EXPLORATORY STUDY OF AN AIRBAG CONCEPT FOR A LARGE TOURING MOTORCYCLE : FURTHER RESEARCH SECOND REPORT

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ABSTRACT

Honda has been conducting feasibility research for airbags mounted on a motorcycle. The concept of this airbag system 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 motorcycle in the forward direction." The study was reported to the 16th ESV Conference in 1998 and the 17th ESV conference in 2001. However, the assessment of injury level using dummies was tentative, as the assessment method on the neck was not firmly established in ISO 13232.

Reporting is made this time on the results of 12 cases of full scale impact tests in seven configurations based on ISO/CD 13232, which established the assessment method of injury to the neck, and on the results of computer simulation of 200 configurations, which calculate the process of dummies falling down to the ground.

The base motorcycle on which the prototype airbag system was mounted for this study, the GL1800, is a model which succeeded the large touring motorcycle, GL1500, used in the previous studies.

Furthermore, to grasp the effectiveness of an airbag in reducing injury potential, while minimizing the potential for inflicting injury, in addition to the assessment tests specified in ISO/CD 13232, full scale impact tests of other configurations and other rider conditions, as well as sled tests were conducted.

It was judged from the results obtained that an airbag system for a large touring motorcycle is feasible.

INTRODUCTION

Honda has been engaged in research aimed at enhancing protection of motorcycle riders since the 1960s [1]. In recent years, a study designed to evaluate the possibility of installing airbags on motorcycles as a means of enhancing motorcycle rider protection during frontal collisions has been conducted. The concept 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 motorcycle in the forward direction". The research for the airbag system for motorcycles has been conducted heretofore in the manner as outlined below:

A prototype airbag system including a sensor system was mounted on a large touring motorcycle, GL1500, and evaluated based on ISO 13232 - Test and Analysis Procedures for Research Evaluation of Rider Crash Protective Devices Fitted to Motorcycles [2]. As the result of a series of impact tests using actual motorcycles (hereinafter referred to as full scale impact tests) and computer simulation, the possibility of an increase in injury potential was noted in some impact configurations, while the overall effect of rider injury reduction seemed likely [3](ESV paper in 1998).

An effort was made to establish a solution for the apprehended phenomenon of increase in injury, that is, the injury on the neck at dummy/ground contact influenced by the airbag. Enlarging the airbag minimized the concern [4] (ESV paper in 2001).

Because many of the differences in injuries with or without the airbags occurred at dummy/ground contact, computer simulation technology was desired to cover that area. As a result of addressing this issue, a simulation technology was developed, which will reproduce with high precision motion at dummy/ground contact [5] (SETC paper, 2003).

As a link between these research projects, full scale impact tests were carried out with a prototype airbag system on a large scooter type motorcycle which uses a different frame design than the large touring motorcycle, using part of ISO 13232. It was judged that an airbag employing the same design concepts as that for large touring motorcycles was potentially feasible for use in the large scooter type motorcycles[6] (IFZ paper, 2004).

While these research projects pertaining to the feasibility of using airbags on motorcycles were being conducted, the method of assessing the level of injury on the neck, which had not been established previously, was established by ISO/CD 13232. Additionally, a simulation technology was obtained by Honda, which enabled researchers to assess the level of injury sustained at the time of dummy/ground contact. These advances enabled researchers to more comprehensively evaluate rider protective devices.

This report will present a series of results from the evaluation of the airbag system for motorcycles, based on the established evaluation methods. For the base motorcycle to mount the airbag, the GL1800 was used, which succeeded the large touring model GL1500 used in the previous research. To further clarify the injury reduction effectiveness as well as the reduction of airbag induced injuries, tests were conducted employing other impact configurations and other rider conditions, in addition to the assessment tests specified in ISO/CD 13232.

CONCEPT OF HONDA AIRBAGS FOR LARGE TOURING MOTORCYCLES

The results of an analysis of fatal accidents to motorcycle riders in Japan are shown in Fig.1[7]. These results indicate that:

- fatal injuries occur mostly (i.e.. 64 percent) during motorcycle frontal impacts;
- most rider injuries (i.e.. 87 percent) are receiving by impacting against objects other than the motorcycle;
- the most frequently and severely injured body region(i.e.. 87 percent) lies in the upper half of the body.

Based on the accident data, a typical fatal accident scenario involves: an impact at the front of the motorcycle, the rider being ejected from the motorcycle, the rider striking an opposing vehicle or ground and receiving a fatal injury to the upper half of the body. From this information, a concept involving non-ejection or energy reduction of the rider was conceived. Subsequently, Honda studied a motorcycle mounted airbag as one implementation of this concept. The concept of Honda's airbag for motorcycles 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 motorcycle in the forward direction".

Additional factors were also considered, including the following, based on past research:

- The airbag position and horizontal forces being supported by the motorcycle itself (eg, even in front to front impacts with passenger cars the airbag should function without the airbag needing to be in contact with the opposing vehicle)
- Maintaining airbag effectiveness as much as possible during various motorcycle crash motions, especially the yaw, pitch and roll motions which tend to occur during motorcycle collisions.

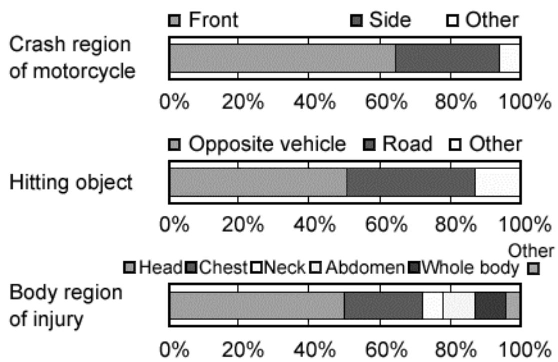


Figure 1. Fatalities of motorcycle accidents in Japan.

TEST MOTORCYCLES MOUNTED WITH PROTOTYPE AIRBAG SYSTEM

Figure 2 shows a test motorcycle equipped with a prototype airbag system. The major specifications of the test motorcycle, the GL 1800, equipped with a prototype airbag system are shown in Table 1: The model has the following features similar to GL1500:

- Having upright riding position, there is a space in front of the rider to deploy an airbag.
- With a low center of gravity and large mass, the motorcycle body will have less pitching and yawing during impact.
- Because the large fairing may receive the collision impact at a higher position than the height of the center of gravity, the body pitching of motorcycle will be lessened during impact.

Figure 3 shows the deployed airbag and Table 2 shows the specifications for the airbag and inflator. The airbag and retainer box were re-designed for the GL 1800 base motorcycle. The results of previous research are reflected in the airbag design; such as a large volume, overall shape well contrived, the shape of the back of bag, which will hold the rider and the support belt connected from the back of bag to the frame of motorcycle. The time required for the deployment of the airbag is approximately 45msec.

A sensor system will judge whether to actuate or not in accordance with the logic shown in Fig. 4 based on the extent of deceleration in the vicinity of the front wheel axis (hereinafter referred to as the deceleration of the front wheel system).

