

Development of New Seat Belt E-pretensioner System

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ABSTRACT

The previous seat belt E-pretensioner that was developed possessed a function for retracting the seat belt with a motor in a pre-crash area when the Collision Mitigation Braking System or brake assistant was operated. However, that operation scenario was limited.

Development efforts to address this issue were conducted to expand the range of operation of the pre-crash area and enhance the comfort of routine use of the seat belt. As for the pre-crash area, according to an analysis of serious injury accidents in which seat belts were worn, the system operation range was increased from 18% to 45%. Regarding the comfort area, by halving the occupant movement during sports driving and the pull-out load on the seat belt, and by reducing the retraction load by 30% when the seat belt is worn, the pull on the seat belt was lightened and the feeling of pressure when wearing the seat belt was reduced, improving comfort.

1. Introduction

Normal seat belts are provided with a locking function called Emergency Locking Retractor (ELR). This lock operates when accelerating or decelerating at approximately 3.9 m/s^2 or when there is a sudden pull on the seat belt. Because there is slack in the seat belt due to the clothing of the occupant, there is a possibility that the occupant will move forward until restrained by the seat belt. If the position or posture of the occupant is not suitable during a collision, the passenger might not be sufficiently restrained by the seat belt. For this reason, seat belt retractors have an emergency retraction function called a pretensioner. If a front collision is detected at a certain deceleration value or greater, the force of a gunpowder explosion causes the seat belt to retract in a short period of time in order to control how much the occupant moves during the collision.

However, because this pretensioner operates after detecting a collision, it is not effective against changes in the posture of the occupant prior to the collision. According to the North American National Automotive Sampling System Crashworthiness Data System (NASS/CDS)⁽¹⁾, approximately 20% of vehicles perform a pre-crash avoidance operation, such as emergency braking or sudden turning of the steering wheel. Due to this avoidance operation, occupants receive an inertial force with a maximum acceleration of approximately 10 m/s^2 . Unless occupants maintain their posture through their own strength, the inertial force can cause a change in posture.

The E-pretensioner reduces these changes in posture prior to a collision, and if there is a collision, the E-pretensioner has a function that quickly retracts the seat belt using an electric motor.

The conventional E-pretensioner has a Collision Mitigation Braking System (CMBS)⁽²⁾ that determines whether there is a risk of a collision and retracts the seat belt if the emergency automatic brakes are activated or if the brake pedal is pushed strongly, activating the electronic braking assistant.

The purpose of development was to further enhance the functions of the conventional E-pretensioner by expanding the pre-crash function, lessening the degree to which the occupant sways during sports driving, decreasing the pull-out load and retraction load on the seat belt, and reducing the feeling of pressure when wearing the seat belt, all of which had been problematic in the conventional system.

2. System Configuration

Figure 1 shows the vehicle layout of the E-pretensioner system and a system configuration diagram. The primary components added to the regular seat belt are the seat belt retractor drive unit and the motor control ECU. In addition, the system is configured such that CMBS and Vehicle Stability Assist (VSA) ECU, etc. are connected to the Controller Area Network (CAN). Also, in contrast to the conventional E-pretensioner, a rotation angle sensor that detects seat belt displacement and speed has been

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added to the ELR in the new E-pretensioner. The rotation angle sensor is provided in both the driver seat and front passenger seat.

2.1. Retractor Drive Unit

The E-pretensioner retractor is a normal seat belt retractor to which a motor, deceleration gear, and clutch mechanism have been added. When the system is not operating, the motor and deceleration gear are separated from the spool. If electric current for motor rotation is turned on in the forward direction, the clutch mechanism activates, the motor and spool are joined via the deceleration gear and retract the belt. If the electric current for motor rotation is turned on in the reverse direction, the clutch is released, and the motor and spool are separated.

The gear material and shape of the gear structure have been revised in order to reduce the gear-sliding sound during comfort operation.

2.2. Rotation Angle Sensor

When spool rotation is detected, the displacement and speed of the seat belt are acquired (Fig. 2).

