Research on Injury of Different Percentile Dummies Based on Vehicle Angle Collision

Yongqiang Wu*, Lingxu Meng, Deyou Yan
Vehicle impact Testing and Research Dept. CATARC Automotive Test Center (tian Jin) Co., Ltd Tian Jin, China.

*Corresponding author: wuyongqiang@catarc.ac.cn

Abstract. Angle collision has a high incidence in traffic accidents, but there are few researches on angle collision in the field of automotive safety. The 50th dummy is the main protection object in vehicle safety design, and the 5th dummy and 95th dummy are not paid enough attention. In this paper, based on the 18 ° sled collision platform of interior fittings, the injury characteristics of 5th dummy, 50th dummy and 95th dummy under the condition of angle collision are studied. The results show that the 5th dummy's chest injury index is the largest; the 50th dummy's pelvis and right thigh force injury index is the largest; the 95th dummy's left thigh force injury index is the largest; which indicate that different percentile dummies are injured in different degrees in the 18 ° angle collision. Based on the test results, it is also suggested that the chest, thigh and other injury of the dummy should be appropriately considered in the evaluation of the interior fittings test.

1. Introduction
The collision direction of two vehicles usually has a certain angle in traffic accidents, it is as shown in Fig. 1. However, there are few researches on the standard regulations and test conditions of angle collision in the field of Automotive safety, especially more attention is paid to the collision overlap rate and less attention is paid to the angle collision in frontal collision. According to the statistical results of relevant data, the incidence of traffic accidents with angle accounts for about 80% of vehicle frontal collision. [1-2] It can be seen that it is of great significance to deeply explore the dummy injury in the vehicle crash test condition with a certain angle for improving China's vehicle crash safety standards and regulations and reducing the occupant casualty rate in traffic accidents.

Fig 1. Schematic diagram of vehicle angle collision.
At present, there is only a certain angle mentioned in "interior fittings of passenger car" in the relevant domestic and foreign vehicle frontal crash standards, but it only verifies whether the dummy's head contacts with the IP during the collision, and does not consider other parts of the dummy and their injury.[3] Therefore, it is still questionable whether the current interior fittings test method can best protect the safety of occupants; Niu Weizhong of Lanzhou Jiaotong University studied the factors influencing the crash worthiness of a SUV under the condition of small overlap frontal oblique angle collision by means of finite element model simulation;[4] RUDD RW analyzed the occupant injury in frontal oblique angle collision, and found that the protective effect of airbag on the occupant is poor;[5] James Saunders Studied the influence of seat belt parameters on the driver's chest and hip injury in 30° collision;[6] Cao Libo of Hunan University also simulated the oblique angle collision between vehicles through the finite element model, and the simulation results verify that the dummy injury cannot be ignored in the oblique angle collision.[7-10]

In order to reduce the occupant casualty rate in traffic accidents, it is necessary to deeply explore the injury characteristics and correlation of different percentile dummies under the condition of angle impact. Therefore, based on the 18° sled collision platform of interior fittings, this paper studies and analyzes the injury characteristics and injury correlation of 5th, 50th and 95th dummy in angle impact condition through test method; in addition, the results of this paper can also be used for reference 11552-2009 "interior fittings of passenger car" provides technical support and basic data support.

2. Summary of test methods
This paper is based on the 18° sled collision platform of interior fittings, the schematic diagram is shown in Fig.2. The sled system is a hydraulic acceleration type collision trolley produced by Mitsubishi Heavy Industries of Japan. Through the accelerated sled collision test method, the 5th dummy, 50th dummy and 95th dummy are taken as the research objects respectively to explore the injury characteristics and correlation of different percentile dummies in the same angle collision.

The test method is as follows: firstly, the longitudinal center line of the vehicle body is adjusted to an angle of 18° with the collision direction and fixed on the transfer tooling, and the tooling is fixed on the sled collision platform through bolt connection; secondly, the 5th dummy, 50th dummy and 95th dummy are respectively placed in the driver's position, and the dummy state is adjusted according to the normal driving sitting posture; then the sensor on the dummy and the sliding platform data are collected. Finally, through the statistical analysis of the dummy damage data after the test, the injury characteristics of three different percentile dummies in the same angle crash test are compared.

The main basis to measure the vehicle safety performance is the injury value of each part of the dummy in the test. The current C-NCAP evaluation system and vehicle crash safety related standards all take the dummy injury of head and neck, chest and abdomen, pelvis, thighs and other parts as the main reference indexes to consider the vehicle safety performance.[11-12] Therefore, the test datas collected in this paper mainly include: dummy head 3ms resultant acceleration, neck bending My, chest
compression, pelvis resultant acceleration and left / right thigh force and other injury indexes, which respectively represent the injury characteristics of dummy head, neck, chest, pelvis, thigh and other parts during the collision.

