

Introduction of Honda ASV-2 (Motorcycles)

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ABSTRACT

For the Advanced Safety Vehicle Project Phase 2 (ASV-2) as conducted by the Ministry of Transport of Japan, two types of prototype “ASV motorcycles” were produced to promote studies on safety. The research topics for the two types of prototype “ASV motorcycles” were selected from two viewpoints:

- Active safety technologies:
 - (1) “Inter-vehicle communication system” which provides information on the mutual presence of motorcycles and automobiles.
 - (2) “Discharge headlight for motorcycles” taking into consideration the high voltage unit and optimizing light distribution.
 - (3) “TUFFUP tires” applied to minimize pressure leaks due to punctures of tubeless tires with a self-seal gel sealed in their double structure chambers.
 - (4) “Air pressure monitor system” which will display air pressure and give an alarm when certain conditions exist.
- Passive safety technologies:
 - (5) “Airbag system for motorcycles” including an airbag, inflator and sensor system.
 - (6) “Advanced safety helmet” to reduce brain damage resulting from rotational acceleration of the head.

It is believed that potential accident reduction effects may be anticipated through the application of these technologies.

1. Introduction

Motorcycles were added as a research subject for Phase 2 (1996 to 2000) of the Advanced Safety Vehicle (ASV) Development Promotion Project. In order to study motorcycle safety, a detailed analysis was made of traffic accidents in Japan, and the research topics were selected from the dual viewpoints of “active safety technologies” and “passive safety technologies”.

The experimental vehicle for studying active safety technologies was a 250cm³ displacement scooter (Foresight) equipped with the inter-vehicle communication system, discharge headlight for motorcycles, self-seal (TUFFUP) tires and the air pressure monitor system. In addition, ABS and turn signal position lights were also applied (Honda ASV-2 experimental vehicle 3).

The experimental vehicle for studying passive safety technologies was a large touring model GL1500 equipped with the airbag system for motorcycles, and an enhanced impact absorption helmet was also employed (Honda ASV-2 experimental vehicle 4). Fig. 1 shows the exterior view of the ASV-2 experimental vehicles 3 and 4. Note that there are also ASV-2 experimental vehicles (automobiles) 1 and 2, which are being researched separately. Details on the Advanced Safety Vehicle (ASV) Development Promotion Project are presented in the separate paper “Introduction of HONDA ASV-2 (Automobiles).⁽¹⁾



Fig.1 Passive (left) and active safety research motorcycles

2. Honda ASV-2 Experimental Vehicle 3 (Active Safety) Technologies

2.1. Outline

An analysis of traffic accident data revealed that intersection collisions and right-turn (cross-traffic) collisions account for the majority of accidents between motorcycles and automobiles involving fatalities. These results also showed that one of the main factors causing accidents was recognition mistakes on the part of automobile drivers. Therefore, experimental vehicle 3 was equipped with the following functions to assist in accident prevention by

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improving visibility at night and pressure-loss resistance due to tire punctures:

- (1) Inter-vehicle communication system, which provides information using a communication system installed on both motorcycles and automobiles to inform riders and drivers of each other's presence.
- (2) Discharge headlight for motorcycles, which improves visibility during nighttime driving.
- (3) TUFFUP tires and air pressure monitor system, which improve resistance pressure-loss due to tire punctures and inform riders of abnormal air pressure.

Fig. 2 shows where these systems are installed in experimental vehicle 3.

2.2. Inter-Vehicle Communication System

2.2.1. Characteristics and Factors of Accidents between Motorcycles and Automobiles

According to Japanese accident data⁽²⁾, accidents resulting in fatalities while riding motorcycles account for 18% of all accident fatalities as shown in the upper left graph of Fig. 3. In addition, the upper right graph of Fig. 3 shows that 63% of fatal motorcycle accidents involve collisions with automobiles. Furthermore, as shown in the bottom graph of Fig. 3, detailed analyses of right-turn collisions and intersection collisions revealed that the main factors were distance and speed recognition mistakes, oversight or the inability to see motorcycles hidden by other automobiles on the part of the first party (automobile). Of these factors,

