

Development of Honda Precrash Safety Technology

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ABSTRACT

In the field of collision safety, conspicuous progress has been made in recent years in occupant restraint devices. Collision avoidance and injury mitigation technologies are also developing rapidly. Various proposals have been made for next-generation systems combining collision avoidance technologies with injury mitigation and occupant restraint technologies. This paper introduces a first step in this direction, the Honda precrash safety technology employed in the Inspire.

1. Introduction

In the field of collision safety technology, significant progress has been made in recent years in occupant restraint devices. Collision avoidance and injury mitigation technologies are also evolving rapidly. A variety of proposals have been made for next-generation systems combining collision avoidance technologies with injury mitigation and occupant restraint technologies.

The companies involved in the Advanced Safety Vehicle (ASV) project, conducted since 1991 under the auspices of the Ministry of Land, Infrastructure and Transport, have proposed various collision avoidance systems employing external sensing technologies such as radar, in addition to injury mitigation systems. Collision avoidance systems that help predict a collision with a vehicle ahead by means of external sensors and automatically applied the brakes have been discussed from Phase I of the ASV project, but further maturation of concepts and technologies was necessary before such systems could be put on the market. The Honda Precrash Safety Technology employed in the INSPIRE represents a first step in the direction of practical application of these technologies. This paper discusses the technologies employed in the Collision Mitigation braking System (CMS) and the E-pretensioner System that make up the new Honda system.

2. Background to System Development

A high percentage, amounting to approximately 30%, of traffic accident fatalities are caused by rear-end collisions^{(1),(2)} (Fig. 1). The majority of these accidents occur at low to medium speeds, and most are caused by inattention,

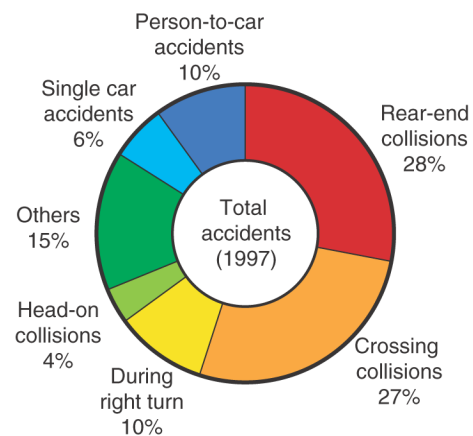


Fig. 1 Breakdown of accident type

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especially forward inattention. Approximately 90% of these accidents occur on straight roads. The majority, 87%, are rear-end collisions with a stationary vehicle (Figs. 2-5). The representative scenario is therefore a collision occurring at a low to medium speed on a straight road due to delay in the driver recognizing the presence of a vehicle ahead as a result of looking to the side, etc.

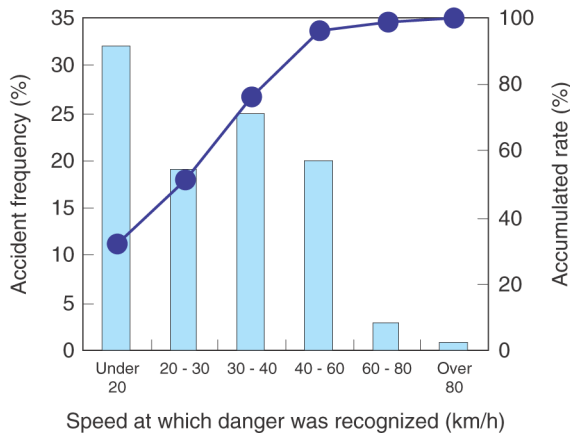


Fig. 2 Frequency of rear-end collisions and accumulated rate in relation to speed at which danger was recognized

