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Research on the Effect of AEB Braking on the Protection of Occupants in Collisions

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Abstract: The application of automatic emergency braking (AEB) can effectively reduce accident injuries and improve vehicle safety, but it also brings new technical problems that need to be solved. In this paper, the possible effects of AEB on the injury of Occupants in the vehicle during the collision process were studied. By establishing a driver side dummy injury evaluation model before and after the AEB effect, the potential impact of AEB equipment on the driver's movement trajectory and various body injury indicators during the collision process is deeply studied. The results indicate that the early action of AEB during the collision process will change the motion trajectory of the passenger dummy before and after the collision, potentially increasing the injury indicators of the dummy's head, neck, and chest before the collision, but to some extent, it will reduce the damage values of various parts of the dummy's body during the collision stage. At the same time, due to the emergency braking of AEB, the driver's position relative to the interior changes, and auxiliary restraint system devices such as airbags and seat belts usually operate according to the normal position of the Occupants, which to some extent exacerbates the damage to the Occupants. Therefore, it is urgent to conduct research on the protection of Occupants in the out of position state under the action of AEB.

With the development of automobile electronization and intellectualization, automotive active safety products such as automatic emergency braking (AEB) and active seat belt have been rapidly developed and widely used, effectively improving vehicle safety performance and significantly reducing accident injuries. Especially the application of AEB can effectively avoid the occurrence of vehicle collision accidents or reduce the degree of injury caused by collision accidents. Before a collision occurs, the AEB system can effectively detect obstacles in front of the vehicle and alert the driver with images or sounds [1]. When the distance between the vehicle and the obstacle exceeds a certain threshold, the system will activate the automatic emergency braking system to prevent or reduce the severity of the collision. However, there are certain safety issues that need to be addressed in the application of AEB. Due to the fact that AEB can cause Occupants to dislocate before impact, the current design of occupant restraint systems usually does not take into account the movement of Occupants in advance. The main purpose of this article is to investigate the impact of changes in the posture of dummies without and with AEB on their final damage.

1. Model building

(1) Passenger model construction

Based on the Madymo software and the active human model of AHM dummy, the simulation model of the driver's side restraint system was developed. As shown in Figure 1 (a), the restraint model includes the AHM dummy, seat belt, white body, steering wheel, steering column, instrument panel, seat, windshield, floor, rest area, and accelerator pedal. In Madymo, the kinematic connections between the submodels are established by rotation and kinematic hinges[2-4].

Compared to many other dummies on the market, the AHM is a finite element dummy with fine skin, bones and muscles similar to the human body. The neck, waist and arms have muscle characteristics, and by controlling the mechanical characteristic curve of the vehicle, the kinematic response of the real human body to the passive load of the vehicle during braking and collision is more similar.

As shown in Figure 1 (b), the total calculation time of this model is 1020ms. The initial speed of the model was set at 64km/h, and from 0 to 344ms, it ran at 64km/h. After 344ms, the AEB system starts to slow the vehicle by 0.7g and drops to 50km/h within 900ms. During 900ms to 1020ms, the waveforms of real cars under 100% frontal crash conditions were loaded to simulate 100% frontal crash (FRB) [2]. The overall calculation program of the model illustrates the 100% frontal collision scenario, where the vehicle is traveling at an initial speed of 64km/h and the speed drops from 64km/h to 50km/h when the automatic emergency braking system AEB is activated[5-7].

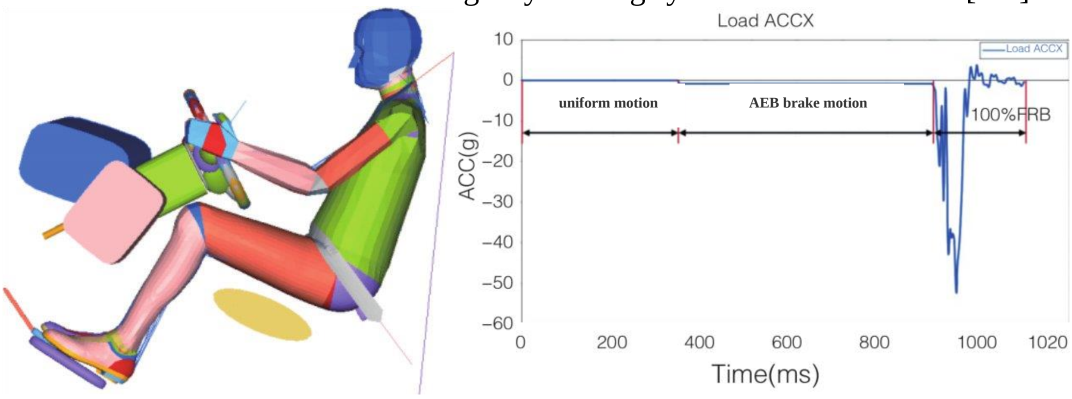


Figure 1: Driver side restraint system model and model loading pulse

(2)Determination of the relative position of person and vehicle

Taking the road position in front of the vehicle center before the accident as the origin and the road front of the vehicle as the positive Y-axis direction, we defined a coordinate system, as shown in Figure 2.

