

A Study on the Effect of Brake Assist Systems (BAS)

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ABSTRACT

BAS assists driver's by automatically increasing their braking power during an emergency brake event when the driver is unable to apply a sufficient brake force.. There are two performance requirements that BAS must fulfill in order to be employed effectively. One is the ability to activate when the driver suddenly applies brakes in an emergency while the other is the ability to provide additional assistance. Further study of BAS activation timing and degree of assistance in relation to driver acceptance is needed. The driver's acceptance of BAS refers to the BAS activation only during an emergency. A study was conducted to clarify drivers' emergency braking characteristics and measure the frequency of BAS activation during normal braking.

One aim of the study was to verify driver characteristics during emergency braking on a test course. The study measured the brake pedal speed, force, and stroke during emergency braking along with the driver's compatibility with BAS activation conditions. Another task was to evaluate BAS with a driving simulator (DS). This study measured the frequency of BAS activation during normal braking by varying the BAS activation timing and degree of assistance. It also examined what the effects and side effects of varying these BAS parameters on the driver.

In conclusion this study evaluates how varying BAS activation timing and its degree of assistance has on the drivers.

INTRODUCTION

A minor difference in collision speed at the time of an accident can be correlated to the number of accident deaths. It has been shown that many average drivers cannot depress the brake pedal with sufficient force during an emergency. This results in insufficient braking performance. To assist these drivers, a power-booster device which automatically increases the braking power during emergency braking (Brake Assist System: BAS) was developed and installed into some vehicles starting in 1997.

To date, driving characteristics during emergency situations have been measured using actual vehicles or driving simulators. However, a few measurements have been made in conjunction with brake pedal operations such as brake pedal stroke depth. In evaluating and predicting BAS effectiveness, it is necessary to study the degree of brake pedal operation.

By evaluating drivers' braking characteristics in both emergency and normal situations, this study draws some conclusions on BAS operational requirements to prevent accidents and its acceptability to drivers.

OVERVIEW OF THE BAS

BAS is a device that predicts a driver's braking intention based on their brake pedal operations. It boosts braking power when it detects an emergency braking situation. There are two methods used to predict a driver's braking intentions based on their brake pedal operations. They are brake pedal depression speed and brake pedal depression force. The already developed BAS systems use one of these methods. In this study, BAS is called the "pedal stroke speed BAS" or "pedal force BAS." The operating principles of each system are shown in Figure 1.

The pedal stroke speed BAS (Figure 1 [a]) uses a driver's brake pedal stroke speed to predict their braking intention. As shown in the figure, when the pedal stroke speed exceeds a certain value (threshold value), the system determines that the driver is depressing the brake pedal during an emergency. This speed will activate the brake power-boosting function.

The pedal force BAS (Figure 1 [b]) uses a driver's pedal force to predict their braking intention. As shown in the figure, when the pedal force exceeds a threshold value, the system determines that the driver is depressing the brake pedal in an emergency and activates the brake power-boosting function.

In order for the two types of BAS to be effective, it is necessary to determine these operational threshold values. In other words, these values must be set so the system will effectively activate only in emergency



situations. The BAS system must meet the following performance requirements:

- (1) It will activate properly and provide the necessary effects in/during an emergency;
- (2) It will not interfere with, adversely affect, or activate during normal driving;
- (3) It will be able to detect emergency braking based only on the drivers' brake pedal operations;

For this study, an experiment was conducted to clarify drivers' braking characteristics in emergency situations. These measurements used an actual vehicle on a test course (Experiment I). In Experiment I, the brake pedal stroke speed and force used in a driver's emergency braking (to avoid an accident) were measured. From this data, the distributions of their characteristics were determined. Based on the results, the proper operational threshold values necessary to successfully activate the pedal force and stroke speed BAS were considered.

Next, an experiment to clarify the frequency of BAS activation during normal driving was performed (Experiment II). In Experiment II, a DS was used to simulate different driving environments for a BAS equipped vehicle. With a test driver driving the vehicle normally, the frequency of BAS activation at different operational threshold values was observed. In addition, the values from Experiment I were studied to balance the BAS effect with the BAS activation during normal driving.

EXPERIMENT I: THE DRIVERS' BRAKING CHARACTERISTICS IN EMERGENCY SITUATIONS CONCLUSION

1. Objective

This experiment examined the driver's braking characteristics by driving an actual vehicle on a test course. Based on the distributions of their braking characteristics, the operational threshold values for BAS to activate successfully were identified.

2. Equipment for the Experiment

Figure 2 shows the test vehicle and the measurement equipment used for this study. Table 1 lists the items measured during the experiment. Figure 2 [e] shows the relationship between the brake pedal force and the cylinder pressure. The vehicle of this experiment has a characteristic to show in Figure 2 [e]. In addition, the examination used the vehicle that necessary the average brake pedal force was about 10 N to operate ABS.

