

Motorcycle Riding Simulator Enabling Experience of Honda's Advanced Brake Systems

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ABSTRACT

In order to spread motorcycles with advanced brake systems, the “Honda Riding Simulator” was utilized as a way to experience advanced brakes. Since Honda Riding Simulator only reproduced the brake feeling based on conventional brake systems at the time of braking, we modified the pitching motion of the simulator and the tire squeal sound generated by the sound system in order to enable users to experience the characteristics of advanced brake systems. In addition, a scenario was created enabling easy comparison of the differences between conventional and advanced brake systems. Test-ride events of the simulator were conducted at the 2007 Tokyo Motor Show. The modified Honda Riding Simulator fulfilled the development goal of providing a safe and efficient means of enabling users to experience the feature of advanced brake systems.

1. Introduction

Honda actively pursues research on advanced brake systems - the Combined Brake System (CBS), the Anti-lock Brake System (ABS), and the Combined ABS that brings the two systems together as an effective technological means to help support safe motorcycle riding. In order for these technologies to be accepted and achieve a greater level of use, it is important to increase user awareness of them. The modification of the Honda Riding Simulator, which was already in use in motorcycle riding schools, was therefore planned in order to provide a safe and efficient means for users to experience and understand the advanced brake systems.

2. Status of Collisions and Social Background

According to World Health Organization (WHO) statistics for FY2004, traffic collisions kill approximately 1.2 million people and injure more than 50 million people annually. Approximately 22.8% of fatalities resulting from injuries occur due to traffic collisions. This figure is 6.7

times the rate of deaths resulting from wars (3.4%) (Fig. 1). Traffic collisions ranked 9th in terms of cause of death in 1990, but are expected to rise to 3rd place in 2020. As the leader in the motorcycle industry, Honda has had a long-term involvement in efforts to increase motorcycle safety.

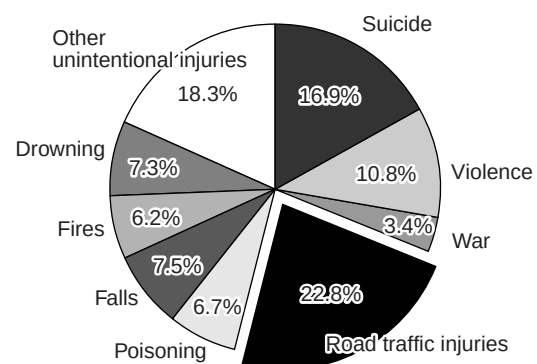


Fig. 1 Distribution of global injury mortality by cause (WHO 2004)

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3. Honda's Safety Technology Initiatives

3.1. Stages of Motorcycle Safety and Safety Technologies

Safety technologies can be broadly divided into two types: "Passive safety" technologies, which function to mitigate impact when a collision occurs, and "active safety" technologies, which function before a collision occurs. Depending on the margin of time before impact, active safety measures can be further classified into support for the rider's avoidance maneuvers, support for recognition of danger, and education to increase safety awareness (Fig. 2).

Honda has conducted research directed towards developing technologies for each of these safety stages. The airbag system fitted on the GL1800, advanced brake system, and inter-vehicle communication system (still in research phase), and the Honda Riding Simulator that is primarily used in Japanese motorcycle riding schools represent some of the outcomes of this research (Table 1).

