Analysis of AEBS Technology and Strategy of Commercial Vehicles



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Abstract
Advanced Emergency Braking System（AEBS） is internationally recognized as the best technology choice for collision prevention. It is of great significance to effectively protect the safety of people's lives and property and improve the technical level of transportation safety in China. In this paper, AEBS technology is analyzed from the regulatory requirements, system functions, test conditions and other aspects, and the typical condition of pedestrians crossing the road is taken as an in-depth analysis of AEBS working process and corresponding indicators, so as to provide reference for AEBS product development, industrial application and test evaluation.
Keywords: AEBS, Control Strategy, Commerical Vehicles

1. Introduction

According to statistics from the World Health Organization, approximately 1.2 million people die in road traffic accidents worldwide each year, of which 46 percent are pedestrians, cyclists, or two-wheeled motor vehicle users, which is even higher in developing countries. There are also many mixed traffic conditions in China, and being dead or wounded is the result of the impact of commercial vehicles with pedestrians or non-motorized vehicles. Specifically, the death toll is more than 4,000 people each year, causing extremely serious casualties and property losses.

Solving those accidents that commercial vehicles collide with pedestrians by using scientific and technological means is of important practical and long-term significance for effectively protecting people's lives and property, improving China's transportation safety technology, and building a strong nation in transportation with which the Chinese people are satisfied.

In combination with the actual needs of transportation safety in China and the implementation of road transportation safety production requirements, the Automobile Transportation Research Center of the Research Institute of Highway Ministry of Transport has formulated and implemented the JT/T 1242 Performance Requirements and Test Procedures for Advanced Emergency Braking System of Commercial Vehicle, which specifies functional requirements and corresponding test procedures for target detection area, impact warning, emergency braking, in-vehicle communication and vehicle-to-road communication, including functional requirements for pedestrian impact prevention and control.

2. Corresponding requirements for AEBS of commercial vehicles of various types are specified in China standards and regulations

Technical Specifications for Safety of Power-driven Vehicles Operating on Roads (GB 7258-2017) stipulates that newly finalized road buses and tourist buses with a vehicle length greater than 11m shall be equipped with an advanced emergency braking system (AEBS) that meets the requirements of the standard. Starting from January 1, 2021, if the advanced emergency braking system (AEBS) is not equipped as required, the inspection result of the GB7258 mandatory inspection item is unqualified.

In the transportation industry, first, Safety Specification for Commercial Vehicle for Cargos Transportation-Part 1: Goods Vehicle (JT/T 1178.1-2018) requires that "goods vehicles with gross mass greater than or equal to 12,000kg and maximum speed greater than 90km/h shall be installed with an advanced emergency braking system (AEBS)"; second, Safety Specification for Commercial Vehicle for Cargos Transportation-Part 2: Towing Vehicle and Trailer (JT/T 1178.2-2019) requires that "towing vehicles with maximum speed greater than or equal to 90km/h shall be equipped with an advanced emergency braking system (AEBS) and their performance shall meet the requirements of JT/T 1242-2019"; third, Safety Technical Specifications for Commercial Vehicles for Road Transport of Dangerous Goods (JT/T 1285-2020) requires that "goods vehicles for transport of dangerous goods with gross mass greater than or equal to 12,000kg shall be equipped with an advanced emergency braking system (AEBS) that complies with JT/T 1242". The above standard clauses will be implemented from May 1, 2021.

3. Basis for setting indicators related to AEBS warning and braking

After AEBS detects the target, it prompts the driver, and sends out a warning signal after determining that there is a risk of impact, and automatically performs emergency braking after determining that the impact cannot be avoided. Table 1 lists the function and warning mode of AEBS at the moments of perception recognition, warning, deceleration, emergency braking, and the end of braking.

