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EXPLORATORY STUDY ON AIRBAG SUITABILITY FOR LOW ENGINE CAPACITY MOTORCYCLES

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Graphical abstract

Abstract

Motorcyclist constituted more than 50% of road deaths in Malaysia. Statistics showed that most fatal motorcyclist crashes involved passenger cars: with sideswipe or side impact reported to be the most frequent crash configurations. Many related studies have been performed to completely understand such motorcycle crashes which resulted in many safety inventions. These include installation of airbag onto motorcycle to study its effectiveness in potentially reducing motorcyclist's injury. However, previous related studies known mainly dealt airbag's effectiveness for large cc motorcycles. Hence, an exploratory study was conducted to study airbag's suitability in mitigating rider's injury during collision for motorcycle with low engine capacity (cc). Two different full-scale crash tests of motorcycle (with and without mounted airbag) side-impacting passenger car were conducted in accordance to ISO 13232. The test results in terms of high-speed video recordings (crash kinematics), motorcycle damage profiles and dummy injuries were analysed and discussed. It could be suggested from the results obtained that an airbag system for low cc motorcycle is feasible and further study is needed for better airbag concept and design which could reduce motorcyclist injury during collision.

Keywords: Underbone motorcycle; airbag; side impact; ISO 13232

1.0 INTRODUCTION

Motorcyclist is inherently a high risk group and generally susceptible to high velocity injury and multiple traumas. They are relatively more exposed to road hazards, therefore more prone to injury than those travelling in any other forms of transportation. This might be due to the lower degree of protection of the motorcyclists [e.g. 1]. In Malaysia, motorcyclists representing more than half of the total road accident related fatalities each year [2-3] with an average of 2% increment annually for the past ten years [4].

Muhammad Marizwan and Várhelyi [2] reported that the most common type of motorcycle fatal crashes involved passenger cars [2]. Furthermore, similar study indicates angular/side impact as the frequent type of collision which contributed the highest number of fatal motorcyclists. Based on statistics from MIROS Road Accident Database System (M-ROADS), approximately 59% of 1,082 analyzed cases (for year 2006-2008) of two-vehicle crashes involved motorcycles impacted the side of passenger cars. According to the modelling results by Pai and Saleh [5], injuries to motorcyclists were the greatest when an overtaking motorcycle collided with a turning vehicle. Such effect appeared to be more severe at unsignalised junctions. The probability of a fatality or severe injury to motorcyclists is much higher as compared to passenger car occupants at this type of junction [6].

Most injuries sustained by Malaysian motorcyclists in fatal road accident are at head and chest [1-2, 7] as illustrated in Figure 1. A study by Hurt *et al.* [8] for 4,500 motorcycle crashes occurring at Los Angeles in the United States showed that the most deadly injuries for the motorcycle crash victims were injuries to the chest and head. In addition to the finding, it is interesting to note that unlike the head, no effective security systems were used by motorcyclists to prevent or reduce thorax injuries. In the same context for type of injury to body region, Moskal *et al.* [9] reported that 50% and 40% of the severely injured motorcycle riders in Rhone, France suffered severe chest and head injuries, respectively.

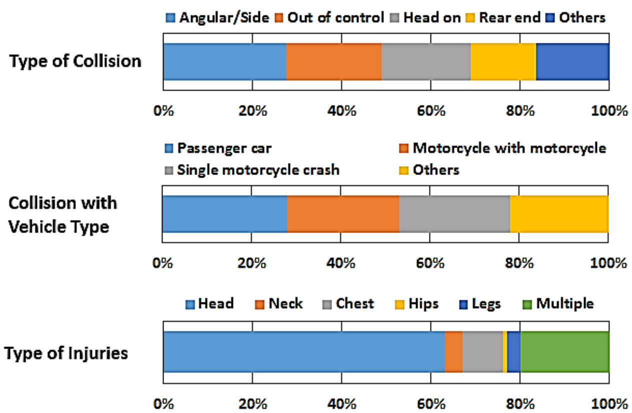

Figure 1 Fatalities of motorcycle accidents in Malaysia [2]

