Assessment of Crashworthiness and Seatbelt Performance of Small Cars in Road Crashes

L. FAUZIANA [a], A. NOOR KAMALIAH [a], M. F. SITI ATIQAH [a], S. V. WONG [a], L. MIMINORAZEANSUHAILA [b]

[a] Crash Reconstruction Unit, Biomechanics and Vehicle Safety Research Centre, Malaysian Institute of Road Safety Research, 43000 Kajang, Selangor, Malaysia.

[b] Fakulti Kejuruteraan Mekanikal, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia.
fauziana@miros.gov.my
http://www.miros.gov.my

Abstract: - This study presents the reliability of small car which is classified as low capacity vehicle in preventing injuries due to road crashes. Crash data was collected and the distribution of injury pattern for different collision conditions were analysed. Assessment of vehicle structure performance and seatbelt in road crashes for the different vehicle capacity shows that the low capacity vehicles have low prevention of all degree of injuries except severe injury. This result demonstrates that the crashworthiness of small cars in Malaysia still needs to be improved. Thus, it could ensure the maximum effectiveness of seatbelts in a road crash. This is crucial in minimising road crash mortality as well as disabilities, especially in the current situation where small car has an increasing trend of population on the road.

Key-Words: - Crash investigation, Crashworthiness, Road traffic injury, Seatbelt, Small cars, and Structural deformation.

1 Introduction

Small car is also known as Low Mass Vehicle (LMV). The basic principles for the structural design of small cars have been published earlier [1-3] and it was reported that minimum curb weight of 600 - 650 kg appears to be feasible. In general, higher deceleration level will be experienced by small cars compared to its heavier opponent in a car versus car collision. In view of this, better compatibility of vehicle structures is an important key to achieve the frontal and side impact protection.

Baumann [4] proposes a compatibility curve based on a constant front-end stiffness for all vehicle sizes. Front-ends of the various vehicle classes would then only differ in terms of the required deformation length: 350 mm for a 700 kg car, increasing in relation to the vehicle mass up to 600 mm for 1900 kg vehicles. The lack of compatibility between cars is considered to be the main reason for the frequent appearance of small vehicles in accident statistics [5]. Crashworthiness refers to the ability of a vehicle to protect its occupants in a crash. To become compatible, the frontal structural stiffness of a low mass vehicle must be at least equal or slightly higher than the stiffness of its heavier counterpart [3,6].

In addition, it was clearly testified by previous researcher [7] that the safety deficits of small cars can be alleviated if the structure and the restraint systems of these cars are designed and optimised for the situation they will most likely encounter in a real world situation, such as a collision against a heavier car. It is well published that road crash is a leading cause of death, which more than 1.2 million peoples were killed worldwide every year and it causes further disabilities for more than 50 million injured victims [8]. One of interventions that lead to success in a reduction in the mortality is the installation and proper use of seatbelts [9-10]. On top of that, the restraint system of any car will only be able to deploy its effectiveness if the passenger compartment does not collapse in a collision [7]. Minimising of structural components intrusion into the cabin and deformation of the passenger compartment are always taken into account in vehicle design.

Malaysia is one of the countries that have the highest vehicle-to-population ratio in the world. In recent years, small car type of passenger vehicle has become more popular and issues related to the reliability of this increasing vehicle population have created considerable concern. For that reason, this study was conducted to assess the overall safety performance and crashworthiness of small cars on the Malaysian roads especially in an event of crash.

2 Methodology

Crash data involving various types of passenger vehicles were collected. In the data collection activity, physical evidences were gathered in order to reconstruct the crash. Photos as well as categorical data were recorded to support the reconstruction work. Based on these evidences, vehicle structural deformation can be further evaluated and seatbelt compliance can be determined. In this study, the passenger vehicle data was classified into vehicle capacity which is low and high. Small car is defined as a small and light passenger vehicle which has cubic capacity below than 1300 ml and curb weight less than 1000 kg. In brief, the classification of vehicle based on its capacity was summarised in Table 1.

Table 1. The classification of vehicle based on its capacity.

Classification	Cubic capacity (ml)	Curb weight (kg)
Low capacity	≤ 1300	≤ 1000
High capacity	> 1300	> 1000

Data was then analysed and probability trend of different types of injuries were obtained. Accordingly, assessment of vehicle structure performance and seatbelt in road crashes for the different vehicle capacity was conducted.

3 Results and Discussions

Based on the high profile crash data, 95% of the total small cars cases are comprise of locally made vehicles. The comparative portion of the locally made small cars as compared to the imported small cars was illustrated in Fig. 1. Therefore, further assessment on these data could reflect the crashworthiness of small cars in Malaysia that mostly have been locally produced.