SETTING UP SENSOR SYSTEM

The judgment of whether to deploy or not of the airbag system will be based on the following conditions:

- Deploy in frontal collisions in which rider ejection from the motorcycle is likely.
- Not to deploy as a result of impacts received during typical riding and handling conditions, including operating over rough roads.

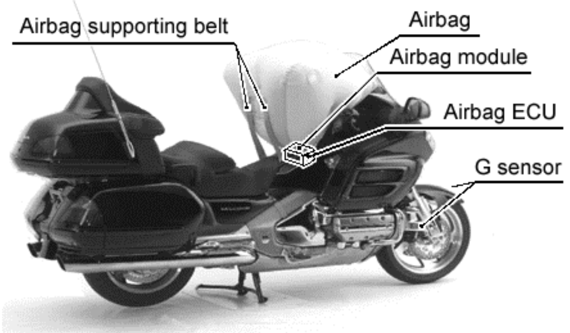


Figure 2. Prototype airbag system installed on the GL 1800 motorcycle.

Table 1.
Specifications of test motorcycle

Manufacturer	Honda
Model	GL1800
Year	2000-2003
Mass (empty, as tested, no airbag)	367 kg (average)
Mass (empty, as tested with airbag)	375 kg (average)
Length, overall	2635 mm
Width, overall	945 mm
Height, overall	1455 mm
Wheelbase	1690 mm
Type	Touring

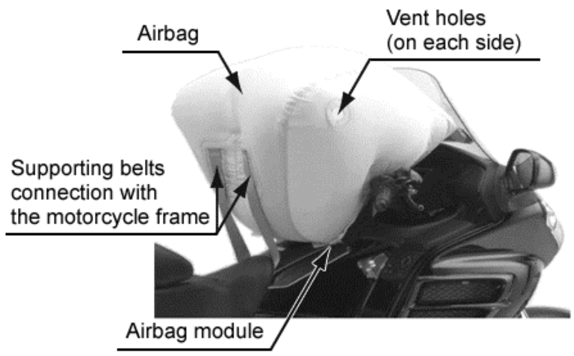


Figure 3. Prototype airbag.

Table 2.
Specifications of prototype airbag

Volume	157 liter (net, inflated)
Height (from the seat) x width x length	750 mm x 720 mm x 640 mm
Vent holes	2 x 45 mm diameter
Rear shape	Forms a concave "V"
Bag mounting	1) to module box 2) to motorcycle frame beneath the seat, via 2 connecting belts
Infrator	Pyrotecnic; Passenger car type; 495 kPa

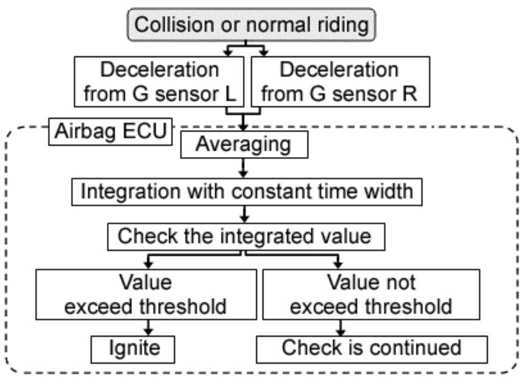


Figure 4. Decision flow for deployment.

Grasping Conditions of Collision to Deploy Airbag

To grasp the conditions of frontal collisions which will cause the forward separation of rider from the motorcycle, impact tests were carried out using the base motorcycle. For the opposing vehicle in the impact testing, the Honda Accord 4-door, 1998~2001 model, of Japanese specifications as shown in Table 3 was used. For the rider dummy, ISO/CD 13232 motorcyclist anthropometric test device (MATD) was used. The impact configurations and test results are shown in Table 4. The forward separation of the dummy occurred at the impact speed of 35km/h, and did not occur at the impact speeds of 25 and 30km/h in both impact configurations to the front and side of opposing vehicle. It was judged from these results that the airbags should deploy at an impact speed of over 35km/h in a frontal impact. The extent of deceleration of the sensor unit was measured in the testing for use as the base data for developing the collision judge logic and the setting of the threshold value as described later.

Grasping Deceleration of Sensor Unit Under Conditions Not to Deploy Airbag

No airbag should deploy during typical running and normal handling, including travel over rough roads, except in the case of an accident. To simulaterunning conditions in which the airbag should not deploy, tests were conducted on running over steps, traveling on roads with depressions, running on rough roads, as well as while performing a “wheelie”. To simulate handling conditions in which the airbag should not deploy, tests were carried out assuming a fall from the platform of a truck while engaged in cargo handling operations and when the front fork receives an impact from an external force. The deceleration of the sensor unit occurring when tested under this variety of running and handling conditions, where the system should not be deployed was measured and used as the base data for creating the collision judge logic and threshold value.

Setting Up Collision Judge Logic and Threshold Value

Collision judge logic and the threshold value for the decision of deployment were decided after studying the data of deceleration of sensor unit, which were grasped from the results of tests under impact conditions to deploy and the conditions of running and handling not to deploy. Figure 5 shows the judgment performance of deployment or no-deployment. The figure shows the ratio of "Threshold value, specified computation value to judge to deploy" over "The maximum computed values for the cases of deployment or no-deployment ". As shown in the figure, a judgment system was obtained, which will deploy in frontal impacts requiring the deployment of an airbag, but not as the result of expected impacts occurring in normal running and handling.

Table 3.
Specifications of Opposing Vehicle

Manufacturer	Honda
Model	Accord, Japan
Year	1998 -2001
Mass	1300 kg (average)
Overall length	4635 mm
Overall width	1695 mm
Overall height	1420 mm
Wheelbase	2665 mm
Engine displacement	1997 cm³

Table 4.
Tests and results to grasp the impact condition that airbag should be deployed

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

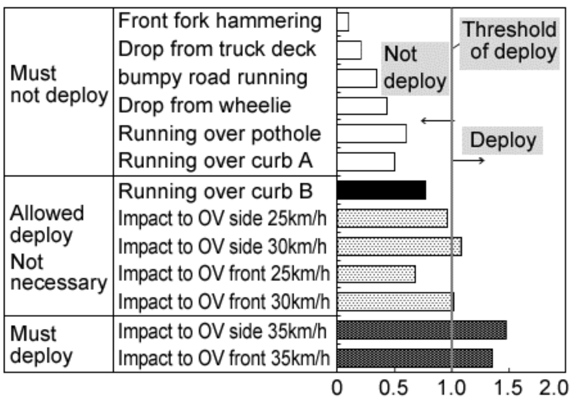


Figure 5. Decision of deployment by integrated impact deceleration.