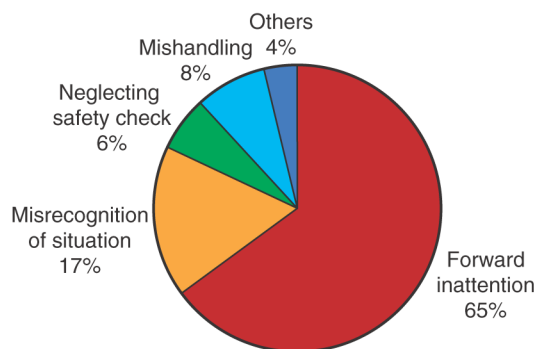


Fig. 3 Cause of rear-end collisions

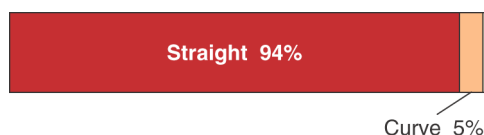


Fig. 4 Road condition at time of accident

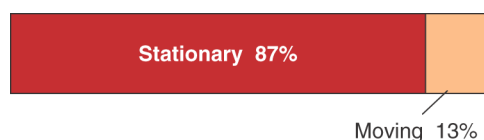


Fig. 5 Status of vehicle ahead at time of accident

3. System Concept and Predicted Effectiveness

The results of studying the conditions in which rear-end collisions occur determined the focus of the research on trying to reduce the number of accidents caused by the driver's inattention. This would be achieved through the creation of a system that supported the driver's maneuvers to help avoid a collision. In this, the role of warnings provided to the driver would be important, and the project therefore studied the effectiveness of the system, the timing of warnings and the driver's reaction time, from the perspective of the relationship between the length of the period of inattention to the road and the occurrence of collisions.

3.1. Study of System Effectiveness from Perspective of Length of Period of Inattention

Simulations were employed to determine the exact nature of driver inattention resulting in rear collisions. The simulations assumed conditions in which the vehicle in front braked when the driver of the following vehicle was momentarily inattentive to the road. Headway time between the vehicles was 1.5 seconds, and the braking speed of the leading vehicle when the driver of the following vehicle was distracted from the road was set at 0.3 G. After the period of momentary inattention the driver of the following vehicle returns their attention to the road, recognizes the situation, makes a judgment, and applies the brakes. The driver's reaction time (from returning attention to the road to applying the brakes) was 1.3 seconds, and the braking speed was 0.8 G. The effect of varying the length of the driver's period of inattention to the road under these conditions was compared.

The results of these simulations are shown in Fig. 6. The horizontal axis shows the speed of the following vehicle and the vertical axis shows the relative velocity at the time of the collision. As the results show, under the conditions of the simulation collisions occur at low to medium speeds, but at high speeds collisions are avoided by the driver's application of the brakes. This indicates that an extended period of inattention to the road is not an often seen factor in the occurrence of rear-end collisions: at low to medium speeds even momentary inattention can result in a collision.

Eye cameras were used to take measurements to determine the length of periods of forward inattention under normal driving conditions. Figure 7 shows the results of these measurements. These results show that normal operations such as using the car stereo or checking the meters require periods of momentary inattention of 1-2 seconds.