In order to characterize the injury characteristics and differences of different percentile dummies accurately, this paper obtains the consistency of the data through multiple test data. Based on the data of many tests, statistical analysis is carried out, and the average value is taken as the final damage condition of the dummy. Through the comparative analysis of the injury data of each part of the three kinds of dummies after the test, this paper deeply explores the injury characteristics and correlation of different percentile dummies in the angle collision, in order to continuously improve the vehicle safety performance, further reduce the traffic accident casualty rate, and better protect the safety of occupants.

3. Analysis of dummy injury

According to the C-NCAP evaluation system and the relevant standards of vehicle crash safety, test datas for five times were randomly selected for each working condition to analyze the injury characteristics of the 5th dummy, the 50th dummy and the 95th dummy in the driving position under the 18 ° collision condition, such as the head 3ms resultant acceleration, neck bending My, chest compression, pelvic resultant acceleration and thigh force, and their injury characteristics relationship.

3.1. Head 3ms resultant acceleration

The head is one of the parts with high injury probability in traffic accidents, and the head 3ms resultant acceleration is one of the main indexes to characterize the degree of head injury. The head 3ms resultant acceleration results are shown in Fig.3.

Fig.3. Head 3ms resultant acceleration of different percentile dummies.

Fig.1 shows that there is no significant difference in the maximum head 3ms resultant acceleration of the three kinds of dummy, which are 47.43g, 49.69g and 47.34g respectively, indicating that the injury degree of the dummy heads are basically the same. The figures also show that the acceleration wave of the three kinds of dummy's head is different. The 5th dummy has the earliest acceleration time and the 95th dummy has the latest. Because the 5th dummy is relatively small, the seat is generally adjusted to the most forward and top position, and the distance between the dummy's head and the steering wheel is relatively close, the contact time between the head and the airbag is earlier than that of the 50th dummy and the 95th dummy during the collision. As shown in the figure, the 5th dummy's head contacts with the airbag at 48.9ms, but the airbag is not fully deployed at this time. Then, under the combined action of the head inertial force and the reaction force of the airbag, the growth of the head acceleration is hindered, and a relatively stable period appears. Until the airbag is fully deployed, the acceleration begins to deflate, and a relative growth occurs.
3.2. Neck bending moment \( m_y \)

The neck bending moment \( m_y \) is one of the main indicators to characterize the degree of neck injury in the collision. From all kinds of frontal impact tests, it is found that the dummy’s neck will bend to a large extent. The results of neck bending \( m_y \) are shown in Fig.4.

![Fig 4. Neck bending \( m_y \) of different percentile dummies.](image)

The results shown in Fig.4 show that the maximum neck bending \( m_y \) of 95th dummy, 50th dummy and 5th dummy are 18.19nm, 63.70nm and 91.01nm respectively, which indicates that the neck injury risk of 5th dummy is higher under the same impact conditions. Because at the moment of impact, the speed of the car body drops sharply, ECU signal triggers the ignition switch of the safety belt, and the dummy moves forward continuously due to the inertia effect. Due to the restraint effect of the safety belt on the chest, the head moves forward relative to the chest, and neck bending \( M_y \) gradually increases from the pre-tightening effect to the force limiting effect. Then, the head and neck contact with the airbag, and the airbag applies force backward to cushion the head As the airbag deflates, the relative displacement of the head and chest decreases and tends to balance, and the neck bending \( M_y \) gradually decreases from negative to positive until the end of the dummy rebound. However, the 5th dummy is small and has little forward impact. At the same time, the seat belt can effectively protect it, resulting in the obstruction of trunk movement, while the head continues to move forward due to inertia, resulting in a significant increase in neck bending \( M_y \).

3.3. Chest compression

Chest compression is an important reference index to evaluate the degree of chest injury, which is the compression of sternum relative to spine. The chest compression are shown in Fig.5.

![Fig 5. Chest compression of different percentile dummies.](image)
Fig. 5 shows that the maximum of 5th dummy is 50.25 mm and the minimum of 50th dummy is 28.11 mm, which indicates that the 5th dummy has a greater risk of chest injury in the 18° collision. Because the 5th dummy is small, the waist safety belt tightly binds the occupant to the seat in the early stage of the collision, which limits the movement of the dummy's trunk. However, the dummy's head moves forward rapidly due to inertia, resulting in a large movement of the chest relative to the spine. The chest of the smaller 5th dummy first makes a second contact with the steering wheel during the collision, and then the chest compression is more obvious due to the compression of the steering wheel. The maximum values of the chest compression of the 50th dummy and the 95th dummy are basically the same, but the curve of the chest compression of the 95th dummy is later than that of the 50th dummy, which is due to the greater compression deformation caused by the obstruction of the chest. The 95th dummy is larger, and its position is relatively backward during the test, and the distance between the chest and the steering wheel is larger, that is, the time of greater compression is relatively backward.

3.4. Pelvis resultant acceleration
Pelvic resultant acceleration is one of the most important criteria to evaluate the effect of restraint system on occupant protection. The test results are shown in Fig.6.

