Paper 272

Proceedings of the Eleventh International Conference
on Computational Structures Technology,
B.H.V. Topping, (Editor),
Civil-Comp Press, Stirlingshire, Scotland

Development of a Vehicle Suspension Finite Element Model for Kerb Impact Simulations

W.Z. Golinski
Safety Development
MIRA Ltd, Nuneaton, United Kingdom

Abstract

Road restraints are tested in the UK to the specifications defined in BS EN 12767 and BS EN 1317 whereas BSI PAS68 defines the requirements for impact testing of security systems. However finite element (FE) modelling can be utilised to reduce both the product development cost and the development time. In some cases the road restraint or security system may be positioned behind a kerb, thus modifying the impact attitude of the vehicle. This paper demonstrates the development of a suspension model for an existing purpose built 2.5t vehicle FE model and validation in a kerb impact scenario.

Keywords: CAE, FE, LS-Dyna, simulation, kerb, impact, BSI PAS68, BS EN 12767, BS EN 1317.

1 Introduction

Road-side vehicle restraint system test standards are defined in the UK by BS EN 12767 and BS EN 1317-2. BSI PAS68 is the specification for the impact testing of vehicle security barriers. MIRA conducts physical crash testing to all of these standards and during the design process of a product, can employ Finite Element (FE) modelling to reduce both the development cost and the development time. Up until now, public domain vehicle models have been widely used for this purpose. Unfortunately, public domain models lack in the detail and accuracy required in order to confidently predict a structure's performance. Therefore, MIRA has developed FE models of all the vehicles cited in these standards to support FE simulation of road restraints and security systems. In some cases the road restraint or security system may be positioned behind a kerb, thus modifying the impact attitude of the vehicle. This paper demonstrates FE model validation in this kerb impact scenario.

2 MIRA vehicle models

Road restraints are tested in the UK to the specifications defined in BS EN 12767 and BS EN 1317 whereas BSI PAS68 defines the requirements for impact testing of security systems. The standards define how to carry out physical tests to approve the product for use. However, the number of physical tests may be very expensive if a number of iterations are required to develop the design. To shorten the design process and reduce the number of crash tests required to verify the design, FE modelling is often utilised.

The standards specify the type of vehicles to be used for testing the product. Reliable vehicle models are required to be able to perform the simulations. Up until now, public domain models were widely used for that purpose. Unfortunately, due to the nature of public domain models their quality and accuracy is sometimes questionable. Therefore, MIRA chose to develop FE models of the whole suite of vehicle models required by the standards to support FE simulation of road restraints and security systems (Figure 1).

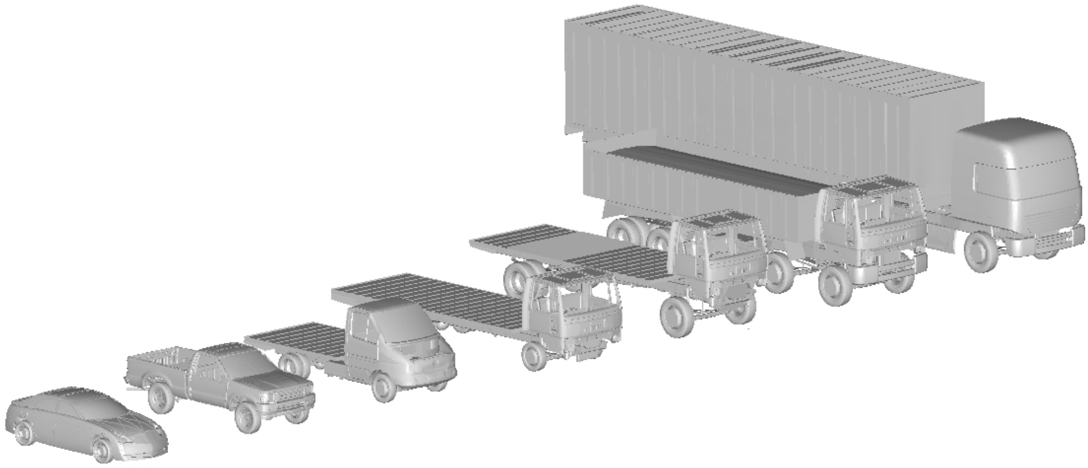

Figure 1: MIRA Ltd Vehicle FE Models.