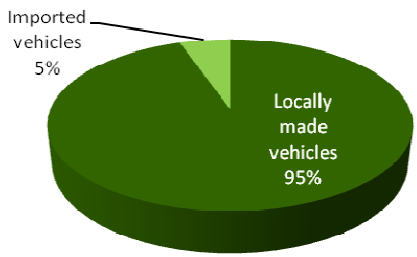
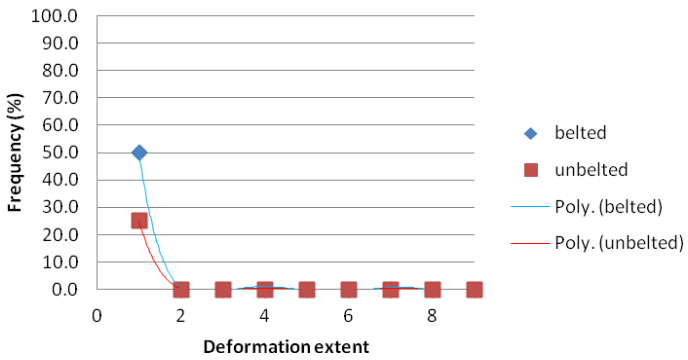


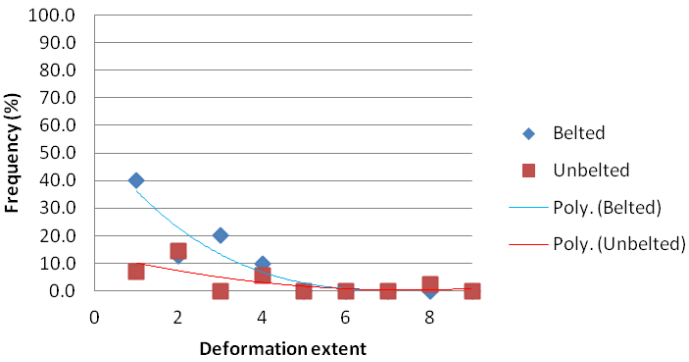
Fig. 1 Distribution of the small cars population in terns of vehicle origin.

In order to assess its performance, ability of small cars in preventing injuries with the existence of its seatbelt restraint system has been compared with big cars. The comparison was observed by plotting the probability of injuries against vehicle structural deformation for different seatbelt compliance condition. These plots enable assessment of vehicle structure performance and seatbelt in road crashes for the different vehicle capacity.

Based on Fig. 2, it can be seen that belted occupant has higher chances to get completely survive in a crash as compared to those unbelted regardless of vehicle capacity. However, probability of occupant in the high capacity passenger vehicle to obtain no injury exists for deformation extent up to the fourth zone. Meanwhile, low capacity vehicle could only reach the second zone of deformation extent to result in no injury to occupants.



(a)



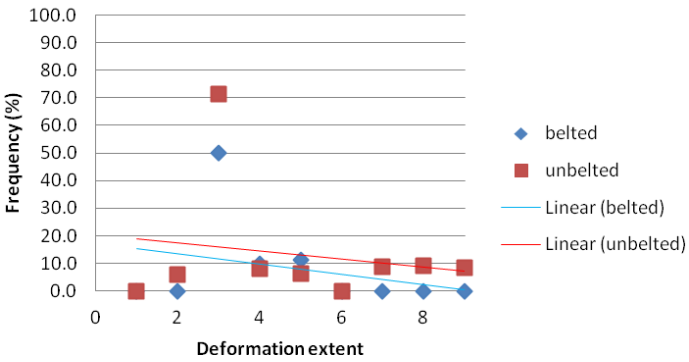
(b)

Fig. 2. Probability of slight injuries at different crash condition for the two class of vehicle capacity: (a) low capacity vehicle, (b) high capacity vehicle.

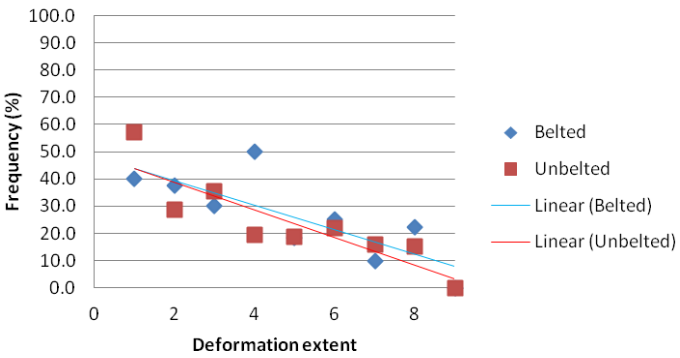
ISBN: 978-1-61804-071-8

The distribution of slight injury pattern for unbelted occupants that being occupied in the low capacity vehicle is a bit higher, approximately at 5% than those belted, as shown in Fig. 3. For the high capacity vehicles, the belted and unbelted injury pattern did not exhibit difference in trend. In comparison of both vehicle capacity classifications, the probability distribution was higher for the high capacity vehicles.

