

Exploratory Study of Airbag for Large Scooter-type Motorcycle

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ABSTRACT

The concept of Honda airbags for a large touring motorcycle is “to reduce the injuries to a rider when impacting with an opposing vehicle and/or opposing object in frontal collisions by absorbing rider kinetic energy and by reducing rider separation velocity from the motorcycle in the forward direction”. In order to verify whether this concept is applicable to a large scooter-type motorcycle, an exploratory study was conducted. First, airbag positioning and supporting structure of the airbag was examined. Then, a prototype airbag system for a large scooter-type motorcycle was produced and tested by utilizing a part of ISO 13232: “Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles”. As a result, it was recognized that an airbag with the same concept as a large touring motorcycle could also be applicable to a large scooter-type motorcycle.

1. Introduction

Honda began its research on motorcycle rider protection in the 1960s⁽¹⁾. Recently, Honda has been researching the feasibility of reducing injuries with a motorcycle mounted airbag system as one of the alternative means of rider protection in the event of a frontal collision. The research results using the GL1500, a large touring motorcycle, was reported at the 16th ESV conference in 1998⁽²⁾ and the 17th ESV conference in 2001⁽³⁾. In these previous investigations, the need for a feasibility study with other types of motorcycles was proposed.

In this research, a large scooter-type motorcycle (hereafter large scooter) was selected, and the applicability of an airbag was studied. Compared to the GL1500 large touring motorcycle, the large scooter had half the weight, step-through-type mainframe and smaller wheels. Using the airbag system established in the previous study with a large touring motorcycle, the preliminary study of an impact sensing system and the installation of an airbag considering a

large scooter structure was conducted, and then a prototype large scooter with an airbag system was fabricated.

The basic evaluation criterion of this study was how much the airbag absorbed rider kinetic energy in the event of a frontal collision. Though the evaluation procedures of this study were based in part on ISO 13232: “Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles”⁽⁴⁾, the evaluation concept was different from that of ISO 13232. The concept of ISO 13232 is to verify the injury reducing effects of a protective device by comparing the results of vehicles with and without rider protective devices. In this study, comparison tests of a large scooter with and without an airbag were not conducted. Also, test configurations that were not relevant to airbags in frontal collisions were not conducted.

The prototype large scooter was evaluated in four collision configurations. Three out of the four were selected from the seven test configurations provided by ISO 13232. The other one was developed by Honda.

In these previous investigations, the need for studies with other types of collisions was proposed. One of those studies

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was a collision configuration in which the front wheel does not hit the opposing subject first (hereafter called an under-ride collision).

This paper provides an outline of an airbag system for a large scooter and the results of the full-scale collision tests.

2. Investigation of Impact Sensing System

The impact sensing system on the large touring motorcycle used the acceleration data of the front fork near the front axle (hereafter front axle G). One issue for the large scooter was whether this same sensing system was also applicable to it. In order to establish a method to give a trigger signal for an airbag deployment, a series of tests, including circumstances in which the airbag must not deploy, were conducted, and the front axle G were recorded during these tests.

2.1. Collision Condition of “Must Deploy”

This airbag system for the large scooter is intended “To activate in the event of a frontal collision when the rider separates from the motorcycle in the forward direction”. In order to investigate collision conditions to cause the forward separation of riders, actual collision tests were conducted. The 1998 to 2001 Japanese Model Honda Accord four-door sedan, was selected as the opposing vehicle. The major specifications are shown in Table 1. A Hybrid II AM50th percentile pedestrian type dummy was used.

Table 2 shows the test results. In the case of a collision against both the front and side of the opposing vehicle, the criteria for collision conditions were determined to be that the airbag “must deploy” at speeds of 30 km/h and higher.

Table 1 Opposing vehicle (Honda Accord) specifications

Length	(m)	4.635
Width	(m)	1.695
Height	(m)	1.420
Wheel base	(m)	2.665
Mass	(kg)	1 300
Displacement	(cm ³)	1 997

Table 2 Collision test results for operational setting

Impact conditions		Dummy motion	Deploy or not
Accord front	20 (km/h)	No separation from MC	Not necessary
	25 (km/h)	No separation from MC	Not necessary
	30 (km/h)	Just before separation from MC	Necessary
Accord side	25 (km/h)	No separation from MC	Not necessary
	30 (km/h)	Just before separation from MC	Necessary
	35 (km/h)	Separated from MC	Necessary

MC: Motorcycle

2.2. Collision Condition of “Must Not Deploy”

Except for special conditions in which continuing to ride is impossible, the airbag system “must not deploy” under defined road conditions such as rough road or irregularities

during operation. In order to examine the effect of road impact on riding continuity and to monitor the front axle G data, the curb over ride test was conducted as shown in Fig. 1.

The wrists of the dummy were modified to be detached by specified tension in excess of that called for in ISO 13232 and were fixed on the handlebar grips.

The resulting dummy condition and driving continuity are shown in Table 3. The front axle G data was measured and collected. The conditions of the dummy and the motorcycle in this test are shown in Fig. 2. From the test results, when at least one hand remained on the handlebar, it was decided that riding can be continued and an airbag system “must not deploy.”

