COLLISION DETECTION USING ADAS SENSOR AND ITS EFFECT ON OCCUPANT INJURY

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ABSTRACT

In real world, Collisions which are faster than NCAP speed are occurring and fatality rate is high in such collisions. In order to solve such the high-speed collisions, it is important to increase the energy absorption amount of the occupant restraint devise. In order to increase the amount of energy absorption, it is necessary to detect the collision early and for the occupant to be restrained at an early timing

We focused on the integrated system using the advanced driver assistance systems (ADAS) sensor as a method to achieve the early airbag deployment timing. And we research whether the collision detection timing can become earlier and the occupant injury can be reduced.

A collision is predicted using the ADAS sensor, and the threshold of an airbag deployment is lowered just before the collision. Furthermore, by lowering the threshold only at the collision speed where an airbag deployment is required, it will prevent an airbag deployment at slight collisions. Also, the threshold is lowered until the rough road toughness can be secured. So the toughness of rough road traveling is equivalent to the conventional one.

For confirming the effect of this sensing system, we conducted simulation using LS-DYNA and the actual vehicle test. The airbag deployment timing was calculated by the simulation results.

In order to calculate the effect on the occupant injury, sled test was also conducted. The input data of floor G and the airbag deployment timing is the results of simulation.

From these results, it was found that the collision would be detected earlier than the conventional one. And we also confirmed the effect of reducing occupant injury.

INTRODUCTION

Front collisions occurring in real world have various collision modes, and the collision speed is various. Regarding the collision speed, the collision that exceed the crash speed of NCAP or regulations such as frontal 56 km/h and offset deformable barrier(ODB) 64 km/h have also occurred. [1][2]

Even if the speed of the own vehicle is low, if the opponent of the collision is a heavy vehicle, it will be a collision with a high ΔV collision. In this case, there is a severe collision similar to the case where own vehicle collides with rigid barrier at the high speed.

Even in such a high ΔV collision, reducing further occupant injury is a challenging point.

According to the results of analysis of the occupant injury factor at head-on collisions, it suggested that there are still many people who were injured by the vehicle body intrusion factor and the occupant restraint factor. [3]

Talking about the body intrusion factor, the body toughness has been improved by the progress of NCAP. Although the energy absorption of the device has also been improved in accordance with the progress of NCAP, further improvement of the energy absorption of the device is required for the occupant protection.

As a method of increasing the energy absorption of the device, there is a method of performing the occupant restraint from the early timing of the collision. One way to achieve that is to make the collision detection earlier.

In this paper, we devised the integrated system using the ADAS sensor. We call it ADAS integrated system. By predicting a collision using this ADAS sensor, we have studied realization of the collision detection at an earlier timing. We also confirmed the effect on the occupant protection performance due to the earlier collision detection.

In this paper, we call that the ignition timing of an airbag is TTF and the TTF of the ADAS integrated system is the early TTF.

METHODS

Conventional System

Generally, the conventional collision detection system uses several G sensors. Figure1 shows as an example. Honda also detects the collision with this method.

As a sensing system for frontal collisions, the SRSUnit is located at the center of the vehicle and satellite sensors are located in the frontal structural members of the vehicle. When the SRSunit detects floor G and it exceeds the collision determination threshold, it is determined that the airbag deployment is needed.

As a method of achieving TTF earlier using the conventional system, it is to lower the collision determination threshold.

In the conventional system, it is acquired three types of the data for setting the collision determination threshold. The first is the data of collision that needs the airbag deployment. We call it airbag ON collision. The second is the data where the airbag deployment is unnecessary. We call it airbag OFF collision. The third is the rough road traveling data. Figure.2 shows the schematic illustration of these waveforms.

These data are large in the following order, airbag ON collision, airbag OFF collision, rough road traveling. In the conventional system, the threshold is determined in the air bag OFF collision. If the threshold can change to low, it will be possible to achieve an earlier TTF than the conventional system.

However, if the threshold changes to low, the airbag deploy in the airbag OFF collision. Therefore, we devised the ADAS integrated system that predicts a collision with the ADAS sensor and the SRS sensor system in order to lower the threshold just before the collision that needs the airbag deployment.