The models were purposely built for road restraint / vehicle security barrier system simulations. Dimensional data and weights were taken from tear downs performed at MIRA, with the material data taken from MIRA's extensive library of material models. The vehicle models were correlated to rigid bollard and flat rigid wall tests to improve their accuracy. To date, the models have also been used successfully in the development of a number of customer products ranging from bollards to road barriers.

3 Kerb

Products such as road barrier parapets or bollards can be installed behind a kerb (Figure 2 and Figure 3). In such circumstances, the simulation will require inclusion of the kerb, as the vehicle interaction with the kerb may affect the impact with the product. Unfortunately, even correlated crash vehicle models will not correctly represent the kinematics of the vehicle while mounting the kerb. To address this issue, it was decided to correlate the vehicle model against a range of kerb impact tests. In the first instance, it was decided to concentrate effort on correlating the 2.5t pickup truck model to kerb impacts.

Figure 2: Road barrier behind a kerb

Figure 3: Bollard behind a kerb

4 Kerb impact tests

Kerb impact tests were performed at the MIRA High Energy Facility (HEF). A Toyota Hi-Lux was selected as a representative vehicle for the 2.5t vehicle model. Based on pre simulations and data from previous road restraint tests involving kerbs, it was decided to perform the following 2 tests to gain data for correlation purposes:

- Kerb height 250mm, impact angle 45deg, Velocity 20mph (~32km/h)
- Kerb height 250mm, impact angle 45deg, Velocity 50mph (~80km/h)

An example test set up is shown in Figure 4.

Figure 4: Kerb Impact test setup

5 Model

The 2.5t pickup truck FE model previously correlated by MIRA to bollard and flat rigid wall tests was used.

During the correlation the exact locations of all the joints in the front suspension including steering arms were measured with a FaroArm and the model updated accordingly. The exact joint locations were refined and the suspension and steering arms were modelled with beam elements to aid the correlation (Figure 5). The rear suspension was also modified to better represent the test behaviour.

All wheels were modified to include better representation of the tyres and the correct inflation pressure. The tyre's tread and side walls were modelled as elastic shell elements with 20mm and 8mm thickness respectively. Tyre reinforcements were modelled as elastic beam elements (Figure 6). Material properties for the tread, side walls and reinforcements were taken from literature [1,2]. The correct tyre pressure was achieved by modifying the input for an airbag model included in each tyre.