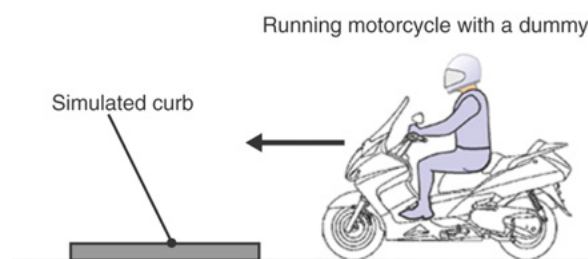


Fig. 1 Simulated curb ride over test

Table 3 Simulated curb ride over test results

Running condition	Dummy conditions /Continuous ride possibility	Deployment
A	No hands separation, possible	Not allowed
B	Single hand detached, critical	Not allowed
C	Hand detached, not possible	Allowed



Fig. 2 Motorcycle and dummy in simulated curb ride over test

2.3. Method to Determine the Operation Status

The logic of the method is “to start integration upon exceeding a certain acceleration value” and then “to activate air bag deployment when the integrated value reaches a given level (hereafter referred to as the threshold)”. The certain acceleration value and the threshold were both examined using front axle G data from crash tests described in section 2.1, and curb ride over tests described in section 2.2. As a

result of the appropriate selection of the two values, the method to determine the operation status was obtained as shown in Fig. 3. Figure 4 shows the sensing decision flow.

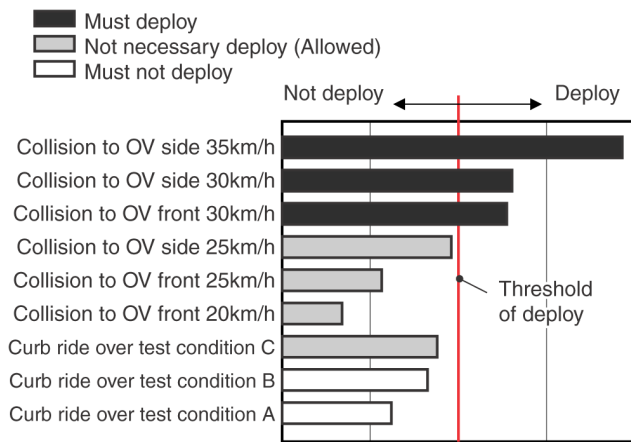


Fig. 3 Decision of deployment by integrated impact deceleration

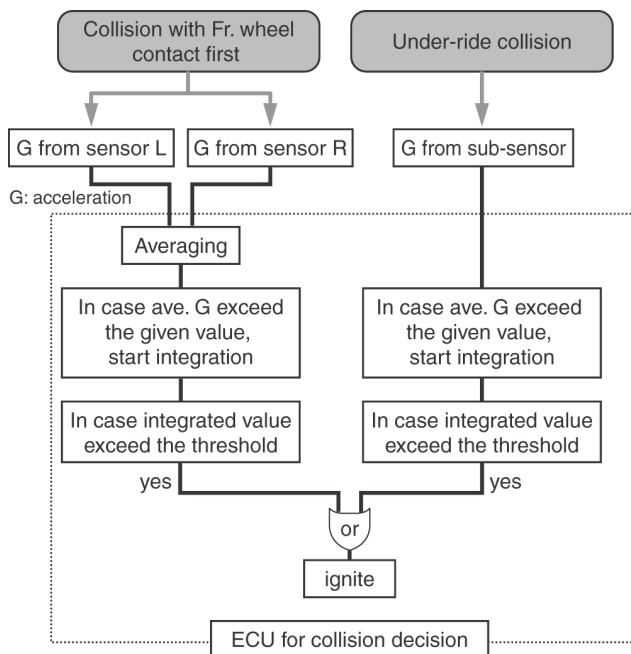


Fig. 4 Decision flow for deployment

3. Outline of a Large Scooter with a Prototype Airbag System

3.1. Overall Structure

Table 4 shows the specifications of a large scooter, a Silver Wing, which was selected as the test subject for this airbag feasibility study, and it has a different design from that of the large touring motorcycle, the GL1500. Figure 5 shows the large scooter with the prototype airbag.

Table 4 Large scooter (Silver Wing) specifications

Length	(m)	2.275
Width	(m)	0.070
Height	(m)	1.430
Wheel base	(m)	1.595
Mass	(kg)	224
Displacement	(cm ³)	582



Fig. 5 Large scooter with prototype airbag system

3.2. Airbag and Inflator

Knowledge gained from the study of an airbag for a large touring motorcycle was reflected in the prototype airbag specifications, such as the size of the airbag, the rear V-shaped airbag panel and the straps connecting the airbag to the frame. Figure 6 shows a prototype airbag system for a large scooter. The deployed volume of the airbag is approximately 150 liters. Deployment characteristics were verified through static deployment tests. This airbag needs about 40 msec to deploy. Airbag performance of rider kinetic energy absorption was proved to be equivalent to the airbag performance for a large touring motorcycle, GL1500, through sled tests.



Fig. 6 Prototype airbag system for large scooter

4. Full-scale Collision Tests

4.1. Test Procedure

The question “whether a similar airbag system that was mounted and studied on a large touring motorcycle can show the same kinetic energy absorbing performance for a large scooter” was evaluated through full-scale collision tests. The airbag system was evaluated in six collision configurations. Five were selected out of the seven collision configurations of full-scale tests provided by ISO 13232. A sixth was added by Honda. However, only four collision configuration tests were conducted, because the airbag effects in two collision configurations were estimated from the other test results as described in section 5.

