to the fact that the rigidwall pendulum causes the main deformations and is the last test to be performed, the results from four separate test simulations without the effects of the pre-loaded structure will most probably lack a distinct amount of accuracy.

### ENERGY-REDUCED PENDULUM

A second possibility is to fix the vehicle in space and to impact with reduced pendulum mass. This can either be done on the full model or on a component model in order to reduce model size. Constraining the model in all directions has the advantage that all barriers can be placed in one model and controlled via *BOUNDARY_PRESCRIBED_MOTION cards. To reach comparable results it is important to reduce the mass of the pendulums by half, respectively setting the mass of the rigidwall to full vehicle mass. This energy reduction is valid only for the mentioned boundary and initial conditions and has to be validated again for the case of changing conditions. The results however are only as good as the validation of this mass reduction coefficient is.

## COORDINATE TRANSFORMATION

The coordinate transformation model is a very subtle solution to this problem. It is based on the single loadcase simulation and demands a high grade of automation. Before the simulation three nodes and their initial coordinates need to be defined and the output of the pre-stressed and pre-strained model data has to be activated using the LS-DYNA keyword function *INTERFACE_SPRINGBACK_LSDYNA. After each loadcase an automated script has to execute the following process. The output structure with all pre-stressing and pre-straining serves as an input file. All nodal coordinates of the displaced and deformed vehicle structure are then transformed using the actual coordinates of the three preliminary defined nodes in relation to their initial positions. This preserves the deformations and places the model in the right position for the next particular loadcase. However this is the most time-consuming method, as it demands an elaborate scripting work and long script processing time. Furthermore the output and the mapping of stresses and strains after each loading just represents the current loading state but neglects the loading history of the parts. Especially for a consecutive low speed loadcase as the CMVSS 215 this factor is of a certain importance.

## SUCCESSIVE SIMULATION

The simulation approach developed at Ingenieurbüro Huß & Feickert combines the advantages of the coordinate transformation with the possibilities of the halved component model. By using the *BOUNDARY_PRESCRIBED_MOTION_RIGID _LOCAL keyword it is possible to achieve an energy-neutral entrainment of the barriers related to the car. In Figure 1 the resulting velocity plot is displayed.

The inactive pendulums and the barrier are connected to the car via constraining their relative motion between a node on each rigid barrier and a node on the vehicle during the impact of the active barrier. For the right starting time of all four barriers during the simulation a system of birth and death times as well as system damping is necessary, showing in figure 1. Thus the pendulums and the barrier are activated one after another. The biggest advantage of this model lies in the independence from user interference.

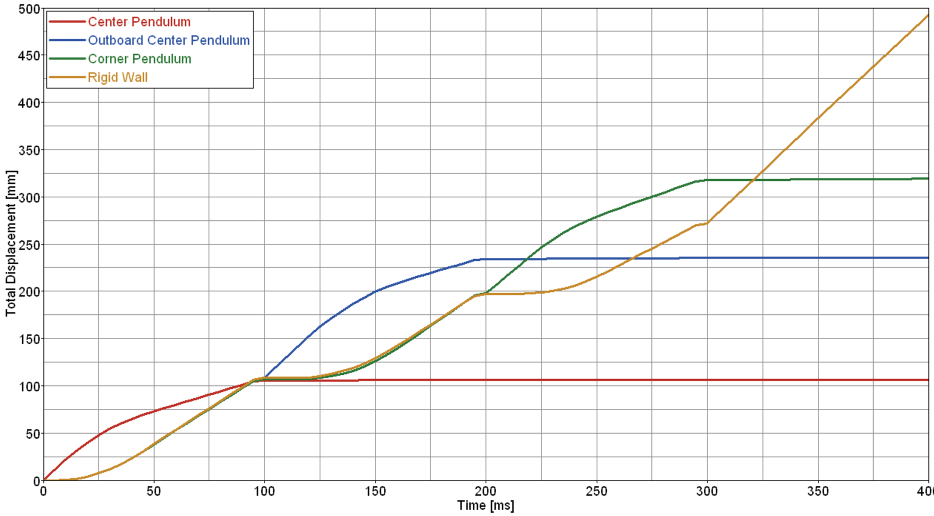


Figure 1: Resulting velocities

## COMPARISON OF SIMULATION RESULTS

The comparison only includes the model with the energy reduced pendulum and the successive simulation. As the single loadcase simulation leads to data that is not accurate enough, the transformation model is too complicated and costly for everyday development use. As we will see the two remaining possibilities have the potential to complement each other.

# TESTING MODEL

The testing model consists of a rigid bullet car frame weighing 1400 kg and a simplified bumper – crashbox system comparable to most modern cars' systems as displayed in Figure 2.