2.3. Motor Control

There are three methods of motor control, and the optimal control that is utilized depends on the purpose of the operation.

(a) Motor current control

The motor current is controlled by Proportion Integral Differential (PID) feedback so that the current approaches a target value. When the motor is stalled, torque is proportional to current, so belt tension can be controlled.

(b) Motor voltage control

When the clutch is released, there is no load applied to the motor, so the motor is in its no-load state, motor drive current does not flow, and current feedback control is not possible. Therefore, motor voltage is controlled at a fixed voltage.

(c) Constant speed control

Using a rotation angle sensor, duty is controlled by feedback so that the output from the rotation angle sensor within a fixed period of time approaches a target value.

2.4. Electronic Control Unit (ECU)

An ECU that controls motors in the new E-pretensioner was developed, with one ECU controlling one motor. Using an Application Specific Integrated Circuit (ASIC) in which a calculation processing circuit, a drive circuit, and a CAN interface are integrated onto one IC, the newly developed ECU has been miniaturized and is lighter in weight in comparison to the conventional ECU (Fig. 3).

The ECU communicates with the ECUs of affiliated systems, such as the CMBS, VSA, and SRS, via the CAN. The ECU receives signals required for pretensioner motor control. Such signals include CMBS and VSA operating state, the yaw rate, longitudinal acceleration, lateral acceleration and the seat belt-wearing state, all of which trigger pre-crash operation. The ECU is also provided with a receiving unit for rotation angle sensor signals and buckle