Features of Collision Judging Sensor System

In the collision judging sensor system, judgment is made upon the extent of deceleration of the front wheel system because it will enable the system to make judgment of deployment at an early time during the crash event. Basically, deployment of the airbag should be completed before the rider reaches the airbag during the collision deceleration of the motorcycle. In a typical motorcycle frontal collision, the front wheel will first contact the opposing vehicle or other object and the deceleration of the sensor and motorcycle frame will occur as shown in the example of Fig.6. As shown in the figure, the extent of deceleration of motorcycle frame is extremely low at the time during which the judgment can be made whether to deploy the airbag using the deceleration of the sensor installed on the front wheel system. Therefore, the judgment of deployment can be made at a faster timing if the deceleration of the front wheel system is used rather than the deceleration of the motorcycle frame.

Also in the sensor system, acceleration sensors are installed on the front forks, both right and left to detect the deceleration of the front wheel system. The sensor system is capable of making appropriate collision judgment based on the deceleration of the front wheel system, computing and judging using the average of detected values by the acceleration sensors on the left and right and removing the influence of the rotary movement of the steering system, which occurs during an angled impact.

FULL SCALE IMPACT TESTS IN ACCORDANCE WITH ISO/CD 13232

Test Method

The airbag system was evaluated in accordance with ISO/CD 13232. With respect to the seven impact configurations shown in Fig. 7, full scale impact tests were carried out using motorcycles equipped with an airbag and those not equipped with an airbag. As described later, in the two configurations of 412-25/50 and 143-35/0, the airbag system was not in operation, and as such no impact test of the base motorcycle was carried out.

For the opposing impact vehicle, the same Honda Accord 4-door of 1998~2001 model of Japanese specifications as used in the impact test for setting sensors was used. This is the opposing impact vehicle conforming to the stipulation of ISO/CD 13232 (Refer to Table 3).

The impact speed in the research was set at a level 4% higher than that specified in ISO/CD 13232 to make the evaluation under stricter conditions. The speed in the parentheses in the figure denotes the speed specified by ISO/CD 13232.

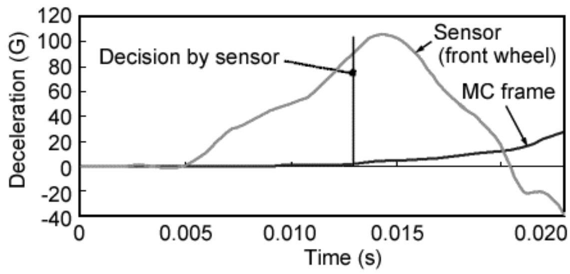


Figure 6. Deceleration of "sensor (front wheel) and motorcycle frame".

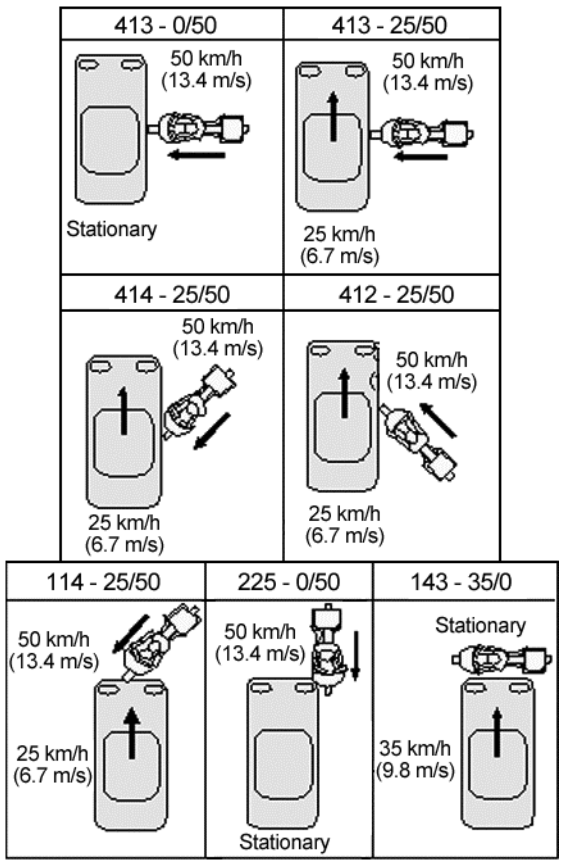


Figure 7. Configurations of full scall impact test.

For the rider dummy, the motorcyclist anthropometric test device (MATD) as defined in ISO/CD 13232 was used. This dummy does not require any connecting cord to the outside, which may affect to the movements of dummy, as an electric measuring and recording system is built inside the dummy. Using the measurement by the dummy and the injury analyzing method shown in ISO/CD 13232, an assessment was made on the level of injuries on head, neck, chest, abdomen and legs.

Test Results

Judgment of Deployment or No-deployment of Airbag, and Judgment Timing

The results of performing impact tests of motorcycles mounted with the airbag system were gathered and analyzed. Out of impact tests conducted in seven configurations the airbags operated in five configurations and were not in operation in two configurations.In the four configurations of 413-0/50, 413-25/50, 414-25/50 and 114-25/50, the deployment of the airbag was finished before the dummy reached the airbag during the crash. This was accomplished by the quick judgment of the sensor system. The judgment timing of sensor system and the time for the dummy to reach the airbag in the four configurations are shown in Fig. 8. As an example of the deployment of the airbag and its effect, Fig. 9 shows the start of impact (t=0), start of airbag deployment (t=20msec), completion of deployment (t=60msec) and nearly finish of the absorption of kinetic energy of dummy (t=120msec) in the case of 413-25/50.

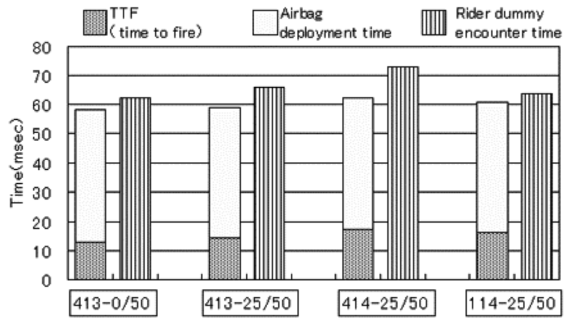


Figure 8. Decision time of airbag deployment from full scall impact tests.