Accidents can be roughly divided into driver reaction stage, braking coordination stage and continuous braking stage. The response time t1 of the driver varies according to the driver's situation, such as gender, age, alcohol consumption, etc., generally 0.3-1s. In order to facilitate calculation, the braking coordination time t2 is uniformly set at 0.3s. It is assumed that the deceleration rate increases linearly and then remains constant during the braking coordination phase. Based on the driver's written records and site investigation, determine the distance of the accident; Choose a reasonable t value, taking into account the driver's physical condition at the time of the accident. Combined with the accident distance and the braking deceleration time t2, the continuous braking time t3 was calculated.

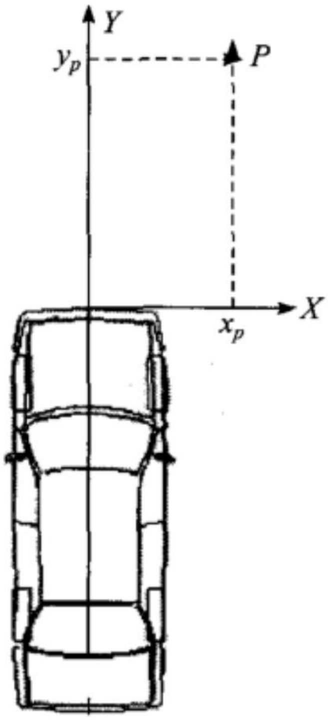


Figure 2: Relative position coordinate system of person-vehicle

The movement of vehicles and pedestrians before the accident is shown in Figure 3. In Figure 3, direction VP is the walking direction of the pedestrian, direction V0 is the forward direction of the vehicle and the Angle between the direction of the pedestrian and the X axis, and Y is the Angle between the direction of the vehicle and the Y axis. Steering coordination time should not be included in the calculation [3]. If the emergency driver turns too late and the vehicle still moves in the original direction without deviating from the Y-axis, then Y=0; In some accidents, if the emergency driver turns and the forward direction of the vehicle is inconsistent with the Y-axis, Y≠0.

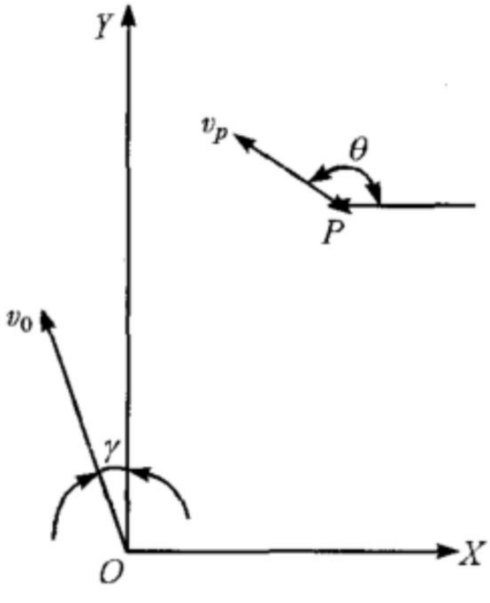


Figure 3: Motion state diagram of a car with people

1s before the accident, the lateral distance xp of the pedestrian relative to the vehicle can be obtained by equation (1):

$$x_p = x_a - v_p t\cos\theta - \left(\frac{v}{3.6}t_3 + \frac{1}{2}at_3^2 + \frac{v_0}{3.6}t_2 - \frac{1}{6}at_2^2\right)\sin\gamma \tag{1}$$

Where, Xa is the position of pedestrian and vehicle at the first impact, m; Vp is the moving speed of the pedestrian, m/s; T is the time before the accident, which is 1s; θ is the Angle of pedestrian movement direction and X-axis, counterclockwise direction, (°); T3 is the duration of braking, s; A is the maximum deceleration, m/s squared; V0 is the speed at which the driver is aware of the danger, km/h; T2 is the coordinated deceleration time, s; y is the Angle between the forward direction of the vehicle and the y axis; It's positive in the counterclockwise direction, theta (°).

The longitudinal distance yp of pedestrians relative to vehicles 1s before the accident can be obtained by equation (2):

$$y_p = \left(\frac{v}{3.6}t_3 + \frac{v_0}{3.6}t_2 - \frac{1}{6}at_2^2\right)\cos\gamma + \frac{v_0}{3.6}t_1 - v_p t\sin\theta \tag{2}$$

Where, t1 is the driver's reaction time, s, and t1+t2+t3=t.

