

Motorcycle-wall crash: simulation and validation

S. Mukherjee, A. Chawla, D. Mohan, M. Singh,
Transportation Research & Injury Prevention Programme
Indian Institute of Technology Delhi
Hauz Khas, New Delhi 110016, INDIA

M. Sakurai, T. Nakatani
Japan Automobile Research Institute, Tsukuba, JAPAN

Abstract

This paper describes the development of the motorcycle (MC) model and validation using a MC – wall Full Scale Test (FST). Individual components like the seat, tires and shock absorbers were tested as per procedures given in ISO13232 [5] and their FE models were validated against the component test data. A crash test of the motorcycle with a rigid wall had been conducted. There is a reasonable match between wall forces in the FST and simulation.

1 Introduction

A wall crash is a standard procedure to evaluate powered transportation devices. The ISO 13232 [5] recommends seven impact configurations with cars to evaluate rider safety. The wall test is important in validating the motorcycle model independent of the car model prior to carrying out motorcycle-car impact simulations.

The methodology of development of the model of the motorcycle has been discussed in details in references [1-4, 6]. An overview of the component models has been presented in section 2. Section 3 of this paper presents an overview of the full model of the motorcycle created by assembling the components mentioned in section 2. The input boundary conditions and interaction set used for wall test simulation has been discussed. Section 3 of this paper compares the overall kinematics of the motorcycle during the wall-crash with simulation results through 10 milliseconds snapshots. In section 4 the wall forces and accelerations of points on the motorcycle predicted by simulation are compared with the recorded wall forces. We conclude that a motorcycle model with sufficient fidelity to predict the forces and kinematics in such crash situation has been developed.

2. Component Models

The motorcycle model developed through the work reported here is designed to simulate more than head on collisions. Grazing impacts and impacts where the car may impact the side of the motorcycle are also targeted. During these conditions, the motion of the dummy is to be predicted accurately. Consequently, the model developed here goes beyond the detail needed to accurately reproduce the wall crash FST only. For completeness, we will also discuss some components that do not have a direct bearing on the outcome of the wall test.

The procedure adapted was to determine the geometry of each component by the use of a Co-ordinate Measuring Machine (CMM). Following which the material properties of the components were determined. The ISO 13232 recommends some component tests to determine static and dynamic behaviour of individual components. These tests were carried out and finite element (FE) component models were verified against the results of these tests. The ISO tests seem to be tuned more towards development of rigid body models. Whenever we have felt the need, we have supplemented the ISO tests by additional tests to facilitate model development and verification.

2.1 Tyre

The tyre model uses shell elements and the tread, sidewall, rim and the spokes were modelled as separate material. Static pressure of 200Kpa was defined in the inner tread and sidewall surfaces of tires. The tyre model is shown in Figure 2.1. A static compression test was performed to partially validate the tyre model



Fig. 2.1: Model of the tyre

2.2 Head light and visor

The head light assembly was modelled by first making a surface model based on the data digitised by the CMM and then making a shell mesh. The model includes the beam structure that supports the shell and attaches to the MC frame. The side mirror was also included in the model shown in figure 2.2.

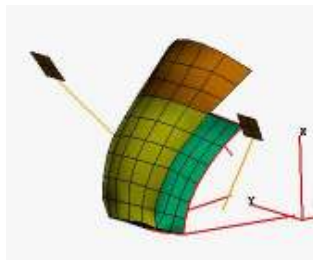


Fig. 2.2: Model of the headlight and the glass

2.3 Fender

The CMM data of the fender was used to create the surface model. It was modeled using shell elements and connected to bike by merging nodes on the frame of the motorcycle with the shell structure. Appropriate material properties were defined. (Fig 2.3)

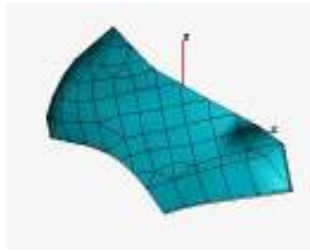


Fig 2.3 The fairing / fender of the MC.

2.4 Fuel tank

The model of the fuel tank is shown in figure 2.4. The geometry of the fuel tank is of significance in determining the trajectory of the dummy post impact though it does not play a significant role in the wall test.