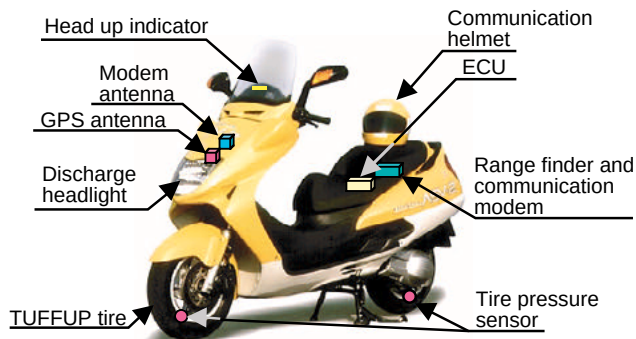


Fig.2 HONDA ASV-2 Active safety vehicle 3

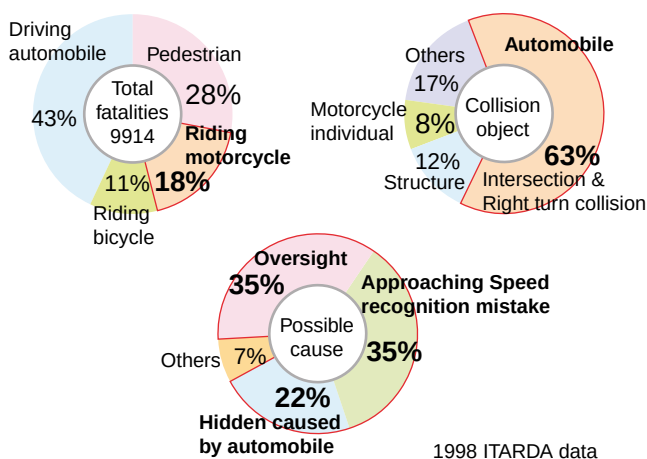


Fig.3 Rate of motorcycle accident in fatalities

approaching speed and distance recognition mistakes accounted for 35% of the total.

Fig. 4 shows the accident modes caused by these factors. Here, right-turn collisions account for 23% of the accidents, and intersection collisions 40%. The frontal projected area of motorcycles is generally smaller than that of automobiles, and it is known that drivers tend to recognize motorcycles as being further away and traveling slower than the actual distance and speed.⁽³⁾

Oversight, such as when a truck, bus or other large-sized vehicle is cruising behind a motorcycle, causing the motorcycle to easily blend into the background, is also thought to be a factor. Being hidden by automobiles is also a typical cause of accidents such as when the forward field of vision of the driver of a vehicle making a right-hand turn is obstructed by a large-sized vehicle stopped or cruising in the opposing right-turn lane, making it impossible to know or predict the presence of a motorcycle cruising in that blind area.

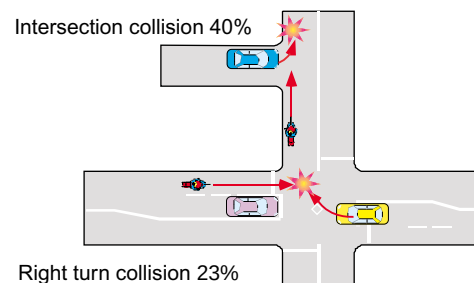


Fig.4 Typical traffic accident between automobiles and motorcycles

2.2.2. Goal of the Recognition Assistance System

We researched a recognition support system by providing various means of assisting motorcycle and automobile drivers to recognize each other's presence. This system aimed to have drivers of automobiles making right-hand turns accurately, recognize motorcycles and to have riders of motorcycles proceeding straight ahead recognize the presence of vehicles which might make a right turn in front of them.

2.2.3. Systems

The recognition support system consists of an electrical control unit (ECU), which performs vehicle information control and communication control, an inter-vehicle communication and range finder modem, and a human-machine interface (HMI). The system configuration is roughly the same for both motorcycles and automobiles.

(1) AVS-2 experimental vehicle 2 (automobile: protection of vulnerable parties in traffic accidents) systems:

A high accuracy GPS, communication and range finder modem, and navigation system are connected to an electronic control unit (ECU), which performs vehicle information control and communication control processing, and the positions of motorcycles, etc., are shown on the navigation display installed on the vehicle in real time. In addition, a high intensity head-up display (HUD) mounted in front of the driver's seat projects symbols onto the windshield and provides voice attention attracting information as necessary.

Fig. 5 shows the block diagram of this system.

An algorithm for calculating the most recent position of the driver's own vehicle based on the GPS position information, vehicle speed, acceleration/deceleration and yaw rate was developed to minimize the estimated positioning error. As a result, a real-time positioning accuracy of ± 5 m was obtained. Fig. 6 shows this positioning algorithm.

