

Transmitted by expert from Japan

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agenda item 3(i))

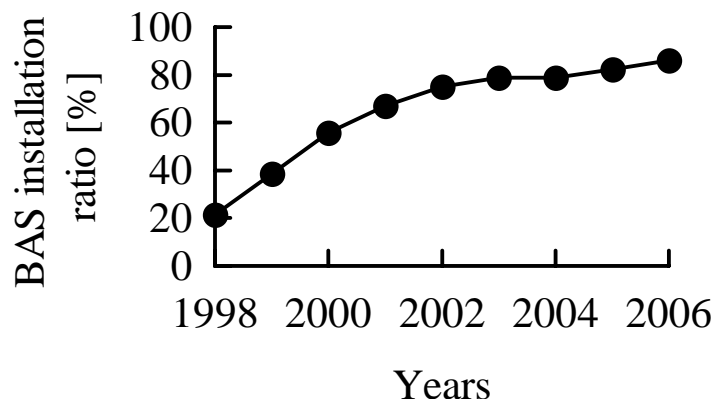
Study on the Activation Timing of Brake Assist Systems (BAS)

Study Background

Drivers having pedal force less than required in an emergency can not get sufficient braking performance.

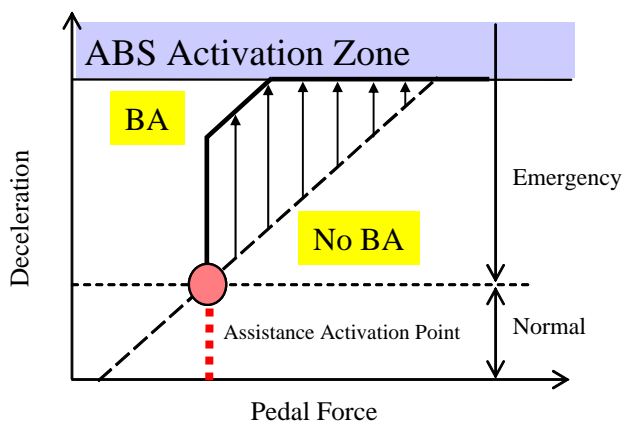


Brake Assist Systems (BAS) enable automobiles to automatically increase braking power during emergency braking

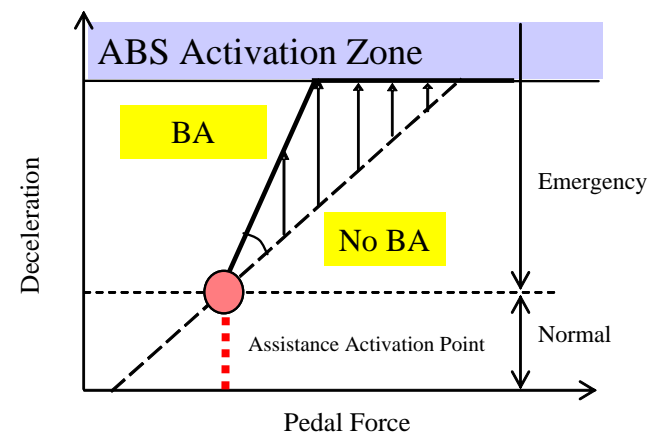


BAS production began in Japan in 1997, and in nine years, BAS installation ratio reached 86.1% of all automobiles to be sold in Japan.

Pedal Stroke Speed Detection Type BAS



Pedal Force Detection Type BAS



Study Objectives



BAS Performance Requirements

- An effective BAS should fulfill the following two requirements.
 - (1) To be able to be activated when a driver brakes in an emergency situation (ease of BAS operation)**
 - (2) To be able to assist (quick set to the ABS full-cycling mode)
(improvement of braking performance)

- Emergency braking characteristics (pedal stroke speed and force) vary depending on drivers. Therefore, a lower activation threshold will be effective for a larger number of drivers; however, it may also activate BAS in non-emergency situations, resulting in unacceptability to drivers.

Study objectives

- (1) To understand drivers' emergency braking characteristics
- (2) To measure the frequency of BAS activation in non-emergency situations

Study Methods

(1) Study on driver characteristics in the emergency braking test using an actual vehicle

What are the drivers' brake pedal stroke speed, force and stroke during an emergency?

