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Analysis of AEB System Effect for Driving Gradient Change

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Abstract. In this study, a control algorithm that improves the brake performance of the AEB (Autonomous emergency braking) system on a ramp was proposed. Because the conventional AEB system-applied vehicle is set up on the basis of flat road conditions, it has limitations in its braking permission time and its collision avoidance performance, which do not consider the effects of a gradient in a ramp environment. To improve braking performance on a ramp, the development of an AEB algorithm that considers the gradient is required. A new braking permission time was proposed by calculating a minimum deceleration distance and TTC (Time to collision) confirmation time required to brake on the basis of force received by a vehicle on a ramp. It was confirmed that the AEB algorithm proposed in this paper improved the collision-avoidance performance compared with the conventional AEB algorithm.

Keywords: AEB (Autonomous emergency braking), Collision avoidance, TTC (Time to collision), Gradient

1 Introduction

Recently, automobile companies and many research institutions around the world have been studying the advanced driver assistant system (ADAS), which improves driver safety and convenience and can reduce the number of accidents caused by driver negligence. A typical part of the ADAS is the autonomous emergency braking (AEB) system. An AEB system that uses a distance sensor to avoid a collision with a frontal object is shown to contribute to reducing collision accidents by approximately 30[%] [1].

Studies of the conventional AEB system include proposals for a method to improve braking permission time by considering road surface conditions, as well as calculation methods of TTC at intersections to overcome limitations resulting from blind zones [2][3]. These conventional AEB system studies and actual AEB system performance evaluations assumed that vehicles operated on flat roads only. In fact, to objectively

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evaluate the completeness of the AEB system, the Euro NCAP AEB evaluation procedure is usually applied [4]. However, an AEB system, which does not reflect changes resulting from the angle of inclination in a road (such as on an actual ramp), will not be able to exhibit accurate brake performance on actual ramps. Therefore, a study is required to determine an AEB system algorithm that considers the angle of inclination on a ramp.

Accordingly, in this study, an AEB algorithm that can avoid collisions on a ramp is proposed by conducting a performance analysis of the AEB system in a downhill road environment. The usefulness of the proposed algorithm is determined by comparing it with the conventional AEB system.

2 AEB System Considering Gradient

In this paper, a new AEB algorithm that considers gradients is proposed by improving the TTC calculation method of the conventional AEB system, which considers only the relative speed and relative distance between vehicles. Fig. 1 shows a block diagram of the proposed AEB system that considers a gradient.

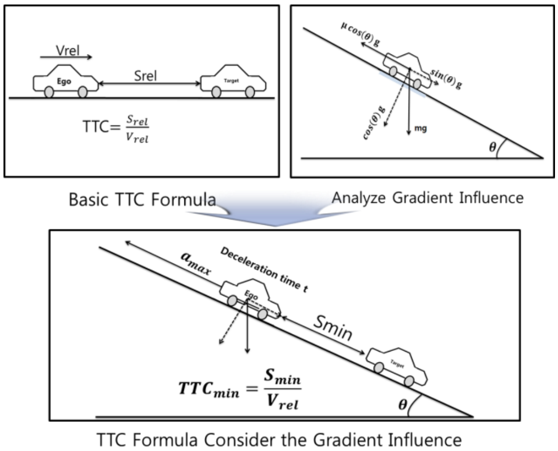

Fig. 1. Block diagram of TTC calculation method that considers a gradient.

The risk index TTC proposed for the conventional AEB system is calculated with a ratio of relative distance (S_{rel}) and relative speed (V_{rel}), as shown in Eq. (1). The risk increases as the value decreases [5].

$$TTC = \frac{S_{rel}}{V_{rel}} \tag{1}$$

The proposed AEB system permits full braking when the TTC condition is satisfied by comparing the collision-risk-index TTC and the new risk index , which considers a gradient.

Effects of the gradient on the vehicle must be also taken into account to safely avoid a collision on a ramp. For this, the AEB system control method proposed in this paper improved the TTC calculation method by using maximum deceleration and minimum deceleration distances.