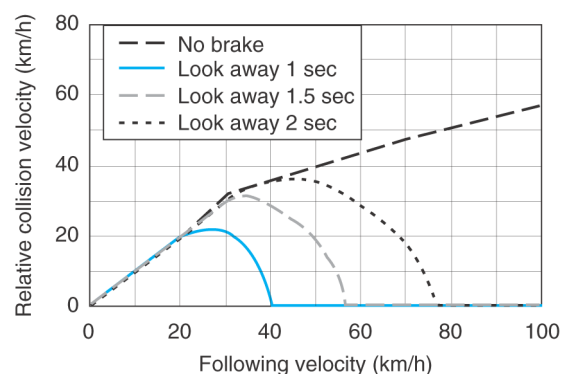


Fig. 6 Simulated collision velocity

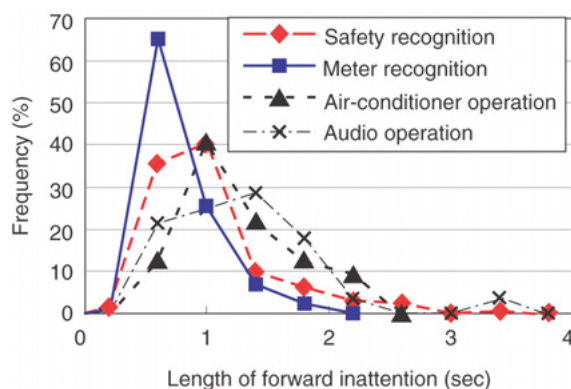


Fig. 7 Length of forward inattention

Simulations were next conducted to compare the effectiveness of the CMS with the provision of warnings only. An average figure of one second from warning to application of the brakes obtained from a driving simulator was employed as the driver's reaction time in the simulations. Braking speed for the automatic emergency application of the brakes was set at 0.6 G. The simulations assumed conditions in which the driver of the leading vehicle applies the brakes at 0.3 G with 1.5 seconds headway time between the vehicles. At this time the system in the subject vehicle goes into operation, and the driver of the vehicle applies the brakes at 0.8 G one second after the warning is provided. The results of these simulations are shown in Fig. 8. The horizontal axis shows the speed of the following vehicle, and the vertical axis shows the relative velocity at the time of collision. The results show that collisions were avoided at low to medium speeds, and the velocity at the time of collision was reduced at high speeds. These results indicate that, while headway and the speed of the following vehicle remain factors, it is possible to help prevent rear-end collisions occurring due to momentary inattention at low to medium speeds.

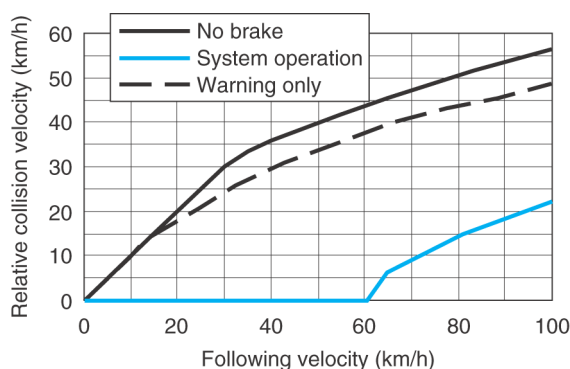


Fig. 8 Effect of CMS system (by simulation)

3.2. Study of Timing of Warnings

A system to support collision avoidance maneuvers that utilizes warnings must provide warnings at a timing enabling the driver to make a judgment and maneuver the vehicle to avoid the accident. A driving simulator was therefore used to study reaction time to warnings. In the tests, reaction times to warnings provided when the vehicle in front braked as the driver of the subject vehicle looked away from the road were measured. Results showed that reaction times of between 0.6 and 1.4 seconds were required. The timing of the provision of

warnings would therefore have to take this range of reaction times into account.

However, if the timing of warnings was increased there was a possibility that warnings would be provided when there was no danger of collision, and if the timing was delayed, there was a possibility that there would not be a sufficient margin of time for the driver to make a judgment and commence maneuvers to try to avoid the collision. Therefore, in both cases there was a possibility that warnings would not be sufficiently effective.

3.3. System to Support Collision Avoidance Maneuvers

On the basis of the results of the studies conducted to this stage, the development aim was established as the creation of a system to support the driver's maneuvers to avoid accidents which would be effective in high risk situations but which would not interfere with the operation of the vehicle under normal driving conditions. A system was proposed that, in addition to sounding a buzzer, would automatically apply the brakes and tighten the seatbelts to provide a tactile warning to the driver when there was a high possibility of collision. The concept stressed the timing of warnings to interfere with the driver as little as possible, and the automatic operation of the brakes to compensate for delays in judgment and the commencement of collision avoidance maneuvers. In addition, when a collision was unavoidable, the seatbelts would be automatically tightened before impact to increase their effectiveness.

Honda has termed the braking system which combines these various functions the Collision Mitigation braking System (CMS), and the seatbelt system is termed the E-Pretensioner System.

4. System Configuration

4.1. System Overview

The newly developed system is made up of the CMS and the E-Pretensioner System. Figure 9 shows the system configuration.

The system is made up of a radar unit to monitor vehicles in front, yaw rate and wheel sensors to monitor the status of the subject vehicle, a hydraulic actuator for automatic operation of the brakes, an electric seatbelt retractor to tighten the seatbelts, a warning display and an electronic control unit (ECU).

The radar system employs millimeter-wave radar⁽³⁾, which functions effectively in a broad range of climatic conditions. This system has a measurement range of approximately 100 m, and is able to detect a vehicle 3 seconds ahead at a relative velocity of 100 km/h. The horizontal detection angle of 16° enables the system to detect vehicles on straight roads and gentle curves.

Figure 10 shows the configuration of the electric seatbelt retractor. In addition to the standard ELR mechanism, this retractor is provided with a pyrotechnic pretensioner and a load limiter. Positioned in parallel to these units are a DC motor and a transmission mechanism to transmit motor torque to the ELR shaft. A clutch mechanism separates the ELR mechanism and the motor torque transmission mechanism when the seatbelt is extended and retracted under normal driving conditions. The electric seatbelt retractor has three operating patterns: warning of approach, retraction control and lock release control.