Figure 7 shows the notation system of the collision configurations based on ISO 13232. Figure 8 shows the collision configurations for the evaluation. Here, a mark of “*” represents the ISO configuration, and a mark of “**” represents the Honda configuration, and a mark of “***” represents the configuration not tested. The collision speed (indicated by km/h) was set to be a little faster than indicated in ISO.

The ISO/CD 13232 (under discussion in ISO/TC22/SC22)-MATD (Motorcyclist Anthropometric Test Device) dummy was used for the full-scale collision tests. The 1998 to 2001 Japanese Model Honda Accord four-door sedan (shown in Table 1) was used as the opposing vehicle. Table 5 shows the measuring items on collision tests.

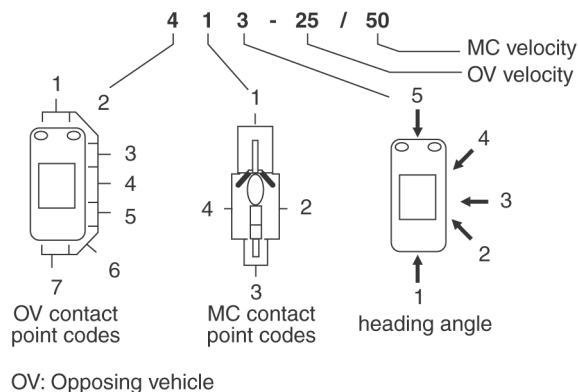


Fig. 7 Indication of impact configuration (ISO13232)

Table 5 Measuring items on collision tests

Head	Head maximum GAMBIT Head injury criterion (HIC)
Neck	Neck injury index (NII)
Chest	Sternum maximum normalized compression (C) Sternum maximum velocity-compression (VC)
Abdomen	Abdomen maximum residual penetration (pA)
Lower extremities	Damage of frangible component of lower extremities (IE)

4.2. Results of Full-scale Collision Tests

4.2.1. Determination of impact sensing system

Figure 9 shows the results of the impact sensing system for the four configurations of full-scale tests. In this figure, TTF (Time to fire) represents the time between the first contact of the large scooter and the opposing vehicle and the time of collision determination by the sensing system, deployment time represents the time for the airbag deploying, and rider encounter time represents the time between the first contact and the rider reaching the deployed airbag. In all four configurations, the airbag was fully deployed before the dummy reached the deployed airbag surface area.

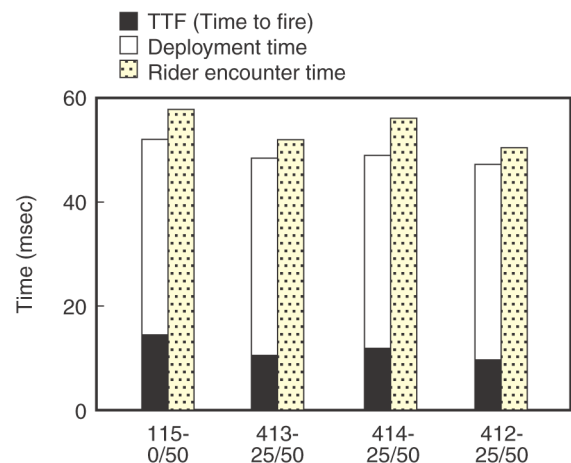


Fig. 9 Comparison of airbag deployment time and rider encounter time

* Evaluated configurations for front collision airbag in ISO13232

** Configurations Honda added

*** Configurations perceived not necessary

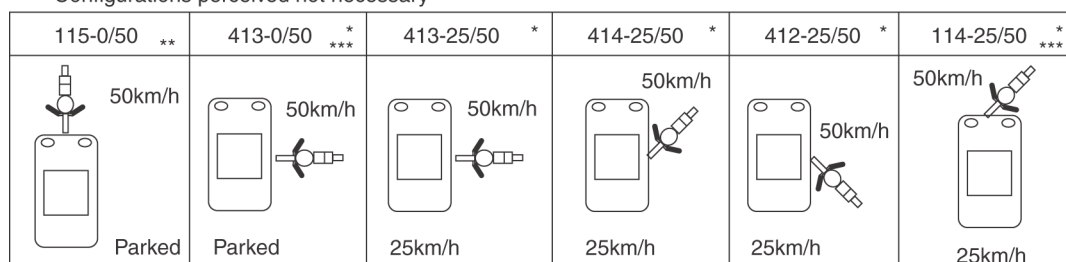


Fig. 8 Impact configurations for evaluation

4.2.2. Injury evaluation for each collision configuration

In the full-scale collision tests, the injury assessment values shown in Table 5 were evaluated using MATD dummy and injury evaluations defined in ISO/CD 13232.

Figure 10 shows the injury evaluation of each relevant area obtained from measured data of the dummy for the four test configurations. The primary impact injury in the figure represents the maximum injury value within 500 msec from the beginning of the collision. The secondary impact injury represents the maximum injury value after 500 msec, which most likely is the dummy's contact with the ground.