3.2. Support for Avoidance Maneuvers

Technologies classified as "active safety" technologies

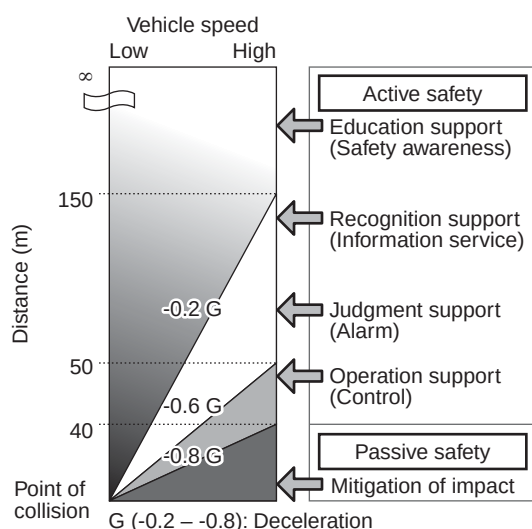


Fig. 2 Safety stages

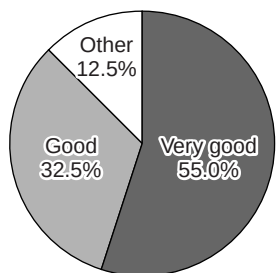


Fig. 3 User assessment of advanced brake systems

Table 1 Safety technologies for motorcycles

	☆ In use	□ Under research
Active safety		
Safety education	☆ Riding simulators	
Recognition support	□ Inter-vehicle communication systems	
Operation support	☆ Advanced brake systems	
Passive safety		
Mitigation of injury	☆ Airbag systems	

are helpful in reducing the number of collisions. Among these, advanced brake systems are technologies that enhance rider confidence.

3.3. Advanced Brake Systems

Motorcycle brake systems originally functioned separately for the front and rear wheels. The center of gravity in relation to the length of the wheel base is higher in a motorcycle than in a four-wheeled vehicle, and therefore there is a higher degree of change in the distribution of vertical load between the front and rear wheels during deceleration. This makes it necessary to appropriately adjust the operation of the front and rear brakes in order to generate a high degree of braking force. In addition, overly forceful application of the brakes can cause the wheels to lock. Honda developed its motorcycle advanced brake systems in order to address these issues. Honda has developed and put into use a number of advanced brake systems. The Combined Brake System (CBS) appropriately allocates braking force between the front and rear wheels with only the operation of the rear brake lever or a pedal. The Antilock Brake System (ABS) functions to help prevent the wheels from locking during braking. The Combined ABS combines these two functions. The goal of the development of the advanced brake systems has been the enhancement of the rider's sense of confidence.

At the same time that Honda continues to perform R&D of safety technologies, Honda also is seeking to increase usage of motorcycles fitted with advanced brake systems. Surveys of existing users of motorcycles fitted with CBS and Combined ABS in Europe show that 87.5% of users have positive opinions regarding the systems (Fig. 3). This indicates that although Advanced Brakes have received good ratings by existing users, in order to promote their widespread usage, it is important to ascertain how we can get new users to select models equipped with advanced brake systems.

4. Use of Riding Simulator to Increase User Awareness of the Advanced Brake Systems

This is where we came up with the idea of utilizing the "Honda Riding Simulator" to promote the features of Advanced Brakes to new users.

4.1. Features of Honda Riding Simulator

In 1988, research commenced on the Honda Riding Simulator as a new educational tool that would offer an experience beyond traditional lectures in the process of traffic safety education. The goal was to offer riders a simulated experience of various riding situations that can arise, to help increase their ability to anticipate and predict potentially dangerous situations on the road. The simulator enables riders to experience programmed scenarios that can result in representative motorcycle incidents while “riding” in a virtual environment of city streets. The base for the new model developed in the project discussed here is the second generation of the simulator, which has been marketed since 2001, chiefly to Japanese riding schools.

4.2. Configuration

Based on the concept of offering the user the sense that they are actually riding is important to the training effect of the unit. The simulator is provided with a motion unit controlled by AC servomotors, and has realistic image projection and high-quality sound production functions (Fig. 4).

4.3. Image System / Audio System / Motion Unit

The simulator’s image system uses a 3D graphics accelerator to project a realistic, high-quality image at 30 frames per second. The audio system uses digital

processing to synthesize sound in real time based on samples of actual sounds. The sound of the engine, for example, changes depending on engine speed and load, and is quite realistic. The audio system also produces a variety of other sounds that express different vehicle states, including the sound of the footrest scraping the road surface, tire squeals, and sounds of impact. The motion unit, which is controlled by a servomotor, can transmit to the rider the feeling of acceleration and deceleration, the sensation of roll, the shock of impact, and the feel of operating steering handles. The simulator excels at providing a realistic experience of the situations that lead to incidents.