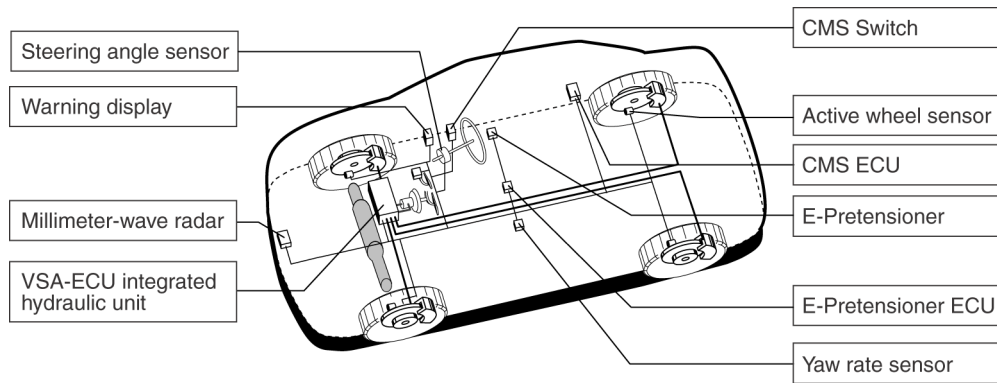


Fig. 9 System configuration

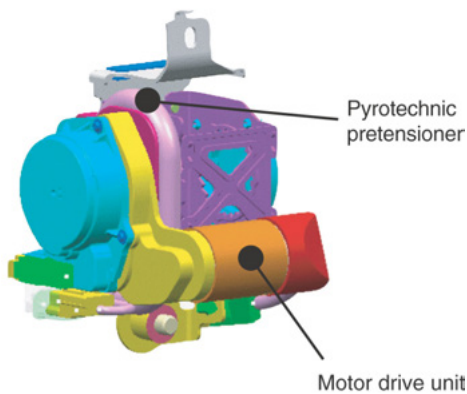


Fig. 10 Retractor with electric pretensioner

Figure 11 shows the basic control flow. A vehicle in front is detected by the radar, and the trajectory of the subject vehicle is estimated from its current status. The system judges the danger of collision and whether or not the collision is avoidable through steering maneuvers. If this is judged difficult, the automatic braking system and the seatbelt retractor go into operation.

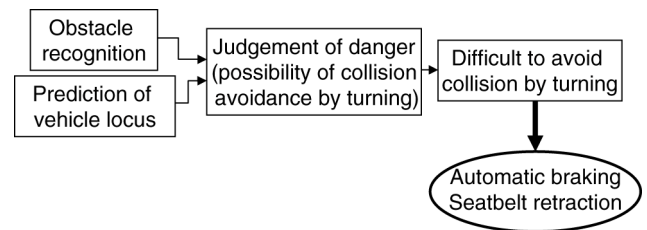


Fig. 11 Block diagram of basic control

4.2. Operating Modes

To ensure that the driver is aware of the warning, in addition to sounding a buzzer, the system lightly applies the brakes and gently retracts the seatbelts to provide a tactile warning. These functions are termed the warning brake and seatbelt warning functions respectively. A braking strength of 0.1-0.2 G was determined from tests as appropriate for the warning brake function. In the case of the seatbelt warning function, tests enabled the establishment of a retraction force and operating pattern that would provide a clear warning to the occupants of the vehicle but which would not interfere with vehicle operation. These functions not only increase the effectiveness of the warnings, but also reduce the delay in the commencement of avoidance maneuvers by the driver.