The relationship between vehicle collision speed v and driving speed vo is:

$$v_0 = \left(\frac{v}{3.6} + at_3 + \frac{1}{2}at_2\right)\times 3.6 \tag{3}$$

The first point of contact between the pedestrian and the vehicle is xa. On further investigation, the first contact position was to the right of the centre of the front of the vehicle and had a positive value. Otherwise you take a negative value. Based on the statements of the pedestrian and the driver, determine the direction of the pedestrian's movement relative to the vehicle prior to the accident, and then determine the Angle between the pedestrian's direction of movement and the X-axis.

2. Result analysis

2.1 Influence of AEB function on position and damage value of dummy after impact

Between 344ms and 1020ms, the model should input AEB braking waves and 100% frontal impact waves to simulate an accident site where the vehicle decelerates from 64km/h to 50km/h at an initial speed of 0.7g (344-900ms) and a rigid obstacle participates in 100% frontal impact (900-1020ms).

If the vehicle is not equipped with AEB and does not have automatic emergency braking, the vehicle should always travel from 0 to 900ms at 64km/h and input the true collision course of the vehicle from 900ms to 1020ms.

According to the analysis in Figures 3 (a) and (b), it can be seen that when a vehicle is equipped with AEB in a collision, it will to some extent affect the shoulder strap force acting on the dummy's chest, but it has little effect on the abdominal belt force of the dummy. After being equipped with AEB, the seat belt acts on the dummy's chest in advance during a collision, causing an increase in shoulder strap force compared to vehicles without AEB. At the same time, before and after equipping with AEB, the impact of the dummy's shoulder strap force on the vehicle during the collision phase is not significant, but there is a significant difference in the damage value and motion trajectory of the dummy's abdominal strap force. Analyzing Figures 4 (c) to (i), it can be found that due to the early action of AEB before the collision, the injury indicators of the driver's dummy's head, neck, chest, and other positions increase and are all earlier than those of vehicles without AEB. However, the highest damage values of each part during the collision phase are lower compared to vehicles without AEB. At the same time, there is little difference in pelvic x-axis acceleration between the two scenarios, and the impact of AEB equipment on the dummy's pelvis is not significant.

Therefore, it can be found through comparison that equipping the AEB will to some extent change the posture and motion trajectory of the dummy during vehicle collisions, causing early damage to body parts such as the dummy's head, neck, chest, and shoulders. However, it will also reduce the body damage value during the collision phase to some extent.