5. Enabling Experience of Advanced Brake Systems on the Simulator

The project discussed here modified the conventional riding simulator to enable users to gain a better understanding of the features of the CBS and Combined ABS advanced brake systems.

5.1. Characteristics of Advanced Brake Systems to be Reproduced

- CBS

Based on operation of the rear brakes only, the characteristics of the CBS differ from those of conventional

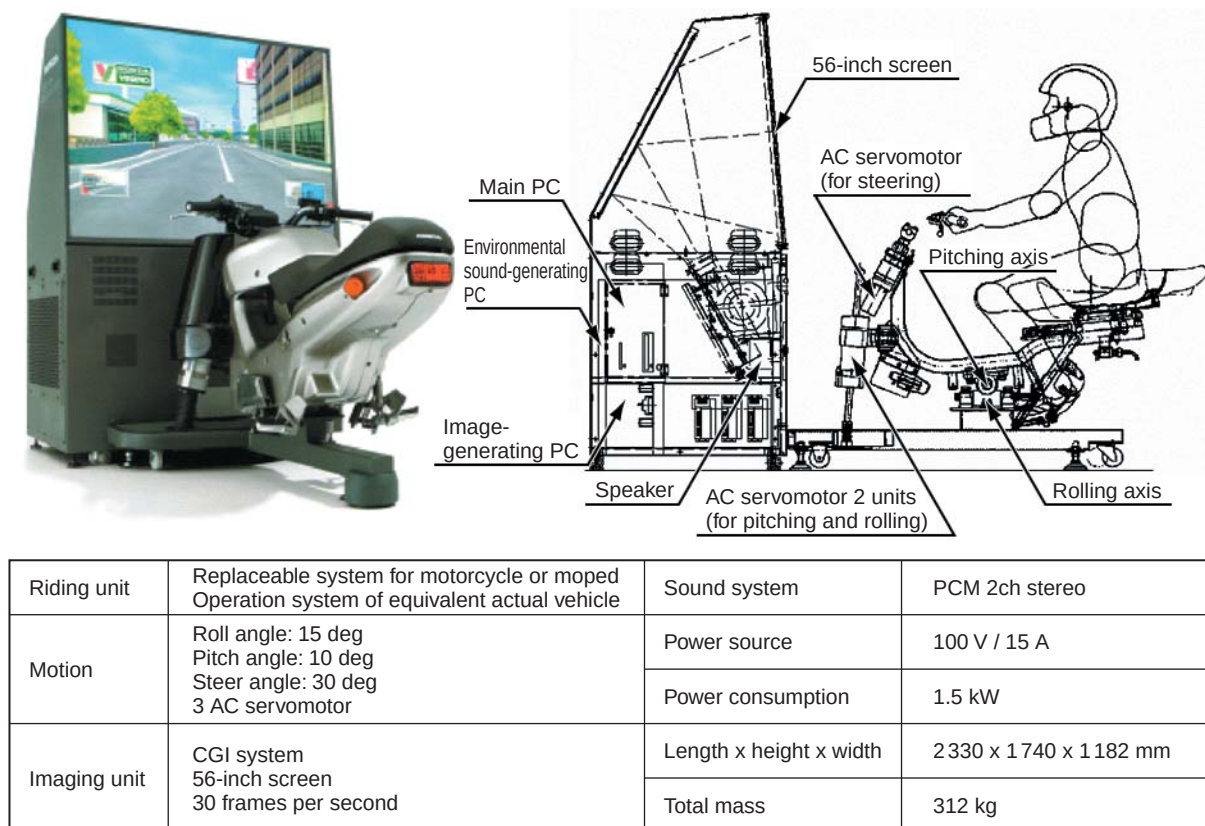


Fig. 4 Honda riding simulator

brake systems in the following respects:

1. Higher level of deceleration for the same application of force on the brake.
 2. Rear wheel reaches the slip limit first.
- Combined ABS

In addition to the features listed above, the Combined ABS is provided with a function that helps prevent the wheels from locking. It has the following characteristics:

1. Operates as CBS up to a level of rider brake input that causes the wheels to lock; operates as Combined ABS at higher levels of brake input.
2. Deceleration varies depending on the coefficient of friction of road surface during ABS operation.
3. Compared to the operation of ABS in a four-wheeled vehicle, it is easier in a motorcycle to feel changes in wheel speed through the chassis and the steering handles.