To calculate the maximum deceleration (a_{max}) and minimum deceleration distances (S_{min}), the deceleration of the vehicle is assumed to be constant. The maximum deceleration can be calculated with Eq. (2), where (μ) is a friction factor. The minimum deceleration distance is calculated as shown in Eq. (3). Using the maximum deceleration and minimum deceleration distances derived by the proposed algorithm, the new risk index TTC_{min} is calculated with the ratio of minimum deceleration distance and relative speed, as shown in Eq. (4).

$$a_{max} = -\mu\cos(\theta)\,g + g\sin(\theta) \quad (2)$$

$$S_{min} = v_0 t + \frac{1}{2} a_{max} t^2 \quad (3)$$

$$TTC_{min} = \frac{S_{min}}{V_{rel}} \quad (4)$$

The new braking permission time is shown in Eq. (5). When TTC is less than or equal to TTC_{min}, the AEB system operates at full braking and avoids a collision.

$$TTC \leq TTC_{min} \quad (5)$$

3 Simulation and Test Results

For the simulation scenario, a situation was set up in which an ego vehicle is approaching at a speed of 60 [km/h] toward a stationary front vehicle. The speed of the vehicle was determined by referring to the speed scenario of ADAC's AEB evaluation procedure [6]. The gradient was set at 4[%], 8[%], and 11[%] on the basis of safety gradients specified by the Ministry of Land, Infrastructure and Transport [7].

To verify the AEB system that considers a gradient, the simulation results were comparatively analyzed using the conventional AEB system and the proposed AEB system. Table 1 shows the simulation results according to the set gradient and vehicle speed conditions. In Table 1, R is the distance between the front bumper of the ego vehicle and the rear bumper of the front vehicle when the ego vehicle is stopped, and V is the speed of the ego vehicle when a collision occurs between the two vehicles.

Table 1. Simulation results according to gradients.

Gradient [%]	Conventional AEB system				Proposed AEB system			
	V [m/s]	Collided/ Avoided	R [m]	Collided/ Avoided	V [m/s]	Collided/ Avoided	R [m]	Collided/ Avoided
4	0.00	(avoided)	0.31	-	0.00	(avoided)	0.83	-
8	3.69	-	0.00	(collision)	0.00	(avoided)	0.77	-
11	4.55	-	0.00	(collision)	0.00	(avoided)	0.87	-

The conventional AEB system avoided a collision by setting a distance of 0.31 [m] from the front vehicle when the gradient was 4[%]. When the gradient was 8[%] and 11[%], the conventional AEB system indicated a collision with the ego vehicle at speeds of 3.69 [m/s] and 4.55 [m/s], respectively. This phenomenon occurred because the conventional AEB system permitted braking at the same time point without considering the gradient. On the other hand, in the case of the proposed AEB system, a collision was avoided for all gradient conditions.

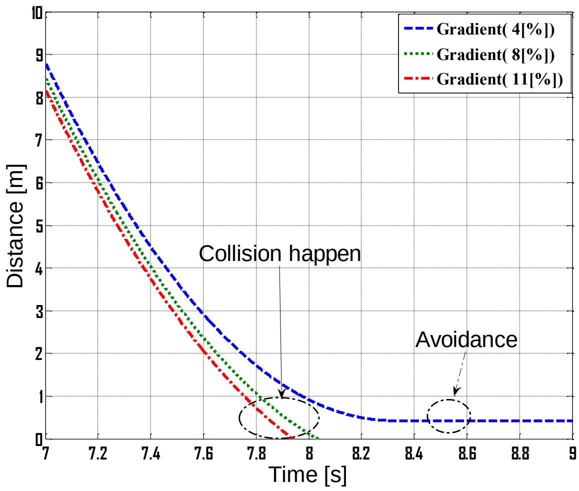

Fig. 2. Simulation result of conventional AEB system.

