Characteristics of passenger car front under-ride crashes in India involving impact to rear-side of heavy vehicles

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I. INTRODUCTION

According to the Indian Government's road statistics report, Road Accidents in India [1], published by the Ministry of Road Transport and Highways for the year 2016, passenger cars were involved in 21.1% of the 136,071 reported fatal road traffic crashes. In terms of fatal road users, passenger cars were the second highest fatal road users (17.9%) next to powered two-wheeler (34.8%) users. An analysis of data collected under the Road Accident Sampling System – India (RASSI) [2], showed that in 72% crashes where a passenger car impacts a heavy vehicle, such as a truck or a bus, there is atleast one fatal or seriously injured victim in the passenger car. Further analysis of the passenger car impacts with the heavy vehicles showed that in 91% of the passenger car front under-ride crashes there was atleast one fatal or seriously injured victim in the passenger car. It is evident from the analyses that passenger car front under-ride crashes result in severe injury outcomes for the occupants of the passenger cars and hence need to be studied in-depth to understand their characteristics.

II. METHODS

Road Traffic Crash data collected between 2011 and 2016 for RASSI were used for this study. All crashes involving passenger cars (1,110 crashes) were assessed to identify the collision partner distribution. It was found that Powered two-wheelers, Fixed Objects and Heavy vehicles formed the majority of collision partners, accounting for 22% (245, 243 and 244, respectively, of the total 1,110 crashes) each. Of these three collision partners, heavy vehicles accounted for the highest fatal injury outcome (41%, or 101 of 244 crashes) for the impacting passenger car. The first crash configuration of these 244 crashes was analysed alongside the injury outcome for the passenger car occupants. It was found that front under-ride of passenger cars (116 of 244 crashes) accounted for the highest fatal injury outcome (28%, or 68 of 244 crashes) for the impacting passenger car. For these 116 front under-ride crashes, analysis of the distribution of the contact plane on the collision partner showed that 59% (68 of 116 crashes) of the passenger cars had impacted the rear of the heavy vehicle.

Of these 68 crashes, one resulted in fire after the under-ride impact, therefore this case was not selected for further study. 67 crashes were studied in-depth in order to identify: distribution of Collision Deformation Classification (CDC) [3] parameters for the passenger car; injury severity distribution of occupants with respect to seating positions; and outcomes of seat-belt usage for occupants in the passenger cars. The delta V values obtained from PC-Crash reconstruction of the crashes (41 of 67 crashes), were also analysed to identify injury outcomes at different delta V speed ranges.

III. INITIAL FINDINGS

Fig. 1 shows the distribution of the CDC parameter, deformation extent. The analysis showed that in 87% of the crashes the direct contact of the impacting passenger car is up to and beyond the windshield.

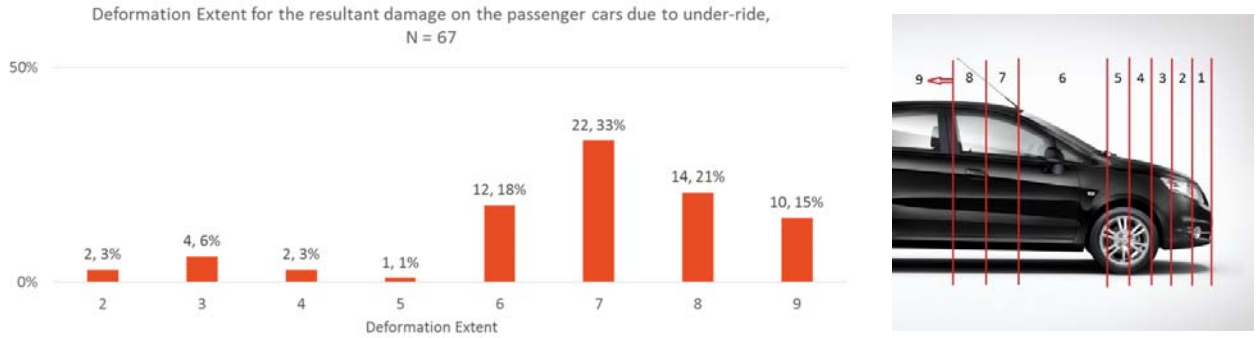

Fig. 1. Distribution of Deformation Extent of the CDC for the under-ride event of the passenger cars.