The development project sought to reproduce the characteristics listed above by making effective use of the simulator motion unit and sound system.

5.2. Reproduction of Operation of Advanced Brake Systems via Sound System and Motion Unit

Figure 5 shows the motion units pitch motion as well as the acceleration and deceleration calculations. The unit's steering equipment is identical to that of an actual motorcycle, and is fitted with sensors that detect the rider's steering operations and inputs them to the computer every 33 msec. Dynamic characteristics are expressed as equations of motion that employ the specifications of the motorcycle as constants. The state of motion for each time period is calculated by integration using the Runge-Kutta-Gill method [Fig. 5 (2)].

5.2.1. Reproduction of operation of CBS

In order to reproduce characteristics 1 and 2 of the CBS, as discussed in 5.1, the operating input to the rear brake is calculated for allocation to the front brake [Fig. 5 (1)]. The fact that the rear wheel has reached the braking limit is expressed by sounds such as tire squeals. Because the simulator is not provided with a motor enabling the motion unit to move longitudinally, longitudinal acceleration and deceleration is expressed by converting it into pitch motion of the motion unit. During deceleration, the front of the motion unit moves as if sinking in response to the level of deceleration. This is to give riders the experience of deceleration by pitching them forward so that their body weight rests on their arms. Pitch motion on an actual motorcycle occurs due to the extension and compression of the suspension, but pitch motion has a different meaning in the simulator because of the reproduction of longitudinal acceleration and deceleration. Because the rider on the simulator experiences the level of deceleration through the pitch motion of the motion unit, as indicated above, the changes in posture of the simulated motorcycle differ from those of a real motorcycle; when the calculated level of

deceleration is high, deceleration is reproduced through a greater degree of pitch motion.

5.2.2. Reproduction of operation of Combined ABS

When the rider's operation of the brakes causes the wheel lock limit to be reached, based on the coefficient of friction of the road surface that is being simulated as defined in the computer, the system is judged as being in ABS operation. Because prediction of ABS performance is not the goal of the system, ABS motion itself is not simulated, and the operating cycles used in the reproduction of ABS behavior are based on actual data for each coefficient of friction of the road surface [Fig. 5

Com: Coefficient of pitching motion of longitudinal acceleration and deceleration component
Cfm: Coefficient of pitching motion of front brake operation component
Crm: Coefficient of pitching motion of rear brake operation component
Ngain: Smoothing coefficient of longitudinal acceleration and deceleration
Scl: Longitudinal acceleration and deceleration adjustment factor depending on velocity
Cbf-Cbr: Brake force distribution coefficient
Pabs: Amplitude of pitching motion expressing ABS operation
Bfi: Rider's front brake input
Bri: Rider's rear brake input
Bfc: Front brake force
Brc: Rear brake force
hz: ABS operation cycle depending on road μ
E: Adjusted longitudinal acceleration and deceleration
Pit: Pitch angle of motion unit
T: Elapsed time
dt: Time increment