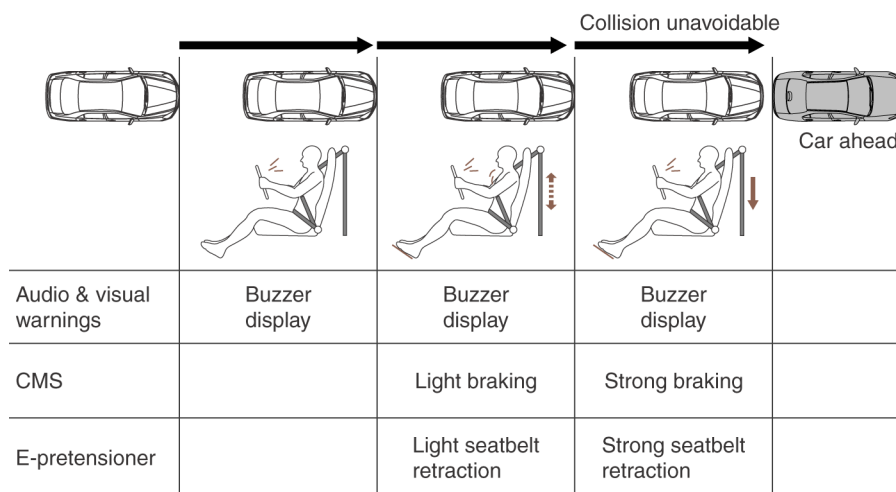


Fig. 12 System operation

The strength of emergency braking was established on the assumption of avoidance of a collision through a combination of braking and steering maneuvers, and with consideration of maneuverability and changes in the driver's posture during automatic application of the brakes. In addition, when the driver applies the brakes, that braking force is added to the automatic emergency braking force. Maximum braking force is therefore produced through a combination of the automatic operation of the system and the driver's application of the brakes.

When emergency braking is applied, the operating pattern for the electric seatbelt retractor switches to approach warning retraction control. In this case also, the retraction force is set at a level which will not interfere with the driver's operation of the vehicle. After a fixed period of time has elapsed from the completion of operation of the three seatbelt retraction modes, if the system judges from the brake signal and vehicle speed data that the retraction can be released, lock release control is engaged. The electric seatbelt retractor operates in response to the radar system, and also in response to emergency braking immediately before collision. The series of operations is shown in Fig. 12.

5. Confirmation of System Functioning in Vehicle Tests

Vehicle tests were conducted to confirm the functioning and effectiveness of the CMS and the E-Pretensioner System.

5.1. CMS

The effectiveness of the CMS in reducing the speed of the vehicle at impact with a stationary forward object was measured in vehicle tests. In these tests an obstacle resembling a vehicle was positioned directly in front of the test vehicle. The test vehicle was driven at the obstacle, and its speed at the time of the collision was measured. Tests were conducted with operation of the CMS and with operation of the warning system only, and results were compared. In both cases, the driver applied the brakes one second after the warning was provided. Figure 13 shows the test results. The horizontal axis shows the relative velocity of the subject vehicle, and the vertical axis shows the velocity at the time of the collision. As Fig. 13 indicates, collision was avoided at low to medium speeds, and the vehicle velocity at impact was reduced at high speeds. As Fig. 2 showed, the majority of rear-end collisions occur at low to medium speeds, and this system can therefore be predicted to be

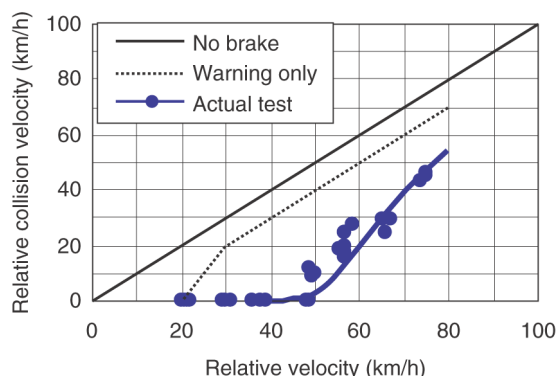


Fig. 13 Effect of CMS system (by actual test)

effective in reducing the incidence of these collisions. Despite the fact that the reaction time of the driver in applying the brakes was identical, the speed reduction at impact was lower in tests conducted with a warning only than when the automatic braking system was in operation.

5.2. E-Pretensioner System

Vehicle tests were also conducted to confirm the effectiveness of the E-Pretensioner System in improving occupant restraint. In these tests the focus was the degree of the forward movement of the vehicle occupants during emergency braking, front barrier crash performance and offset barrier crash performance.

5.2.1. Degree of forward movement during operation of brakes before collision

Vehicle tests were conducted to confirm the effectiveness of the E-Pretensioner System in reducing the degree of the forward movement of the vehicle occupants during emergency braking.