Fig. 2 shows the relative distances between the vehicles as a simulation result when the conventional AEB system was applied. The conventional AEB system avoided a collision on a gradient of 4[%], but collisions occurred at gradients of 8[%] and 11[%]. The conventional AEB algorithm had a limitation in that safe collision-avoidance performance was not derived because the braking permission time was not varied according to the gradient.

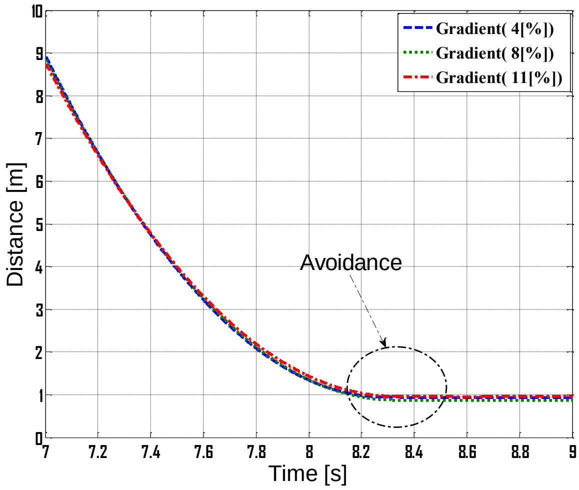

Fig. 3. Simulation result of proposed AEB system.

Fig. 3 shows the relative distance between the vehicles as a simulation result when the proposed AEB system was applied. The AEB algorithm proposed in this paper avoided collisions in all established gradient conditions from 4–11[%]. As the gradient increased, it was confirmed that the distance between the front bumper of the ego vehicle and the rear bumper of the front vehicle became smaller when the vehicles were stopped. The proposed AEB system algorithm successfully avoided a collision because an accurate braking permission time could be calculated by considering the effect of the gradient on the vehicles.

4 Conclusion

In this paper, an AEB algorithm that considers a gradient was proposed. To determine the usefulness of the proposed AEB system, the simulation results were comparatively analyzed on ramps for the conventional AEB system and the proposed AEB system. Through the simulation results, it was confirmed that collision avoidance performance is limited in a conventional AEB system with respect to the calculation of the braking time point in a ramp environment. On the other hand, for the proposed AEB system, a new braking permission time point was proposed by calculating the minimum deceleration distance and TTC confirmation time required for braking on the basis of force received by a vehicle on a ramp. It was confirmed that collisions were safely avoided in all gradient conditions set up for the simulation.

The AEB algorithm proposed in this paper improved the performance of the AEB system on a ramp by avoiding collisions with a front vehicle. This was accomplished by deriving a braking permission time point that considered the angle of inclination. In future, a study will be carried out for an AEB system algorithm that considers road surface conditions as well as the gradient.

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References

1. NHTSA National Highway Traffic Safety Administration: DEPARTMENT OF TRANSPORTATION (2015)
2. Cho,H., Kim,B.: A Study on Cooperative Intersection Collision Detection System Based on Vehicle-to-Vehicle Communication. Advanced Science and Technology Letter Electrical Engineering, pp.121--124(2014)
3. Kang ,T., Yoo,W., Kim,N., Soh,M., Kwon,J., Hong,T., Park,K.: A Study on the Brake Time for AEB system Considering Road Condition. KSAE, pp.737--744(2014)
4. Wesley, H., Iain, K., Alix, E., Matthew, A., Colin, G. : AUTONOMOUS EMERGENCY BRAKING TEST RESULTS, Thatcham Research, UK(2013)
5. Cho,H., Kim,B.: Performance Limits Analysis of Collision Detection System Based on Automotive Radar in Ramp. Advanced Science and Technology Letters , Electrical Engineering, pp.117--120 (2014)
6. Comparative test of advanced emergency braking systems. Test report, ADAC Vehicle Testing(2013)
7. Korea Ministry of Government Legislation, http://www.law.go.kr/main.html