Figure 11 shows the condition of the large scooter and the dummy in the [115-0/50]-collision configuration. In this configuration, even though the motorcycle showed a significant vertical pitching motion, the airbag absorbed the kinetic energy of the dummy without forward separation. The primary impact injuries show that HIC = 15.4, GAMBIT = 0.08 and Chest deflection = 25 mm. Serious injury values were not observed.

Figure 12 shows the motion of the large scooter and the dummy in the [413-25/50]-collision configuration. Although the large scooter showed yawing motion after the initial impact, the airbag absorbed the kinetic energy of the dummy and prevented the contact of the dummy with the opposing vehicle. The primary impact injuries show that HIC = 28, GAMBIT = 0.1 and Chest deflection = 15 mm. Serious injury values were not observed.

Figure 13 shows the motion of the large scooter and the dummy in the [414-25/50]-collision configuration. The large scooter showed yawing motion after the collision. The different direction of movement of the dummy and the large scooter decreased the absorbing effect of the airbag. The dummy separated from the large scooter scraping the C-pillar of the opposing vehicle and contacted the ground. The primary impact injury caused by the impact between the dummy's head and the opposing vehicle showed that HIC =



Fig. 11 Dummy and motorcycle in configuration [115-0/50]

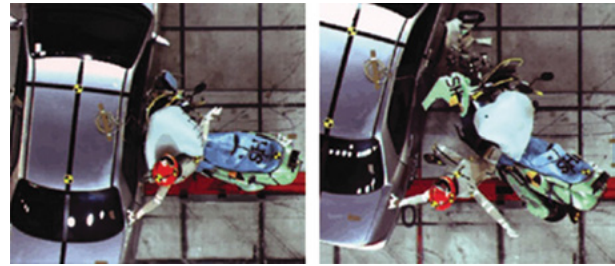


Fig. 12 Dummy and motorcycle in configuration [413-25/50]

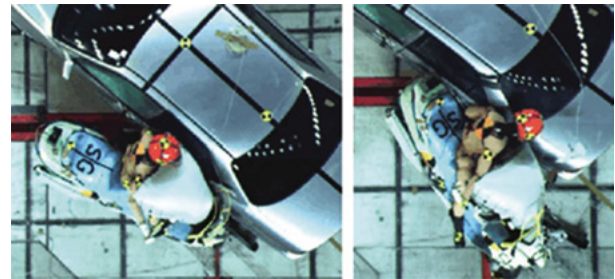


Fig. 13 Dummy and motorcycle in configuration [414-25/50]

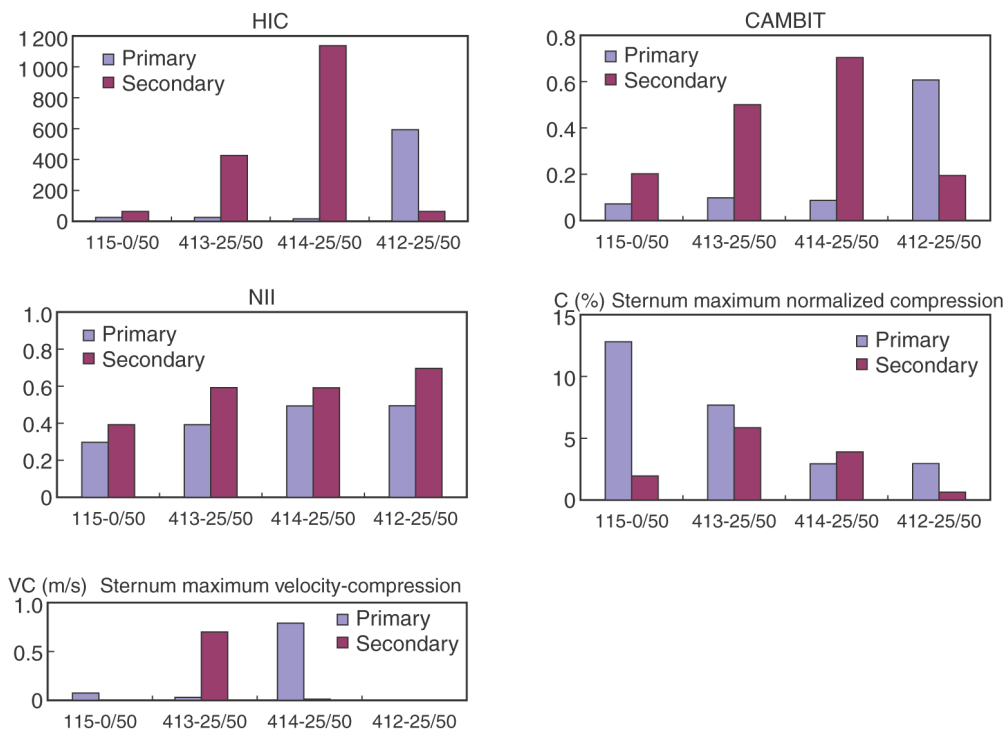


Fig. 10 Measured dummy injuries in collision tests

14 and GAMBIT = 0.09. Serious injury values were not observed. But for the secondary impact sequence, significant dummy injury was caused by ground impact, and injury evaluation values of HIC = 1138 and GAMBIT = 0.73 were observed. It was important to investigate whether or not the airbag contributed to these serious injury values. As shown in Fig. 14, the scenario of this serious injury was different from the harmful phenomenon of the head's first contact with the ground in the previous investigation by Iijima et al (1998) for the large touring motorcycle.