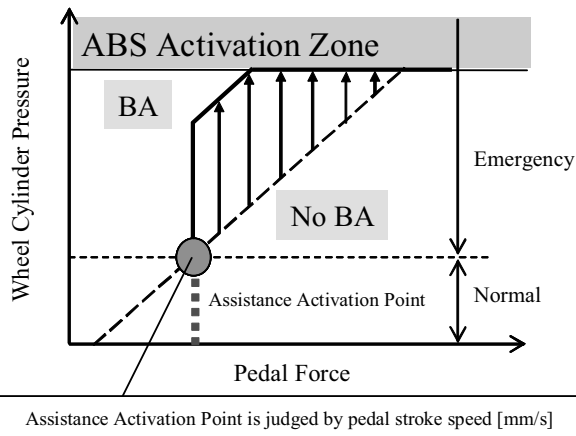
For this experiment, a test point was built on the straight section of the test course to simulate an intersection with poor visibility (overall length: about 3 km; outward and return route lengths are about 1 km each). At this point, a dummy vehicle was suddenly deployed in front of the test vehicle to induce an emergency action. Figures 3 and 4 show the experimental setting and appearance of the dummy vehicle. The dummy vehicle was made of processed expanded polystyrene and painted like a real vehicle.

The test drivers in Experiment I were 57 ordinary Japanese drivers (38 males and 19 females in their 20s to 80s, who were hired and paid as test subjects).

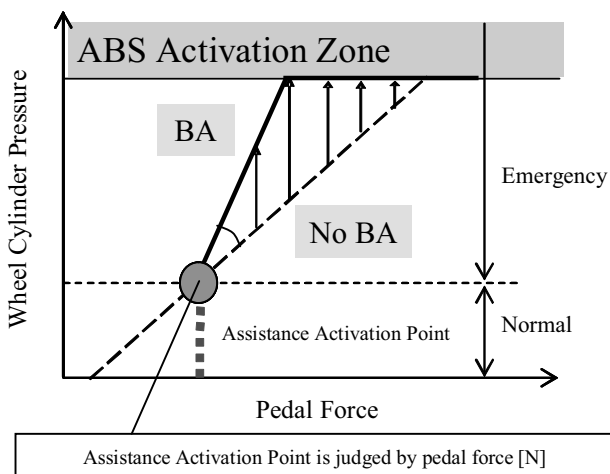
3. Experimental Method

Because this experiment involved an emergency situation, the test drivers were told to follow another vehicle. They were not told about the dummy vehicle. The schedule for this experiment is provided in Table 2.

In order for the test driver to become used to driving, he/she was instructed to follow another vehicle that repeatedly braked at 1-3 m/s². The distance between the vehicles was determined by each test driver. After



(a): Pedal stroke speed detection type BAS



(b): Pedal force detection type BAS

Figure 1: Operating Principle of BAS

one lap, the test driver was subjected to the sudden appearance of the dummy vehicle which was released between the two vehicles.

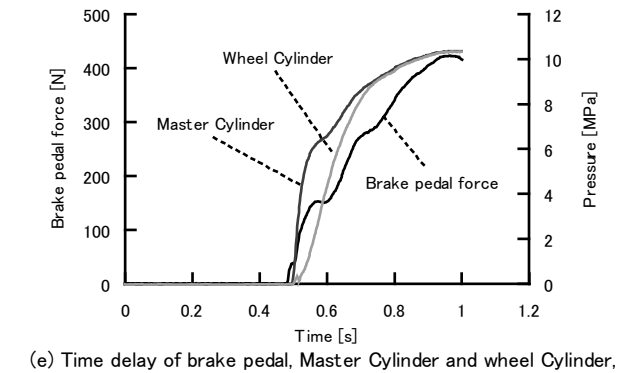
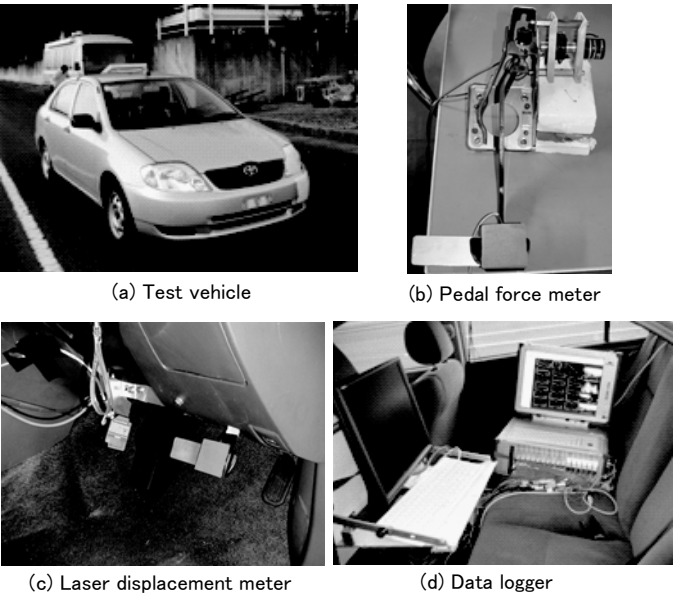