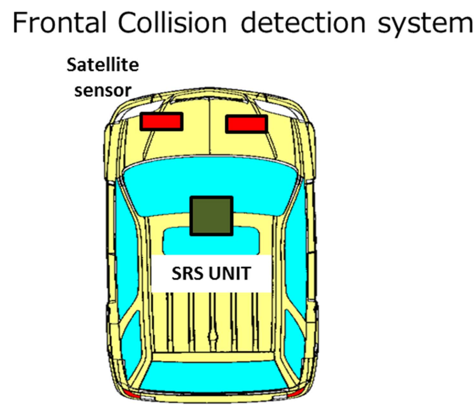

Figure 1. Conventional G sensor system

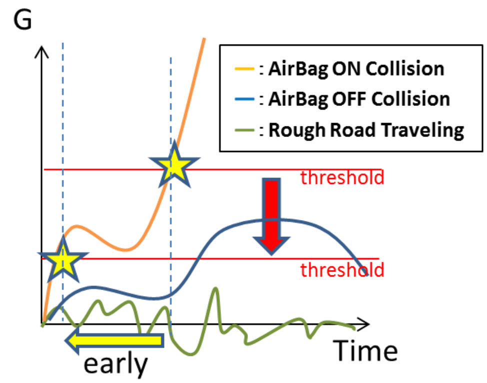

Figure 2. An image of the waveform necessary for the threshold setting

ADAS Integrated System

The overview is shown in Figure 3. The ADAS integrated system has the one radar and the one monocular camera. And it also uses its own vehicle information such as the vehicle speed.

In the prediction method, the ADAS sensor will recognize the kind of object, the relative distance and the relative speed of the opponent. Assuming that the relative speed will continue until the collision, the timing at which the vehicle will pass by the relative distance and the relative speed in the longitudinal direction of the vehicle will be calculated. Furthermore, the amount of the overlap at which the vehicle passes from the relative distance and the relative speed in the vehicle lateral direction will be calculated.

If there is overlap amount with own vehicle, since there is a possibility of collision, the collision prediction flag is set to ON. This flag is always sent in the CAN cycle, and the reliability of the data is checked by continuity of the flag. If it is determined that the flag is highly reliable information and it is determined that the flag is the last flag before the collision, the collision prediction decision flag is set. We call the flag Pre-CDS (Pre-Collision Detection Signal). The SRS sensor system always checks the Pre-CDS and the SRS sensor system immediately lower the threshold when it detects the Pre-CDS.

In addition, as activating condition of the ADAS integrated system, it is added that the own vehicle speed is 40 km/h or more in the mode of the collision to object and the relative speed is 80 km/h or more in the CarToCar collision.

If this system does activate when the own vehicle speed is low, there is a possibility that the airbag may deploy even with a slight collision which does not require the airbag deployment. In order to prevent this situation, the ADAS integrated system has this activating condition.

In this paper, the collision determination threshold is lowered to the level at which the airbag OFF is secured in the rough road traveling.

Although it is the system that lower the threshold immediately just before a collision, considering the CAN cycle and measurement error, it is conceivable that the threshold is lowered for several 100 msec before the collision.

For this time, even if the vehicle passes through pothole, curbstone or like these object, the ADAS integrated system is kept to ensure the airbag OFF. As a result, the real world toughness is equivalent to the conventional system.

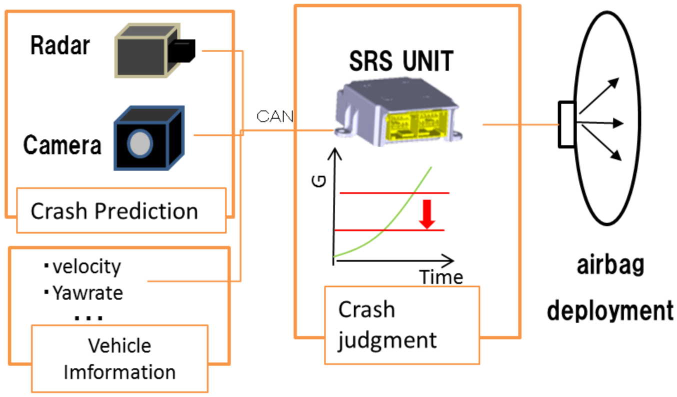

Figure 3. Overview of the ADAS integrated system

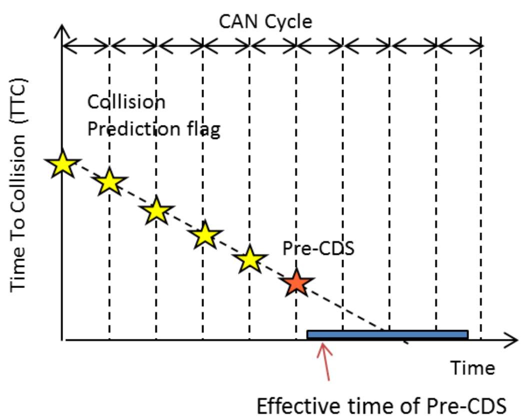

Figure 4. Image of the CAN cycle and the Pre-CDS flag

Performance of Recognition of ADAS Sensor

The point is whether the radar and the camera can recognize the object until just before the collision. This is the reason why the collision threshold is lowered just before the collision. We confirmed the recognition performance of an oncoming vehicle using mass production radar. The radar is located on the end of the cart. The cart passed through the side of the actual vehicle at 50km/h. Figure 5 shows the radar test condition and the data of this test.