Figure 15 shows the motion of the large scooter and the dummy in the [412-25/50]-collision configuration. The large scooter started yawing just after the collision. The large scooter and the dummy moved in different directions. The dummy barely contacted the airbag and the dummy's head contacted the roof-edge of the opposing vehicle. But injury evaluation value showed that HIC = 600 and GAMBIT = 0.6, so the injury likelihood was low. It was determined the airbag did not contribute to the serious injury measured during the ground contact.



Fig. 14 Dummy contact ground in configuration [414-25/50]



Fig. 15 Dummy and motorcycle in configuration [412-25/50]

Except for the case of ground impact in [414-25/50]-collision configuration, serious injury values were not measured in the four test configurations throughout all measured events including contact with the airbag, contact with the opposing vehicle and contact with the ground.

5. Rider Kinetic Energy Absorbing Performance of Airbag

The energy absorbing performance of the airbag was evaluated under the concept of the following goal:

“To reduce the injuries to a rider when impacting with an opposing vehicle and/ or opposing object in frontal collisions by absorbing rider kinetic energy and by reducing rider separation velocity from the large scooter in the forward direction”.

From this viewpoint, the energy absorbing effect was evaluated in six collision configurations. Five were configurations of frontal collision specified in ISO 13232. The remaining configuration was uniquely examined by Honda. The effects of the airbag were classified as follows:

- Effective: The airbag effectively absorbs the kinetic energy of the dummy's upper body so that contact against the opposing vehicle does not occur.
- Slightly effective: The airbag absorbs some kinetic energy of the dummy's upper body so that only some contact against the opposing vehicle occurs.
- Not effective: The airbag does not absorb any kinetic energy of the dummy's upper body such that contact against the opposing vehicle occurs without sufficient impact reduction.

The energy absorption performance was decided from measured chest deflection data and the degree of contact between the dummy and the airbag observed in video review. The occurrence of contact of the dummy's upper body against the opposing vehicle was judged by contact marks, video review and the recorded acceleration of the dummy's head.

Table 6 shows the result. The full-scale collision test of [413-0/50] and [114-25/50] were not conducted and the absorption performance of the airbag was estimated by the following logic.

The yawing motion of the motorcycle affected the absorbing energy performance of the air bag. Greater yaw-motion caused lower absorbing performance of the airbag. As shown in Fig. 16, the magnitude of the yawing motion of a large touring motorcycle during the effective time period of airbag energy absorption in 6 configurations were ranked as [115-0/48] (=) [413-0/48] < [413-24/48] < [414-24/48] < [412-24/48] < [114-24/48].

Also as shown in Fig. 17, the magnitude of yawing motions of a large scooter were ranked as [413-25/50] < [414-25/50] < [412-25/50]. So in these three configurations,

Table 6 Rider kinetic energy absorbing effectiveness of airbag

	115-0/50	413-0/50	413-25/50	414-25/50	412-25/50	114-25/50
Large scooter (Silver Wing)	Effective	Effective*	Effective	Slightly effective	Not effective	Not effective*
Large motorcycle (GL1500)	Effective	Effective	Effective	Effective	Effective	Slightly effective

* Estimated result

the yawing trend of a large scooter is the same as a large touring motorcycle. From these results, it can be concluded that both motorcycle types had the same trend of yaw motion in the six collision configurations used for evaluation. Therefore in the collision of a large scooter, it was determined to be reasonable that the yawing motion of [413-0/50], which was not tested, should be smaller than that of [413-25/50], and the yawing motion of [114-25/50], which was also not tested, should be larger than that of [412-25/50]. Therefore, [413-0/50] with smaller yawing than [413-25/50] was expected to show a larger absorbing effect than [413-25/50]. That meant “Effective” because the judgment of [413-25/50] was “Effective.” In the same way, [114-25/50], in which yawing is larger than [412-25/50], was expected to be “Not effective” because [412-25/50] was “Not effective.”

As shown in Table 6, the airbag on a large scooter scored 3 “Effective” configurations, 1 “Slightly effective” configuration and 2 “Not effective” configurations out of the 6 collision configurations. On the other hand, a large touring motorcycle scored 5 “Effective” configurations, 1 “Slightly effective” configuration and zero “Not effective” configurations. Although the airbag energy absorbing effect for a large scooter was limited and smaller compared to that of a large touring motorcycle, the concept to absorb rider kinetic energy and to reduce rider separation velocity with an airbag attached to a motorcycle was observed to potentially be applicable to a large scooter.