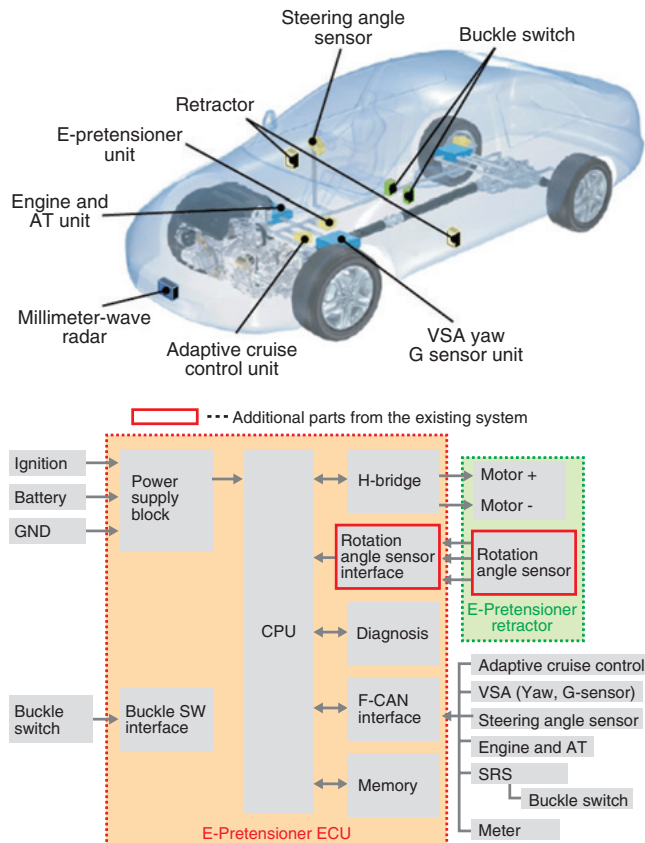


Fig. 1 Vehicle layout and system configuration diagram

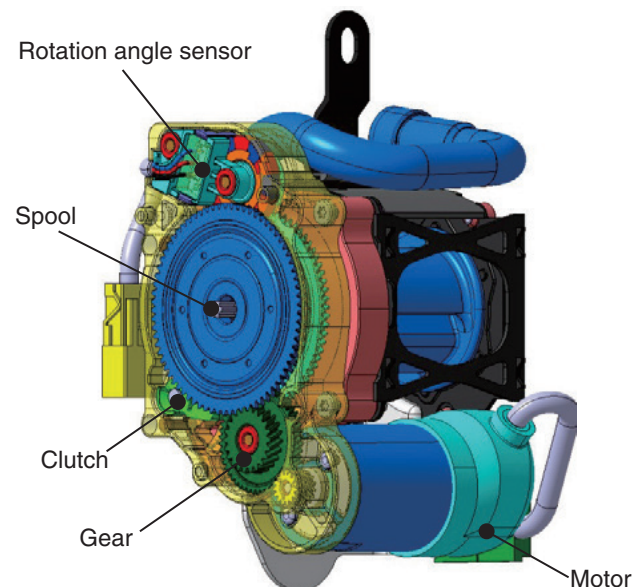


Fig. 2 E-pretensioner retractor

switch signals. These signals are processed by the CPU and they control the motor through Pulse Width Modulation (PWM).

2.5. Buckle Switch

A seat belt-wearing state signal is required for the motor to retract the seat belt when the ignition is OFF. The buckle switch has been added because the seat belt-wearing signal cannot be received from the CAN when the ignition is OFF.

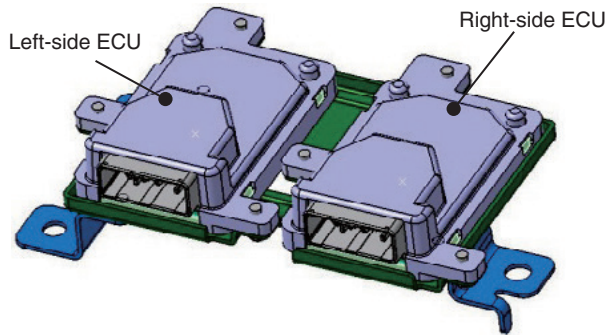


Fig. 3 E-pretensioner ECU

3. Explanation of the New E-pretensioner Functions

The new E-pretensioner functions can be classified into functions during pre-crash emergency retraction, which occurs during emergencies, and comfort functions that increase the comfort of routine use of the seat belt. Because the conventional E-pretensioner only operated in a pre-crash area during an emergency, the operation scenario was limited. However, because a comfort function has been added to it, the new E-pretensioner functions even during routine use and enhances the comfort of the seat belt.

The details of the functions are described below.

3.1. Emergency Retraction Function during Pre-crash

This is a function for retracting the seat belt during an emergency to control the changes in posture of the occupant prior to the collision when the risk of a collision is judged to be higher than that of the normal driving state. The seat belt is retracted by electric current control. Retraction in the shortest amount of time, approximately 100 msec, is possible at a shoulder belt tension force of 100 N. When the inertial force that acts on an occupant is low, it would feel very uncomfortable to the occupant to have the seat belt retract at a high tension force. Therefore, the target value of motor current is set according to the situation, and retraction occurs in the following cases.

- During lateral slip or sudden turns: Retraction occurs when the VSA lateral slip control Active Yaw Control (AYC) function operates and when the steering wheel is turned abruptly (Fig. 4).
- During shock input: When the SRS sensor detects a

collision, seat belt retraction occurs to prepare for a possible secondary collision (Fig. 5).

3.2. Comfort Function

By decreasing swaying of the occupant during sports driving, lightening the pull of the seat belt during routine use, and reducing the seat belt retraction load, the feeling of pressure when wearing the seat belt was mitigated. Also, when the seat belt is worn, there is a function that automatically retracts slack in the seat belt and a function that assists the seat belt storage operation.

The following operation modes exist:

(a) Dynamic mode

When vehicle speed has reached or exceeded a set value and when braking deceleration and turning acceleration have reached or exceeded their set values, the seat belt tension is increased and the swaying of the upper body of the occupant is decreased (Fig. 6).

(b) Welcome mode

When the seat belt is worn, after the seat belt tongue is inserted into the buckle, the seat belt is retracted at a constant speed and the slack is retracted.