It corresponds to the situation when a vehicle whose the radar is located in the center of the vehicle collided with 50% overlap. Figure 5 shows the radar data. The horizontal axis shows the true time until passing and the vertical axis is the passing time calculated by the radar.

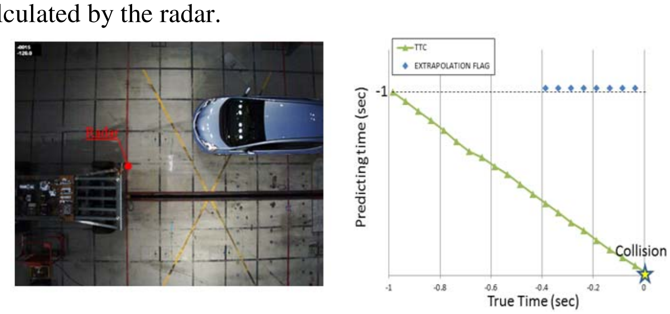

Figure 5. Radar test condition and the data of this test

The main focus point of this data is whether the vehicle can be recognized or not just before the collision. According to the data, extrapolation occurs just before the collision. Therefore, as reliable data, the information about 400 msec before the collision is the last information of the radar. From this fact, it may be impossible to detect the object for 400 msec before collision, but the travel distance during this time of period is only about 5 meter. So it is sufficient as the recognition performance before the collision, because it is considered that the situation does not change while traveling the distance of about 5meter. For the recognition performance of the camera, we also tested on the image processing software where the machine learning was conducted. The right side of Figure 6 is the recognition result assuming just before the collision. Although the vehicle is large relative to the whole image, it was found that recognition is possible.

Figure 6. Camera recognition test the right picture is assumed just before the collision

Calculation of TTF Using ADAS Integrated System

The threshold at the time of receiving the Pre-CDS is lowered to the airbag OFF during the rough road traveling. Therefore, when calculating the early TTF of the ADAS integrated system, it is an important that how much threshold is lower than the conventional threshold.

We used the rough road traveling data acquired by the actual vehicle test. It was assumed that the rough road data was the same as the pothole and curbstone modes. The test speed was selected to meet the conditions that the alignment of the vehicle change and the tire burst occurs.

The collision data for calculating the TTF was obtained from the simulation data with LS-DYNA and some actual vehicle test data.

In addition, in order to verify whether the ADAS integrated system is widely effective, the study was carried out on two models.

RESULTS

Results of Small Size Sedan

Figure 7 shows the rough road data acquired by the actual vehicle test. The conventional threshold is the red line. The value was decided by the airbag off collision.

In the ADAS integrated system, the airbag off is a target in rough road traveling. Therefore, it becomes the blue line. This is the 44% threshold lower than the conventional threshold.

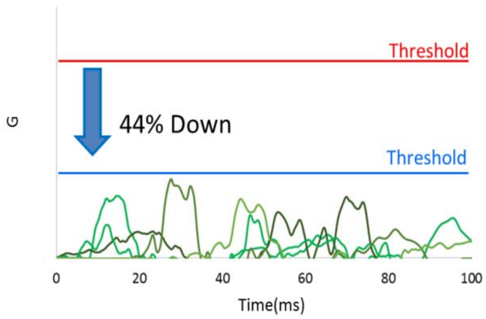

Figure 7. The data on rough road traveling and the threshold

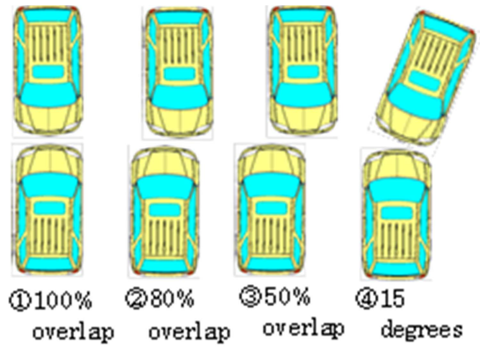

Figure 8. Collision modes and mode No. of the simulation

In order to confirm the effect on the TTF, simulation was conducted in the modes 1 to 4 shown in Figure 8. The collision speed was 60 km/h.