(2) Study on activation frequency with a driving simulator

What is the frequency of BAS activation in non-emergency situations when BAS activation timing and effects are changed?

Item	Subject	Verification method
Driver characteristics	Understanding drivers' braking characteristics in an emergency	Emergency brake test on test tracks
Activation frequency	BAS activation frequency in non-emergency situations	Brake test using a driving simulator (DS)

(1) Study on Drivers' Characteristics in the Emergency Braking



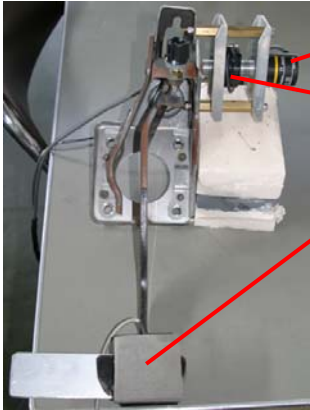
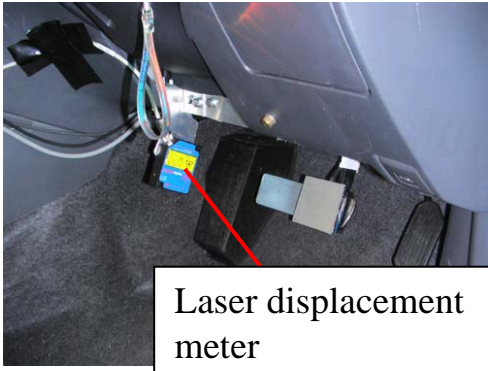
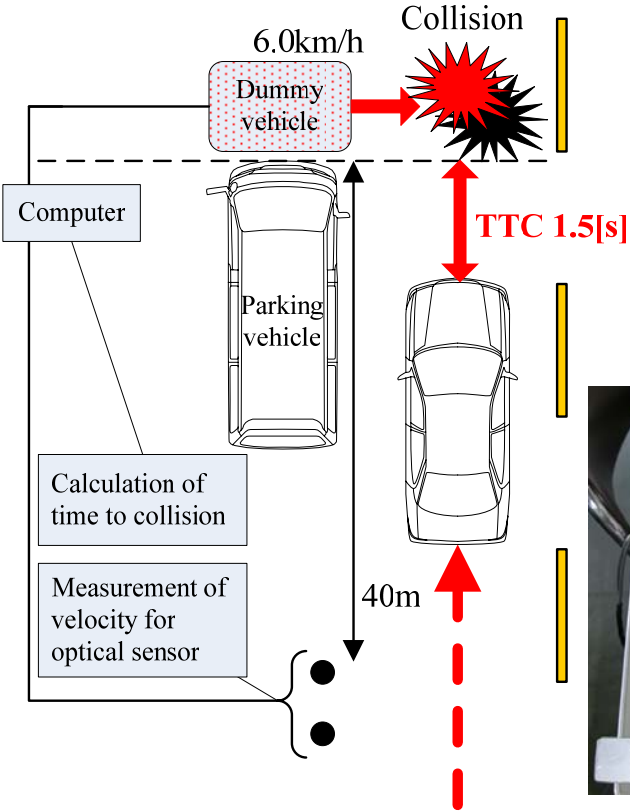
(a) A dummy car suddenly came out from the front left side.



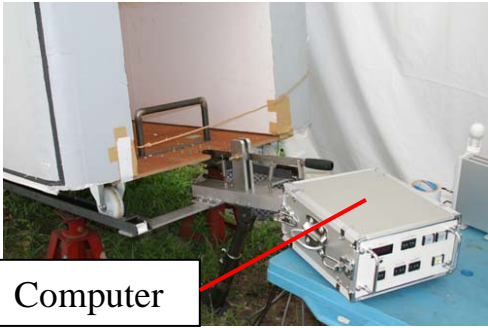
(b) The driver became notice of the car coming out.