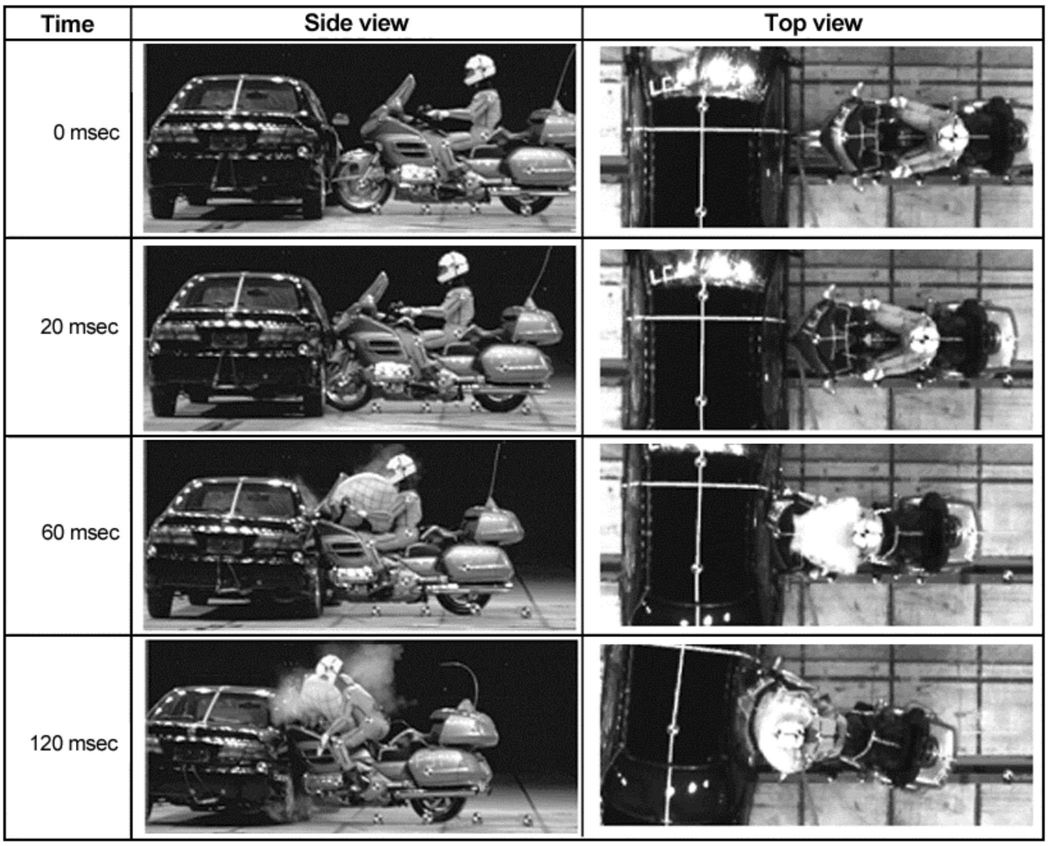


Figure 9. Sample of airbag deployment and effectiveness.

In case of 225-0/50, the dummy contacted the airbag before the deployment was completed. But, the extent of injury resulting from interference with the airbag was not measurable. (Refer to the section dealing with the analysis of injury described later.)

In the two configurations of 412-25/50 and 143-35/0, the airbag was not deployed due to the judgment of no-deployment by the sensor system. In case of 412-25/50, the motorcycle did not decelerate significantly, colliding with the opposing vehicle then diverting its direction along the side of the opposing vehicle. 143-35/0 is not the case of a frontal impact, the objective of the airbag system. It is a configuration in which the motorcycle is collided by an opposing vehicle from its side, an impact in which the airbag should not to be deployed.

Analysis of Injuries

With respect to the indices of injuries in the seven impact configurations, the results of analysis based on ISO/CD 13232 are shown in Table 5 in the changes of AIS (abbreviated injury scale) by body regions and in changes of NIC (normalized injury cost) of the whole integrated body. AIS = 1 is equivalent to light injury while AIS = 6, fatal. NIC = 0 is equivalent to no injury and NIC = 1 fatal. Positive indices show benefits and negative indices show risks. In the two configurations of 412-25/50 and 143-35/0 where the airbags did not deploy, riders sustained no injury from the airbag as a matter of course.

Viewing from the benefits of airbags by region of the body in five configurations where the airbags deployed, there was benefit of 3 in the change in AIS in legs, in the two configurations of 114-25/50 and 225-0/50. Viewing from the point of risk by each of body region, there was a risk of 1 in the change of AIS in the head in the two configurations of 414-25/50 and 114-25/50. Those were due to the injury indices measured when the dummy contacted to the ground. Viewing the change in NIC of all integrated body locations in the five configurations where the airbags deployed, two configurations had benefits of 0.11 and 0.16, while two other configurations had no influence, and one configuration had a risk of 0.07.

The changes in total average NIC of seven impact configurations are shown in Table 6, taking into account the occurrence frequency of impact configuration as shown in the accident database of ISO/CD 13232. The total average benefit is 0.03, and the total average risk is zero.

It is judged, therefore, that the airbag has no risk from the assessment of full scale impact tests based on ISO/CD 13232.

EVALUATION OF RIDER INJURY REDUCTION PERFORMANCE BY COMPUTER SIMULATION

Method of Computer Simulation

Rider injury reduction performance was evaluated by computer simulation based on ISO/CD 13232. However, the evaluation area specified by ISO/CD 13232 is limited to the area up to 0.5 seconds after the dummy hits the opposing vehicle (hereinafter referred to as primary impact sequence). In the computer simulation used for this research, evaluation was made until the time of dummy/ground contact (hereinafter referred to as secondary impact sequence) after the primary impact sequence. Honda obtained the computer simulation technology used in the assessment to enable the simulation of the level of injury until the time dummy/ground contact. (Refer to the SETC thesis). The explicit FEM software of FEM mode base (LS-DYNA) was used as the software for this simulation.

Based on the results of measurement of deformation characteristics of opposing vehicles in impact and those of full scale impact tests, the computer simulation method used in the assessment was prepared. And, based on the results of full scale impact tests in accordance with ISO/CD 13232, the extent of coordination of the measured indices of injuries in the computer simulation was validated. As the results of validation, comparison of the results of full scale impact tests on major injury indices and those of computer simulation are shown in Fig.10 to Fig.12. The HIC in the primary impact sequence is shown in Fig.10 while the HIC in the secondary impact sequence is shown in Fig.11. The maximum compression rate on the chest in the primary impact sequence is shown in Fig.12. Shown in Table 7 is the occurrence of the fracture of femur, knee, tibia in the domain combining the primary and secondary impact sequence (hereinafter referred to as entire impact sequence). From the results of validation of the

Table 5.
Airbag injury benefits and risks, by impact configuration and body region

Collision configuration	AIS change					NIC change
	Head	Neck	Chest	Abdomen	Leg	
413 - 0/50	0	0	0	0	0	0
413 - 25/50	0	0	0	0	0	0
414 - 25/50	-1	0	0	0	0	-0.07
412 - 25/50	--	--	--	--	--	--
114 - 25/50	-1	0	0	0	3	0.11
225 - 0/50	0	0	0	0	3	0.16
143 - 35/0	--	--	--	--	--	--

Table 6.
Average benefits and risks, all tests

Total average benefit	0.03
Total average risk	0
Ratio of risk / benefit	0

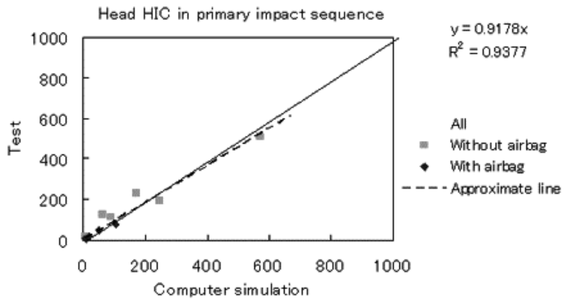


Figure 10. Correlation of head HIC for primary impact sequence.