Paramount efforts to improve the safety of motorcycle have led to many related safety inventions which include motorcycle personal protective equipment (PPE) (e.g. helmet and protective clothing) and safety technologies (e.g. airbag and Antilock Braking System, ABS). The effectiveness of PPE especially helmet to reduce the risk of head injury, death and disability of motorcyclist in the event of a crash has been proven in many previous studies [10-13]. Passive safety device such as motorcycle airbag also has a high potential to reduce rider's injury risk particularly in a frontal collision [14-16].

Due to the potential of mitigating motorcyclist's injury, many studies related to motorcycle airbag have been carried out to explore its feasibility which mainly dealt with motorcycle with large engine capacity (cc) [17]. Recent development of such airbag system has been established for large touring motorcycle, Honda Gold Wing [18-19]. However, little is known about airbag's feasibility studies for low cc motorcycle except for an airbag's computer simulation study carried out by Bhosale [20] for low, 100cc Indian motorcycles. Therefore, an exploratory study via full-scale crash test was conducted to study airbag's suitability in reducing rider's injury during collision for this class of motorcycle (<150cc). This class of motorcycle is commonly known as "underbone" motorcycle due to its high number and growing trend in Southeast Asia especially in Malaysia, which constituted more than 90% of total registered motorcycles [21].

2.0 METHOD

The crash test facilitated study into two critical areas: i. to explore airbag's feasibility for low cc motorcycle in mitigating motorcyclist's injury against side collision with stationary passenger vehicle, and ii. to ascertain the effectiveness of standard helmet as protective device in reducing head injury to motorcycle rider.

2.1 Test Configuration

Two sets of crash tests were conducted for this study with the first test as a baseline without airbag and the second test with airbag. The selected motorcycles used for the tests was 100cc Honda Wave which, in principle, represents a common motorcycle-type on Malaysian roads. The motorcycle (2 units for 2 tests) was crashed perpendicularly onto the side of a stationary opposing vehicle, an MPV (Perodua Alza), at impact speed of 48 km/h in accordance to configuration 413 of ISO 13232 standard (Figure 2).

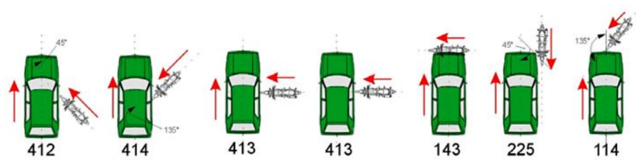

Figure 2 Full-scale crash test configurations as described in ISO 13232 [22]

2.2 Motorcycle Anthropomorphic Test Device

The motorcycle rider was represented by an instrumented motorcycle anthropomorphic test device (MATD) (Figure 3) equipped with standard open-face type helmet (MS1:1996 and MS1065:2001 compliance) and protective clothing. The MATD is a modified Hybrid III, 50th percentile male test dummy. Data acquisition system (DAS) was installed inside the dummy body with 48 multi-channel conditions to assess injury to the head, neck, chest and lower and upper extremities.

Figure 3 MATD [19]

2.3 Airbag

A standard driver's airbag of passenger car was considered for the test due to space and fitment constraint at the mount area. The airbag was mounted onto centre of the motorcycle handlebar. A mechanical contact switch (tape switch) attached to a jig at the front-most part of the motorcycle was used to trigger the airbag upon impact.

2.4 Pre-Crash Equipment Setup

This study did not consider propulsion system to propel the motorcycle during the crash test due to limitation of appropriate facilities. Instead, a trolley system to carry motorcycle to achieve the targeted speed was internally developed for this study. The motorcycle trolley was attached to the side of a sport utility vehicle (SUV), which in this case a Toyota Fortuner 2.7L. Several test runs were performed prior to the crash test in order to achieve tolerable intended test speed. Phantom® high-speed cameras (v9.1 and Miro 3) set at 1,000 fps were used in the crash tests to record kinematics of the motorcycle rider during crash tests. The test speed was recorded via speed sensor of Aries Technology, Inc.™ which can cater to speed of up to 150 km/h.