(c) Emergency braking



- Optical encoder
- Potential meter
- Pedal force meter
- Measured items



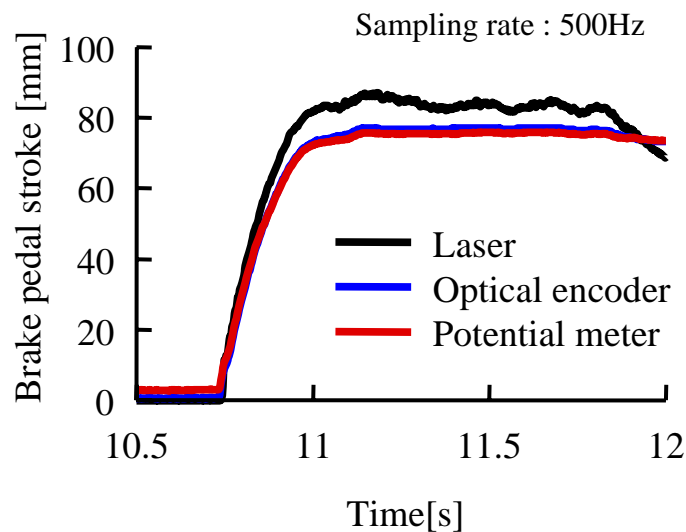
Brake pedal force, speed and stroke, and longitudinal acceleration

(1) Study on Driver Characteristics in the Emergency Braking (Data Processing)

Characteristics representing brake pedal stroke speed and force can be expressed by maximum instantaneous values, average values in a given period, etc.

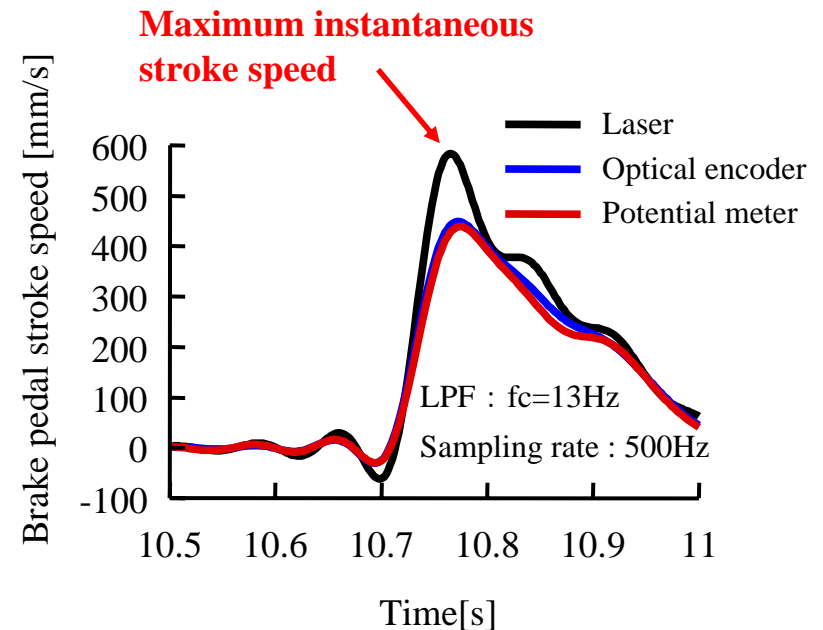
In this analysis, the **maximum instantaneous speed and pedal force** were used as representing values.

We will need to examine which representing values are appropriate as BAS activation thresholds.