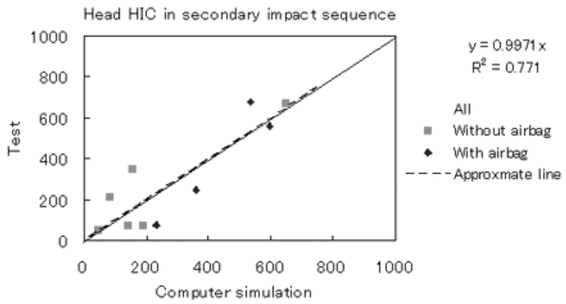


Figure 11. Correlation of head HIC for secondary impact sequence.

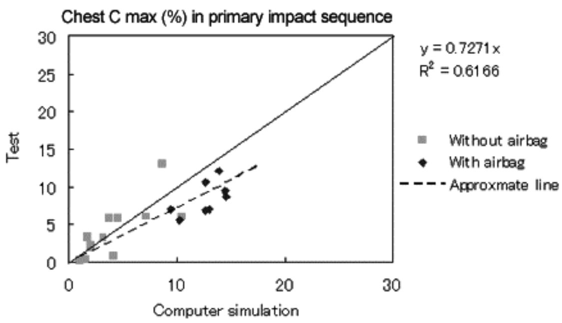


Figure 12 Correlation of chest compression (Cmax %), for primary impact sequence.

Table 7.
Correlation of leg fracture for entire impact sequence

Fumurs

		Full scall tests: Fracture	Full scall tests: No fracture	Present collect
Simulations	Fracture	0	1	96%
	No fracture	0	23	

Knees

		Full scall tests: Fracture	Full scall tests: No fracture	Present collect
Simulations	Fracture	0	0	100%
	No fracture	0	24	

Tibias

		Full scall tests: Fracture	Full scall tests: No fracture	Present collect
Simulations	Fracture	1	0	100%
	No fracture	0	23	

extent of this coordination, the computer simulation was judged to be capable of assessing the risk - benefit of injuries on 200 configurations specified in ISO/CD 13232.

Results of Computer Simulation

By using the computer simulation technology described above the evaluation of benefits and risks was conducted on 400 cases in 200 configurations based on ISO/CD 13232.Computer simulation was not conducted for the 79 impact configurations that the airbag was not expected to deploy because of no influences to rider injury. We conducted 242 cases in 121 configurations and with and without an airbag.

Figure 13 shows the results.Total average benefit is 0.048, risk is 0.004. Benefit/Risk ratio is 0.083, and average net benefit is 0.044. From these results, it can be said that this airbag system has an appropriate performance of rider injury reduction.

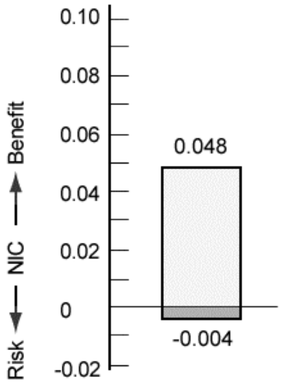


Figure 13. Total average benefits and risks, 200 impact configurations.

TESTS UNDER VARIOUS CONDITIONS AND THEIR RESULTS

The purpose of impact tests in seven configurations of ISO 13232 is to assess the risk and benefit in typical collisions. In addition to these evaluation based on ISO/CD 13232, to clarify the effectiveness of airbags in reducing injuries while minimizing the potential injuries caused by airbags, other tests were conducted by employing other configurations of impact and other rider conditions.

Influence of Rider's Size

In order to validate the differences in the absorbing performance of the rider's kinetic energy by the airbag and the differences in the presence of injuries in interference with the airbag when the size of riders changes, sled tests were carried out using three sizes of dummy. A dummy of standard size, AM50%ile (H-III), one representing smaller size, AF05%ile (H-III), and a dummy representative of large size, AM95%ile (H-III), were used. The measurement and assessment of injury indices were made in accordance with the stipulations and information of FMVSS 208[8][9] with respect to the head, neck and chest. As to the AM50%ile dummy neck, we replaced it with the MATD neck for measurement and evaluation based on ISO/CD 13232.

The acceleration waveform of sled in the tests was based on the deceleration waveform caused on a motorcycle when the motorcycle collides against a stationary opposing vehicle at a speed of 50km/h. The acceleration waveform is shown in Fig.14. The conditions of motorcycle and dummy set on the sled are shown in Fig.15.

The change in the upper half of the dummy body in the test results is shown in Fig.16. The figure shows that if the speed change was 50 km/h the energy is absorbed 100%, whereas if it exceeds 50 km/h the dummy rebounds from the airbag and if it is below 50 km/h the energy is not fully absorbed. As compared with the AM50, the standard dummy, the absorbing performance of the airbag is reduced for the larger AM95, and is enhanced in the smaller AF05. None of these three dummies separated toward the front of motorcycle. Figure 17 shows the condition in which the absorption of the kinetic energy of the dummy ceases. The results of measurement of injuries on dummies are shown in Table 8. There was no injury index that exceeded the criteria for the head, neck and chest in any of the three dummies used.

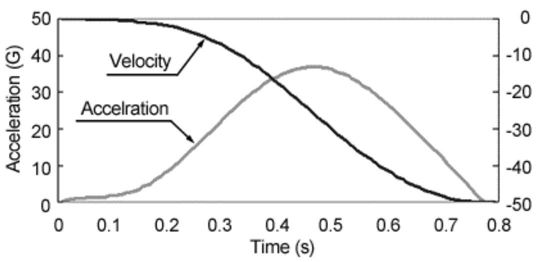


Figure 14. Acceleration and velocity change of motorcycle, in sled tests.

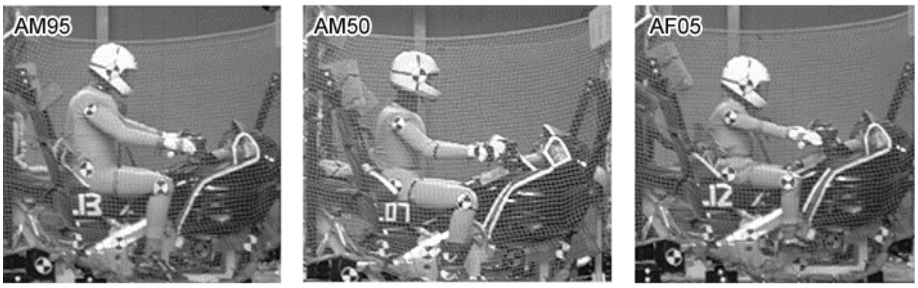


Figure 15. Initial dummy posture in sled test.

