# EVALUATION OF VEHICLE BODY STIFFNESS/STRENGTH FOR CAR TO CAR COMPATIBILITY

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## ABSTRACT

When considering a car to car frontal crash between a small light car and a large heavy car, it is necessary to evaluate the stiffness and strength of each vehicle body. As interactive force at the contact surface cannot be measured directly in a car to car crash test, a simplified practical method has been developed to estimate the interactive force based on the vehicle deceleration. The adequacy and consistency of the proposed method was verified by using the principle of conservation of energy. The calculated force-deformation curves revealed that the interactive force reached the maximum designed strength of the small light car based on the ODB (Offset Deformable Barrier) test for crash protection, while the force level was far below the corresponding design limit of the large heavy car. It was observed that the relatively lower stiffness of the small light car resulted in absorbing a larger share of the total input energy of the system when crashed into the large heavy car. By analyzing the interactive force profile in detail, it was found that the maximum impact force and the end of crash force could be used as a barometer to assess car to car crash compatibility.

## ESTIMATE OF INTERACTIVE FORCE

A method was developed in this study to estimate impact force based on deceleration measured on a vehicle. It was assumed that impact force of a vehicle was equivalent to a summation of inertial forces of mechanical parts and body structure. Mechanical force was thought to be a combination of inertial forces of the engine block and the suspension frame while structural force was calculated separately at the struck side and the non struck. A barrier test was conducted to verify the validity of the developed method. Figure 1 shows the estimated force curves calculated from decelerations measured on the tested vehicle. Mechanical force, structural force and the total impact force were plotted. Figure 2 compares the estimated impact force and the measured barrier force. The estimated force shows slight oscillation possibly because of body vibration during the crash. The entire profile, including the gradient of force rising and the maximum force level, was almost identical between the two curves. The results suggested that the developed method was proved to be valid to estimate impact force of a vehicle.

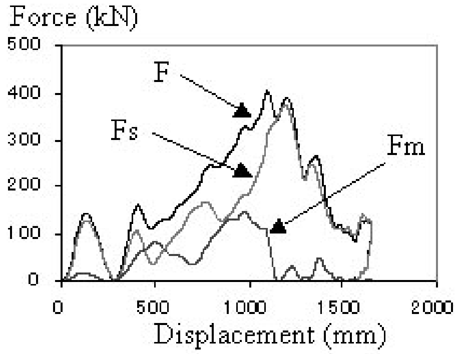


**Figure 1. Estimated Impact Force.**

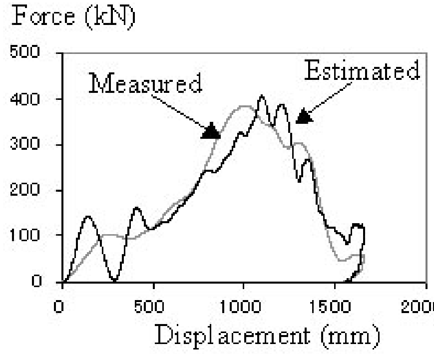


**Figure 2. Estimated and Measured Forces.**

**ANALYSIS OF CAR TO CAR CRASH**

A car to car offset frontal crash test was conducted between a small light car and a large heavy car. The vehicle weights were 1,314 kg and 2,000 kg respectively. The impact speed was 56.7 kph for both cars and the overlap ratio was 52% for the small car. Figure 3 shows body deformation of both cars after the crash. The entire magnitude of deformation was larger in the small car and deformation was found around the right front-pillar.

In order to explain an energy sharing mechanism that brought larger deformation on the small car, it is necessary to analyze force-deformation curves for two cars. Body deformation is, however, not able to be measured directly in a car to car crash. Displacement of the body can be calculated by double-integrating the cabin deceleration but it includes rigid body motion. In this study, it is hypothesized that the center of gravity of the entire system including two cars can be regarded as an origin of gross deformation for both cars. The body deformation can be calculated by subtracting the rigid body motion from the displacement of the body. Figure 4 shows the estimated force-deformation curves of the two cars. The maximum magnitude of estimated deformation was larger in the small car as observed in the test. The maximum force level was around 450 kN for both cars because the force was generated by mutual interaction.

Small Car　　　　　　Large Car

**Figure 3. Body Deformation of Two Cars After Crash.**

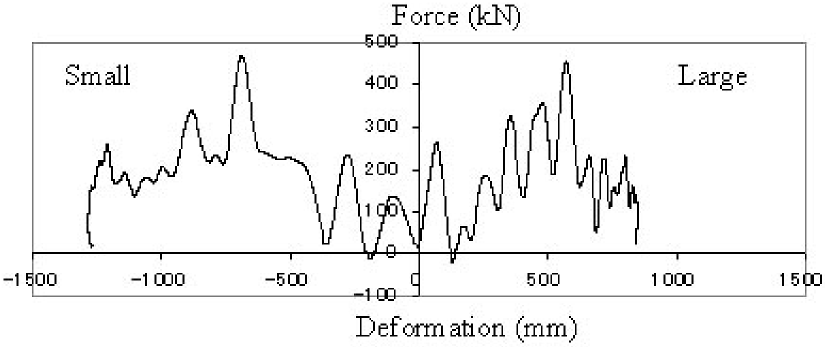


**Figure 4. Estimated Force-Deformation Curves of Two Cars.**

**DISCUSSION**

The force-deformation profile of the small car can be symbolized as a simple polygon as shown in Figure 5. A linear increase in force up to the maximum peak *Fmax* represents the stiffness of a crashing vehicle. This is convenient when considering the progress in deformation between two cars with different stiffness. The second stage can be characterized by a rectangular profile. In an overload condition, the force level in the second stage is lower than the *Fmax* because the mechanical force drops off. The magnitude of the force during the second stage can be called '*End-of-Crash Force*', as it determines the end of body deformation. The higher the *ECF* rises, the less the cabin deformation grows. Thus the analysis revealed two possible indicators of cabin strength: *Fmax* and *ECF*. These two indicators should be considered in the evaluation of cabin strength under overload conditions.

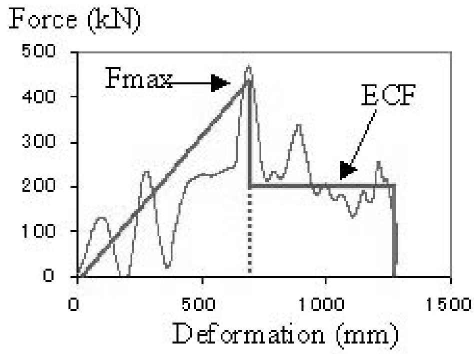


**Figure 5. Symbolized Force-Deformation Curve.**

**REFERENCES**

1) Edwards, M., Happian-Smith, J., Byard, H., Davies, H., Hobbs, C., 'Compatibility – the essential requirements for cars in frontal impact', Proc. Vehicle Safety 2000, 3-17.

2) Steyer, C., Delhommeau, C., Delannoy, P. 'Proposal to improve compatibility in head on collisions', Proc. 16th ESV Conference, 682-692.