Numeric differentiation

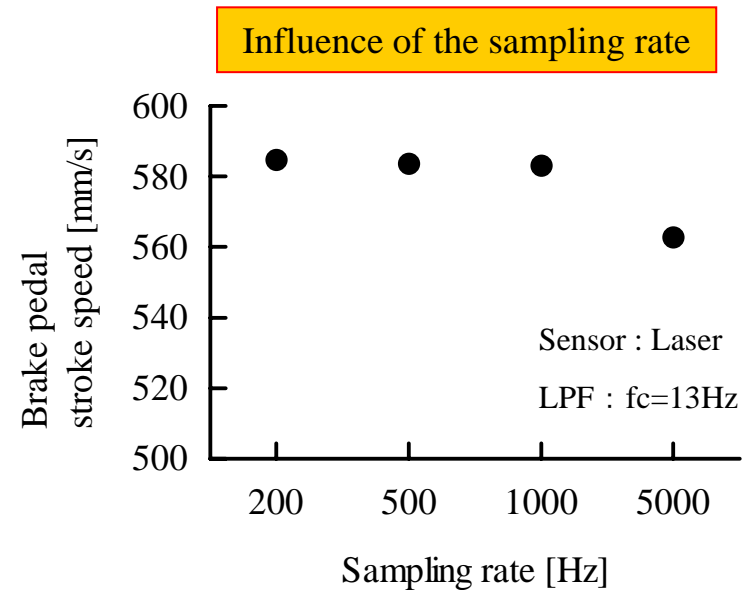
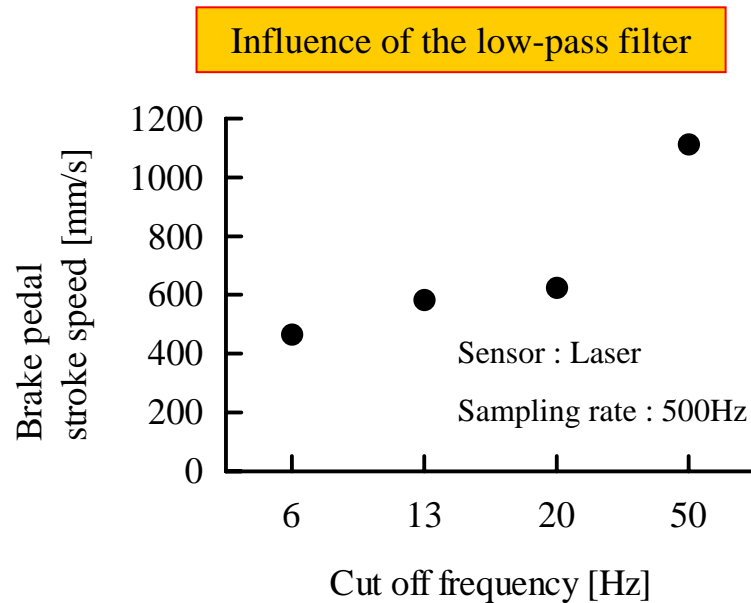
Low-pass filter:
3rd-order
Butterworth filter



• Influence of measurement sensors

In measuring the pedal stroke, the response varies with different measurement sensors. Therefore, the results cannot be compared as they are if different sensors were used for measurement.

(1) Study on Driver Characteristics in the Emergency Braking (Data Processing)



- Influences of the low-pass filter and sampling rate**

In calculating the brake pedal stroke speed, the characteristics of the low-pass filter and the influences of the sampling rate on data should be considered. For example, increasing the cut-off frequency from 13 Hz to 50 Hz would nearly double the stroke speed.

In this study, the data processing methods of BAS-installed vehicles are not identified. Therefore, data were processed in each test based on the following conditions.