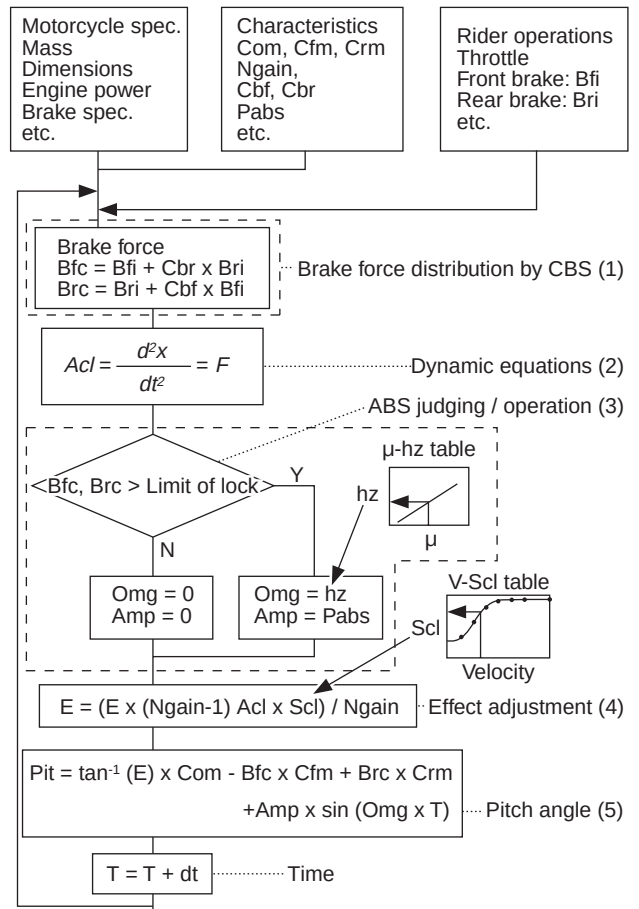


Fig. 5 Motion system control flow

(3)]. Until the wheel lock is reached, the brake system operates as a CBS and reproduces characteristic 1 of Combined ABS as listed above. To enable the rider to experience the behavior of a real motorcycle, characteristic 2 of Combined ABS is reproduced during ABS operation via pitch motion corresponding to the level of deceleration, which varies depending on the coefficient of friction of the road surface. Adding the sine wave component of the operating cycle that expresses ABS operation [(Fig. 5 (5))], which is determined by the coefficient of friction of the road surface, enables reproduction of characteristic 3 of Combined ABS. The amplitude of the sine wave component is determined by sensory evaluation. The squeal noise during ABS operation is produced by multiplying the conventional brake squeal noise by a folded-back waveform of the negative component of the sine wave that represents half the operating cycle for the ABS (Fig. 6). In this simulator, when the motion unit is moving, the calculated longitudinal acceleration and deceleration includes high-frequency noise, and is discontinuous at take-off and when the motorcycle is stopped. Because of this, the pitch angle is not substituted for longitudinal acceleration and deceleration as is, but is multiplied by the longitudinal

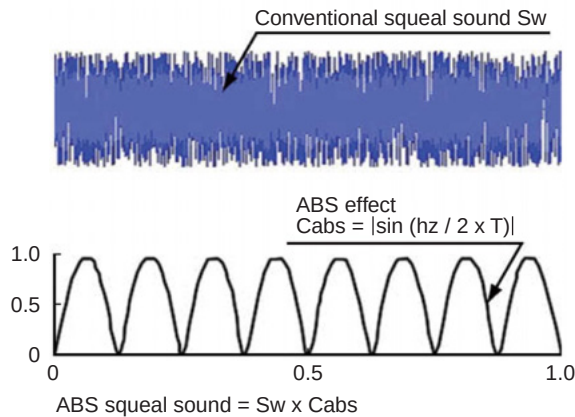


Fig. 6 ABS squeal sound

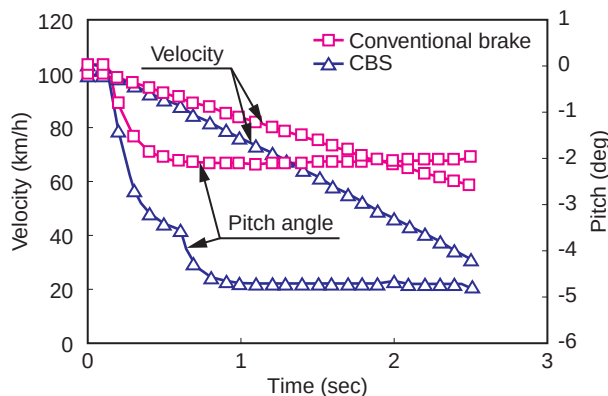


Fig. 7 CBS versus conventional brake

acceleration and deceleration adjustment factor depending on velocity, which is low at low speeds, and then further smoothed, for use as pitch motion. In addition, one of the characteristics of motorcycles is that the moment of inertia in the direction of pitch is lower than in a four-wheeled vehicle, and the vehicle's posture therefore responds more quickly to operation of the brakes. In order to reproduce this characteristic, the level of pitch motion is increased based on brake operation [Fig. 5(4), (5)].