3.0 RESULTS

3.1 Kinematics Analysis

Analyses of high-speed recordings showed that motorcycle rider experienced different kinematics and impacts to the side of the MPV (Figure 4). For the baseline test, it was observed that the head impacted and penetrated through the vehicle's window while the chest and the abdomen hit the motorcycle's handlebar. As for the test with airbag, the head collided with the roof rail of the MPV and the knee rammed the door panel. The airbag was fully deployed at approximately 35 milliseconds (Figure 5). In both tests, the rear of the motorcycle moved upward as a result of the impact.

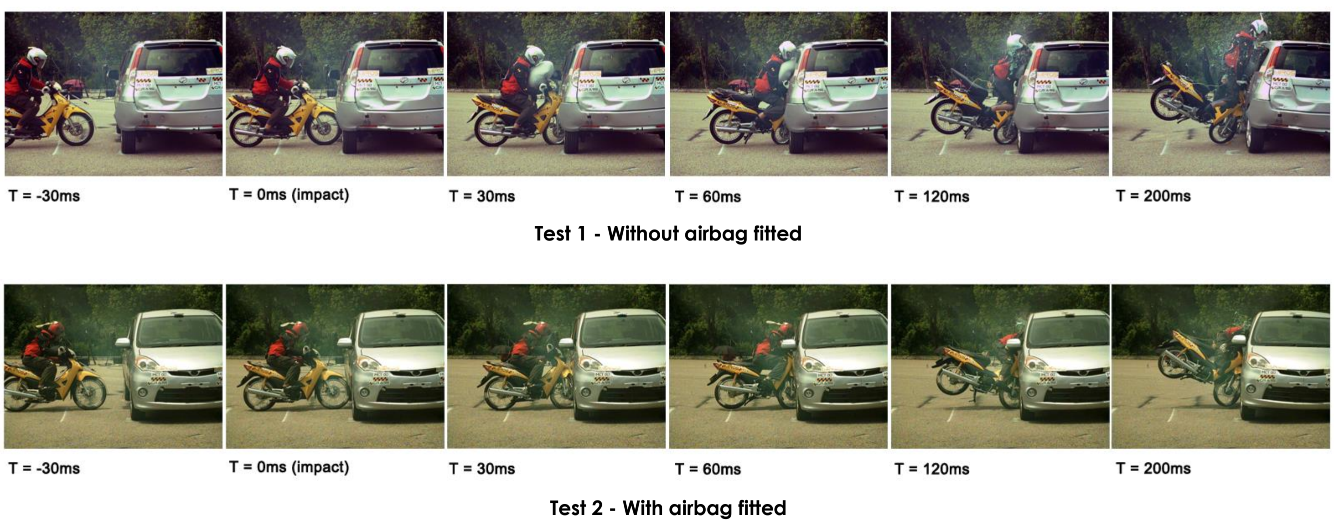

Figure 4 Time sequence of motorcycle crash tests (top: test without airbag fitted; below: test with airbag fitted)

Figure 5 Airbag at full deployment

3.2 Motorcycle Damages

Both motorcycles underwent significant damages after the crash tests. Spokes were torn off from the front wheels and major deformations could be observed on the wheels which had seriously changed shape in both tests. Substantial differences in height, overall length and wheelbase could also be observed for both motorcycles (Table 1).