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Fig. 2 shows the distribution of the CDC parameter, specific vertical location (SVL). For 72% of the crashes there is a direct contact of the complete height of the passenger car.

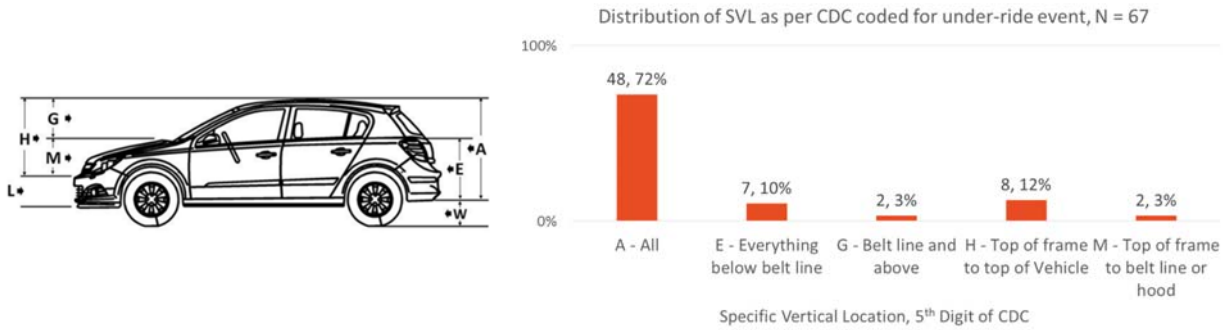


Fig. 2. Distribution of Specific Vertical Location of the CDC for the under-ride event of the passenger cars.

Fig. 3 shows the distribution of the CDC parameter, specific longitudinal location (SHL). For 78% of the crashes there is a direct contact of more than one-third of the width of the passenger car.

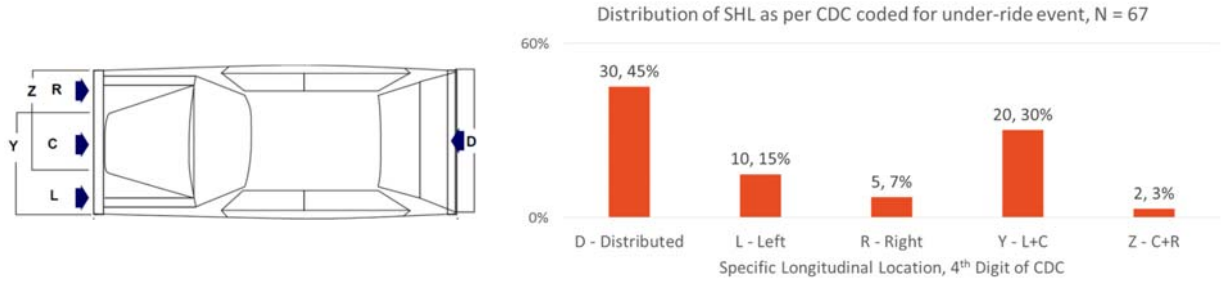


Fig. 3. Distribution of Specific Longitudinal Location of the CDC for the under-ride event of the passenger cars

The injury severity distribution for the 246 occupants in the 67 passenger cars is detailed in Fig. 4. The injury severity with respect to seating positions is detailed in Fig. 5. It was observed from these figures that 67% of the passenger car occupants suffered either serious or fatal injuries. Front-row passengers and drivers had a higher incidence of fatal or serious injuries (87% and 79%, respectively) compared to other row occupants.

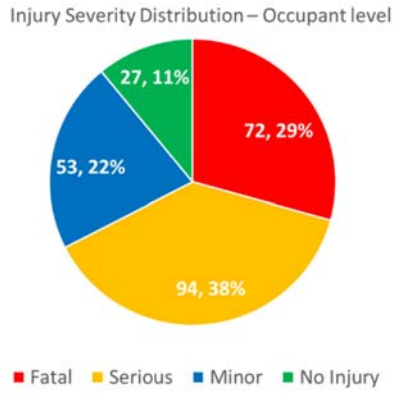


Fig. 4. Distribution of Injury Severity of the 246 occupants of the passenger cars.