As the mode 5, we confirmed the effect of the TTF in the actual vehicle CarToCar test with 50% overlap and collision speed of 50 km/h. In this collision, the opponent vehicle selected a heavier vehicle. As the result, this actual vehicle test has ΔV which is equivalent to the simulation of 60 km/h CarToCar. In these modes, the calculation results of the TTF are shown in Figure 9.

Depending on the collision mode, there was the change of about 7 msec to 13 msec earlier.

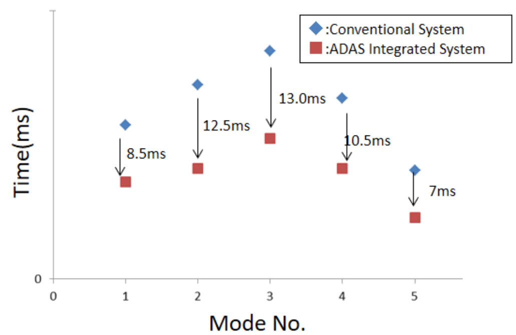

Figure 9. Difference between the TTF of the ADAS integrated system and the conventional TTF

Results of Middle Size Sedan

The test data of the rough road traveling in this vehicle is shown in Figure 10. The red line is the conventional threshold, and the blue line is set based on the rough road traveling data. In this vehicle, the threshold was lowered by 64%.

In order to confirm the effect on the TTF, the simulation was conducted in the CarToCar and the mode in which the vehicle collided with a fixed object. Figure 11 shows these simulation modes. The collision speed was 40 km/h, 50 km/h, 60 km/h and 70 km/h.

By using the ADAS integrated system, Table 1 shows the amount of TTF earlier than the conventional system. Depending on the mode, at the collision speed of 50 km/h or more, it is about 7 to 15 msec earlier. At the collision speed of 40 km/h, it was earlier than 50 km/h.

Compared to the small size sedan, the middle size sedan had similar results. From this, it is considered that the ADAS integrated system can be widely effective.

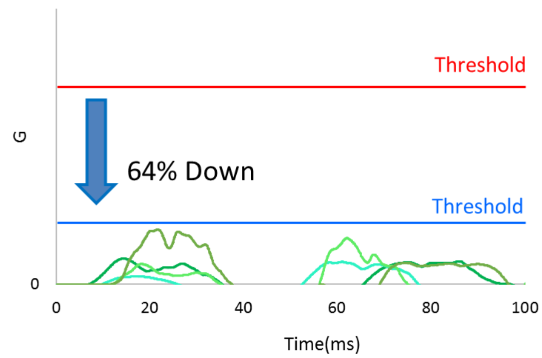

Figure 10. The data on rough road traveling and the threshold

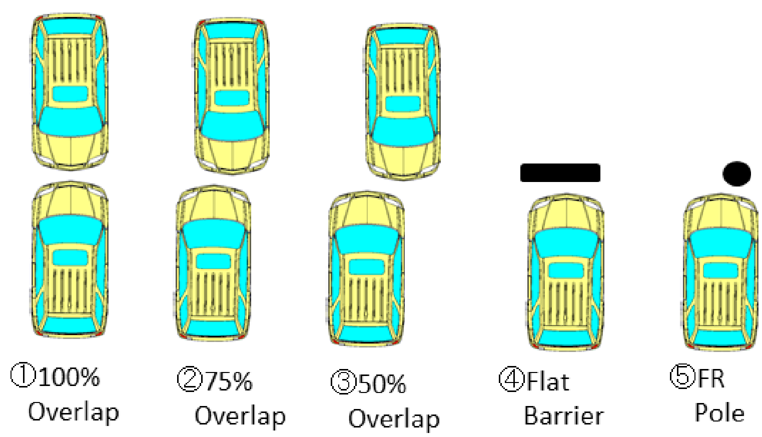

Figure 11. Collision modes and mode No. of the simulation

Table 1. Difference between TTF of ADAS integrated system and conventional one

Unit: msec.

mode No	40km/h	50km/h	60km/h	70km/h
CarToCar100% OverLap	21.5	13.2	11.6	7.1
CarToCar75% OverLap	19.6	14.8	13.1	11.6
CarToCar50% OverLap	19.4	13.2	11.2	9.2
Flat Barrier	19.4	13.1	11.3	7.1
FR Pole	34.6	15.9	13.3	11.6

Effect on Occupant Injury

By achieving the early TTF, it was confirmed that whether the initial constrained could be increased and the occupant injury could be reduced by the sled test. It was confirmed by conducting the sled test.