In the tests, emergency braking was applied before collision, and the degree of the forward movement of the vehicle occupants due to deceleration was measured with and without operation of the E-Pretensioner System. Results were compared for occupants of three different sizes (AM 95 percentile, AM 50 percentile and AF 5 percentile) under identical test conditions, as shown in Fig. 14. In all cases, the operation of the E-Pretensioner System reduced the degree of forward motion. This effect is due to the difference in operation between the E-pretensioners and standard seatbelt retractors. In standard seatbelt retractors, the ELR lock mechanism is set to operate at a higher rate of deceleration than that occurring during emergency braking, while the E-pretensioner retracts the seatbelt from the commencement of braking, further reducing slack in the belt.

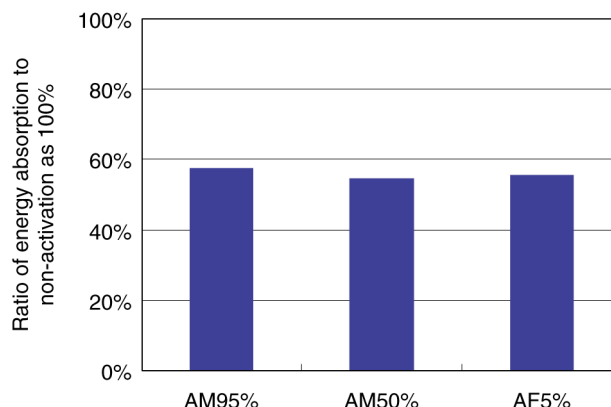


Fig. 14 Comparison of head displacement at 1G braking

5.2.2. Initial restraint performance in front collision

Figure 15 shows the results of the tests of occupant restraint performance with and without operation of the E-Pretensioner System. The tests measured the amount of energy absorbed by AM 50 percentile, AM 95 percentile and AF 5 percentile occupants at the initial stage of a front collision at 55 km/h. Results showed improved initial restraint performance for AM 50 percentile and AF 5 percentile occupants.

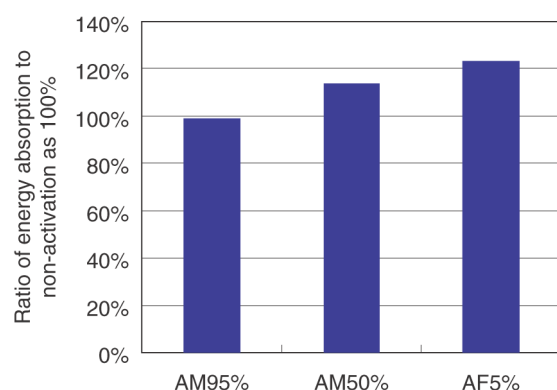


Fig. 15 Comparison of energy absorption in frontal barrier crash

5.2.3. Initial restraint performance in offset barrier crash

Occupant restraint performance with and without the operation of the E-pretensioners was compared at braking speeds corresponding to an offset barrier crash. Tests were carried out under the abovementioned conditions, and the initial energy absorption for an AM 50 percentile occupant were compared. The results of these tests are shown in Fig. 16, and confirm that the operation of the E-pretensioner also improves initial restraint performance in offset barrier crashes.

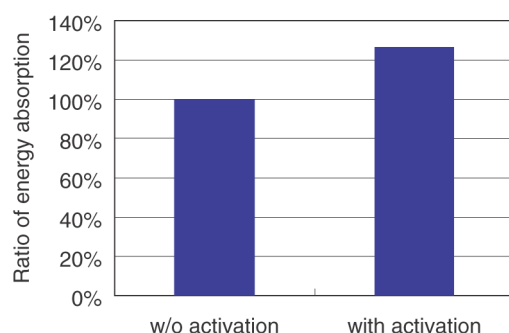


Fig. 16 Comparison of energy absorption in offset barrier crash

6. Conclusion

A Collision Mitigation braking System (CMS) combining external sensing technology employing millimeter-wave radar with automatic braking has been developed. This system will be effective in helping reduce injuries occurring in rear-end collisions. The system has been designed to support the driver's collision avoidance maneuvers while not interfering with the driver's operation of the vehicle.

The CMS can be expected to be effective in helping reduce the number of rear-end collisions occurring at low to medium speeds, at which the majority of these accidents have been shown to occur. This effectiveness has been increased through combination with an E-Pretensioner System that increases occupant restraint performance and provides the driver with tactile warning of an impending collision through the seatbelt.

Honda has combined these technologies and employed them in an actual vehicle as the Honda Precrash Safety System.

References

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