Figure 7 shows a comparison of conventional brakes and CBS brakes calculated on the simulator. The graph shows deceleration and pitch motion resulting from use of the rear brake in isolation. This example shows that the CBS produces 1.78X the deceleration of the conventional brake system for the same level of the rear brake operation. Adding in the increase in pitch motion that is used to express deceleration, as discussed above, the CBS produces 2.28X the deceleration than the conventional brake system, enabling the user to experience a high level of deceleration. Figure 8 shows a comparison of a real motorcycle and the simulator during ABS operation. Wheel speed in the real motorcycle and pitch motion on the simulator are superimposed on the graph. This example is for braking on dry asphalt. The speed of the front wheel of the real motorcycle varies in a cycle of approximately 8 Hz. Also, in the simulation, the pitch angle varies approximately 8 Hz. This motion expresses the deceleration occurring due to the change in the speed of the front wheel in the real motorcycle. Figure 9 shows the amplitude of the tire squeal noise produced at the time of operation. The waveform of the noise also displays an

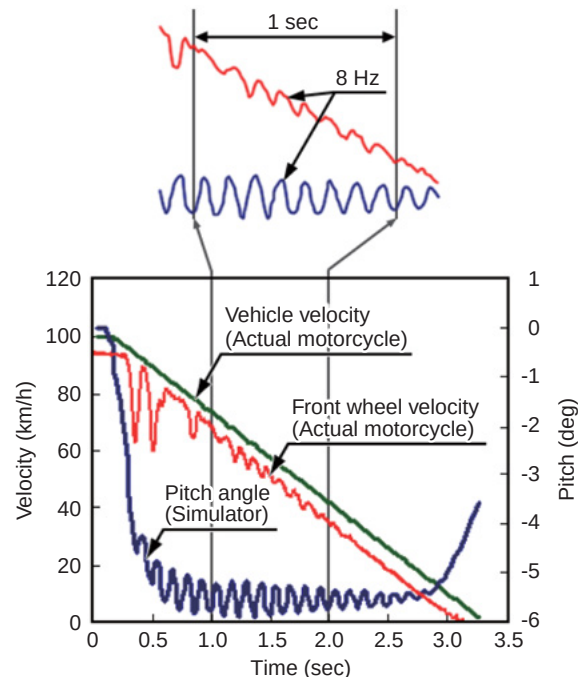


Fig. 8 Pitching motion as feeling of deceleration

8 Hz cycle. This indicates that the modes of expression of the characteristics of a real motorcycle incorporated in the simulator enable users to realistically experience the operation of advanced brake systems.

5.3. Simulator Scenarios

The monitor on the simulator control panel features a brake system menu enabling switching between conventional and advanced brakes. Initially, the concept of the system was to switch brake systems while the user was riding down the virtual street in order to enable the difference between conventional and advanced brake systems to be experienced. However, it was decided that given the fact that the vehicle speed at which a particular scenario was entered and the response to the scenario varied from rider to rider, and that the rider's attention was directed to other factors, in many cases the rider would not be attentive to the difference between brake systems. Based on these considerations, a specialized