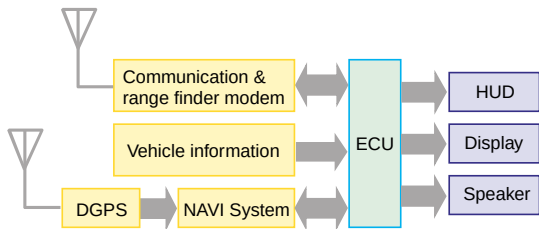


Fig.5 Block diagram of automobile system

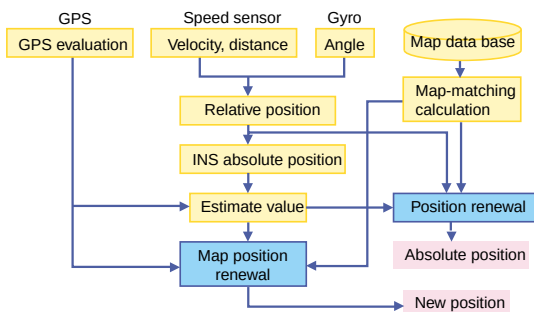


Fig.6 Estimated positioning algorithm

The system detects motorcycles and automobiles around the intersection at a distance of approximately 200 m before the intersection, and extracts vehicles likely to intersect with the future course of one's own vehicle from the cruising vectors of one's own vehicle and the other vehicles.

In particular, when a motorcycle is extracted, an enhanced symbol appears on the navigation display as shown in Fig. 7.

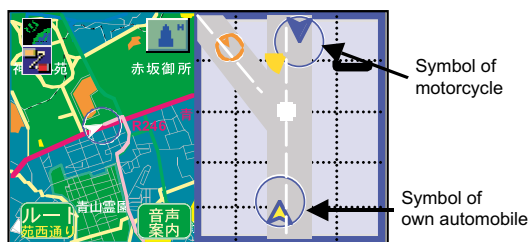


Fig.7 NAVI display information

When the course intersecting conditions obtained from the time required for the other vehicle to reach the intersection and the approach time for one's own and the other vehicles match, the system displays a caution symbol on the HUD as shown in Fig. 8 and provides a voice message.

The main contents of the inter-vehicle communication are identification (motorcycle/automobile vehicle type identification), current position (latitude and longitude), vehicle speed, estimated position, position of next intersection, arrival time at next intersection, number of

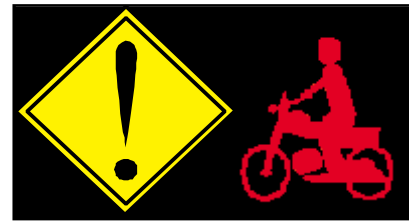


Fig.8 HUD Caution symbol

vehicles from which signals are received, one's own vehicle's state (brake, turn signal, etc.) and so on for a total data communication volume of approximately 40 bytes. The data update cycle is automatically varied depending on the speed, intersection approach and other states of one's own vehicle to comprise an autonomous decentralized communication network.

(2) AVS-2 experimental vehicle 3 (active safety) systems:

Motorcycles require lightweight and compact components; so experimental vehicle 3 was not equipped with a navigation system. Therefore, in place of referencing digital map data, the latitude and longitude of intersections in the direction of the automobile's path are obtained via inter-vehicle communication. The motorcycle system judges whether the future cruising courses intersect based on the position of one's own vehicle as determined by the GPS, the cruising vector calculated with the azimuth data and the automobile cruising vectors. Fig. 9 shows the system block diagram. In consideration of the characteristics of motorcycles, the HMI was provided with two notification systems, a head-up indicator (HUI), which allows for confirmation within the peripheral vision of the driver, and a voice message from a speaker built into the helmet. Fig. 10 shows where this equipment is installed on experimental vehicle 3.

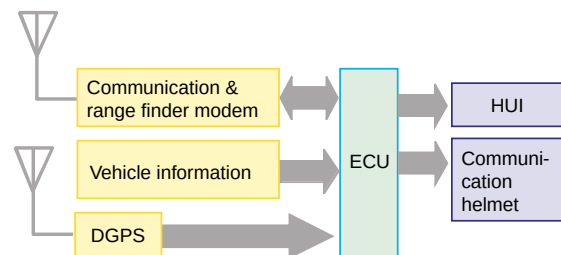


Fig.9 Block diagram of motorcycle system

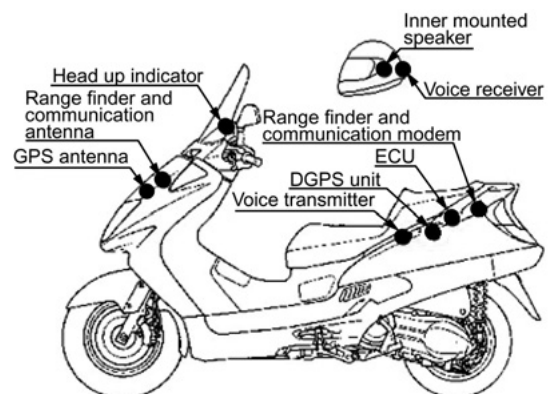


Fig.10 Outline of motorcycle system

The motorcycle path is determined while maintaining balance through two inputs, steering angle and body weight shifting, so the steering mode differs from automobiles in that the roll and yaw angle variation are detected, mainly using visual information, and which are then fed back to the path. Particularly around intersections and in other cases where caution must be given to the surrounding circumstances, providing alphanumeric information or diagrams may draw attention toward these displays and cause riders to shift their line of sight from the outside world.