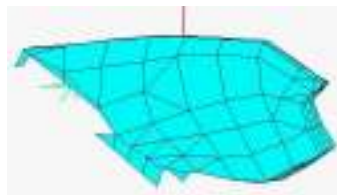


Fig 2.4: The model of the MC fuel tank

2.5 Seat and frame

The model of the seat is made using solid elements on top to represent the foam supported by a shell element layer at the bottom to represent the backing plate. It is shown in figure 2.5 assembled on the frame. The model of the seat frame assembly was verified by carrying out a static compression test. The figure also shows the semi-cylindrical impactor used in simulating the test.

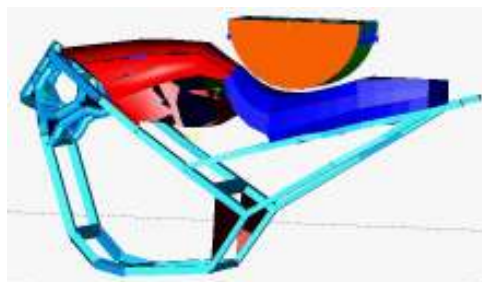


Fig.2.5 Model of the seat and frame

In addition to the above major components, the bike engine, silencer, cover below seat and engine casing were added. Section property and material data were incorporated for different components. A complete kinematic model of the front and rear suspension linkages with correct bending stiffness of members and spring-damper characteristics was included in the model. The assembled model is shown in Fig 2.6.

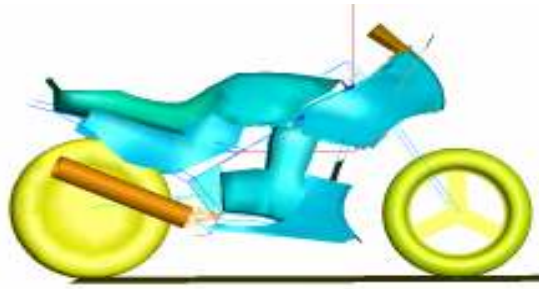


Fig. 2.6: The motorcycle model without Leg Protector

3 Procedure for wall crash simulation

The Full Scale Test (FST) was conducted at the Japan Automobile Research Institute (JARI) using a Kawasaki GPZ 1989 model. The impact velocity of the motorcycle was 47.6 km/h. Forces on the wall, accelerations of the CG and of a point under the seat were recorded.

3.1 Simulation Environment of Motorcycle Wall Crash

Boundary condition and the material properties were defined in PAMCRASH. The rigid wall option was used to define the stationary rigid wall of infinite mass. The mass, location of CG and the moment of inertia of the motorcycle was adjusted to the available data by inserting nodal masses at selective locations. Coefficient of friction between the front tire and the rigid wall was set to 0.6. The material set of motorcycle components was given an initial velocity of 47.6 Km/hr and a gravity field was defined for them. The model incorporates rotation of the tires using joints defined between the tires and the respective axles. In addition to forward velocity, tires were given an initial angular velocity corresponding to the initial linear velocity of the motorcycle and tire radius.

The front suspensions have been modelled with two spring damper elements on either side of the tyre. The rear suspension mechanism was modelled using one spring damper element and six rigid links connected by joints to model the linkages. The road surface was modelled by using rigid shell elements. A surface-surface contact interface was defined between the tyre and the road. Surface-node interactions have been defined between the tyre, radiator, engine block, and engine block cover that are initially not in contact but interact due to the deformation after impact.

3.2 Pictorial comparison of Simulation and FST

Figure 3.1 presents a comparison of kinematics of the MC in the simulation with that in the experiment through snapshots taken at 20 milliseconds intervals.



