Estimation of Driver Fatality Ratio Using Computational Modeling and Objective Measures Based on Vehicle Intrusion Ratio in Head-on Collisions

R. Setpally, R. Moradi

Faculty: H. M. Lankarani

Department of Mechanical Engineering

Abstract. The National Highway Traffic Safety Administration (NHTSA) has introduced a Driver Fatality Ratio (DFR), based on the Fatality Analysis Reporting System (FARS) and General Estimating System (GES) crash Involvement statistics, which has produced good estimates of the aggressive behavior of vehicles in crashes. The DFR proposed by NHTSA is based on the statistical data, which makes it difficult to evaluate DFR for other vehicle categories (e.g., crossovers, etc.), which are relatively new in the market as they do not have sufficient crash statistics. This research work proposes a new methodology based on computational reconstruction of impact crashes and objective measures to predict the DFR for any vehicle. The objective measures considered include the ratios of maximum intrusion, peak acceleration, and weight for the two vehicles in head-on collisions. Factors which directly influence fatal injuries to the occupants are identified and studied to develop a relation between these objective measures to the DFR. The proposed method is then validated for a range of Light Trucks and Vans (LTVs) against a passenger car, and is then used to predict the DFR of cross category vehicles. Factors which influence these objective measures in predicting the DFR are discussed. Results from this study indicate that the ratio of intrusions produces a better estimate of the DFR and can be utilized in predicting fatality ratios for head-on collisions.

1. Introduction

According to United States crash statistics, one third of all passenger cars in U.S. are LTVs and of all the vehicle collisions which occur in the US, over 50% accidents occur between LTVs and cars, out of which 81% of fatal injuries are in passenger cars [2]. DFR is used to study the incompatibility between vehicles of specific category, which is based on FARS and GES. But the statistical data is not available for new cars and crossovers which motivated to do this research work to find out a way to predict the DFR of new vehicles. The statistical DFR for range of LTVs against passenger cars is

Full Size Van		1:6.0
Full Size Pickup		1:6.2
Sport Utility Vehicle (all)		1:4.3
Minivan		1:2.6
Compact Pickup		1:2.6

.

Fig 1. DFR for Frontal LTV to car crashes[1]

The main idea behind this research is to calculate DFR in terms of factors which cause fatal injuries to the occupants. The approach used in this research for calculating DFR for specific vehicle category is to measure the ratio of major factors which influence the injury potential to the occupants in the collision. The incompatibilities between two vehicles directly lead to high intrusions and acceleration in smaller vehicle. These two factor along with weight factors for all the vehicle are assessed in frontal impact modes to find a correlation with the statistical Driver Fatality Ratio. By using the same target car (Passenger car) and varying the bullet car (each bullet car representing different class of LTVs) Ratio of intrusions, accelerations, Weight are measured. Figure 2 shows the FE models of the vehicles used in the research.
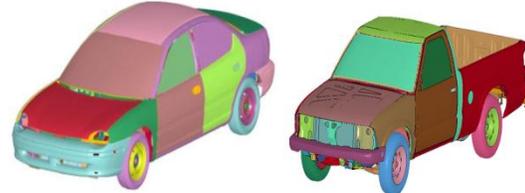

Fig 2. Finite Element Models of Neon and S10

2. Experiment, Results, Discussion, and Significance

Series of virtual crash tests are conducted by having a constant bullet car as dodge neon and varying the bullet car for range vehicles representing a range of LTV's, where both vehicles travelling at a speed of 35mph. Intrusions and accelerations are measured and the corresponding ratios in comparison with statistical DFR are shown in table 1.

Table1:Comparison of objective measures with statistical DFR

VEHICLE CATEGORY	FATALITY RATIO	WEIGHT RATIO	INTRUSIONS				ACCELERATIONS		
			FIREWALL	FOOT-BOARD	A-PILLAR	AVER-AGE	LEFT SEAT	RIGHT SEAT	AVER-AGE
Chevy s10-Dodge Neon	1:2.6	0.8:1	1:2.5	1:2.4	1:2.5	1:2.5	1.2:1	1.3:1	1.2:1
Dodge Caravan-Dodge Neon	1:2.6	1.5:1	1.3:1	1:2.6	1:2.4	1:2.5	1:2.5	1:2.4	1:2.4
Ford Explorer-Dodge Neon	1:4.3	1.7:1	1:4.3	1:11	1:4.2	1:4.2	1:15	1:7.0	1:11
Ford F250-Dodge Neon	1:6.2	2.3:1	1:1.3	1:6.3	1:12	1:6.3	1:4.3	1:5.1	1:4.7
Ford Ecoline-Dodge Neon	1:6.0	1.6:1	1:6.1	1:6.0	1:5.9	1:6.0	1:6.2	1:4.4	1:5.3