Therefore, visual information is provided using a method which reflects a high intensity LED (yellow) with a wide horizontal emitting surface to the center of the windshield in a manner which can easily be recognized even with peripheral vision, and the amount of information was limited to the minimum necessary, 1 bit. Fig. 11 shows an example of the reflected image. In addition, a communication helmet was developed which provides high quality voice sound by a transmitter installed on the motorcycle and a receiver installed on the exterior of the helmet. Fig. 12 shows a photograph of this helmet. Phrases, which could be readily understood and were completed within 2 seconds, were created for the voice message.

(3) Inter-vehicle communication and range finder modem:

The radio waves from GPS satellites are cut off among high-rise buildings or under bridges, etc., and the accuracy of location often drops due to the effects of multipass, etc. Therefore, we developed a spread spectrum (SS) communication range finder modem that allows measurement of relative distance during inter-vehicle communication under these types of conditions. The spread spectrum communication system provided anti-multipass characteristics and can measure the distance to

communicating parties while communicating information, thus ensuring redundancy without adding new equipment when used together with a high accuracy GPS. This inter-vehicle communication and range-finder modem is mounted on both motorcycles and automobiles, and communication control uses carrier sense multiple access (CSMA). Future improvements in communication control, communication speed and processing speed rate are expected to allow inter-vehicle communication between all vehicles (approximately 1,000 vehicles) within a 300 m radius centering on intersections.

2.3. Discharge Headlight for Motorcycles

A discharge headlight like those used on automobiles was also newly developed for motorcycles to improve visual recognition when driving at night. Discharge headlights have the characteristics of a luminous intensity approximately two times, a life five times or more, and power consumption of approximately 70% of conventional halogen type headlights.

However, employing discharge headlights on motorcycles presented the following technical issues:

- (1) Discharge headlights are ignited by high voltages of approximately 20 kV, and the high voltage parts are close to the rider, so particular care must be given to safety when using discharge headlights on motorcycles.
- (2) The rider's eye point is higher than for automobiles, so riders look down on the boundary between light and dark from above. In addition, the difference in brightness appears greater as the center area becomes brighter.

These technical issues were resolved as follows, making it possible to mount the optimum discharge headlights on motorcycles.

2.3.1. Assuring Safety of High Voltage Parts

The headlight and igniter were integrated to enclose the high voltage parts completely inside the headlight housing, and the construction incorporates thorough electrical leak prevention measures to prevent riders from being subjected to electric shocks even when the unit is submerged. Fig. 13 shows the discharge headlight construction.

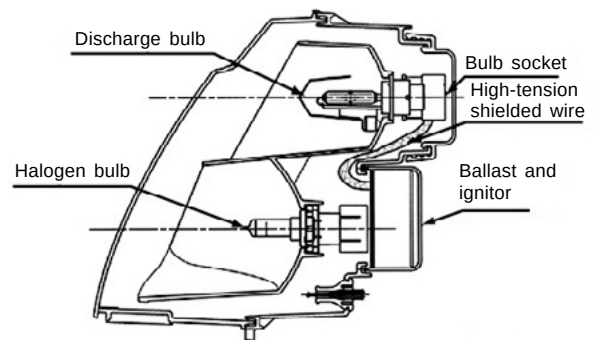


Fig.13 Cross section of discharge headlight

2.3.2. Setting a Light Distribution that Provides a Sense of Brightness

The bulb light flux of discharge bulbs increases compared to halogen bulb headlights, so the center area becomes brighter. However, this makes more distant and peripheral areas seem darker.

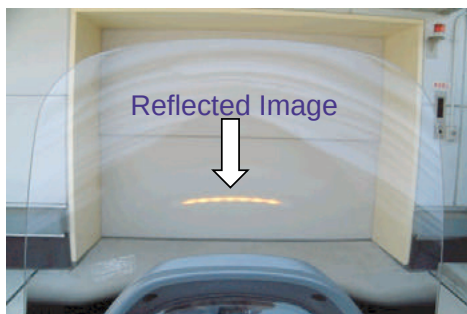


Fig.11 HUI image



Fig.12 Communication helmet

The above-mentioned contents were taken into account when setting brightness targets, and confirmation by running tests showed that the sense of brightness is greatly affected by the brightness of the range which riders normally view and the peripheral brightness. When the light was distributed focusing on this point, a sense of brightness double or more than that of conventional halogen headlights was obtained.

