

Development of a Test Method to Evaluate both Stiffness and Interaction of Compatibility Performance

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ABSTRACT

Compatibility is important in order to secure mutual protection in collisions between large and small vehicles. To enhance compatibility, good structural interaction and stiffness matching are important elements. This paper proposes a test method that uses a moving deformable barrier (MDB) to evaluate compatibility performance that includes not only structural interaction but also stiffness matching.

This new deformable barrier is aimed at the simulation of offset Vehicle-to-Vehicle collisions with compact vehicles. This simulation is based on real world crash research, and takes into account three separate load interactions between the impacting vehicles. These areas of interaction include the impacting vehicle's power unit to the opposing vehicle's wheel, the impacting vehicle's lower rail to the opposing vehicle's lower rail, and the impacting vehicle's wheel to the opposing vehicle's power unit. In general, the largest disparity in stiffness can be found between the power unit and the wheel, with the power unit being stiffer than the wheel. These factors were studied with both impacting vehicles being modeled as a combination of three springs. As a result, a more accurate estimate of vehicle loading in a vehicle-to-vehicle collision is obtained by using three individual load paths across the width of the vehicle as opposed to the uniform stiffness simulated in a conventional barrier.

In order to simulate the front body stiffness of a typical compact vehicle, a newly developed deformable barrier is proposed. The barrier has several divided honeycomb layers of varying stiffness both horizontally and longitudinally. The results using the new MDB were closer to those obtained in the Vehicle-to-Vehicle testing, as compared to those of the conventional barrier test.

Finally, the proposed MDB shows promise for the evaluation of compatibility performance by more accurately simulating Vehicle-to-Vehicle collisions with compact vehicles.

INTRODUCTION

In the real world there are a variety of vehicles of many varying weights in use, and in general the most common collisions are those between vehicles of different weights. As a result, a number of studies are being conducted on these types of collisions.

What is important in a collision between vehicles of differing weights is the reduction of aggressiveness, or in other words, partner protection performance. It should be noted this does not imply the improvement of the protection performance of the smaller vehicle only.

The factors which determine this partner protection performance include the weight of the large vehicle, the interaction performance of the structural components, and the stiffness characteristics of the front of the vehicle⁽¹⁾.

A number of studies are being conducted on the evaluation of partner protection performance such as the FWDB (full width deformable barrier) test method⁽²⁾ and the PDB (progressive deformable barrier) test method⁽³⁾.

The FWDB test method focuses on the evaluation of the interaction performance, while the PDB test method evaluates the interaction and stiffness.

In this study, for the purpose of evaluating the aggressiveness of a large vehicle, a Deformable Barrier (hereinafter termed as "DB") that simulates the characteristics of a partner vehicle in a collision will be developed. Through the application of an Offset MDB (moving deformable barrier)⁽⁴⁾⁽⁵⁾⁽⁶⁾ test and the new DB face, a test method will be proposed which is capable of simultaneously evaluating the factors of partner protection performance, namely, weight, structure interaction, and stiffness.

INVESTIGATION OF ACTUAL CRASHES AND THE SETTING OF EVALUATION PARAMETERS

First, in order to establish the evaluation parameters, we conducted an investigation of Vehicle-to-Vehicle (hereinafter referred to as “V-to-V”) crashes in the United States.

DATA SOURCES

The following sources of data were used in the crash investigation.

NASS-CDS1998-2005 and FARS1998-2005 data base for 1998-2006 model year vehicles

- Frontal Collision without roll-over
- Vehicle-to-vehicle
- Fatality
- Seat-belt buckled

OVERLAP RATE DISTRIBUTION (NASS-CDS DATA)

In order to set the overlap rate conditions for the test, an investigation was conducted of the real world collision overlap rate using the NASS-CDS data. The overlap rate was calculated by dividing the value of “Direct Damage Width” by that of “Maximum Width.” (Fig. 1)