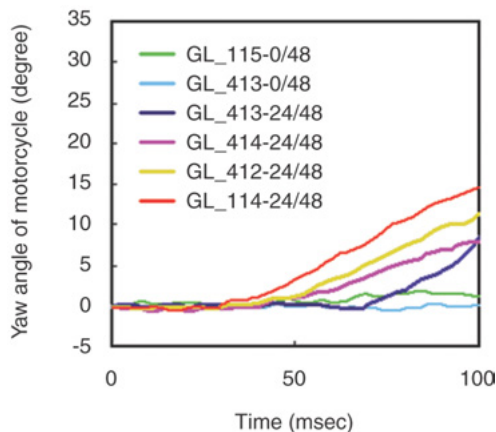


Fig. 16 Yaw motion of large touring motorcycle

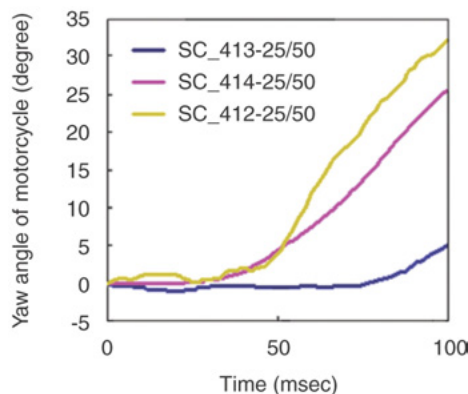


Fig. 17 Yaw motion of large scooter

6. Examination of Under-ride Collision

A collision pattern where the front wheel does not collide first (hereafter under-ride collision) is a potential collision scenario. This pattern occurs, for example, when a large scooter collides with a truck trailer. In this collision, the space between the rider and the opposing object surface (hereafter rider protective space) can be too small for the timing to begin deployment by the impact sensing system using front axle G. As shown in Fig. 18, the following three events are evaluated to be the cause of this:

- (1) The front upper portion of the large scooter behind the front end of the front wheel collides first. So the rider protective space becomes smaller than that of the direct front wheel collision.
- (2) The collision impact is transmitted from the impacted front upper portion to the front axle via the mainframe and the steering system structure affecting the timing of deployment.
- (3) The large scooter has a step-through-type mainframe that results in greater bending due to external front forces as compared with conventional motorcycles.

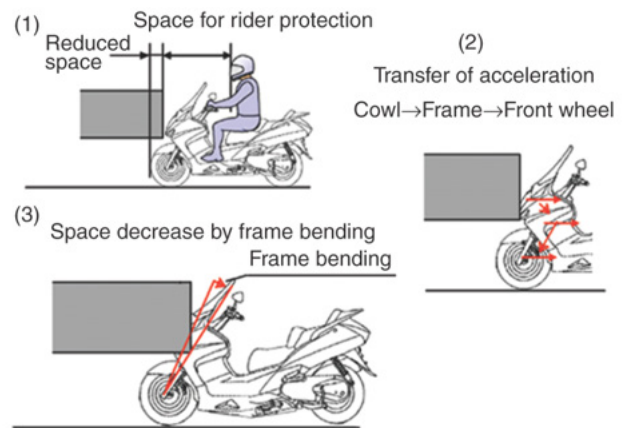


Fig. 18 Cause of protection space reduction in under-ride collision

6.1. Verification of Characteristics of a Baseline Scooter

Tests for the under-ride collision were carried out with a baseline scooter. The tested scooter collided with a stationary trolley that applied the parking brake at 50 km/h. The sensing system timing, the motion of the scooter and the dummy were recorded. The trolley used is shown in Fig. 19. A Hybrid II AM50th percentile pedestrian type dummy was used.

Figure 20 shows the conditions of the dummy and the tested scooter at the beginning of the collision ($t = 0$ msec); the completion point of the collision determination by the sensing system (23 msec); the theoretical completion of the airbag deployment (63 msec), and the dummy contacting with the surface of the opposing object (82 msec).

These results show that the impact sensing system that

was used from the study of an airbag system for a large touring motorcycle did not adequately function for the large scooter. Thus, additional research was required.

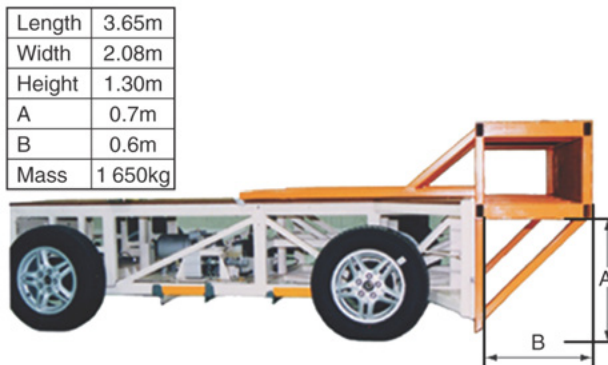


Fig. 19 Opposing trolley used in under-ride collision test

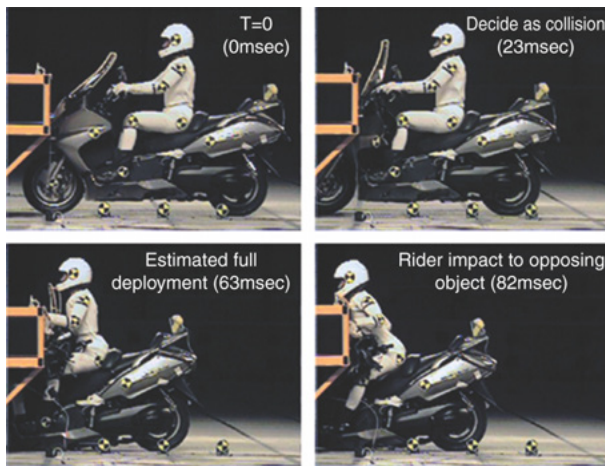


Fig. 20 Dummy and motorcycle in under-ride collision without airbag

6.2. Conceivable Methods for Further Development

The following three methods and their combinations were proposed for further development of the air bag system.