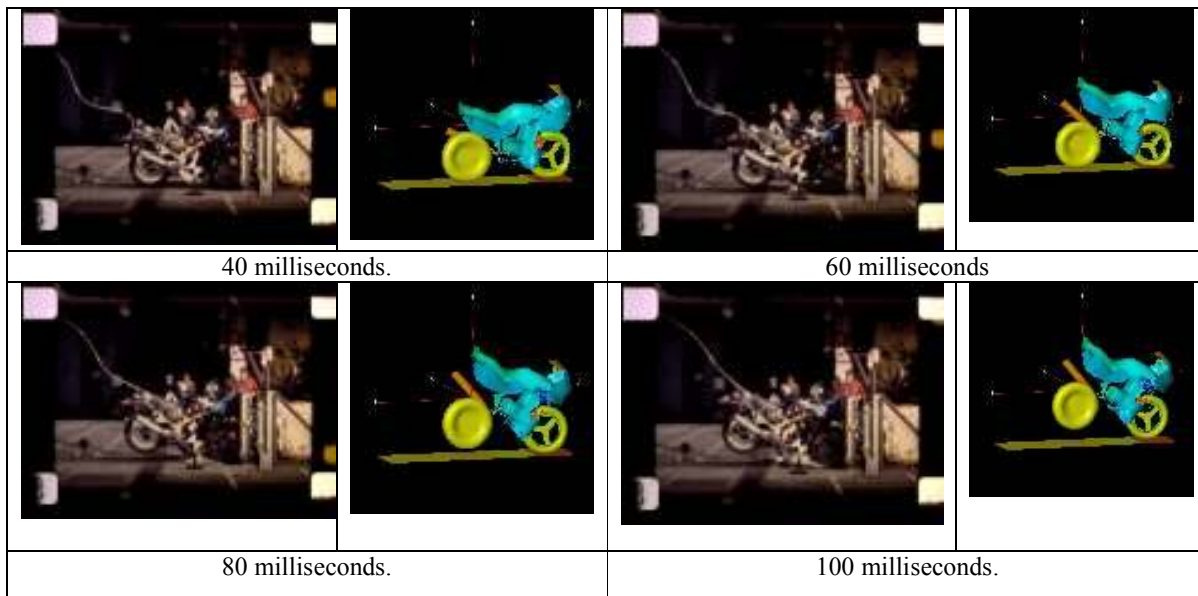


Fig 3.1: Kinematics of the MC – wall simulation and the FST at every 20 milliseconds.

From this figure it can be seen that the kinematics of the test match very closely with that of the simulation. The timing at which the front fork starts to bend, the time when the rear wheel lifts off from the ground as well as the inclination of the MC at all points of time matches very well between the simulation and the experiment.

4 Quantitative validation of impact model

The impact lasts for about 100 milliseconds following which the motorcycle and wall separate. This is seen more clearly in figure 4.1 which overlays the wall forces and simulated wall forces for the first 100 milliseconds of impact. Good correspondence is seen between the time history of force obtained in simulation and in the FST. This is very important as the kinematics as well as the wall forces, we feel, are important factors in the car – MC impacts.

4.1 Force History

The wall force curve has two prominent humps with each hump being associated with sub-peaks. The benefit of carrying out the simulation is in being able to associate the force history to events during the impact. The first hump, which lasts for about 12 milliseconds is due to the initial impact on the front tire. When the tire starts rebounding from the wall the bulk of the motorcycle is still moving forward. This results in bending of the front suspension. Thus, after 12 milliseconds of the tire touching the wall the front suspension starts bending. This relieves the load on the wall. The front suspension continues to compress for first 14 milliseconds of tire touching the wall following which the front suspension bottoms out.