OBJECTIVE MEASURE

VEHICLE CATEGORY	WEIGHT RATIO	INTRUSIONS				ACCELERATIONS		
		FIREWALL	FOOTBOARD	A-PILLAR	AVERAGE	LEFT SEAT	RIGHT SEAT	AVERAGE
Toyota Rav4 - Dodge Neon	1.2:1	1:1.6	1:1.7	1:1.7	1:1.7	1:3.7	1:2.6	1:3.1
Chevy C1500-Dodge Neon	1.52:1	1:2.7	1:38	1:2.7	1:2.7	1:3.4	1:2.3	1:2.8
Ford Taurus - Dodge Neon	1.3:1	1:2.2	1:2.3	1:9.4	1:2.2	1:10	1:4.9	1:7.4

From the graphs and Tables presented, it can be inferred that the weight ratio of the vehicles involved in collision are completely different from the statistical DFR. With increase in weight of the vehicle, the stiffness incompatibility between vehicles is increasing in turn. These acceleration ratios are completely different from the DFR. The intrusion ratios at firewall, foot-well and A-pillar show correlation with the DFR. It can be observed from the table 1, in case I where the three incompatibilities (mass, stiffness and geometric incompatibilities) are within the acceptable range, the produced intrusion ratios completely coincide with the DFR. In case II, the A-pillar and foot-well intrusion ratios are in synchronization with DFR, but the firewall ratio is different from DFR because the frontal geometric structure of Dodge Caravan causes it to experience more intrusions on the firewall than Dodge Neon. In case III, because of high stiffness incompatibility of SUV the foot-well intrusions differ with DFR but the A-pillar and firewall intrusion ratios are almost the same as DFR. In case IV, the three incompatibilities are extremely high causing the under ride of the smaller car into bigger vehicle producing firewall and A-pillar intrusion ratios different from the DFR. The foot-well ratio though is similar to the DFR. In case V, the three incompatibilities are just enough to produce intrusion ratios at firewall, foot-well and A-pillar which coincide with the value of DFR. After validating the proposed methodology, the preceding vehicles representing different vehicle classes are selected and the validated methodology is applied on them to evaluate their DFR. Three vehicles selected are ToyotaRav4,ChevyC1500 and Ford Taurus representing a full-size car. Frontal crash simulations are conducted for these vehicles against a passenger car and the Summary of the objective measures in these cases are shown in table 2.

Table 2:Summary of the objective measures

By observing the above table we can say that the DFR of Toyota Rav4, Chevrolet C1500 and Ford Taurus are 1: 1.7, 1: 2.7 and 1: 2.2.

3. Conclusions

During the comparison of objective measures it was found out that, proposed methodology works differently for different vehicle combinations. When the three Incompatibilities (mass, stiffness and geometric) are within the acceptable range the new method of approach can directly approximate the DFR. During validation, it was observed that ratios of intrusions produced consistent results which were identical to statistical DFR values. After validation, the proposed method is used to evaluate DFR of Toyota Rav4 representing Compact SUV, Chevy C1500 representing light weight Pick-up and Ford Taurus representing Full-size car and predicted as 1: 1.7, 1: 2.7, 1: 2.2. From the results discussed in this study, it can be concluded that "Ratio of Intrusions" provides better estimate for the DFR when there is no under-ride of smaller car in to bigger vehicle and huge difference in stiffness. Ratio of Accelerations provides better results when the crash energy developed during collision is absorbed equally between cars involved in collision. This is possible only when two similar vehicles collide against each other. With introduction of composites it is unlikely that weight ratio can be used to predict DFR. DFR is difficult to estimate from the acceleration ratio since acceleration depends on the stiffness of the body. This method is accurate when there is no geometric incompatibility. By observing the intrusion ratio we can approximately predict the DFR of a vehicle during the design stage and make necessary changes to it to decrease the aggressive before it is sent out for production.

References

[1] Gabler H.C., Hollowell W.T., "The Crash Compatibility of Cars and Light Trucks," *Journal of Crash Prevention and Injury Control*, January 2000.

[2] Gabler H.C., Hollowell W.T., "NHTSA'S Vehicle Aggressivity and Compatibility Research Program," U.S. NHTSA, United States, Paper No. 98-S3-O-01, January 2001.