SHARING OF COLLISION ENERGY BETWEEN CARS IN FRONTAL IMPACTS

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Introduction

It has been generally accepted that car mass is an important factor in two vehicle collisions, with the occupants of the lighter vehicle experiencing more frequent and more severe injuries. The apparent dominance of mass in relative injury risk has been shown in the numerous statistical studies of real life frontal collisions between dissimilar cars. These studies have shown that Relative Injury Risk is proportional to Mr^n; the exponent n increases from n=1 to n=2.8/3.7 as injury severity increases from minor (AIS 1) injuries to fatalities. Extensive research has been carried out into the compatibility of dissimilar cars in frontal collisions (1-7), and into the possible methods of reducing the size and mass effect. Wood & Simms (8) proposed a theoretical model for the apparent mass effect for frontal collisions between dissimilar cars. The central tenet of this theory is that the apportionment of collision energy between the colliding pair is a function of the structural collapse forces at maximum dynamic crush. (Up to the instant of maximum dynamic crush, the interface forces between the two vehicles are a combination of structural collapse and inertial forces, with the consequence that the structural force balance only becomes valid at maximum dynamic crush, when the vehicles have no relative velocity, i.e. the inertial forces at the interface are zero.) This theory, which was used in combination with a generalized characterization of the energy absorption characteristics of the car population with Monte Carlo simulation, predicted Relative Injury Risk versus Mass Ratio characteristics which were similar to the real life data over the collision speed range, up to EES values of 25m/s.

Objective

The objective of this work is to use the model of matching the structural collapse forces at maximum dynamic crush to evaluate the manner in which collision energy is shared between the colliding pair of cars, and to identify the relationship between RIR, Mr, and Er.

Results

Figure 1 shows the variation of Er with Mr and EES for the smaller car. This graph shows that for low speed impacts, the Er is close to 1. This means that each car absorbs collision energy in proportion to its mass. As the collision severity increases, the Er diminishes. It also diminishes with increasing Mr, indicating that at the higher collision severities and at higher Mrs', the proportion of the collision energy absorbed by the smaller, lighter car is greatly increased.

Figure 2 shows the variation in RIR with Mr and Er. As Mr increases, so does RIR, while the RIR increases with the inverse of the Er. For example, the RIR equals 10 when the Mr is 2 and Er is 0.5. Regression analysis of the mean RIR, Mr, and Er characteristic is shown in figure 2, yields the relationship:

$$RIR = \frac{Mr^{2.4}}{Er^{1.12}}$$

This regression has a coefficient of determination of r^2=0.98.

Conclusions

The model shows that the RIR is frontal collisions between dissimilar cars is a function of the Mr and the Er, i.e. the proportions of collision energy absorbed by each of the colliding pairs of cars. The analysis shows that for the present car population, the Er diminishes with increasing impact severity, i.e. the smaller car absorbs an increasingly disproportionate share of the collision energy. The model indicates that in high speed collisions with, for example, a Mr of 2, the RIR for the smaller car is, on average, 10 times that of the larger car. Analysis of the data shows that alteration of the energy absorption characteristics, i.e. the structural characteristics of the vehicle such that the energy absorption ratio, Er, is 1 (each car, irrespective of size, absorbs half the collision energy) would result in a decrease in RIR in high speed collisions to 4.7, i.e. a reduction of 53%.

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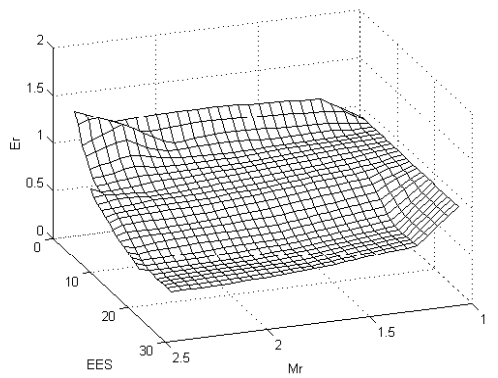

Figure 1

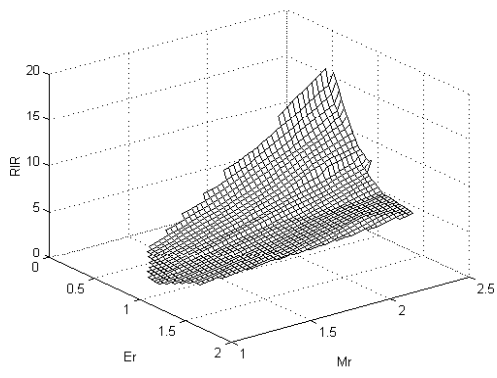

Figure 2