For example, the probability of slight injury occurrence was decreased to 10% when the belted occupant in the low capacity vehicle deformed to the fourth zone. Meanwhile, this percentage of probability was recorded by the high capacity vehicles only after the eight zone of deformation extent exceeded. Less than that, the probability of occupant to get slight injury is more up to 42%.



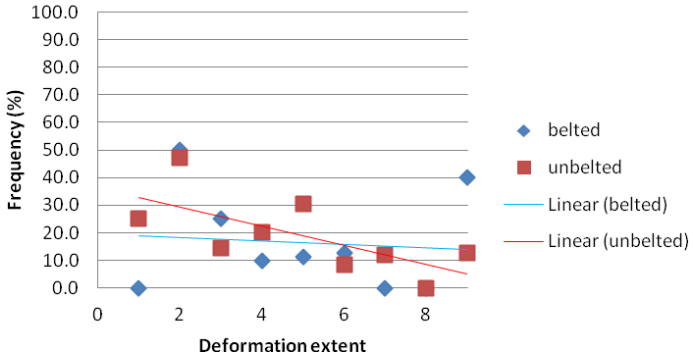
(a)



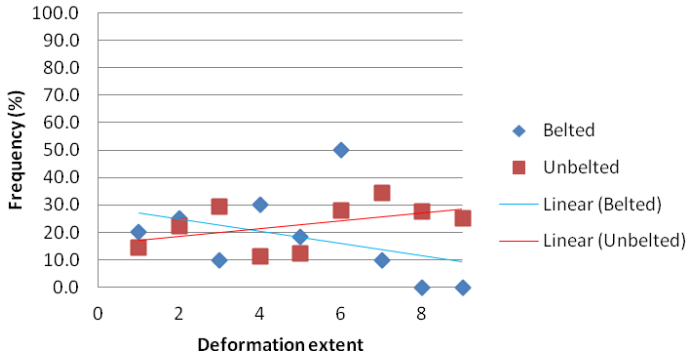
(b)

Fig. 3 Probability of slight injuries at different crash condition for the two class of vehicle capacity: (a) low capacity vehicle, (b) high capacity vehicle.

The low capacity vehicles remain the probability of belted occupant in suffering severe injury approximately at 17% ± 2. Unlike the low capacity, those belted occupants who were occupied in the high capacity vehicles have a decreasing trend of probability as deformation extent increase (see Fig. 4). There are contrary trend of severe injury probability of the unbelted occupant between the low and high capacity vehicles, which are decreasing and increasing respectively. This means, the low capacity vehicle has better performance in preventing sever injuries compared to the high capacity vehicle.



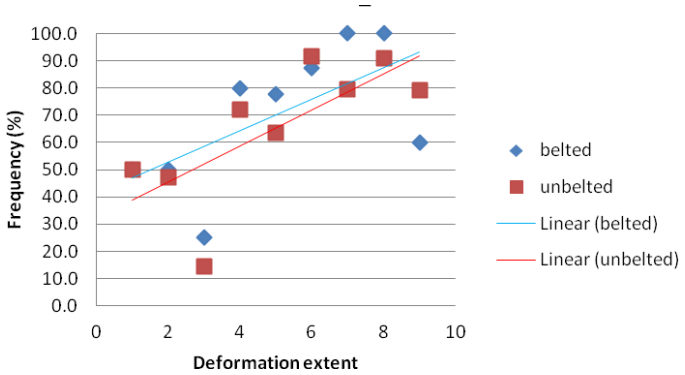
(a)



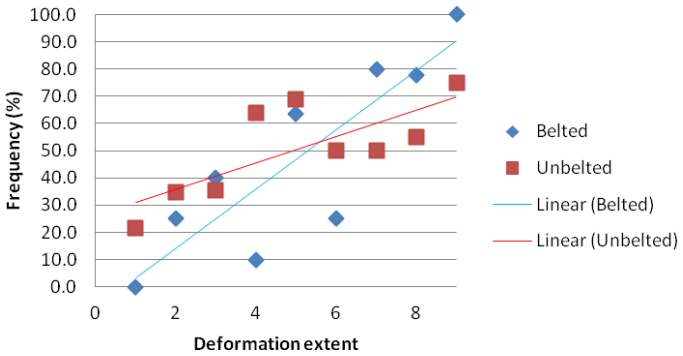
(b)

Fig. 4. Probability of severe injuries at different crash condition for the two class of vehicle capacity: (a) low capacity vehicle, (b) high capacity vehicle.