Table 1 - Timetable of Warning Levels and Modes

Moment	T_0	T_1	T_2	T_3	T_4
Function	Target perception and recognition	Level 1 warning	Level 2 warning	AEB	End of braking
Warning mode	No prescriptions	1mode (hearing or touch)	2modes (seeing, hearing, or touch)	No prescriptions	No prescriptions

T_0 is a reminder of detecting a target (when it is perceived and recognized only, but a warning is not sent), when AEBS tracks the target to determine whether there is a safety risk. T_1 is the level 1 warning moment, when AEBS determines that there is a potential impact risk and the risk level is lower, for the purpose of avoiding frequent warnings and false alarms caused by premature warnings, so T_1 shall not be too early. T_2 is the level 2 warning moment, when AEBS determines that there is an impact risk and the risk level is higher, so the vehicle can decelerate. T_3 is the autonomous emergency braking moment, when AEBS determines that the impact cannot be avoided and the risk level is the highest, so the vehicle decelerates to a stop. T_4 is the moment when the impact occurs or the braking ends. In the warning stage, the driver controls the vehicle. In the level 2 warning stage, AEBS can brake and decelerate, but it cannot perform emergency braking. Deceleration in the warning stage can reduce the intensity of emergency braking, and at the same time, it also prompts the following vehicles to respond in time to avoid rear-end collision.

According to the research on AEBS strategy, JT/T 1242 standard stipulates related indicators for warning and braking.

First, for warning indicators, if TTC is greater than 4.4s, AEBS shall not issue an impact warning. The level 1 impact warning shall be generated 1.4s before the emergency braking stage, and the level 2 impact warning shall be generated 0.8s before the emergency braking stage, as shown in Table 1: $T4-T1 \leq 4.4s$, $T3-T1 \geq 1.4s$, $T3-T2 \geq 0.8s$.

Second, for deceleration indicators, the deceleration in the warning stage is limited, and the deceleration of the subject vehicle in the warning stage shall not exceed the maximum value between 15 km/h and 30 percent of the total deceleration.

Third, for emergency braking indicators, it is required that the emergency braking stage shall not start until TTC or ETTC is greater than or equal to 3 s, as shown in Table 1: $T4-T3 \leq 3s$. The braking deceleration in the emergency braking stage shall be ≥4m/s2.

4. Example of AEBS pedestrian crossing impact prevention test

In the *Performance Requirements and Test Procedures for Advanced Emergency Braking System for Commercial Vehicle* (JT/T 1242-2019), items 7.4.1 to 7.4.8 corresponding to the test conditions are "target detection distance test, target detection width test, target vehicle

static test, target vehicle movement test, curve lateral target recognition test, false response test, pedestrian test, vehicle-to-road communication test.

Specifically, "7.4.7 Pedestrian Test" stipulates: At the beginning of the test, the vehicle under test accelerates to 60 km/h along the planned lane centerline and maintains a certain distance. The driver holds the position of the accelerator pedal and maintains the vehicle speed. B-B is the centerline of the lane of the subject vehicle. At the same time, a pedestrian moves along the A-A path 6 meters away from the center line of the test lane from the left side of the vehicle under test as instructed, where the acceleration distance (F) of the pedestrian is 1.5 m. Point L is the impact point between the subject vehicle and the pedestrian. When the pedestrian is 4.5 m away from point L, the target speed of 8 km/h shall be reached. If the AEBS of the subject vehicle stops automatically or crashes, the test ends, as shown in Figure 1.