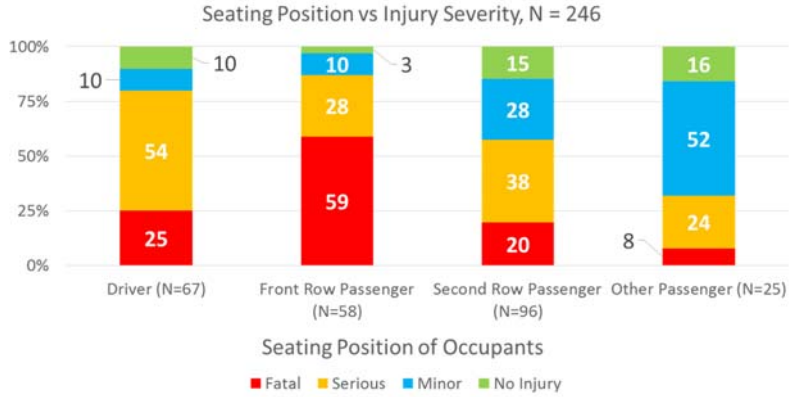
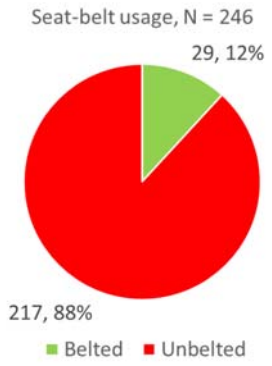


Fig. 5. Distribution of Injury Severity of the 246 occupants of the passenger cars with respect to their seating positions.

The use of seat-belts was analysed and the results are detailed in Fig. 6. The distribution of injury severity for the belted occupants of the different seating rows is detailed in Fig. 7. There was very low seat-belt usage amongst the occupants (12%). It was also found that even with the wearing of a seat-belt there was a high probability of fatal/serious injuries to driver and first-row passengers (62% and 86%, respectively).



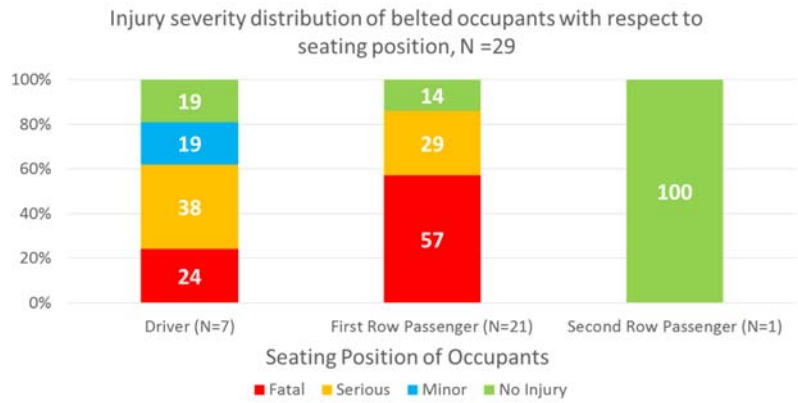


Fig. 6. Distribution of Seat-belt usage of the 246 occupants of the passenger cars.

Fig. 7. Distribution of Injury Severity of the 29 belted occupants of the passenger cars with respect to their seating positions.

PC-Crash software was used for reconstructing the study sample to determine impact speed and related parameters. 41 of the 67 crashes could be reconstructed. For these reconstructed cases, the cumulative distribution of the delta V values is shown in Fig. 8. From Fig. 8 we can see that the 85th percentile of the delta V values obtained for the passenger cars using PC-Crash reconstructions was 56 kmph.