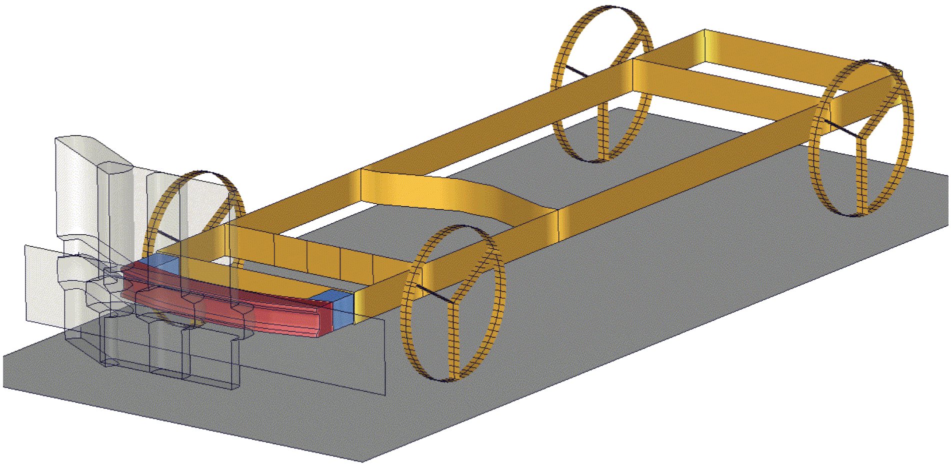

Figure 2: bullet car with simplified bumper system

For the simulation of the energy reduced component model, the weight of center, outboard center and corner pendulum is adjusted to 700 kg ($0{,}5 \cdot m_{vehicle}$). The weight of the rigid wall barrier is 1400 kg. The rigid bullet car frame is constrained in all DOF.

The three pendulum barriers in the successive simulation are adjusted to the equivalent vehicle weight 1400 kg. The rigid wall is loaded with four mass elements each weighing 25.000 kg resembling an infinite weight of the wall.

# SIMULATION RESULTS

Figure 3 shows the maximum plastic strains in the test bumper system at the end of the test after all four pendulum impacts. As expected there is nearly no difference betweeen the result of the successive simulation and the obtained data from the mass reduced pendulum impacts. The fixed vehicle shows a very close resemblance to the full successive simulation for the given boundary conditions.

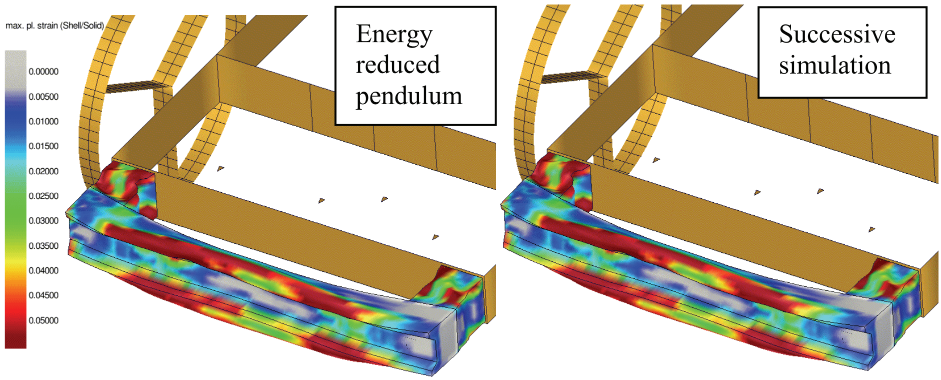


Figure 3: Max. plastic strains in simulation model

The higher deformation in the right crashbox results from the corner pendulum and the main deformation in the beam are caused by the rigid wall. The results show that for the described masses and velocities the reduced energy pendulum simulation is sufficient in its predications. However for any change in boundary and/or initial conditions a new approximated mass reduction has to be validated.

# SUMMARY AND CONCLUSION

| Loadcase | Preparation time | Processing time | Result accuracy | User interaction |
|---|---|---|---|---|
| Single loadcase sim. | o | - | - | -- |
| Energy reduced pendulum | + | + | + | ++ |
| Coordinate transformation | - | -- | + | ++ |
| Successive simulation | + | + | ++ | ++ |

Figure 4: Summarizing matrix of loadcases

As a conclusion both simulated models are capable for everyday development use. While the mass reduced component model saves time and resources its results show the same reliability as the results obtained from the successive model. However the constraining of the bullet car might lead to a clearly higher loading of the bumper structure for different boundary conditions such as barrier velocities. The single loadcase simulation is clearly the worst way to simulate the loading according to CMVSS215. The energy reduced pendulum method is strongly depending on the validation for the specific loadcase. Changing boundary conditions needs a new validation with a certain effort. The coordinate transformation method needs scripting or human intervention in order to transform the impacted vehicle to the original position and map the results of the previous loading on the transformed vehicle. Moreover effects which result from the loading history are neglected. The most accurate method for simulating a multi-impact loading such as CMVSS215 is the here discussed successive simulation method.

# REFERENCES

1. Hallquist, J. O., LS-DYNA. Keyword User's Manual. Version 971, Livermore Software Technology Corporation, Livermore, 2007.

2. Canada Motor Vehicle Safety Standard No. 215, CMVSS 215: Bumpers – Passenger Cars