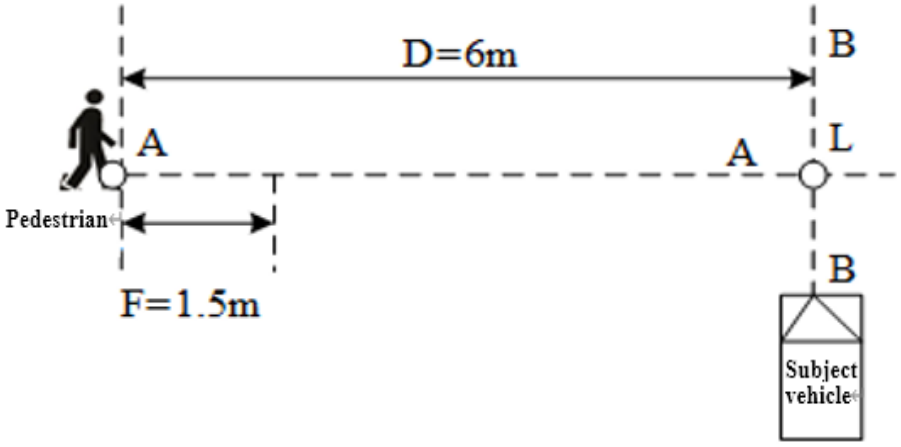

Figure 1 – Schematic Diagram of Pedestrian Test

For the pedestrian test in 7.4.7 of the standard, the actual conditions are used, i.e., conditions that pedestrians cross the adjacent lane and enter the subject lane. According to the standard requirements, the speed of the subject vehicle is 60 km/h, the speed of pedestrians is 8km/h, the distance between pedestrians and the preset impact point L is 6m, and the distance between the subject vehicle and the preset impact point L is 60m (standard pedestrian detection minimum distance requirements).

With a lane width of 3.75m, the deceleration of the subject vehicle is 20km/h in the event of an impact, where the deceleration in the AEBS level 2 warning stage is 5km/h, and the deceleration in the emergency braking stage is 15km/h (the standard requires the emergency braking deceleration in the pedestrian test shall not be less than 20 km/h). Take the average braking deceleration 5m/s2 of the subject vehicle in the emergency braking stage as an example, the AEBS conditions that pedestrians cross the adjacent lane and enter the subject lane are shown in Figure 2.

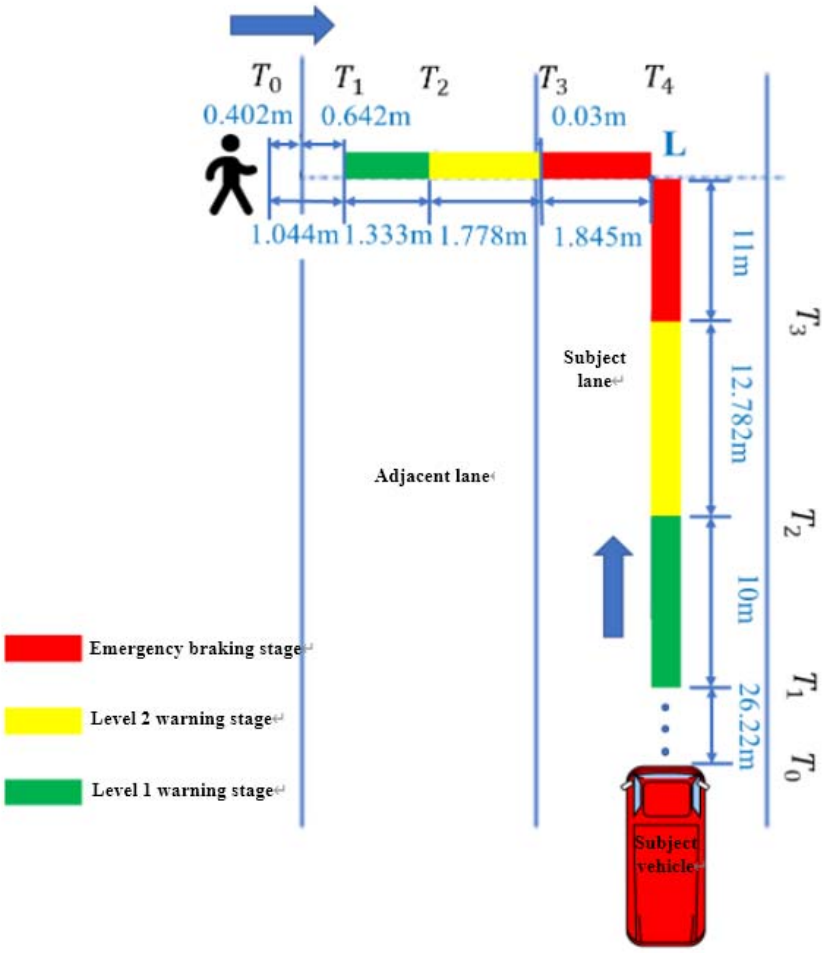

Figure 2 –Example of Pedestrians Crossing the Subject Lane

Moment T_0: The distance between the subject vehicle and the pedestrian preset impact point is 60m, and the distance between the pedestrian and the outermost side of the adjacent lane is 0.402m. Moment T_1: After 1.57s, the pedestrian gets into the line of the adjacent lane line for 0.642m, and AEBS triggers the level 1 warning. Moment T_2: After 0.6 s, the pedestrian is 1.75m from the subject lane, and AEBS triggers the level 2 warning. Moment T_3: After 0.8s, the pedestrian gets into the line of the subject line for 0.02m (which can be judged as entering the line of the subject lane), and AEBS triggers the emergency braking. Moment T_4: After 0.83s, the deceleration of the subject vehicle reaches 20km/h.