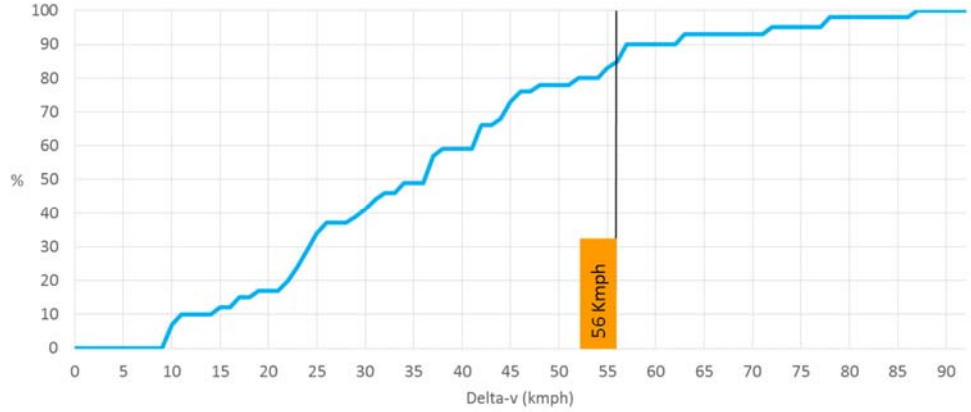


Fig. 8. Cumulative Distribution of delta V experienced by passenger cars during impact with heavy vehicle in under-ride crashes.

An analysis was also carried out to compare the injury outcomes for the impacting passenger car at various delta V range. This comparison is shown in Fig. 9. From Fig. 9 we can observe that, irrespective of delta V values, the probability of fatal/serious injury outcomes to occupants of the passenger cars in such crashes is very high.

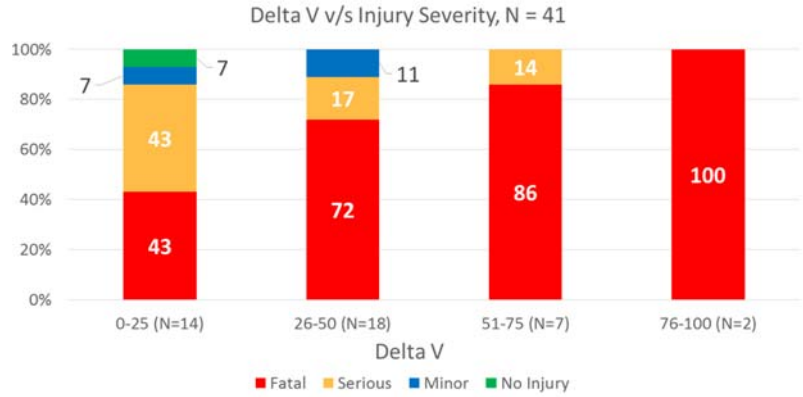


Fig. 9. Delta V vs Injury Severity of passenger car distribution.

IV. DISCUSSION

It is evident from the analyses that occurrence of fatal or serious injuries to occupants in passenger cars are very high in passenger car under-ride crashes. There has been a significant improvement in crashworthiness of passenger cars by provision of crumple zones, passenger safety cocoon and passive safety systems. However this has not been of much use in passenger car under-ride crashes as evident from the distribution of extent of collision damage and injury severity of belted occupants as identified in the results of this study. This can be contributed to the difference in stiffness, geometry and mass difference between the collision partners. It is hence evident that there is necessity for heavy vehicles to be provided with structural components that can help in absorbing the impact energy, which in turn will help to reduce the severity of impact for the passenger car during such crashes. It is a world-wide accepted practice to achieve this through installation of rear under-ride protection devices (RUPD) in the heavy vehicles. The further study area for these type of crashes would be to check availability of RUPD in the heavy vehicles involved in such crashes, study their effectiveness in reducing the impact severity for the passenger cars and to make necessary changes to the government regulations to facilitate the installation of effective RUPDs in heavy vehicles.

The data analysed for the purpose of this study is the crash data collected for the RASSI database from five different locations across India. There is no national database available in India with details of crash parameters as available in RASSI which can be used for representativeness studies. The under-ride crashes analysed for this study are primarily from expressways, national and state highways and are representative of under-ride crashes happening in these road-types all across India.

V. REFERENCES

[1] Ministry of Road Transport and Highways, Government of India, *Road Accidents in India - 2016*, New Delhi, India.

[2] N Rameshkrishnan, “The New In-Depth, At-the-Scene, Accident Investigation Database in India“, IRCOBI 2013.

[3] Collision Deformation Classification, SAE Surface Vehicle Standard, SAEJ224, March 1980.