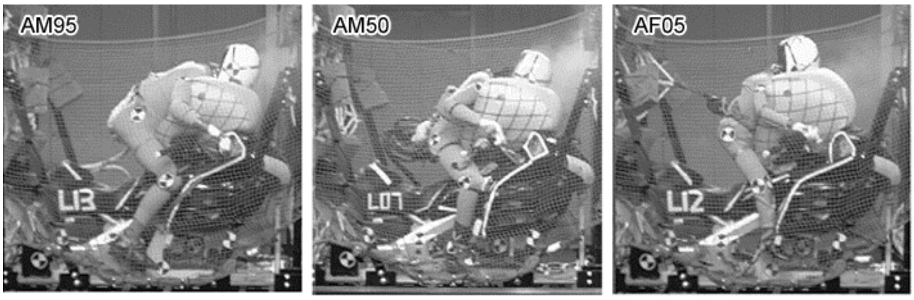


Figure 17. Dummy posture at the moment when kinetic energy absorbed with airbag.

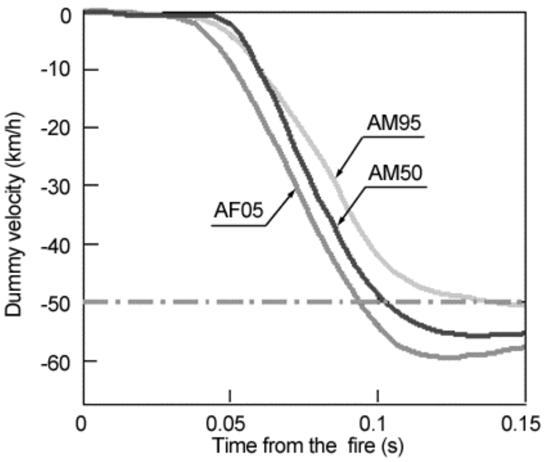


Figure 16. Velocity change of dummy's upper body.

Table 8.
Dummy injury indecis in sled test results

Dummy size	Head HIC	Neck Nij (or NII)	Chest D max.
AM95	52 (not over 700)	0.56 (not over 1)	32 (not over 70mm)
AM50	134 (not over 700)	2.0 * (not over 4)	26 (not over 63mm)
AF05	134 (not over 700)	0.73 (not over 1)	17 (not over 52mm)

* Neck NII is defined by ISO/CD 13232, NII 4 is approximately AIS 2. Other injury assessment are defined or informed by FMVSS 208.

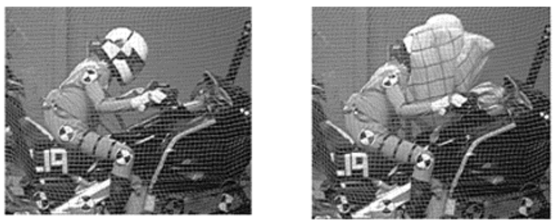
Influence of Airbag Deployment in Tilted Forward Posture of Riders

One needs to consider that motorcycle riders change their posture during riding. In particular, the rider should not be seriously injured by the deploying airbag even if the airbag deploys while the rider takes a posture tilted forward into the area of airbag deployment. A static deployment test validated that no injury will be inflicted by the deployment of the airbag. It was assumed in the validation tests that the rider dummy would take "a marginal forward tilt to enable them to secure a sufficient visibility in the front". Dummies representing standard size, AM50%ile (H-III), and AF5%ile (H-III), representative of smaller size, were used. The measurement and assessment of injuries were made in accordance with the stipulations of FMVSS208 with respect to the head, neck and chest. As to the AM50%ile dummy neck, we replaced it with the MATD neck for measurement and evaluation based on ISO/CD 13232.

The conditions of the dummies before and during the deployment of airbags in shown, the case of AM50 is shown in Fig.18 and that of AF05 in Fig.19, respectively. In either of cases, the airbags deployed first in the vicinity of chest and neck and then interfered with the head and bent the neck of the dummy backward. The results of indices of injuries on the dummies are shown in Table 9. For both AF05 and AM50 no recorded injury index exceeded the criteria.

AM50 Before deployment AM50 During deployment

Figure 18. Static inflation test with forward leaning AM50-dummy.



AF05 Before deployment AF05 During deployment

Figure 19. Static inflation test with forward leaning AF05-dummy.

Table 9.
Measured dummy injury in static inflation test with forward leaning dummy

Dummy size	Head HIC	Neck Nij (or NII)	Chest D max.
AM50	168 (not over 700)	1.55 (not over 4)	5.5 (not over 63mm)
AF05	37 (not over 700)	0.53 (not over 1)	0.4 (not over 52mm)

* Neck NII is defind by ISO/CD 13232, NII 4 is approximatery AIS 2. Other injury assessment are defined or informed by FMVSS 208.

Influence of High-speed Impact and Influence of Passenger

To judge the feasibility and effectiveness of the airbag system, it is necessary to validate whether the airbag will retain the rider kinetic energy absorbing performance, including its strength, under more severe impact conditions. To present more severe impact conditions for this analysis, the combined conditions of two-up riding and higher impact speed were set. The addition of the condition of two-up riding was used to analyze the potential compression of rider's chest influenced by the phenomenon that the passenger will push from the back while the rider is held by the airbag in the front.

The impact test was set as follows: To a stationary motorcycle equipped with the airbag the opposing vehicle, a Honda Accord, will collide at a speed of 75 km/h. Having the opposing vehicle collide with a stationary motorcycle is used to suppress the pitching of motorcycle body, and therefore is considered more appropriate for the purpose of the test. The impact speed was set at 75 km/h in an attempt to be inclusive of most of accident speeds, referring to accident data of ISO/CD 13232 as shown in Fig.20. For the rider dummy, the MATD was used and indices of injuries were measured and assessed in accordance with ISO/CD 13232. For the passenger dummy, AM95%ile (H-III) was used, as it would have the greatest impact to the rider dummy and airbag. Since the assessment of injury using an AM95 dummy would require wired electrical measurement, which should be avoided in full scale impact tests of motorcycles, no assessment was made of indices of injuries to the passenger dummy.

During the impact test, the rider dummy was caught between the airbag and passenger dummy as shown in Fig.21. Afterward the passenger dummy separated to the front of the motorcycle, but the rider dummy stayed on the motorcycle which absorbed its kinetic energy. In the test, no breakage was caused to the airbag. The measured injuries indecis on the rider dummy during primary impact sequence are shown in Table 10. In the index of injury to the upper half of the dummy body, injury which should be directly attributable to the airbag, no injury index countable by AIS was caused on the head, neck and abdomen except AIS 1 in the chest.

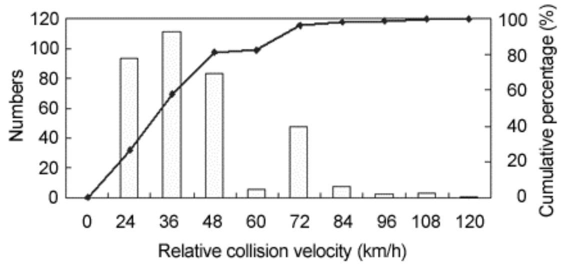


Figure 20. Frontal collision speed based on ISO 13232 accident data.