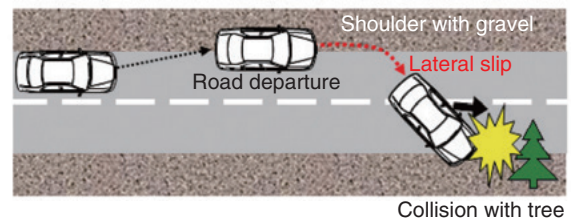


Fig. 4 Example of collision with lateral slip

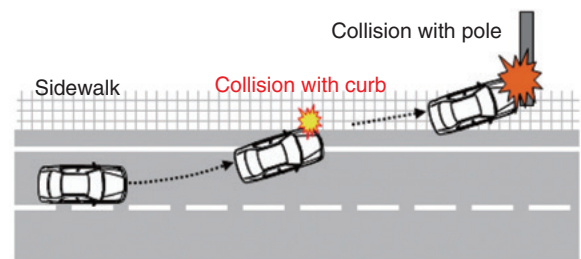


Fig. 5 Example of multiple collisions

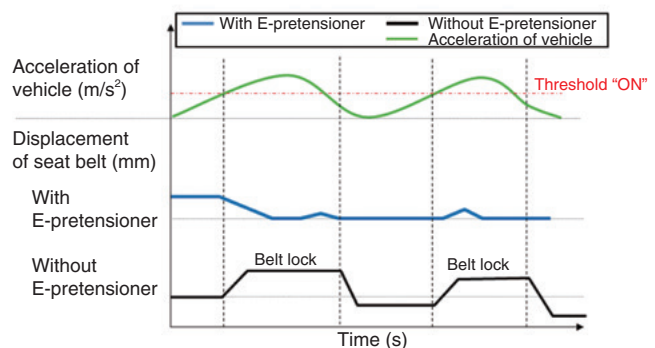


Fig. 6 Dynamic control

(c) Seat belt storage function

When the seat belt is unbuckled or after the seat belt is withdrawn from its fully retracted state, the seat belt is retracted by constant speed control in order to store the seat belt. In order to prevent seat belt retraction from feeling uncomfortable, retraction speed is set according to the quantity of seat belt that is to be retracted. Up to 150 mm from the seat belt-wearing position, the seat belt is retracted at a relatively rapid speed. At 150 mm and greater, the seat belt is set to retract slowly so that it is difficult for the tongue of the seat belt to become caught on the occupant's arm or clothing (Fig. 7).

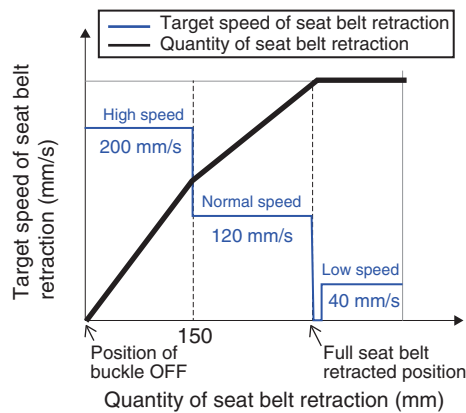


Fig. 7 Speed control in retraction function

4. Application Effect

The effects of the new E-pretensioner functions are shown below.

4.1. Pre-crash Area

By adding a pre-crash function, this newly developed E-pretensioner is estimated to be capable of increasing the range in which the system operates from 18% to 45%, according to an analysis of serious injury accidents occurring when seat belts were worn that are recorded in the NASS/CDS database (Fig. 8).