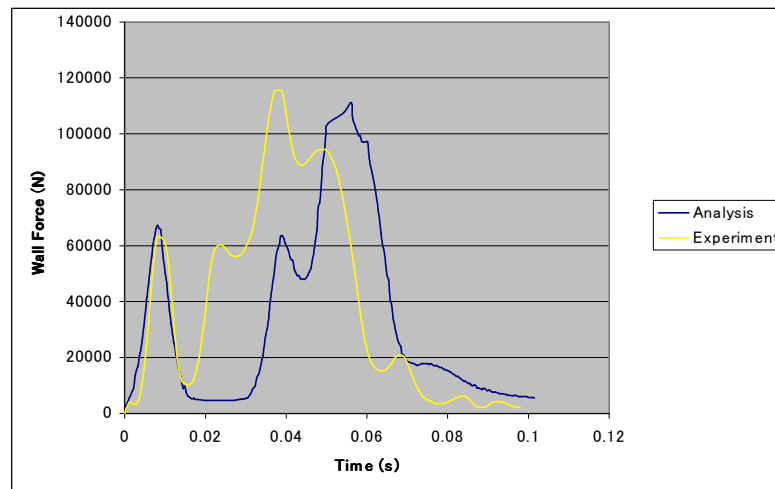


Fig 4.1 Wall forces for the FST and the simulation

The radiator impacts the front tyre and starts compressing the front tyre against the wall 20 milliseconds after the first impact. Following this event, the whole mass of the motorcycle bears down on the tyre through the radiator. This causes the wall forces to rise for the second time. In the simulation this event happens about 20 milliseconds late. We are not yet able to account for this delay and are looking into it. Eight milliseconds after engine and the radiator make contact the front light comes in contact with the wall. The small peak to the left of the second hump is attributed to this. The slump in this zone is due to the material failure of the front light. The peak of the wall forces is obtained after 28 milliseconds, following which the motorcycle starts rebounding. During the rebound the motorcycle frame moves with the front tyre and radiator staying in contact. After 60 milliseconds of the front tyre touching the wall the rear tyre starts to lose contact with the ground. This is reflected in the wall force curve as the right small peak on the second hump.

The events mentioned above can be seen clearly through the simulation as hosts of other time history, other than the wall forces are available in the .DSY and .THP files. Since the wall forces conform well, we have reason to have confidence in the sequence of events seen in simulation during the impact do actually occur.

4.2 Acceleration History

The simulated accelerations of the point near the CG of the motorcycle were also compared with the experimental values (Fig 4.2). The simulation peaks are about double the magnitude of the experimental magnitudes. Of significance is that the accelerations show rapid reversals in the simulation but appear as a hump with fluctuations in the experimental data. The discrepancy in the magnitudes could be due to the structural vibrations in the model. The engine has been modelled as rigidly mounted on the frame. The engine is actually mounted on pins supported on elastomeric grommets specifically to reduce vibrations. To get the exact match of the acceleration curves the energy loss elements, which introduce additional damping in the structure, need to be included. We thus conclude that the current model is not well validated for predicting structural vibrations.

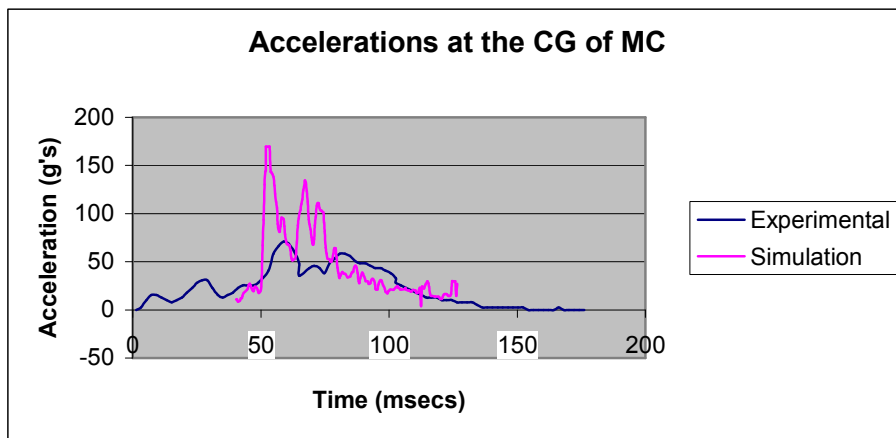


Fig. 4.2 Accelerations at the CG of the MC in the FST and in the simulation.

5. Conclusion

Development of a FE model for a motorcycle has been described. Simulation of wall crash using the model has been presented. The results of the simulation have been evaluated against a full scale test carried out at JARI. The kinematics of the motorcycle is reproduced well. The simulation predicts the wall forces accurately. Insight is obtained into the mechanics of the impact. The model at this juncture, does not predict the accelerations at the CG or other points on the frame accurately. The model has been developed to conduct simulations of car-motorcycle impacts. For that purpose, we consider the model to be well validated.

References:

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