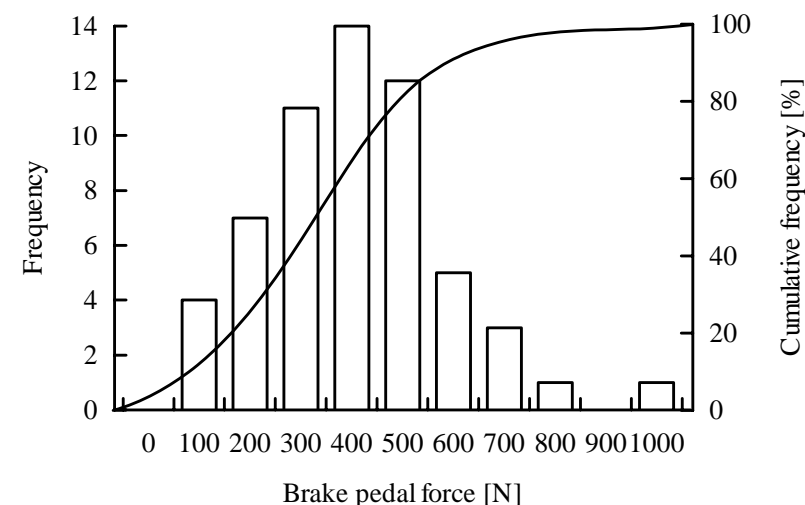
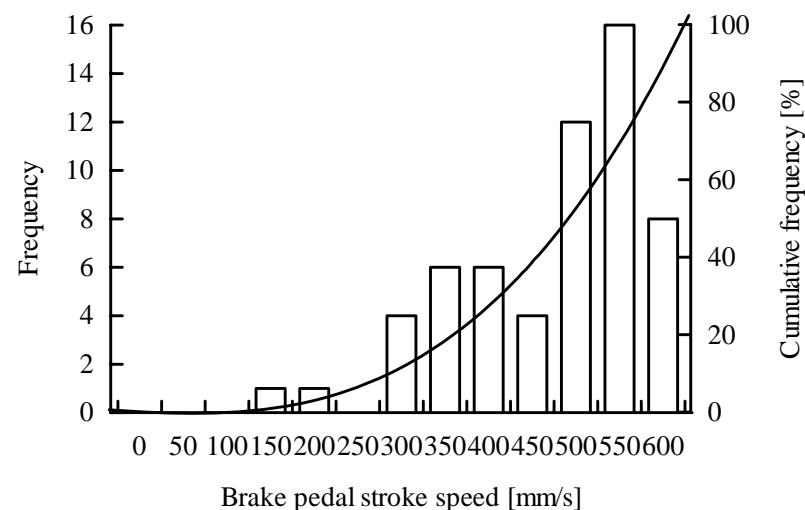
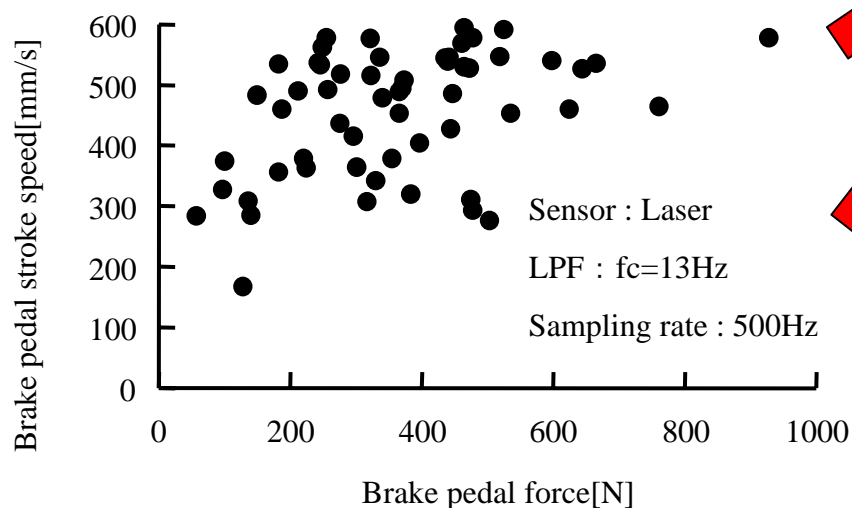
Measurement method: laser displacement meter, Representing values: maximum brake pedal stroke speed and pedal force, Low-pass filter: cut-off frequency of 13 Hz, Sampling rate: 500 Hz

(1) Study on Driver Characteristics in the Emergency Braking (Test Results Using an Actual Vehicle)

Relationship between the driver's brake pedal stroke speed and pedal force during emergency times

57 test subjects (Japanese) (in their 20s to 80s, 38 males and 19 females)