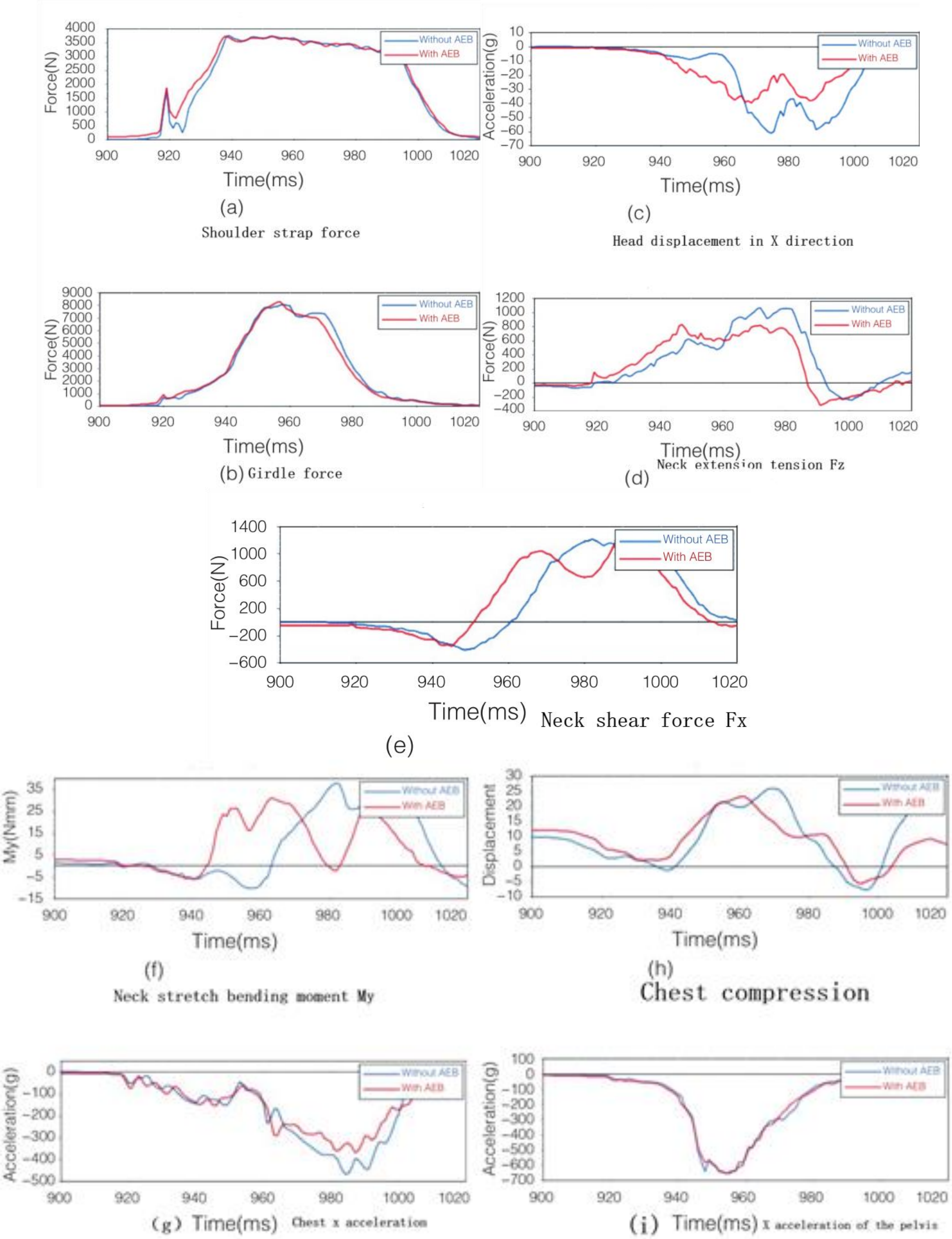
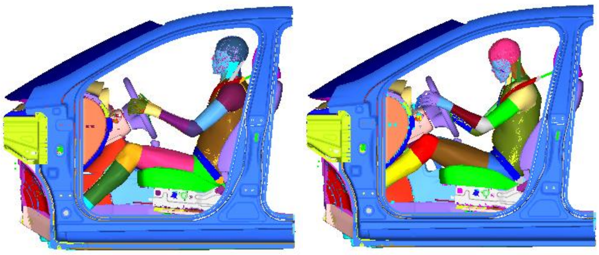


Figure 4: Comparison of motion posture and damage of the dummy with or without AEB braking after collision

2.2 Analysis of head injury caused by AEB in vehicle passenger protection

To further investigate the impact of AEB on the head injury of the dummy during the collision process before and after actuation. Based on the AEB experiment, a passenger protection model on the driver's side was established to study the impact of AEB intervention on passenger injury in frontal collisions under existing passive safety development strategies, as well as the impact of AEB intervention on driver posture before and after, as shown in Figure 5.



Without AEB With AEB

Figure 5: Occupant Protection Evaluation Model

By comparing the damage situation of the THUMS human model before and after AEB system intervention in a frontal collision, the injuries to various parts of the passenger's upper body are shown in Table 1. Analysis shows that the risk of skull injury for passengers has increased by 281%, the risk of brain injury has increased by 125%, the risk of rib injury has increased by 58%, the risk of visceral injury has increased by 48%, and the risk of lower limb injury has increased by 12%. It can be seen that the AEB effect leads to changes in passenger posture, which to some extent exacerbates passenger injury.

Table 1: Comparison of passenger injuries before and after AEB action

Injury Estimation Indicator	**Without AEB**	**With AEB**	**Chang**
Skull von Mises	0.285 MPa	1.087 MPa	281%
intracerebral pressure	85.3 kPa	191.9 kPa	125%
Rib strain	0.12	0.19	58%
Visceral pressure	0.636 MPa	0.94 MPa	48%
lower limbs von Mises	141 MPa	157.6 MPa	12%

3. Conclusion and Prospect

This article establishes a driver side dummy injury evaluation model before and after the AEB effect through simulation, and conducts in-depth research on the impact of vehicle equipped with AEB on the driver's motion trajectory and injury indicators of various body parts during the collision process. Furthermore, the impact of AEB effect on passenger injury in the vehicle is evaluated. The results show that:

(1) During the collision process, the early action of AEB will change the motion trajectory of the passenger dummy before and after the collision. The seat belt will restrain the forward leaning movement of the dummy in advance, which may increase the injury indicators of the dummy's head, neck, and chest before the collision, and to some extent reduce the damage values of various parts of the dummy's body during the collision phase.

(2) Due to the emergency braking of AEB, the driver's position relative to the interior changes,

while auxiliary restraint system devices such as airbags and seat belts operate according to the normal position of the passenger under existing passive safety development strategies. The change in passenger posture caused by AEB to some extent exacerbates passenger injury.

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