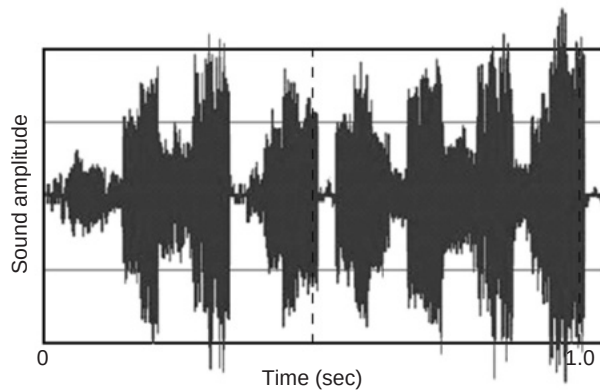


Fig. 9 Squeal sound during ABS operation

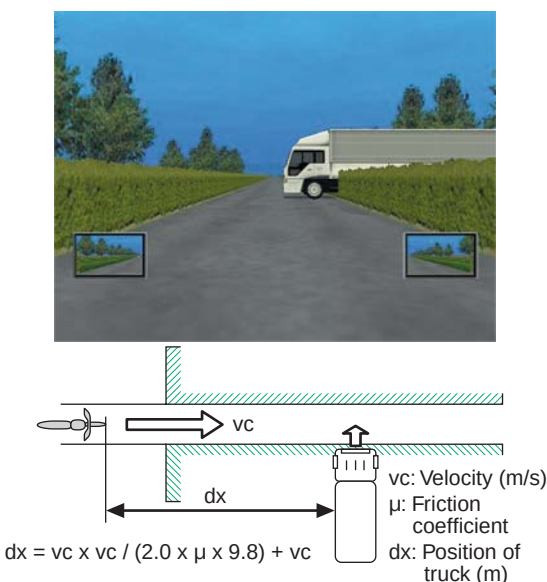


Fig. 10 Brake test course

course enabling a simpler comparison of the brake systems was employed. This is a straight course, rather than a street scene, in order to enable the rider to experience the difference in the brake system efficiently in a short period of time. Both sides of the road are planted with a hedge in the image to prevent the rider from having an unobstructed view of the sides of the road. In the scenario presented, the rider is riding down the straight road at a predetermined speed, when a truck emerges from the hedge in front into the path of the motorcycle (Fig. 10). This models a type of head-on collision that could easily occur in an urban environment. The position at which the truck appears is a position established by the shortest braking distance as determined by the coefficient of friction of the road surface when the motorcycle commences deceleration from the predetermined speed, plus a "free running distance" corresponding to a 1-second delay in brake response. The rider is instructed to apply the brakes quickly when the truck appears in order to bring the motorcycle to a halt and prevent a collision. The rider goes through this emergency braking scenario twice, using conventional and advanced brake systems. Following this, the free running distance, which shows the speed of the brake response, and the braking distance needed for application of the brakes until the motorcycle was stopped are displayed on the monitor. In addition, if a collision or crash has occurred, the reason for the crash (wheels locking, collision with truck) is displayed. Because this scenario is simple, it makes it easier for the rider to comparatively understand the difference between the brake systems.

6. Test Rides of Simulator at the 2007 Tokyo Motor Show

In addition to being the automotive industry's largest exhibitions, motor shows represent an opportunity to publicize company activities both domestically and overseas and to increase awareness of company concepts. They are therefore ideal venues in which to conduct activities aimed at increasing awareness of the advanced brake systems. Accordingly, a riding simulator enabling users to experience advanced brake systems was set up in the Honda motorcycle booth of the 2007 Tokyo Motor Show, and visitors were offered test rides for approximately two weeks. The scenario discussed above was employed, and the Combined ABS was set as the brake system. The speed of the motorcycle when the truck appears was set at 60 km/h, which is the speed limit on local streets in Japan. During the Tokyo Motor Show, 2 255 people experienced the operation of advanced brake systems on a demonstration simulator. An average of 140 persons rode the simulator on a trial basis, daily. Since test rides on the simulator took less time and effort than it would to ride a real vehicle, they were deemed efficient. In addition, although it would be very difficult to carry

out an actual brake operation on a real vehicle for one riding scene in which a track jumps out suddenly onto a course, the special features of the simulator enabled the rider to experience the advanced brake system safely.

7. Conclusion

Almost all the visitors who used the simulator during the Tokyo Motor Show responded positively when asked their impressions of the advanced brake system. Respondents felt more relaxed when braking using the advanced brake system, and understood the system. This demonstrates that the simulator is effective in enabling users to safely and efficiently experience the advanced brake systems. In the future, other uses for the simulator will be considered, including its use in safety education conducted from the perspective of helping prevent riders from overestimating advanced brake systems.

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