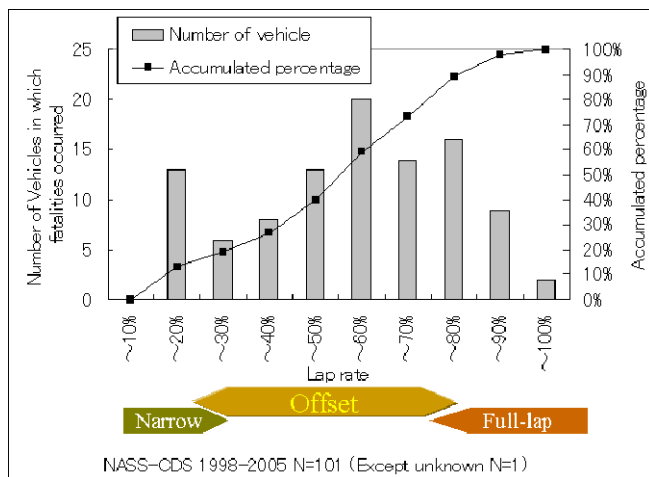


Fig. 1: Overlap Rate Distribution of V-to-V Collisions

Frontal collision cases can be generally categorized into 3 types: full-lap collision, where two lower rails come in contact with the opposing vehicle, offset collision, in which only one lower rail comes into contact, and narrow lap collision, where the lower rails do not contact the opposing vehicle. Taking into consideration the position of the lower rails in the most commonly used vehicles, the overlap rate of 25% to 75% is categorized as an offset collision and the range over 75% is designated as a full-lap collision. The range lower than 25% is categorized as a narrow lap collision.

65% of the V-to-V collisions studied were categorized as offset collisions. The narrow and full lap collisions accounted for 16% and 19% of the cases respectively. The data showed the offset case to be the most prevalent with an average V-to-V overlap of 53%.

CLOSING SPEED DISTRIBUTION (NASS-CDS DATA)

In order to set the test speed, an investigation was conducted into the closing speeds of the colliding vehicles using the data from NASS-CDS. The closing speed was calculated by adding the “delta V” values of the two vehicles. (Fig. 2)

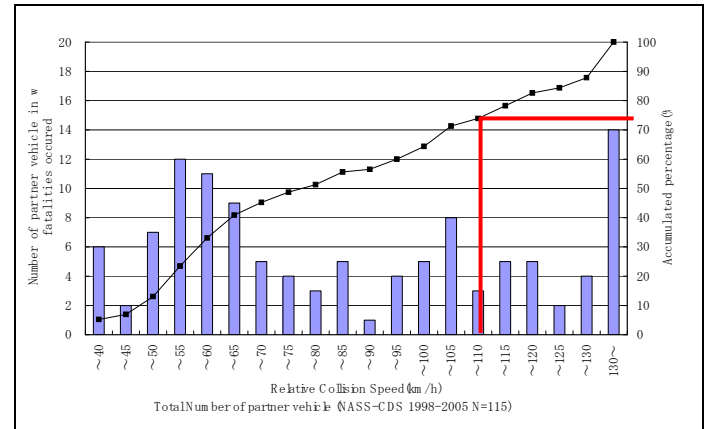


Fig. 2: Distribution of Closing Speed in V-to-V Collisions

According to the distribution chart, approximately 75% of the total crashes sampled have a closing speed of less than 110km/h.

DISTRIBUTION OF TARGET VEHICLES' WEIGHTS (FARS DATA)

Next, for the purpose of setting the target vehicle specifications, the weight distribution of the vehicles involved in fatal accidents was examined using the FARS data. The results are shown in Fig. 3.

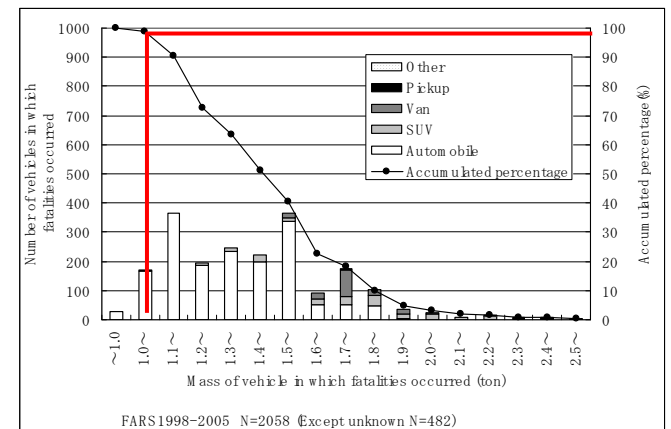


Fig. 3: Distribution of Target Vehicles' Weights in V-to-V Collisions

The results show that close to 99% of the target vehicles are found in the range above a net weight of 1.0 ton.

SETTING OF EVALUATION PARAMETERS

Based on the previously reviewed real world crash data, the following evaluation parameters were chosen to represent a severe offset frontal crash test condition.

The overlap rate was set at 50% based on the results from Fig. 1.

The V-to-V closing speed was set at 110 km/h (55km/h for each vehicle) based on the results from Fig. 2.