2.3.3. Setting an Illumination Gradient which does not Produce a Sense of Brightness Contrast

As the brightness of the center area increases, more distant areas seem darker when the vehicle body undergoes pitching, etc. When the vehicle body tilts forward, the light distribution shifts toward the vehicle and the driver's eyes are unable to follow the rapid change in illumination from the center area to the cut line. Therefore, by setting the same gradual change in illumination as conventional halogen headlights which do not produce a sense of brightness contrast, we achieved a light distribution with the same lack of brightness contrast as conventional headlights.

2.3.4. Light Distribution when Mounted on the ASV

The discharge headlight provided an enhanced light distribution with 2 times the sense of brightness, 1.3 times the range and 1.5 times the light distribution range as conventional halogen headlights, thus increasing the visual range when cruising at night. In addition, the potential for glare affecting occupants in opposing vehicles or the vehicle in front was reduced to near that of halogen headlights without adding a levelizer by setting a gradual change in illumination near the cut line. Fig. 14 shows the light distribution performance for the developed discharge headlight.

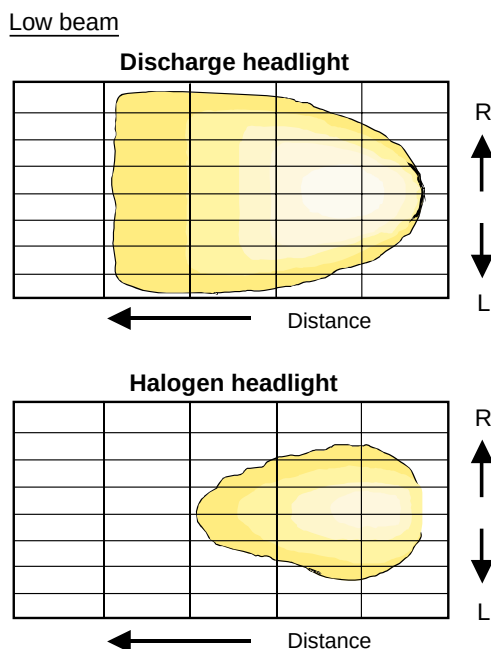


Fig.14 Headlight distribution performance

2.4. Tires with Pressure-Loss Resistance Functions (TUFFUP Tires)

As motorcycles are not generally equipped with spare tires and to help reduce pressure loss from punctures we developed a tubeless tire with a dual structure on the tire air

chamber side, and a newly developed special self-sealing gel sealed in a chamber on the tread side. This gel consists of various types of fibers and ceramic powder mixed in a highly viscous gel containing propylene glycol and adhesives, etc., and is sealed in a 1.2 mm thick chamber in the upper portion of the tire. This gel is constantly pressed by the tire air pressure, so if a hole opens in the chamber, the gel is extruded to the outside, and the fibers, etc. in the gel are pinched by the elasticity of the tire rubber to prevent air leaks.

This is the same principle used by the previously developed TUFFUP tube, which boasts mass production results of over one million units. The performance target is the ability to run up to the tire life even with a hole made by a 3 mm diameter nail. Fig. 15 shows this tire construction, and Fig. 16 shows the mechanism for preventing air leaks.

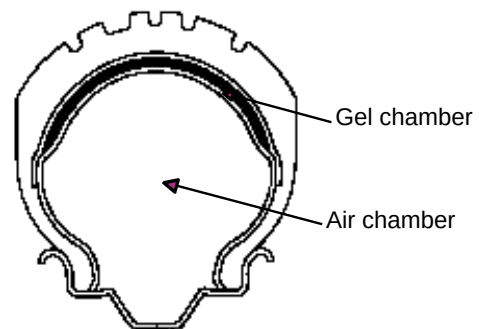


Fig.15 Construction of TUFFUP tire

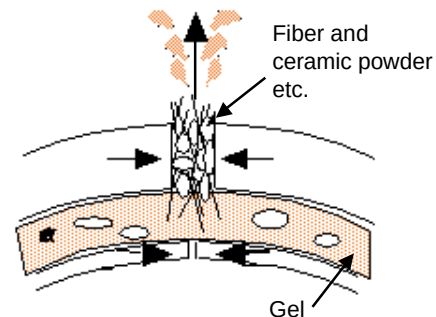


Fig.16 Puncture-plugging mechanism

2.4.1. Air Pressure Monitor System

Air pressure monitor systems are a pending technology that have been desired as a technology for notifying motorcycle riders in advance of drops in air pressure while cruising. Fig. 17 shows where each device is installed on experimental vehicle 3. As shown in Fig. 18, air pressure and temperature sensors are integrated with the tire valve inside the tire, and periodic radio wave signals are sent using power from the built-in battery. The battery life is set at six years or more. The radio waves are sent to a receiver installed in the vehicle body, and are then processed and shown on the display.