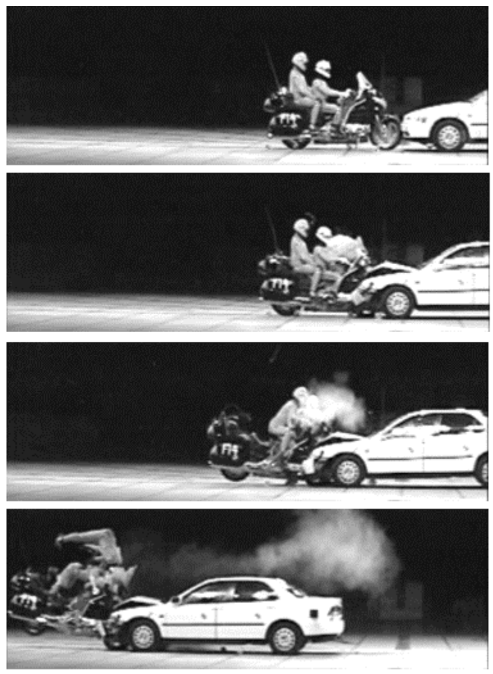


Figure 21. 75km/h impact test with passenger.

Table 10.
Measured injury of rider dummy in 75km/h full scall impact test

Rider dummy	Injury by body region (AIS)			
	Head	Neck	Chest	Abdomen
MATD	0	0	1	0

Front Wheel Non-impact Collision (Under-ride Impact)

In a variety of frontal collision accidents, there is a configuration in which the front wheel of the motorcycle will not be the first point of contact with the opposing vehicle or object, such as in the collision of a motorcycle to the platform of a truck (hereinafter referred to as Under ride impact). Under ride impact tests were conducted to validate whether rider injury reduction would be possible in the present airbag system wherein the timing of deployment decision and the airbag deployment decision are based on the deceleration of the front wheel system.

To an impact trolley, as shown in Fig.22, to which brake is applied, a motorcycle mounted with an airbag was collided at a speed of 50 km/h. To the opposing trolley, a colliding plane was attached simulating the platform of a truck. The principal dimensions of the impact trolley are shown in Table 11. The MATD was used for the rider dummy, and measurement and assessment of injury index was made in accordance with ISO/CD 13232.

As the results of the under ride impact test, the timing of collision judgment by the sensing system was 30msec. after initial impact. The dummy did not directly hit the opposing impact plane, rather the dummy made contact with the airbag in the process of deployment, and the airbag absorbed the kinetic energy of the dummy. Figure 23 shows the conditions of the airbag and dummy. The results of evaluated injury index are shown in Table 12. No airbag related countable injury index took place on the head, neck, chest and abdomen in terms of AIS.

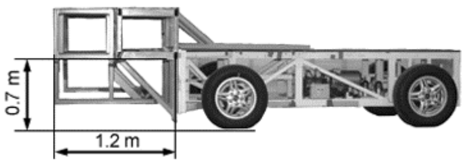


Figure 22. Opposing trolley used under-ride impact test.

Table 11.
Opposing trolley specificastions

Mass	1750 kg
Overall length	4250 mm
Overall width	2080 mm
Overall height	1300 mm

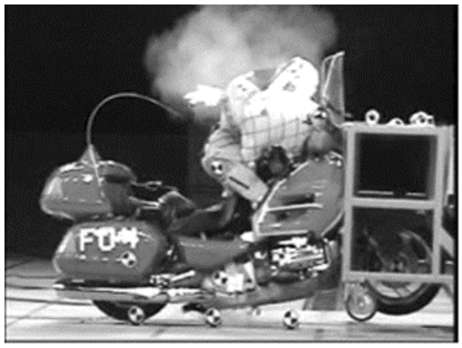


Figure 23. Under ride impact test.

Table 12.
Measured injury in under ride impact test

Rider dummy	Injury by body region (AIS)			
	Head	Neck	Chest	Abdomen
MATD	0	0	0	0

EXAMINATION OF RIDER INJURY REDUCTION EFFECTS OF THE AIRBAG

Using the evaluation to assess the risk potential of airbags based on ISO/CD 13232 and from the results of other validation, a judgment was made regarding the use of airbags. As regards the benefit of the effect of reducing injury it appears that a clear conclusion can not yet be made. Namely, in the impact test on 50 km/h level as specified in ISO/CD 13232, no severe injury index has occurred on the base motorcycle without the airbag. From the measured index of direct injury on the dummy, therefore, the effects of injury prevention and reduction by the airbag are not visible. Accordingly, the rider injury reduction effects expected of the airbag will be examined by analyzing the fatal accident data in the base motorcycle used for the airbag tests and test results this time.

Analysis of Accident Data in Base Motorcycle Used for Airbag test

The conditions of the occurrence of injuries in actual accidents involving the base motorcycle used for the airbag test appear different from the case of other motorcycles because of the characteristic of being a large and heavy motorcycle. The accident data were analyzed from this point of view. Figure 24 shows the result of an analysis of the relationship between the collision speed in frontal collision and the number of fatalities in motorcycle riders. "All motorcycles" are based on the fatal accident data of motorcycles except those with displacement less than 50cc in the years from 2000 to 2002 in Japan [10] "GL" is based on the fatal accident data of Honda GL1000, GL1100, GL1200 and GL1500 from 1975 to 2003 in the U.S.A.[11]. As the result of filtering to cases with required information, "All motorcycles" represent the data of N=700 while "GL" N=234. The base motorcycle used in this study was applied to and interpreted as forming a part of "GL". Collision speed data in the chart were obtained as follows: The original data did not show the actual collision speed, but rather the perceived speed at which the rider felt the collision was unavoidable(hereinafter referred to as precipitating speed）. Both motorcycle and opposing vehicle collision speed were calculated by multiplying the precipitating speed by 0.7. The number 0.7 is set based on the report of motorcycle accident analysis issued by USC [12] . The collision speed here is assumed to be the combined speed of motorcycle and opposing vehicle; in case of collision against the front of opposing vehicles the sum total of both speeds; in case of collision to the side of opposing vehicles the speed of motorcycle; and, in case of collision to the rear of opposing vehicles the speed of opposing vehicle was deducted from that of the motorcycle.

According to the results of an analysis of the accident data, the fatal accidents covered at 50km/h level accounted for approximately 70% of "All motorcycles" and about 30% of "GL". It can be seen that as compared with "All motorcycles", "GL" is less likely to sustain fatal injury on the same collision speed. Because of this characteristic of "GL", no severe injury index was measured in the impact test at 50 km/h of the base motorcycle.

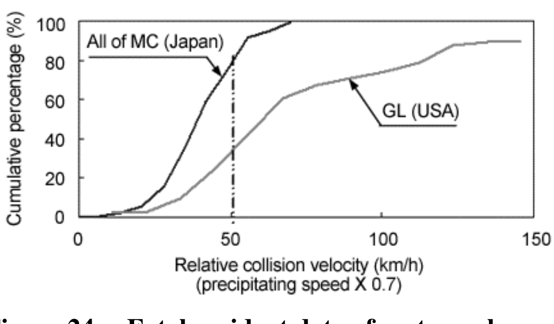


Figure 24. Fatal accident data of motorcycle.