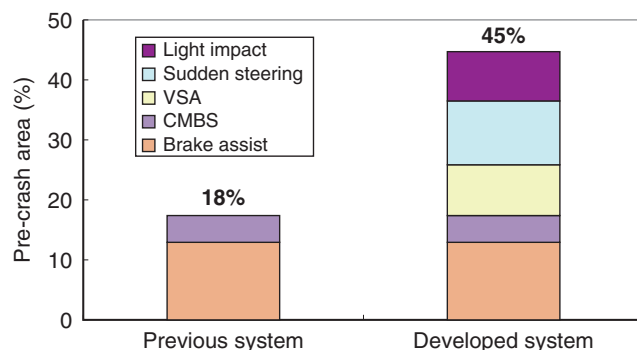


Fig. 8 Comparison of pre-crash area

4.2. Comfort Area

By adding the Dynamic Mode, seat belt displacement during sports driving on a winding test course was able to be reduced by a maximum of 42 mm with respect to the normal amount of seat belt extension, and the amount of movement of the upper body of the occupant could be controlled to a maximum of 100 mm (Fig. 9).

Also, when the seat belt is stored, retraction by a spring is assisted with a motor, making it possible to halve the force of the spring, halve the seat belt pull-out load, and reduce the retraction load when the seat belt is worn by 30%. This lightens the pull on the seat belt, and reduces the feeling of pressure when wearing the seat belt, thereby increasing seat belt comfort (Fig. 10).

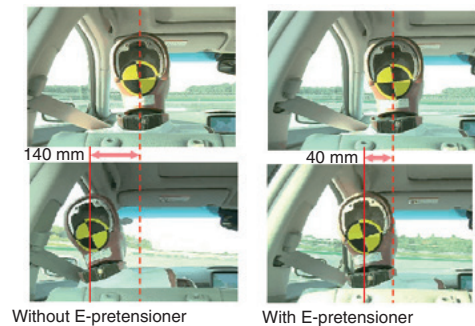
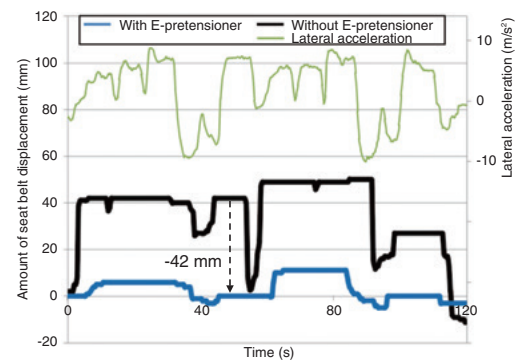


Fig. 9 Photographs of occupant posture in turn test

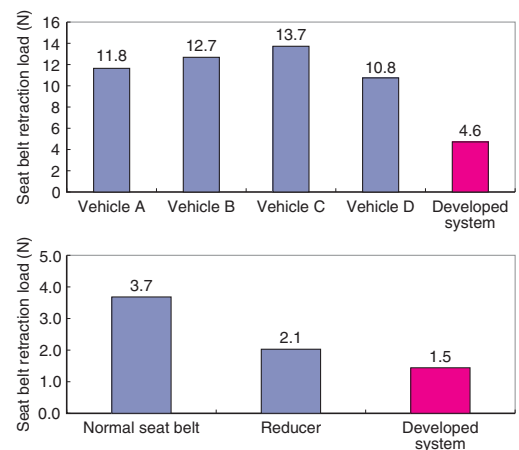


Fig. 10 Seat belt pull-out load and seat belt retraction load

5. Conclusion

A new E-pretensioner function was developed and its effects were confirmed. Those effects are as follows.

- (1) In addition to the conventional CMBS and brake assistant functions, in affiliation with the VSA and SRS systems, the system operation range in the pre-crash area was increased from 18% to 45% compared to that of the conventional system.
- (2) By adding a comfort function that operates during normal use of the seat belt, the occupant movement amount during winding and sports driving was halved.
- (3) By halving the seat belt pull-out load and reducing the retraction load by 30%, the seat belt pull was lightened and the feeling of pressure when the seat belt is worn was reduced, thereby increasing seat belt comfort.

References

- (1) <http://www.nhtsa.gov/NASS>
- (2) Kamiji, K., Kodaka, K., Akaba, H.: Development of Honda Precrash Safety Technology, Honda R&D Technical Review, Vol. 16, No.2, p.115-120

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