See Table 2 for the specific measurement results of state parameters of the subject vehicle and pedestrians at T_0-T_4 Moments. 1.736m/s^2 is the average braking deceleration of the subject vehicle in the T_2 and T_3 stages, and 5.0 m/s^2 is the average braking deceleration of the subject vehicle in the T_3 and T_4 stages.

Table 1 - Table 2 Measurement Results of AEBS Pedestrians Conditions

Moment / State parameters	T_0	T_1	T_2	T_3	T_4
Timeline	0	1.57s	2.17s	2.97s	3.8s
Lateral offset	6m	4.956m	3.623m	1.845m	0m
Rear clearance	60m	33.78m	23.78m	11m	0m
Speed of subject vehicle	60km/h	60km/h	60km/h	55km/h	40km/h
Braking deceleration of subject vehicle	0	0	1.736m/s^2	5.0m/s^2	/

5. Conclusion

From the perspective of representative conditions, regarding the pedestrian test conditions in JT/T 1242, the Euro NCAP remote pedestrian crossing test conditions are used for reference, in combination with the characteristics of China's traffic status, and taking into account the driving characteristics of expressways and urban roads. That is, the remote test conditions correspond to a dangerous scenario where pedestrians cross a lane and enter the subject lane, and in such scenario, the performance of the AEBS system from warning to emergency braking can be fully tested. In reality, when the safety distance is insufficient, it is unnecessary and too late to go through all the stages from warning to emergency braking. For example, in the scenario of the "Gui Tan Tou" (where a pedestrian or a non-motor vehicle suddenly rushes out from the roadside when there is a blind spot ahead the subject vehicle, which easily causes impact accident), if a pedestrian suddenly jumps out from close range, the AEBS system may directly enter the emergency braking stage.

From the perspective of rational strategies, pedestrians shall be perceived and recognized after entering the adjacent lane, and a level 1 warning can be given after AEBS determines that there is a potential hazard. If the pedestrian continues to move forward, the risk level will increase, and the system will give a level 2 warning after determining the risk level. In the level 2 warning stage, if pedestrians enter the subject lane and the system determines that the impact cannot be avoided, then the autonomous emergency braking state is activated, and meanwhile it shall be ensured that the driver's operation on the brake pedal does not affect the optimal braking effect of AEBS. If pedestrians find that the subject vehicle passes and stop in the adjacent lane when they cross a road, that is, pedestrians have a clear intention not to enter the subject lane, the system shall be able to re-determine the risk level and make the correct response of slowing down and passing or performing emergency braking.

In a word, from the perspective of scientific and technological innovation, the application of new technologies is also an important part of scientific and technological innovation. We do not expect to solve all problems through one technology, but wish to gradually promote the application under "limited time and space, limited elements, limited conditions, and limited prerequisites". AEBS is tested and evaluated under the conditions specified by the standard, applied under the conditions specified in the manual, and plays an effective role under the specified conditions, which can promote the safety and high-quality development of transportation.

6. References

- LIU Ying, HE Jinpeng, LIU Weiguo, et al.Research on Pedestrian Test Scenes of Automatic Emergency Braking System [J]. Automobile Technology, 2014(3):35-39.
- Chen Chao. Research on AEBS Urban Road Condition Test and Evaluation Method [D].Xihua University, 2016.
- Niu Chengyong,Su Zhanling,Hu Xiong,Wang Jie,Wu Kunlun. Test and Research of Commercial Vehicle Advanced Emergency Braking Pedestrian System[A]. China Society of Automotive Engineers.2020 [C]. China Society of Automotive Engineers,2020:1.