- (1) To strengthen the front upper frame member against a collision. This would help reduce the loss of the rider's protective space and simultaneously increase the impact acceleration of the scooter body and front axle. This would lead to a quicker determination for deployment.
- (2) To install an additional sensor on the front upper portion of the scooter body in order to advance the deployment determination timing.
- (3) To strengthen the mainframe in order to help prevent the reduction of the rider protective space due to mainframe bending.

Those elements were examined by utilizing computer simulation.

6.3. Examination of Improvement Methods by Computer Simulation

Honda had proposed a need for computer simulation technology to estimate injury level of the dummy, prior to ground contact. That was presented in "Exploratory Study of Airbag Concept for a large Touring Motorcycle" unveiled at the 16th ESV Meeting in 1998⁽²⁾. As unveiled at the SETC conference in 2003⁽⁵⁾, Honda introduced computer simulation technology that allowed for the precise estimation of the dummy's motion in the event of a collision. By using this technology, the proposed elements were examined.

First, the above mentioned under-ride collision with the baseline scooter was simulated by computer. Figures 21 and 22 show the comparison of vehicle deformation and mainframe acceleration between an actual test and a simulation.

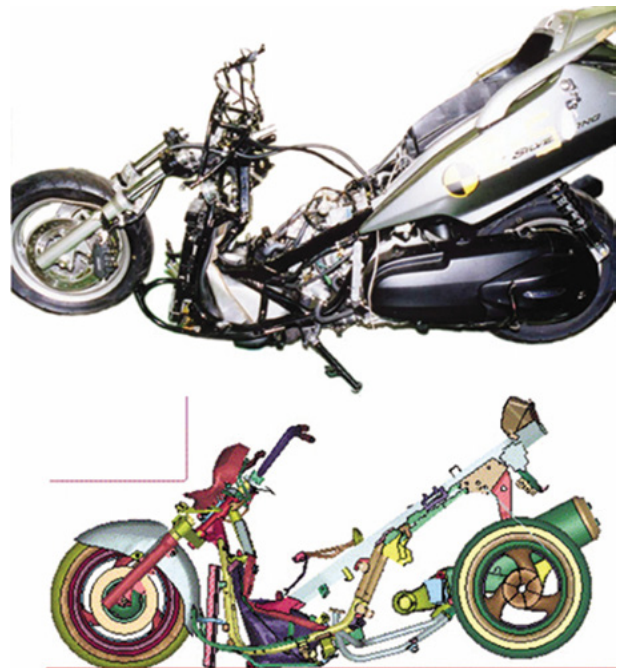


Fig. 21 Comparison of frame damage result between full scale test (FST) and computer simulation (CS)

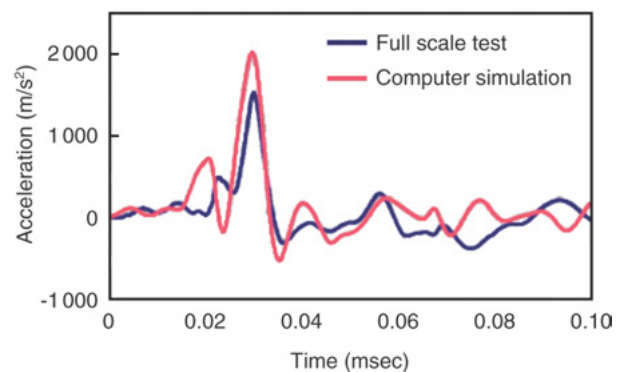


Fig. 22 Comparison of acceleration on frame between full scale test (FST) and computer simulation (CS)

6.4. Examination Result of Improvement Elements by Computer Simulation

The investigation with computer simulation provided output including the collision determination timing of the sensing system, rider protective space, and injury level of the rider's head, chest and so on with a deployed airbag. Through the examination of outputs, two practical countermeasures were proposed to achieve rider protection. One was to strengthen the cowl stay and the other was to attach a sub-sensor on the cowl stay. Figure 23 shows the modifications. Figure 24 shows the simulation results for the modified model. The determination flow for airbag deployment by the sensing system with the added sub-sensor is shown in Fig. 4.