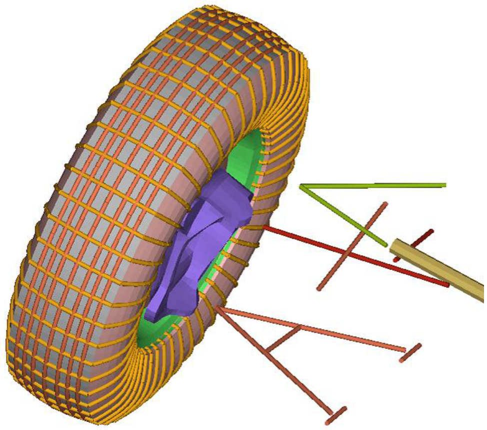

Figure 5: Front suspension

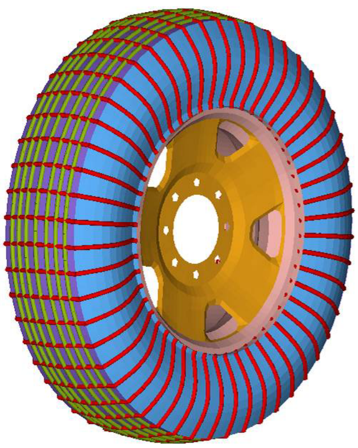

Figure 6: Tyre model

During the task, no structural changes were made to the chassis or the body, therefore the model response in bollard and flat rigid wall impacts remained unaffected. Vehicle model updates in order to achieve correlation were made to the suspension dampers, springs and also joint stiffness. The friction coefficient between the tyre and the ground/kerb was carefully modelled to include the static and dynamic values as well as the decay coefficient. The steering system inertia was also represented in order that the caster angle would restore the wheels to the correct attitude within a reasonable time-frame, thereby ensuring that the vehicle direction after the major kerb contact event was correctly represented. The final vehicle model remains visually much as it started, but significant updates to the front suspension have increased the confidence in the final result (Figure 7).

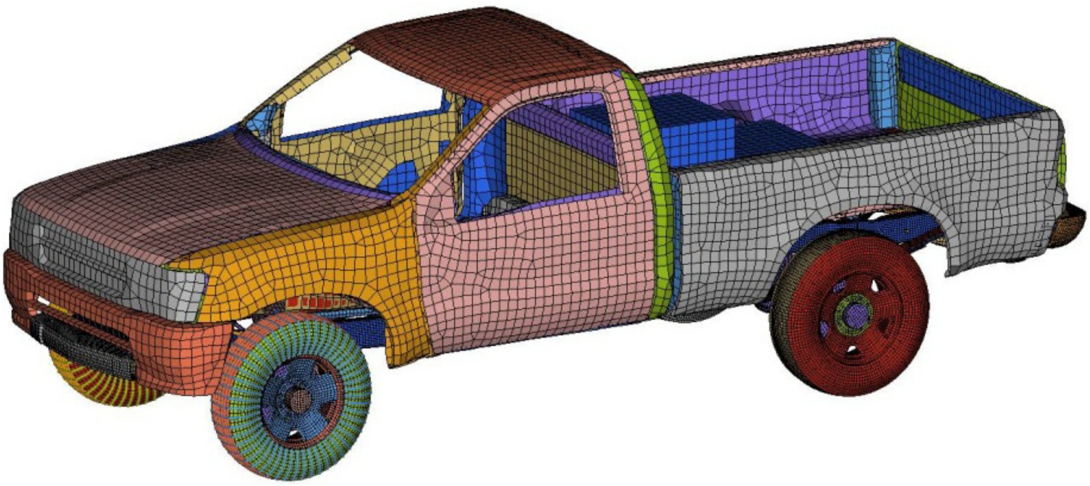

Figure 7: Correlated 2.5t pickup truck model

To verify the kinematics of the vehicle model mounting the kerb, the global rotations of the model (roll, pitch and yaw) were compared against gyroscopic data taken from the test vehicle.

6 Results

At 20mph the 2.5t pickup truck model predicts correctly the overall kinematics of the vehicle seen in the test (Figure 8). Some discrepancies to the magnitude remain, however it has to be remembered that the product will be placed close to a kerb and therefore only the initial mounting of the kerb is of interest.

Regarding the 50mph test, again the model continues to predict the main events well but the time and magnitude differences are more pronounced than in the 20mph test (Figure 9).

For comparison purposes the original crash model response is included in Figure 8 and Figure 9 showing the improvements achieved during the projects.

7 Summary

MIRA's 2.5t pickup truck model represents well the overall kinematics of the kerb impact. As a result of this project, the kinematics of the model have been improved significantly compared with the original crash model response. During the correlation only the suspension and wheels, in particular the tyres, were modified therefore the crash capability of the model was not affected.

Although some discrepancies remain between the model and the tests, it is believed that the current model can be successfully used to develop / assess kerb profiles or road restraint/ security systems installed behind a kerb.