In general, fatality distribution for the low capacity is higher than the high capacity vehicles. It can be seen in Fig. 5 that that the 50% probability of fatalities was recorded by the belted occupant in the low capacity vehicles when vehicle structural deformation just exceeding the first zone. Otherwise, the 50% probability of fatalities was reached by the high capacity vehicles when deformation extended up to the fifth zone. For the high capacity vehicles, the unbelted occupant initially indicates fatality probability trend higher than the belted occupants until deformation exceed the sixth zone.



(a)



(b)

Fig. 5 Probability of fatalities at different crash condition for the two class of vehicle capacity: (a) low capacity vehicle, (b) high capacity vehicle.

This result indicates that the high capacity vehicle has better performance in terms of fatality prevention as compared to the low capacity. In conclusion, the low capacity vehicle has better performance in terms of resulting severe injuries due to road crashes as compared to the high capacity. On the other hand, the high capacity vehicles recorded higher performance in preventing other types of injuries, fatalities, slight and none.

5 Conclusion

In this study, assessment of crashworthiness and seatbelt performance of small cars, which has been classified as low capacity vehicle has been conducted. Comparisons of vehicle structural deformation as well as seatbelt effectiveness for the low capacity vehicles against the high capacity vehicles show that the low capacity vehicles has low prevention of all degree of injuries except severe injury. Probability of occupant that occupied in the high capacity passenger vehicle to obtain no injury exists for deformation extent up to the fourth zone, whereas it low capacity vehicle could only be reached until the second zone of deformation extent. Likewise, the probability distribution was higher for the high capacity vehicles to result in the same degree of injury to the occupants. For the severe injuries, the low capacity vehicles beat the high capacity, in which it remain the probability of belted occupant in suffering severe injury approximately at 17% ± 2. Unlike the low capacity, those belted occupants who were occupied in the high capacity vehicles have a decreasing trend of probability as deformation extent increase. Meanwhile, it has been shown that the high capacity vehicle has better performance in terms of fatality prevention as compared to the low capacity. These findings demonstrate that the crashworthiness of small cars in Malaysia needs some improvements in terms of its safety. This is crucial in minimising road crash mortality as well as disabilities, simultaneously with the increasing trend of small car population on the road.

6 Acknowledgement

The authors wish to express their gratitude to all members of Crash Reconstruction Unit under the Vehicle Safety and Biomechanics Research Centre and Malaysian Institute of Road Safety Research, through the fund of VS102029, for supporting this research.

References:

[1] P. Frei, R. Kaeser , R. Hafner, M. Schmid, A. Dragan, L. Wingeier, M. H. Muser, P. F. Niederer and F. H. Walz, Crashworthiness and Compatibility of Low Mass Vehicles in Collisions SAE Transactions J. of Passenger Cars, SAE 970122, 1997.

[2] Niederer P., Muser M., Walz F., Kaeser R., Brunner A., Occupant Safety of Low Mass Vehicles, Proc. Conf. Stapp (37), p1ff., SAE 933107, 1993.

[3] Robert Kaeser, Felix H. Walz and Anton Brunner, Collision Safety of a Hard Shell Low Mass Vehicle. Accident Analysis & Prevention, Vol. 26, No. 3, 1994, pp. 399-406

[4]Bauman, K.H.: "Sicherheitskonzept fur Kompaktfahrzeuge bei MercedesBenz" Tagung im Haus der Technik, Essen 12./13.06, 1996.

[5] Evans L. and Frick M., Driver fatality risk in two car crashes dependence on masses of driven and striking car, Proc. Conf. ESV 13, 1991.

[6] Kaeser R, Muser M, Spiess O, Frei P, Guenat J, Wingeier L, Passive Safety Potential of Low Mass Vehicles, Proc. Conf. IRCOBI 1995, p337ff.

[7] Frei P, Kaeser R, Muser MH, Niederer PF, Walz FH, Vehicle Structural Crashworthiness with respect to Compatibility in Collisions, 1999.

[8] Peden M, Scurfield R, Sleet D, Mohan D, Hayder AA, Jarwan E, Mathers C:World report on road traffic injury prevention 2004. World Health Organization, Geneva; 2004.

[9] Bandstra R, Meissner U, Warner C Y: Seat belt injuries in medical and statistical perspective. 2009 (http://wwwnrd.nhtsa.dot.gov/pdf/Esv/ esv16/ 98S6W25.pdf], Paper number 98S6W25, accessed 5 October 2011).

[10] FIA Foundation for the Automobile and Society: Seatbelts and child restraints: a road safety manual for decisionmakers and practitioners. London; 2009 (http://whqlibdoc.who.int/road_safety/2009/9780956 140302_eng.pdf, accessed 30 September 2011).