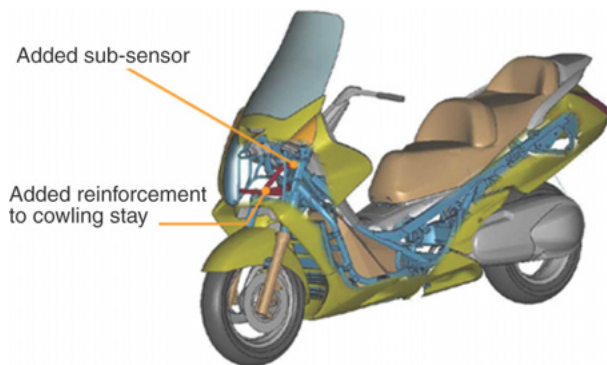


Fig. 23 Modification for under-ride collision analyzed by computer simulation

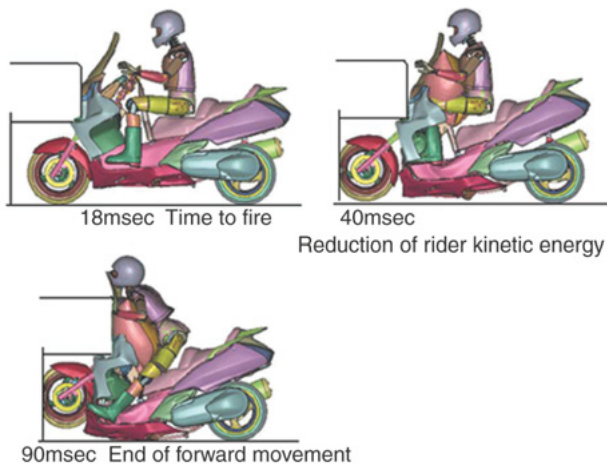


Fig. 24 Dummy and motorcycle movement with modification

6.5. Results of Under-ride Collision Test of Modified System for Large Scooter

The large scooter under-ride test was conducted with the modified airbag system. A Hybrid III AM50th percentile pedestrian type dummy was used and the measurement of the injury data as described in Table 7. Other test conditions were the same as the baseline scooter under-ride collision test mentioned at section 6.1.

The results were as follows.

Decision for deployment was made by the signal of the sub-sensor that came earlier than the signal of the main-sensor.

As shown in Fig. 25, the dummy encountered the airbag still deploying in this configuration. The primary impact injuries show that $HIC = 221$, neck tension = 45 Nm and chest deflection = 56 mm. Serious injury values were not observed.

It was confirmed that the airbag for a large scooter can maintain its protective capability for riders in an under ride collision.

Table 7 Measuring items on under-ride collision test

Head	Head injury criterion (HIC)
Neck	Tension, compression, flexion, extension
Chest	Chest deflection

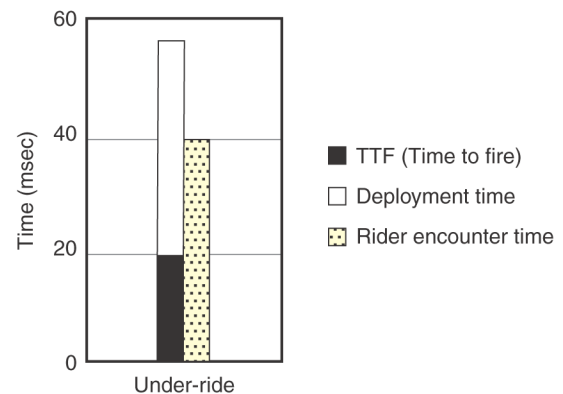


Fig. 25 Comparison of airbag deployment time and rider encounter time in under-ride condition



Fig. 26 Dummy and motorcycle in under-ride collision configuration

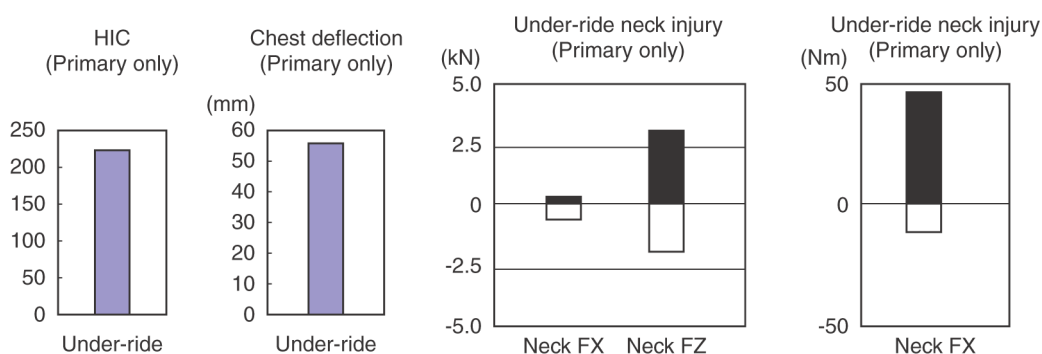


Fig. 27 Measured dummy injuries in under-ride collisions

7. Conclusion

- (1) By detecting and calculating the impact acceleration of the front fork near the front axle, a large scooter sensing system:
 - could properly determine operation status representing collision/ non collision conditions, and
 - could properly deploy the airbag before the rider has reached the deployed area in four cases of collision configuration with an Accord at the speed of 50 km/h.
- (2) Although the absorption performance of an airbag system fitted to a large scooter was limited to fewer collision configurations as compared to the large touring motorcycle, the concept of absorbing rider kinetic energy and reducing rider separation velocity with an airbag might be feasible for a large scooter.
- (3) For an under-ride collision, the air bag for a large scooter might maintain a protective effect for riders if the large scooter has a sub-sensor on the front upper portion and a main sensor at the front fork near the front axle.
- (4) Computer simulation proved to be effective for the examination of the crash characteristics of the motorcycle and for the investigation of modifications to the sensing system.

8. Future Issues

It has been proven through this study that an airbag may be effective when applied to a large scooter. Additional research needs to be done. The following items are listed as future issues: verification of applicability to other types of motorcycles; verification of effectiveness with different postures or sizes of a rider; risk-benefit analysis based on full-scale collision tests defined by ISO/CD 13232; and, injury evaluation until the rider contacts the ground through the use of computer simulation.

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