Air leaks must be recognized before significant pressure loss occurs so that the rider can stop the motorcycle. Therefore, the system shortens the interval for calculating and transmitting the air leak speed in accordance with the leak rate in order to notify the rider of the air leak as quickly

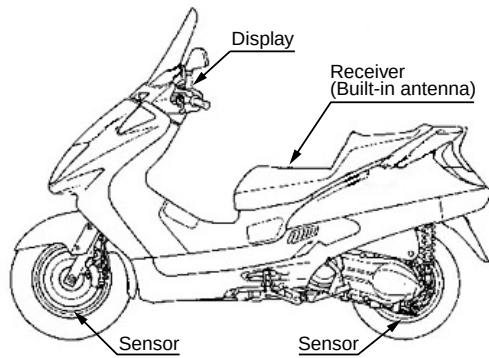


Fig.17 Layout of air-pressure monitor system

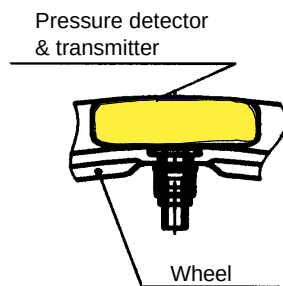


Fig.18 Construction of air-pressure sensor

as possible. The system also monitors the temperature inside the tire to predict tire bursting due to abnormally high temperatures of 100°C to 150°C, and warns the riders in advance.

Drops in the air pressure due to normal air permeation leakage from the tire rubber can also be monitored, so riders can be advised to maintain the appropriate air pressure. This is also effective for improving fuel economy and tire life, and for ensuring cruising performance.

3. Honda ASV-2 Experimental Vehicle 4 (Passive Safety) Technologies

The experimental vehicle shown in Fig. 19 was used to study an airbag for motorcycles and a helmet with improved performance in impact absorption as passive safety technologies.

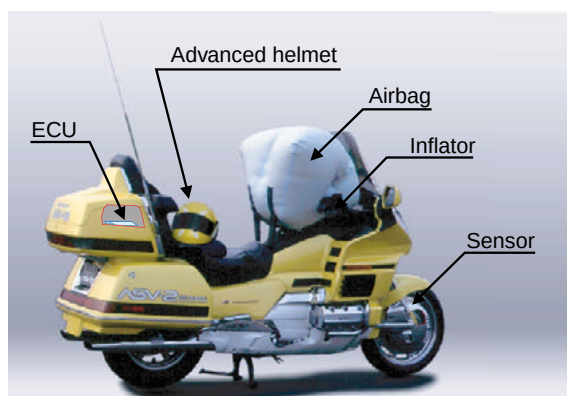


Fig.19 "ASV-2": Motorcycle for passive safety research

3.1. Airbag System for Motorcycles

The airbag system for motorcycles aims to reduce the rider's injuries caused by hitting the opposing vehicle or another object by absorbing the rider's energy in a forward collision using an airbag.

3.1.1. Overview of Prototype Airbag System

Based on the results of initial fundamental research, we decided to use the specific large-sized model (GL1500) shown in Fig. 19 for our study. The bag and inflator were determined through static inflation tests and sled tests, etc. Then the sensor system was investigated with various running tests and crash tests using a number of cases, and a prototype airbag system was fabricated.

The bag specifications were determined as shown in Table 1 to achieve high performance in the areas of restraining the rider and absorbing energy and impact. The features of the airbag are a V-shaped airbag rear surface, which the rider contacts during a collision, and belt supports connected to the frame below the seat, etc.

Table 1 Specifications of prototype airbag

Volume	(liter)	120
Height × width × length	(mm)	630 × 500 × 615
Vent holes	(mm)	φ50 × 2 holes
Bag mounting point	1) module box 2) motorcycle frame, via 2 connectiong belts	
Inflator:	Pyrotechnic, passenger car type, 450kPa maximum pressure	

The sensor system consists of acceleration sensors attached on the right and left of the bottom case of the front fork and an ECU which processes and evaluates these acceleration values. The faster of the right and left acceleration value processing results activates the inflator and inflates the airbag. Fig. 20 shows the appearance of the airbag.



Fig.20 Prototype airbag

3.1.2. Full-scale Crash Tests for Prototype Airbag System

Full-scale crash tests were carried out using real vehicles under various crash modes to ascertain system operation and the injury reducing effects of the airbag for riders.