Vehicle used: one compact car

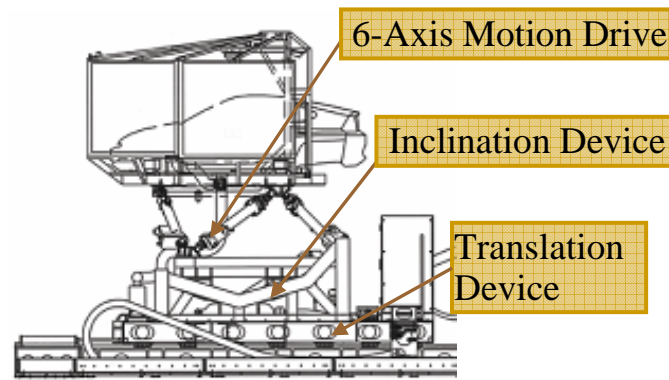


Distribution of drivers' braking characteristics

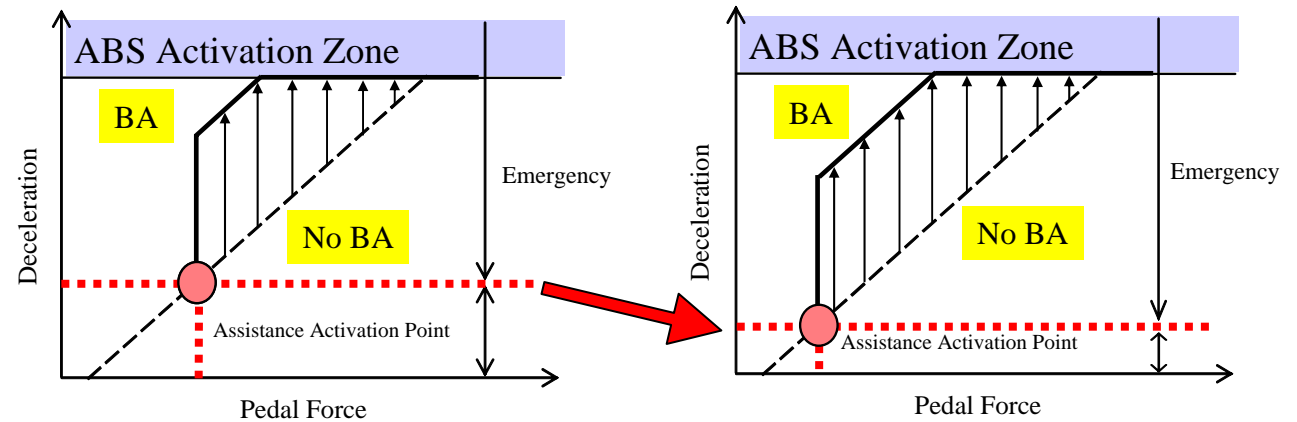
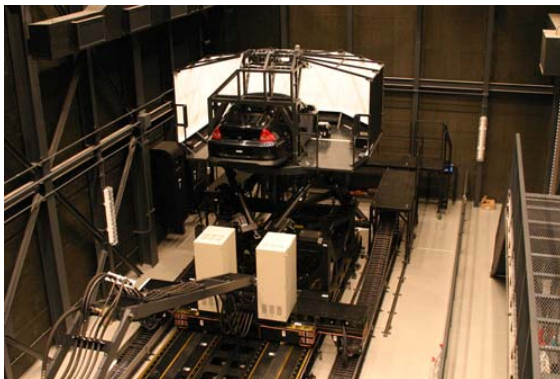
	Average	Minimum	Maximum
Brake pedal stroke speed [mm/s]	456.4	167.6	595.0
Brake pedal force [N]	364.0	56.0	927.4

Since these values may vary with vehicles' braking characteristics and drivers' physical attributes, more data will need to be collected.

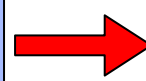
(2) Study on Activation Frequency with a Driving Simulator



- **Horizontal direction**
Maximum acceleration:
 6.0m/s^2 (short period)
 5.0m/s^2 (continuous)
Maximum jerk: **10.0m/s^3**
- **Vertical direction**
Maximum acceleration: **3.0m/s^2**
- Response frequency: **5Hz**
- Translation device stroke: **8m**