The target vehicle selected for the test was a Small-PC class vehicle with a net weight of 1.0 - 1.1 tons based on the results of Fig. 3. The total weight of the test vehicle was set at 1,200 kg to account for the extra weight of two average males.

Finally, of major significance to this study is the Deformable Barrier Face on the MDB that will be used to represent the small PC class vehicle. The characteristics of the DB will be given consideration in the following sections.

NECESSITY OF USING VARYING STIFFNESS CHARACTERISTICS

In this section, consideration is given to the handling of vehicle loading during V-to-V collisions. This is done to clarify the key points necessary for a DB to represent the test vehicle and is needed before attempting any specific DB design.

First, consideration was given to the load paths distributed across the vehicle's width in a V-to-V collision. The difference in the generated load for each of the separately identified load paths was confirmed based on the load distribution during a FWDB test. Next, a comparison was made between a V-to-V model that assumes a uniform stiffness along the front of the two impacted vehicles and a model that assumes load paths with differing stiffness's across the front of the two vehicles.

NONUNIFORMITY OF FRONTAL STRENGTH AND LOAD PATHS IN V-TO-V COLLISION

In the case of an offset V-to-V collision, the inboard portion of the impacting vehicle contacts the outboard section of the opposing vehicle. Similarly, the inboard portion of the opposing vehicle contacts the outboard section of the impacting vehicle. Mori and others suggest that in an offset V-to-V collision, there are three load paths⁽⁷⁾. These load paths (as shown in Fig. 4) are the wheel to the opposing vehicle's power unit, the lower

rail to the opposing vehicle's lower rail, and the power unit to the opposing vehicle's wheel.

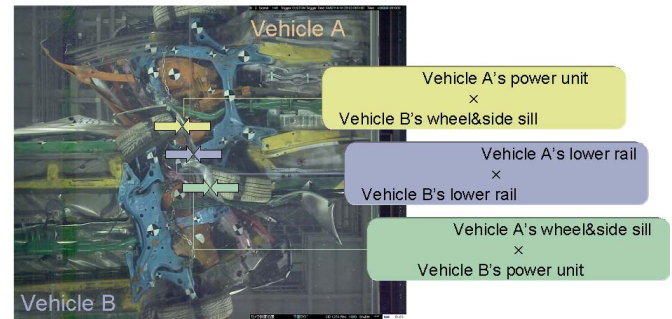


Fig. 4: Three Load Paths in Offset V-to-V Collisions

Next, the resulting load for each of the three load paths was investigated. Fig. 5 shows the load distribution in the FWDB test for a Small-PC vehicle.

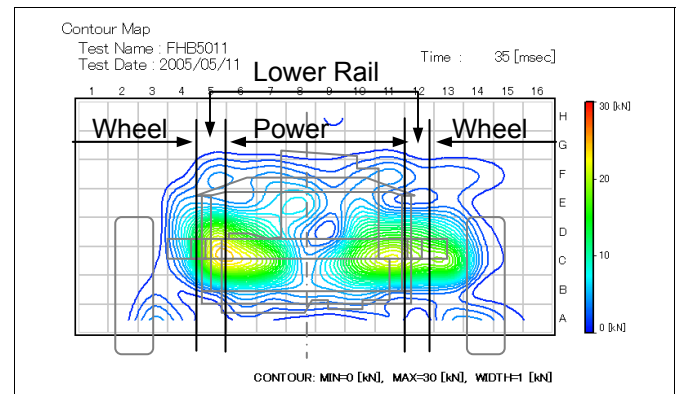


Fig. 5: Load Distribution of FWDB Test on Small-PC

As can be seen in the figure above, the load in the outboard 1st to 4th and 13th to 16th columns, where the wheels are located, is lower compared to the load in the 5th to 12th columns where the power unit and lower rails are located. In general a vehicle's energy is absorbed by the two lower rails in a frontal collision. The resulting load is concentrated on the lower rails themselves and the power unit which they support.

As shown above, in the case of an offset collision the impact vehicle's soft wheel area comes into contact with the opposing vehicle's hard power unit. At the same time the impact vehicle's hard power unit collides with the opposing vehicle's soft wheel area.

COMPARISON OF UNIFORM STIFFNESS AND VARYING STIFFNESS USING A SPRING MODEL

The conventional DB used for frontal collision evaluations has uniform stiffness characteristics across its width. In contrast, it was demonstrated in the previous section that the stiffness characteristics of an actual vehicle varies greatly with vehicle width and that the hard section of a vehicle will likely come into contact with