Figure 2: Test Vehicle and Measuring Devices

Table 1: Measuring Devices and Measured Items

Instruments	Measured Items
Laser displacement meter	Brake pedal stroke displacement
	Accelerator pedal opening
Pedal force meter	Brake pedal force
Data logger	Data storage by time synchronization (sampling frequency: 500 Hz)
Pressure meter	Pressure in master cylinder & wheel cylinder
Video camera	Images of front of vehicle & driver's actions

Table 2: Laps and Description of Each Experiment

Laps	Description
1st lap	Follows the preceding vehicle and repeatedly brakes at 1-3 m/s ²
2nd lap	Emergency braking in response to sudden appearance of the dummy vehicle (first)
3rd lap	Emergency braking in response to sudden appearance of the dummy vehicle (second)

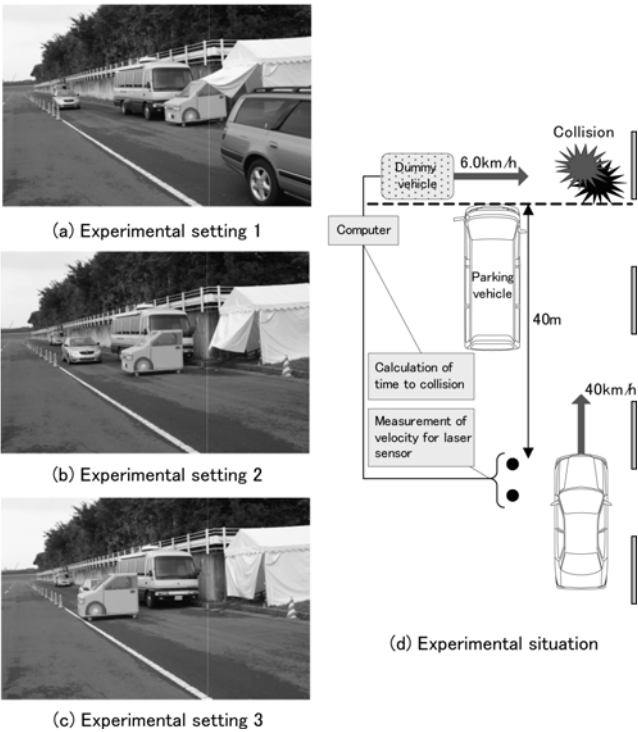


Figure 3: Dummy Vehicle Sudden Appearance Test for Measuring Emergency Braking Characteristics

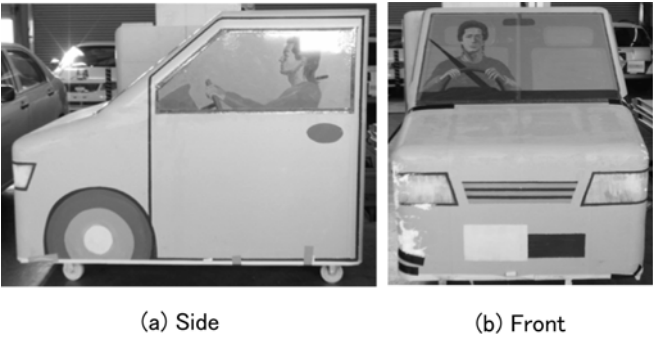


Figure 4: Appearance of the Dummy Vehicle

The front vehicle kept the test vehicle's speed to 40 km/h when the dummy vehicle suddenly appeared. The dummy vehicle's timing was set to yield a Time To Collision (TTC) of 1.5 s. This was calculated using both the dummy vehicle and test vehicle's speed. The test vehicle's speed was measured by a laser sensor at a point 40 m behind the collision point. The dummy vehicle was fixed on a ramp with a hook that was controlled by an automatic control unit. When the hook was lifted and lowered, the lock was released and the dummy vehicle was quickly placed in front of the test vehicle. The previously-measured dummy vehicle and test vehicle speeds were input into the control unit for each experiment. This unit automatically operated the hook to ensure a collision within the prescribed TTC.

The test was repeated in a similar manner to see the changes in the driver's brake pedal operation characteristics after emergency braking. After the first