Table 1 Comparison of measured motorcycle damages

Measurement	Test 1: Without airbag	Test 2: With airbag
Difference in height after crash	65 mm	90 mm
Difference in overall length after crash	695 mm	295 mm
Difference in wheelbase	290 mm	130 mm
Front wheel	Spokes were torn off from the wheel in both tests	
Front fork	Major deformation to the wheel into the shape of number '8' in both tests	

3.3 Motorcyclist Injury

The motorcycle rider was subjected to head injury equivalent to Head Injury Criteria (HIC) value of 104.5 and 881.2 for test without airbag (Test 1) and test with airbag (Test 2), respectively. These however, were still within the HIC threshold value of 1000. The rotational acceleration of the head (Generalized Acceleration Model for Brain Injury Threshold - GAMBIT) was recorded low (0.15) for Test 1, but the value was high (0.91) for Test 2. The Abbreviated Injury Scale (AIS) severity value was recorded serious (AIS 3) for rider's head in the test with airbag while the AIS value was recorded maximum for the rider's chest (AIS 6) in the baseline test as summarized in the Table 2.

Table 2 Comparison of injury results between both crash tests

Body region	Test 1: Without airbag	Test 2: With airbag
Head	HIC 104.5 / 1000 GAMBIT 0.15 / 1.00 AIS 0	HIC 881.2 / 1000 GAMBIT 0.91 / 1.00 AIS 3 (Serious)
Neck	-	-
Chest	AIS 6 (Maximum)	AIS 0
Upper extremities	-	-
Lower extremities	-	-

4.0 DISCUSSION

The use of standard helmet protects the head of the rider from suffering critical injury in the event of an impact, providing a cushion that prevented any direct impact with the side of the MPV. Although the speed of impact was only at 48 km/h, results from the crash test revealed that the helmet impact foam (liner) cracked and the rider was subjected to serious HIC and AIS values. The helmet had undergone a significant impact and shall be replaced. The rider suffered maxillofacial injury (bruises) on the face due to the impact with roof rail of the MPV. This could be prevented had the safety visor hinge not broken and failed upon helmet contact with the MPV. Availability of protective visor mounted to the helmet was not sufficient to prevent injury on the face as visor does not provide optimal safety protection except for wind and rain protection.

In an analysis of the use of airbag on a motorcycle, the crash test indicated that the injury level of the chest was reduced from critical to minor. The deceleration of the chest was significantly reduced as a result of the full deployment of airbag during the collision. However, the fully-inflated airbag was still inadequate to restraint the rider's head from impacting the roof rail of the MPV. This was due to its low volume specifically designed to protect the driver of a passenger car.

In contrast, a rider of a motorcycle without the passive safety device sustained critical injury to the chest caused by huge impact with the motorcycle handlebar and the door panel of the impacted MPV. Thus, further study is needed for more effective airbag design in term of appropriate size, dimension and deployment time for low cc motorcycle. Moreover, the newly design airbag should be capable of absorbing the motorcycle rider's kinetic energy and restraining the rider's head and upper body region during the forward motion, particularly in a right-angled collision. Consequently, reduction of impact force between the rider and the impacted vehicle could be achieved, which could lead to mitigation of injuries. However, it is worth to be noted that the interaction between the airbag and the motorcycle rider would be different due to complexity of the dynamics in a motorcycle crash as well as variations in rider sizes and positions.

5.0 CONCLUSION

The study is an important initiative towards exploring airbag suitability for low cc motorcycle in Malaysia. From the crash tests, it could be suggested that the capability of airbag in term of reducing injury level sustained by rider of "underbone" motorcycle is feasible. Nonetheless, further research is required to gather deeper understanding and better knowledge of the subject matter in order to develop effective motorcycle airbag. Since this class of motorcycles are commonly used in Malaysia and are in increasing trend, provision of such passive safety device could potentially benefit the nation in reducing the number of fatalities and severe injuries in road accidents involving motorcyclist. Lastly, the protection offered by motorcycle airbag is still insufficient without proper wearing of standard helmet and personal protective equipment which have their limits.

Finally, the views expressed in this paper are those of the authors and do not necessarily represent the views or policy of MIROS or any other organization.

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