In the sled test, the floor G of mode 2 in Figure 8 was used. In this study, the large amount of overlap collision was selected because it was severe collision. On the other hand, considering the real world, the number of accidents with 100% overlap is small. Therefore, 80% overlap collision was selected. The occupant injury was compared in this test using the TTF of the conventional system and the ADAS integrated system.

Since the effect on the head injury was expected by the early TTF, we focused on the head injury. The sled test and the head G-Strokes(S) are shown in Figure 12. When comparing the head G-S, the head G decreased. Calculating the HIC, it decreased by 27%. In addition, the head restraint was made from the initial timing of the collision, so that the head stroke decreased because the energy absorption of the device increased.

From this, the ADAS integrated system is effective for the occupant protection performance.

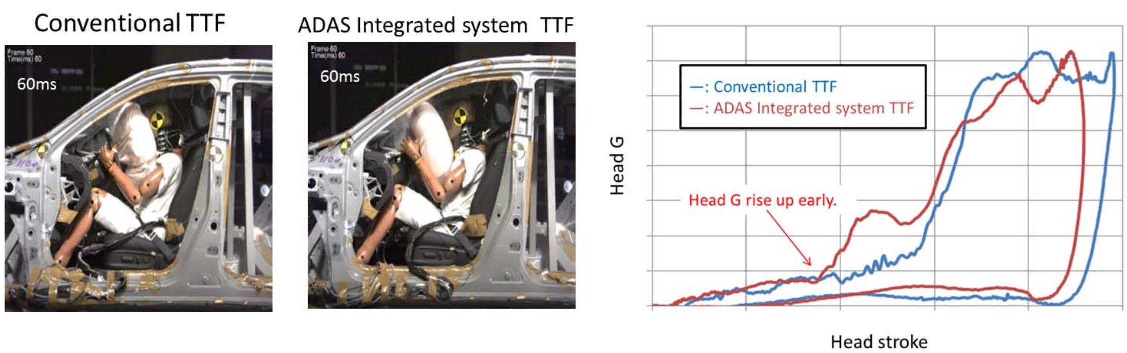

Figure 12. Sled test at 60ms and the results of the head G-S

DISCUSSION

According to the evolution of ADAS in the future, if the rough road can be detected, there is a possibility that the threshold may further be lowered because it is not necessary to secure the rough road toughness. If a sensor for ADAS alone can detect a frontal collision with high reliability, it may be possible to deploy an airbag before collision.

There is the mass production system which detect a side impact before the impact and deploy an airbag. [4]

We investigated whether there is an effect on occupant injury by achieving further early TTF. We made a comparison by simulation using MADYMO. The simulation was conducted in the mode 3 in Figure8.

Figure 13 shows the simulation results. The HIC in the TTF of the conventional system is set to 1. The results indicated that the HIC also can decrease, as the TTF gets earlier.

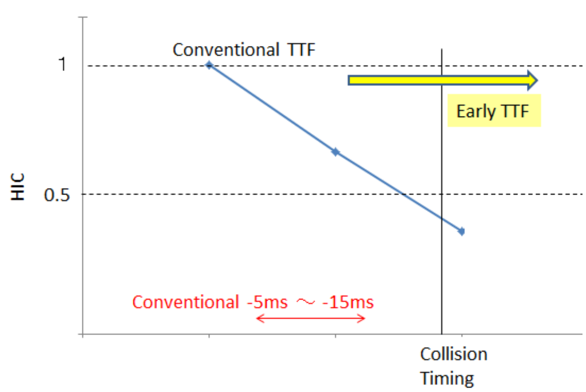

Figure 13. The early amount of the TTF and reduction of the HIC

CONCLUSIONS

By using the ADAS integrated system, it was found that the collision detection was possible at the earlier timing than the conventional system. Although it depends on the collision modes, the TTF can be made form about 7 msec to 16 msec earlier than the conventional TTF in the mode of the collision of 50 km/h or more. In addition, it is considered to be widely effective system because it was confirmed in two car models and it had the similar effect.

As the results of the early TTF, we can also confirm reduction of occupant injury due to increase of the initial constraint and increase of the energy absorption amount of the device.

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