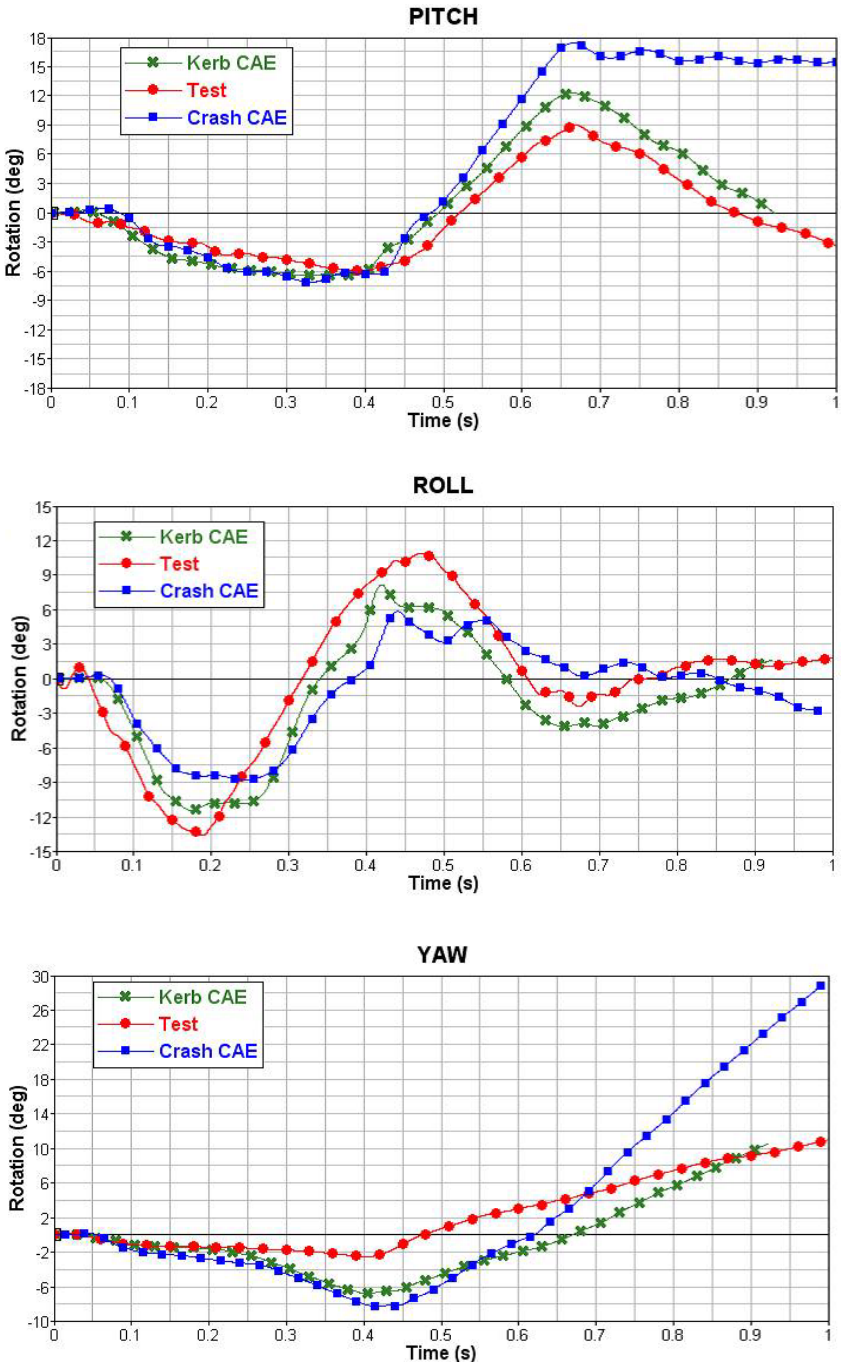

Figure 8: 20mph Comparison

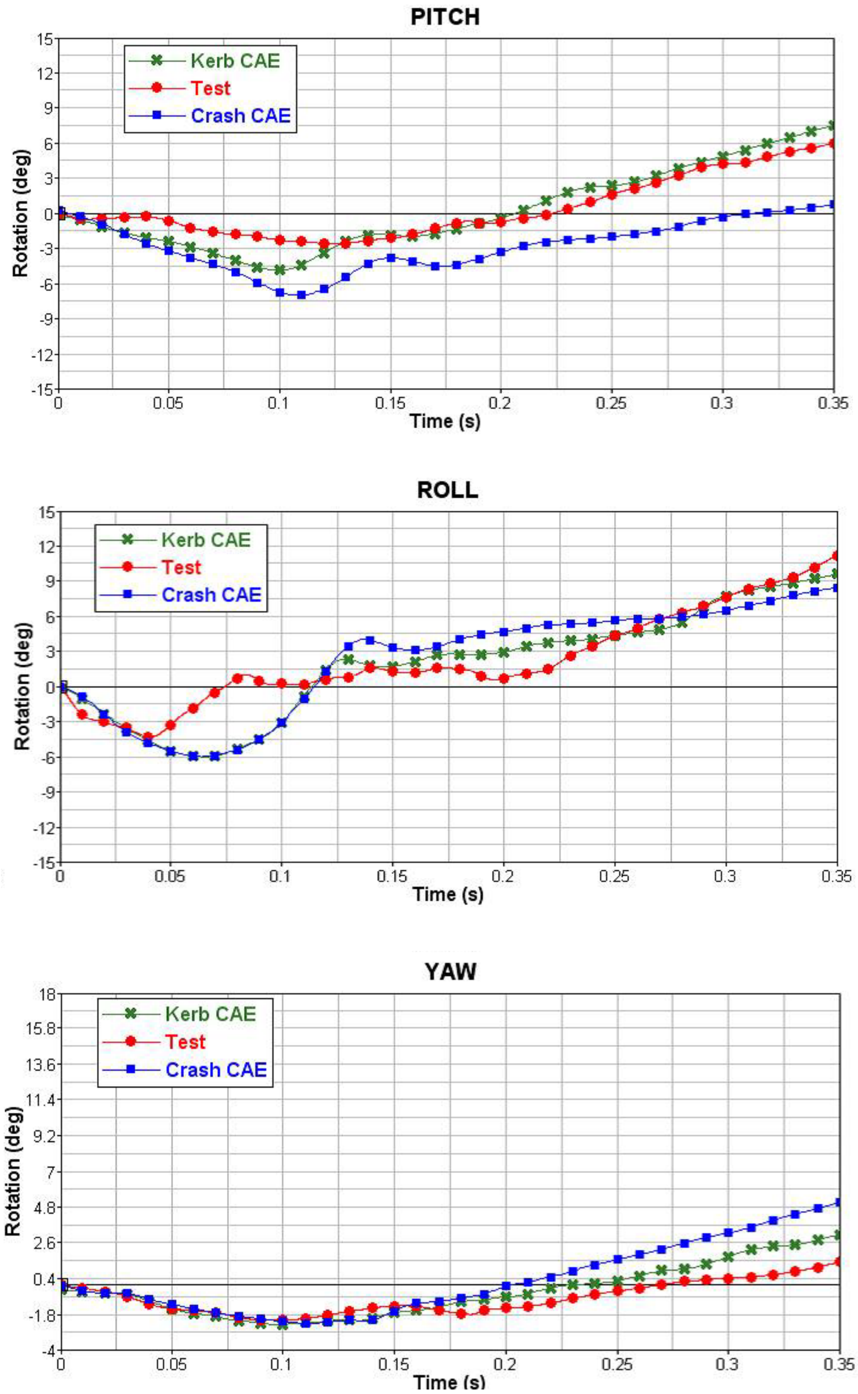

Figure 9: 50mph Comparison

References

[1] F. Orengo, M.H. Ray, C.A. Plaxico, “Modeling Tire Blow-Out in Roadside Hardware Simulations Using LS-Dyna”, IMECE’03, Washington, US, 2003

[2] J.D. Reid, D.A. Boesch, R.W. Bielenberg, “Detailed Tire Modeling for Crash Applications”, ICrash 2006, Athens, Greece, 2006