Fig. 6 shows that the maximum value of pelvic resultant acceleration of the 50th dummy is higher than that of the 5th dummy and the 95th dummy, which are 61.38g, 51.05g and 44.76g respectively, indicating that the pelvis of the 50th dummy is at greater risk of damage under the condition of 18° collision. Because the 5th dummy is small. The seat belt tightly binds the occupant to the seat in the early stage of collision, which greatly limits the movement of the dummy trunk. At the same time, the seat is adjusted to the front and top during the test for the 5th dummy, resulting in a short distance between the dummy knee and the IP. The limited interior space limits the free movement of the knee in the process of severe collision. Due to 95th dummy is larger, the knee movement space of the dummy is limited. The reaction force increases and the pelvic resultant acceleration decreases when the knee contacts with the IP.

3.5. Thigh force
During the process of violent impact, the thigh often has a secondary collision with the IP in the car. The numerical results of the left / right thigh force of different percentile dummies are shown in Fig.7 and Fig. 8.
Fig 7. Left thigh force of different percentile dummies.

Fig. 8. Right thigh force of different percentile dummies.

Fig.7 shows that the left thigh force injury value of 95th dummy is greater than that of 5th dummy and 50th dummy, and Fig.8 shows the right thigh force injury value of 50th dummy is greater than that of 5th dummy and 95th dummy, which indicate that the left thigh of 95th dummy is at greater risk of injury in 18 ° collision condition, while the right thigh of 50th dummy is at greater risk of injury. Because the longitudinal center line of the car body is at an angle of 18 ° with the collision direction. The dummy moves to the middle of the interior during the collision. Because the 95th dummy has a heavy body, large inertia and limited leg movement space, the left knee collides with the IP first, which produces a large impact force and consumes a lot of energy, greatly buffering the impact of the right thigh.

4. Conclusion
In this paper, the injury characteristics of 5th dummy, 50th dummy and 95th dummy under the condition of angle impact and their correlation are studied through the test method based on the 18 ° sled collision platform of the interior fittings.

1. Under the condition of 18 ° impact, there is no significant difference in the degree of head and neck injury among the three dummies, which indicates that the protective effect of the restraint system on the driver's head and neck is basically the same.

2. Under the condition of 18 ° angle impact, the chest injury index of 5th dummy is higher than that of 50th dummy and 95th dummy, which indicates that the chest injury risk of 5th dummy is higher in angle impact accident.
3. Under the condition of 18 ° angle impact, the pelvic injury index of 50th dummy is higher than that of 5th dummy and 95th dummy, which indicates that the pelvic injury risk of 50th dummy is higher in angle impact accident.

4. Under the condition of 18 ° impact, the left thigh of 95th dummy is the most damaged, while for the right thigh, the 50th dummy is the most damaged.

5. According to the test results, it is suggested that the chest, thigh and other injuries of the dummy should be appropriately considered in the evaluation of the interior fittings.

References

[1] Ragland Carl L, Fessahaie Osvaldo, Elliott Daniel. Evaluation of frontal offset oblique collision test conditions [C]/International Technical Conference on the Enhanced Safety of Vehicles, Paper 2001(17-385).

[2] SULLIVAN K, HENRY S, LAITURI T R A Frontal Impact Taxonomy for USA Field Data[J]. SAE International Journal of Passenger Cars Mechanical Systems, 2009, 1(1): 406-429.

[3] National Automotive Standardization Technical Committee. The interior fittings of passenger car: GB 11552-2009, Beijing: China Standard Press, 2009.

[4] Niu Weizhong, Xu Pengshan, Liu Jinxin. Research on the measurement method of pelvis motion track of sled test dummy [C]. The 16th China International Symposium on automobile safety technology, 2013, 452-456.

[5] RUDD R W, SCARBORO M, SAUNDERS J. Injury analysis of real-world small overlap and oblique frontal collisiones[C]. 22nd ESV Conference, Paper 2011(11-384).

[6] SAUNDERS J W, KUPPA S, PRASAD A. NHTSA’s frontal offset research program[C]. SAE Paper 2004-01-1169.

[7] Yan Lingbo, Ding Zongyang, Cao Libo, et al. Study on the driver injury in vehicle to vehicle oblique crashes[J]. Journal of Hunan University(Natural Sciences), 2016, 43(4): 59-66.

[8] Cao Libo, Zhang Ping, Yan Lingbo, et al. A study on driver injury in oblique and small overlap crashes under car to car collision[J]. Automotive Engineering, 2016, 38(2): 174-180.

[9] Fei Jing, Chen Keming, Yue Zhongyao, et al. Study on development and optimization of driver restraint system for car-to-car oblique collision[J]. Chinese Journal of Automotive Engineering, 2014, 4(5): 335-341.

[10] Liu Youbao. Study on drivers’ injury in oblique crash under car to car collision [D]. Hunan university, 2014.

[11] National Automotive Standardization Technical Committee. The protection of the occupants in the event of an off-set frontal collision for passenger car: GB/T 201913-2007. Beijing: China Standard Press, 2007.

[12] China New Car Assessment Progress (C-NCAP) 2021.