

Research on Pedestrian Protection of C-NCAP

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Abstract: This paper introduces the NCAP 2018 pedestrian protection head collision analysis method in China, and studies the effects of the main factors affecting the head injury, including the strength, tilt angle, thickness and stiffness of the hood. Pedestrian protection is a frontier and hot issue in the field of automotive safety technology. With the promulgation of China's pedestrian protection regulations, the development trend and direction of pedestrian protection technology are forecasted. The core of passive safety technology for pedestrian protection is the absorption of collision energy. The main technical route includes the application of new materials and the improvement of safety structures. Active safety technologies that can prevent accidents will gradually be called new trends in the field of automotive safety research.

Keywords: C-NCAP; Pedestrian protection; Head collision; Engine hood

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I INTRODUCTION

In recent decades, with the continuous growth of the urban population, the rapid development of the automobile industry, the increasing possession of cars, and the safety of people in road traffic have been widely concerned. Pedestrians are the main players and vulnerable groups of road traffic. According to statistics^[1], pedestrian accidents accounted for 49% of total traffic accidents in 2015 in global road traffic accidents, of which the number of pedestrian deaths in road traffic accidents in China accounted for 30% in the world. According to the accident analysis, more than 60% of deaths from pedestrians are related to head injuries, and 20% of head injuries are related to the hood.

At present, EU countries, the United States, Japan, and Australia have all established relevant pedestrian protection standards^{[2][3][4]}. In the NCAP technical regulations system, European E-NCAP and Japan's J-NCAP have detailed pedestrian protection test laws and regulations, and have perfect pedestrian protection head test methods to adjust. China first issued the industry recommendation "Protection of Pedestrians in Auto Crashes" in 2009, but there is no relevant content of pedestrian protection in C-NCAP. Until 2017, China Automotive Technology and Research Center released "C-NCAP Management Rules (2018 Edition)", will be formally implemented on July 1, 2018^[5].

When a pedestrian and a vehicle collide, the most vulnerable parts of the pedestrian include the thigh, calf, and head. Therefore, the pedestrian protection impact test is mainly divided into thigh impact test, calf impact test, and head-type impact test for adults and children, as shown in Figure 1. Pedestrian protection is the main content of current pedestrian protection tests and analysis by examining the most vulnerable parts of the technical indicators such as bending moment, acceleration, HIC damage value and so on.

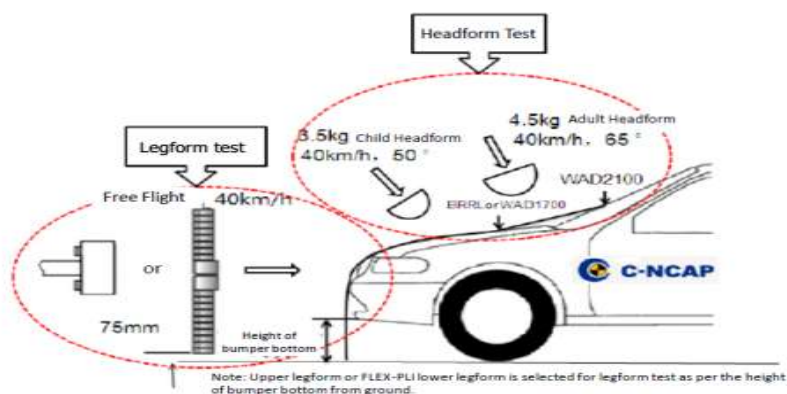


Figure1 Pedestrian protection test

II C-NCAP 2018 HEAD EVALUATION METHOD

The 2018 edition of C-NCAP adopts the grid point method or even-area method to perform head-type tests and scores based on whether or not the vehicle manufacturer is required to provide components, such as engine bonnets, and head-type test area prediction results.

2.1. Head-type collision area grid point method

- (1) Mark the longitudinal centerline of the vehicle on the bumper, upper hood, windscreen, and roof.
- (2) On the longitudinal centerline of the vehicle, along the outer contour of the front of the vehicle, an envelope distance marker is set from WAD1000 to WAD21000 at an interval of 100mm, as shown in Figure 2.
- (3) From the marked point on the longitudinal centerline, mark the sides of the vehicle on both sides of the vehicle to the reference line on the side of the hood at an interval of 100mm. This 100mm should be measured in the horizontal direction in the transverse vertical plane of the vehicle.
- (4) On the A-pillar, the intersection of the transverse vertical plane and the lateral reference line should be marked.
- (5) When there is a grid point below the outline of the outer wheel of the vehicle, the outer contour of the vehicle is simulated in the horizontal direction from the neighboring grid points near the front direction, and the grid points are marked on the tape, instead of the point below.
- (6) If the grid points are on the wiper structure, simulate the upper outline of the vehicle with tape, ignoring the structure of the wiper.
- (7) Remove points less than 50mm from the side reference line.
- (8) Mark all the grid points, the child's head test grid points will be prefixed with "C", adult head test grid points will be prefixed with "A".
- (9) The origin of the grid point is the intersection point of the longitudinal centerline of the vehicle and the WAD1000 envelope C(0,0). Other points are marked and named by the column and row. The vehicle is marked with a negative column on the left and a positive column on the right, as shown in Figure 3.
- (10)