Analysis of Effectiveness of Airbags Seen from Impact Velocity of Rider Dummy to Opposing Vehicle

With respect to the results of full scale impact tests as specified in ISO/CD 13232, an examination was made on the effects of preventing impact by the motorcycle rider to the opposing vehicle or reducing the rider's impact velocity through the suppression of the forward separation of the rider, which was the aim of the airbags. In both impact configurations of 413-0/50 and 413-25/50, head injury to the dummy on the base motorcycle without airbags was prevented. In the base motorcycle without airbag, the HIC of the dummy head which hit the opposing vehicle was 115.1 in the case of 413-0/50 and 122.3 in the case of 413-25/50 as shown in Fig.25. Figure 25 shows for reference the HIC that occurred in the airbag-equipped motorcycle. Though the HIC of the base motorcycle is larger than that of the airbag-equipped motorcycle, it is still low and under AIS 1.

The result of an analysis of dummy motions, disclosed that the absolute head velocity of the dummy at the time of impact to the opposing vehicle on the base motorcycle without airbag was 8.0m/s in case of 413-0/50 and 10.0 m/s in case of 413-25/50 as shown in Fig.26. The results of helmet tests conducted in connection with the study are shown here in Fig.27 In accordance with the helmet test method of JIS (JIS T8133-2000) [13], an impact test was carried out wherein a plane anvil was impacted with the top of the helmet used in the full scale impact tests. According to the results of this helmet test, HIC 2500 is exceeded at impact velocity of approximately 7 m/s when hit against the plane of the rigid body. Therefore, at the impact velocity of 8.0m/s in the case of 413/0/50 and at 10.0 m/s in case of 413-25/50, there exists a possibility of causing serious injury to the head depending on the shape and hardness of colliding object. This could happen in actual accidents wherein various opposing collision vehicles and other objects of collision exist, and they constitute part of fatal accidents in the low-speed collision of the accident data formerly described. In the airbag-equipped motorcycles, the impact to the head which occurred in the base motorcycle could be prevented or reduced.

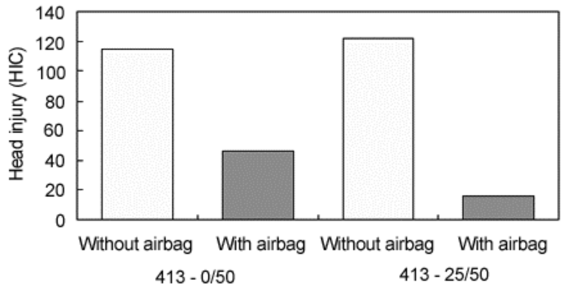


Figure 25. Head HIC in 413-0/50 and 413-25/50.

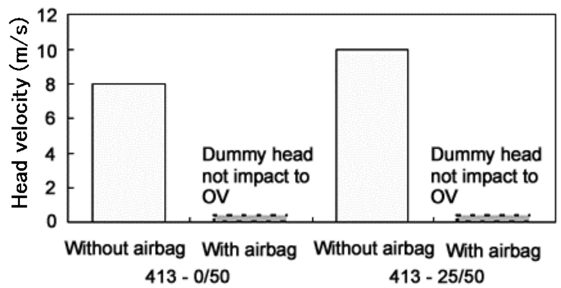


Figure 26. Head velocity of impact to opposing vehicle.

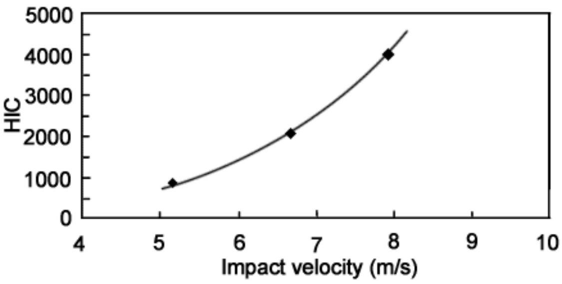


Figure 27. Helmet impact test result.

Effect of Rider Injury Reduction Expected in More Collision Conditions

From the results of analysis of fatal accident data described above, rider injury reduction is desired in much higher collision speed ranges. The airbag absorbed the kinetic energy of rider dummy in the impact test at a speed of 75 km/h and prevented the rider dummy from forward separation from motorcycle without causing injury through the interference with the airbag. Therefore, the effect of reducing fatal injury can be expected in collisions at a speed on the 75 km/h level of "GL", as seen in the accident data described above.

The effects in impact in high-speed ranges were validated in some of the impact configurations in the assessment by computer simulation described above. For instance, in the impact configuration of 414-0/72 shown in Fig.28, injury indices as shown in Table 13 were calculated. In the impact configuration, the rider's head impact to the opposing vehicle, which occurred to the base vehicle, is prevented by the airbag and the injury of the rider is substantially reduced.

In the results of assessment of indices of injuries on the dummy in a series of full scale impact tests of ISO/CD 13232, the rider injury reduction effects of the airbag did not show clearly. However, from this examination, an expectation is held that the airbag system will considerably contribute to the reduction of fatal injury and serious injuries of riders.

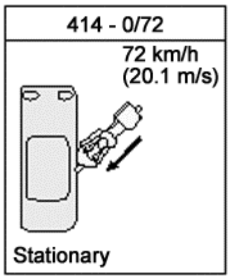


Figure 28. Benefit impact configration from computer simulation

Table 13.
Injury change, 414-0/72

Collision configulation	AIS change					NIC change
	Head	Neck	Chest	Abdomen	Leg	(Whole body)
414 - 0/72	4	0	0	0	3	0.80

＊ Positive number means benefit, negative number means risk

CONCLUSION

GL1800 equipped with prototype airbag system was evaluated by full scale impact tests based on ISO/CD 13232, computer simulation and other tests set up by Honda.

As the result, the following findings were obtained:

- The sensor system, making judgment by detecting and calculating the deceleration of the front wheel system, was capable of properly judging deploy/no-deploy against the situations of collision/non-collision.
- As the result of full scale impact tests in accordance with ISO/CD 13232, the total average risk was zero in seven configurations.
- As the results of computer simulation analyzing the time until dummy/ground contact with and without airbags in 200 configurations, the total average benefit was 0.048, risk was 0.004. It can be said that the performance of rider injury reduction system is appropriate.
- As the result of validating impacts under a variety of conditions which should be taken into account, including two-up riding impact, 75 km/h impact, different sizes of rider, rider posture tilted forward ,as well as the under ride impact, no unacceptable phenomena have occurred.
- As the result of studying the effectiveness, based on the accident data, of the base motorcycle and the test results of the airbag, it was possible to conclude that the airbag system is effective in reducing fatal and serious injuries to riders.

It is judged from the foregoing that the airbags for large touring motorcycles would have the possibility of becoming a reality. Development will be made in future aiming at putting the airbags to practical use in consideration of durability, weather ability, reliability, commodity value and productivity.

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