These full-scale crash tests were carried out as prescribed by ISO 13232 (Motorcycles - Test and Analysis Procedures for Research Evaluation of Rider Crash Protective Devices Fitted to Motorcycles)⁽⁴⁾. One of the seven full-scale crash

test modes prescribed by ISO 13232 which was unrelated to this airbag was eliminated. On the other hand, five other modes such as impact at a higher speed (72 km/h), with a passenger, and in the forward leaning position were added, and the full-scale crash tests shown in Fig. 21 were carried out.

6 Configurations from ISO full scale test standard					
Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
48 km/h	48 km/h	48 km/h	48 km/h	48 km/h	48 km/h
24 km/h	24 km/h	24 km/h	24 km/h	Parked	Parked
5 Configurations added for airbag feasibility research					
Test 7	Test 8	Test 9	Test 10	Test 11	
48 km/h	72 km/h	72 km/h	With passenger 48 km/h	Forward leaning 48 km/h	
Parked	Parked	Parked	Parked	Parked	

Fig.21 Configurations of full scale impact tests

The dummies were ISO 13232-MATD (Motorcyclist Anthropometric Test Device), and measurements, etc. were taken to evaluate the injury to the head, neck, chest, abdomen and leg portions.

The opposing vehicles used in the tests were 1988 to 1990 year model Toyota Corollas based on ISO 13232.

Fig. 22 shows the airbag functioning time span in the full-scale crash tests.

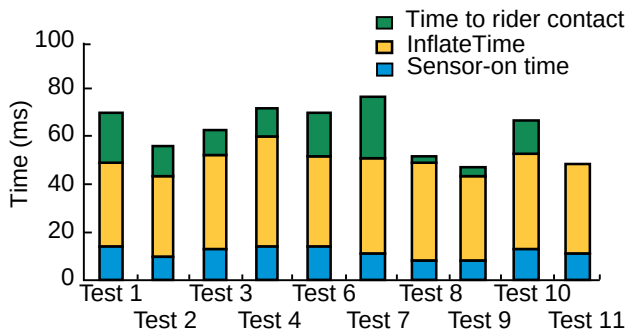


Fig.22 Airbag timing data from full scale tests

The sensor-on time is the time from the start of the crash until the ECU outputs the ON signal, the inflation time is the time from when the ON signal is output until the airbag completes inflation, and the time to rider contact is the time from when the airbag is completely inflated until the rider contacts the bag. In the Test 5 impact mode, it was found that the prescribed impact acceleration was not produced so the airbag system did not activate. Except for Test 5 and the forward leaning position Test 11, the rider arrived at the airbag after it was completely inflated, indicating that the airbag activated on time and achieved inflation.

The effects of the airbag on the injury were obtained by comparing each of the nine test modes with and without the airbag based on the ISO 13232 injury evaluation method from the results of dummy measurements in the full scale crash tests. Fig. 23 shows these results, and indicates the

change in the Abbreviated Injury Scale (AIS) for each body region. The total effect on the whole body is indicated by the change in the Normalized Injury Cost (NIC). Here, NIC = 1 is equivalent to death. When injury is reduced by the vehicle equipped with the airbag, this is shown as a benefit. Conversely, when injury increases this is shown as a risk.

These effects of the airbag on injury mainly appear in the head and neck portions. Examining the total NIC values for the whole body, the airbag reduced injury in Test 1, Test 2, Test 8 and Test 9. On the other hand, the airbag had adverse effects in Test 3 and Test 4. In addition, the airbag had no effect in Test 5, Test 6 and Test 7.

In other test results, an injury measurement value expressed by AIS did not occur for the rider on the front of the seat in Test 10 with a passenger. Also, a value suggesting neck injury was measured in Test 11 for forward leaning position impact.

The rider protective effects of the airbag were understood with this study. In the future, countermeasures must be taken to counteract the adverse effect phenomena, and tests must be carried out to confirm the effects under even more diverse impact conditions.