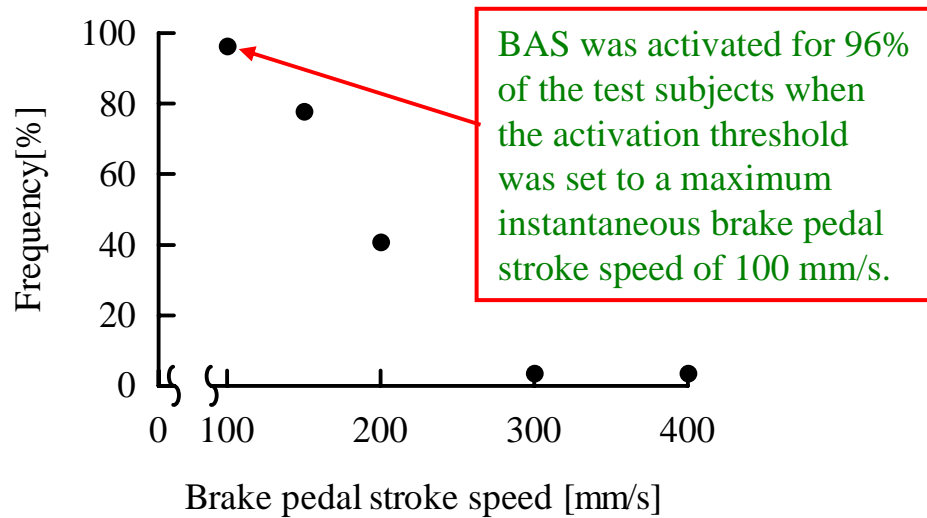
Driving test with DS



Study on brake pedal stroke characteristics in normal times

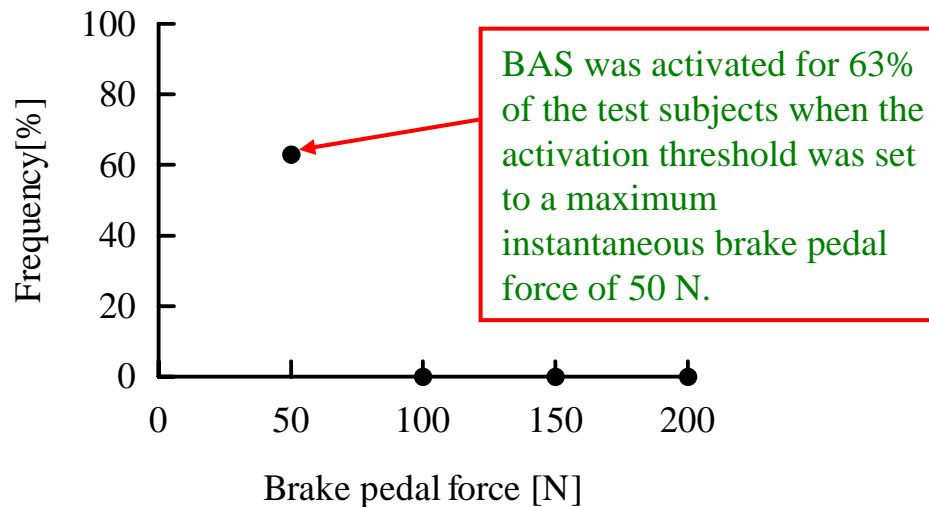
BAS activation frequency in non-emergency situations

(2) Study on Activation Frequency with a Driving Simulator (Test Results)



BAS activation frequency [%], assuming the maximum instantaneous brake pedal stroke speed in normal braking situations as activation thresholds
(Pedal stroke speed detection type)

Thresholds (Brake pedal stroke speed [mm/s])	Activation frequency [%]
100	96
150	77
200	40
300	4
400	4



BAS activation starting frequency in normal braking situations [%] (Pedal force detection type)

Thresholds (Brake pedal force [N])	Activation frequency [%]
50	63
100	0
150	0
200	0

If the activation threshold is set to a lower value, BAS may be activated even in non-emergency situations, and therefore, it will result in unacceptability to drivers. This should be well considered in determining activation thresholds.

Summary

- In 2006, as much as 86% of automobiles to be sold in Japan were equipped with a BAS, but its effects and side effects such as activation in non-emergency situations are still unknown.

- **This study aims at examining the effects and side effects of BAS activation timing on drivers.**

- Study results:
 - [1] **Study on driver characteristics in the emergency braking using an actual vehicle** identified drivers' braking characteristics in emergency situations.
 - [2] **Study on activation frequency with a driving simulator** identified the side effects of BAS activation timing on drivers.
 - [3] It was found out that measuring and data processing methods affected the measurement data.

Summary

- If the activation threshold is set to a lower value, BAS may be activated even in non-emergency situations, and therefore, it will result in unacceptability to drivers. This should be well considered in determining activation thresholds.
- Generalization based on the results of this study is difficult at this moment since this was conducted using only one compact car. Further study is needed using vehicles with different braking characteristics (pedal force and stroke characteristics, driving posture, etc.).
- It is necessary to study how drivers' physical attributes, transportation environment, etc., in different countries affect activation thresholds.
- It is also necessary to examine what representing values are appropriate as BAS activation thresholds, including the consideration of measuring and data processing methods, when determining the requirements of activation thresholds.
- Based on the above-mentioned points, data should be further collected and examined.