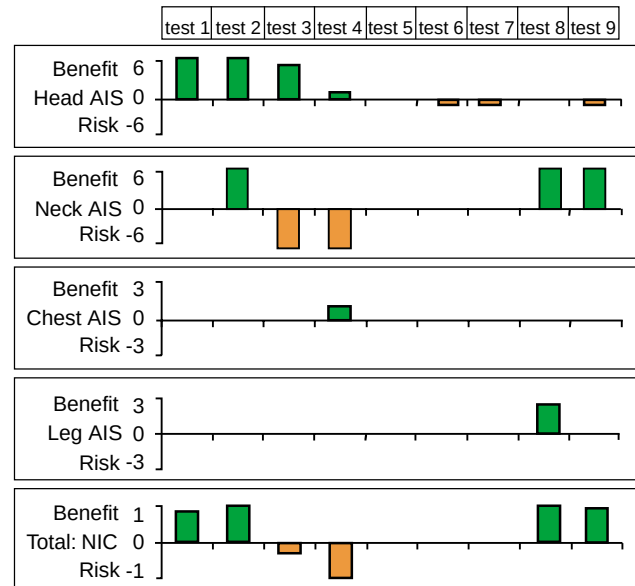


Fig.23 Airbag injury risks and benefits

3.2. Advanced Safety Helmet

Helmets exhibit significant head protection effects for motorcycle riders during accidents, but even when wearing a helmet the greatest cause of death is still head injuries as shown by the accident data⁽²⁾ in Fig. 24. Moreover, in recent investigations of accidents involving motorcycle rider fatalities it is said that 20 to 30% of head injuries are caused by impacts involving mainly rotational acceleration. This study pursued the new viewpoint of reducing brain injury caused mainly by rotational acceleration of the head.

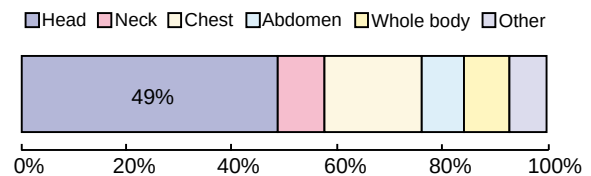


Fig.24 Body region of fatal injury

3.2.1. Outline of Prototype Helmet

A new impact absorption layer was set between a double liner as shown in Fig. 25, and the helmet construction allowed both liners to move around this layer. This construction reduces the rotational movement transmitted to the head when impact type rotational force acts on the helmet.

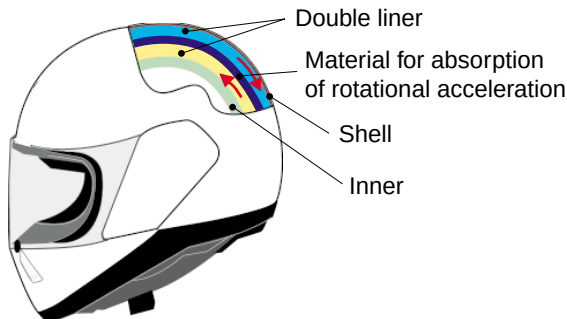


Fig.25 Prototype helmet

3.2.2. Preliminary Test Results for the Prototype Helmet

Fig. 26 shows the results of measuring the rotational acceleration produced on the head portion when the head of a Hybrid III dummy wearing a helmet is dropped from a height of 2.5 m onto a 45° incline concrete surface.

The prototype helmet reduced the maximum rotational acceleration value compared to the base helmet, indicating the feasibility of countermeasures.

In the future, optimization of construction and materials must be studied, and research on methods for evaluating performance from this perspective is also necessary.

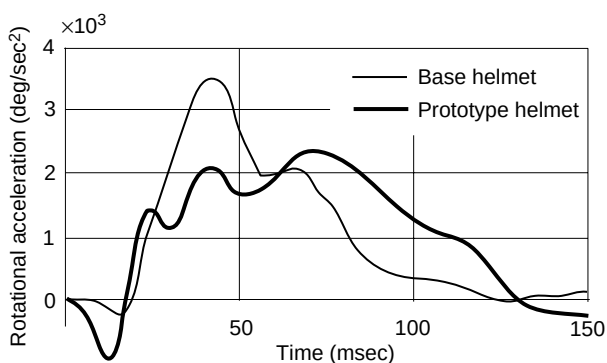


Fig.26 Test result of prototype helmet

4. Conclusion

In response to the ASV-2 project, we have conducted research on active and passive safety technologies for motorcycles, calculated the accident reduction effects of the developed technologies based on the accident effect estimation method of the Japan Automobile Research Institute, and believe that the potential accident reduction effects shown in Table 2 may be expected.

The motorcycle safety technologies introduced in this paper are still in the feasibility study phase, but research is currently proceeding for some of these technologies with the aim of actual application.

Table 2 Effect of motorcycle accident decrease rate

ASV vehicle 3 systems	Fatalities	Casualties
Inter-Vehicle communication system	– 12.2%	– 8.9%
Discharge headlight for motorcycles	– 0.3%	– 0.03%
TUFFUP tires	– 0.3%	– 0.04%
Air pressure monitor system	– 0.5%	– 0.06%
Total	– 13.3%	– 9.0%

ASV vehicle 4 systems	Fatalities	Casualties
Air bags for motorcycles	– 6.1%	– 7.6%
Helmet with improved performance	– 7.5%	– 1.2%
Total	– 10.6%	– 7.6%

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