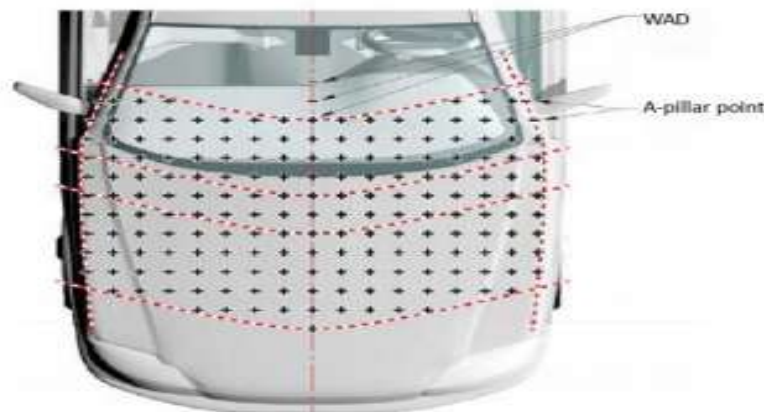


Figure2 Marking diagram of headform test grid points

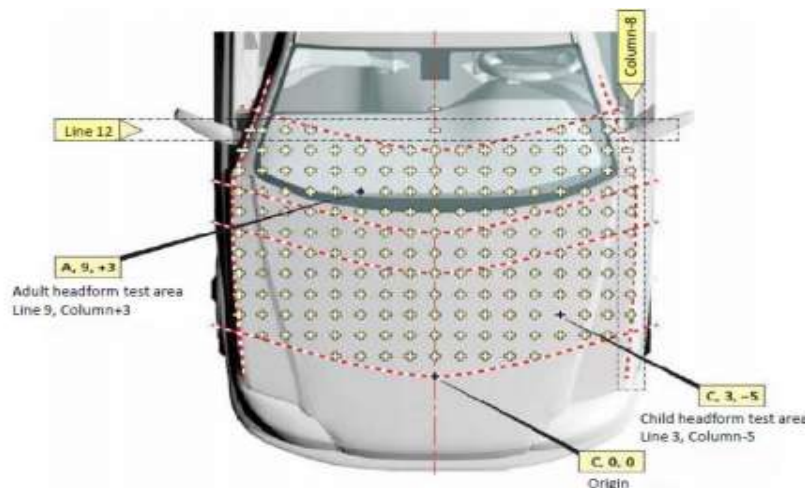


Figure3 Numbering of the headform impact area grid points

2.2. Head-type collision zone equal-area method

- (1) Starting from WAD1000, measure the distance between the WAD1000 and the reference side of the hood along the outside contour of the hood with a flexible tape or a flexible wire, and divide this distance into twelve equal parts, marking the division point between the two side reference lines.
- (2) The flexible line is in contact with the foremost point of the WAD1000. The flexible line intersects the two side reference lines in the transverse vertical plane of the vehicle. The distance between the two points of intersection is measured, and the distance is divided into twelve equal parts between the two side reference lines. Mark the equipotential points.
- (3) Connect the corresponding twelve points in the two measurements. These lines intersect the WAD1000 and mark the intersection.
- (4) According to steps (1), (2), (3), WAD1500 and WAD2100 are equally divided into twelve.
- (5) Connect the corresponding intersection of WAD1000 and WAD1500 and the corresponding intersection of WAD1500 and WAD2100 respectively.
- (6) The head type test area is divided into 12 equalization areas. Each of the equalization areas is divided into 4 areas, and a total of 48 equalization areas are used. The test points are numbered with the marks of the area where the test points are located, as shown in Figure 4.

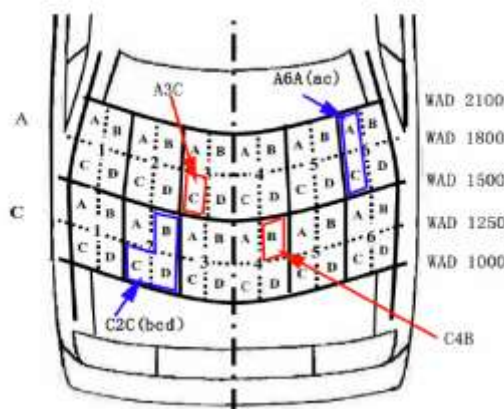


Figure4 Marking of equivalent divisions of headform test zone

2.3. Head crash analysis scoring method

C-NCAP uses the HIC₁₅ head damage value to make a final score on the head. The HIC calculation method is shown in formulas (1) and (2):

$$A_R = \sqrt{A_X^2 + A_Y^2 + A_Z^2} \quad (1)$$

$$HIC = (t_2 - t_1) \left[\frac{\int_{t_1}^{t_2} A_R \cdot dt}{(t_2 - t_1)} \right]^{2.5} \quad (2)$$

In the formula: A_X 、 A_Y 、 A_Z are the acceleration values in the three directions of the head impactor, and the unit is g, t_1 、 t_2 are the two moments in the collision, $t_2 - t_1 \leq 15ms$.

C-NCAP scores HIC₁₅ damage separately for each grid point. The damage range is shown in Table 1.

Table1 Colors comparison of the predicated values of headform test

HIC ₁₅ Interval	Color
HIC ₁₅ <650	Green
650≤HIC ₁₅ <1,000	Yellow
1,000≤HIC ₁₅ <1,350	Orange
1350≤HIC ₁₅ <1700	Grey
1700≤HIC ₁₅	Red

C-NCAP stipulates that the head-on collision score is 12 points, and the sum of the points scores of all grid points or areas is divided by the sum of the highest available points of all grid points or areas to obtain the percentage of the first type test score, and the percentage is multiplied by 12 to obtain the final score of the type test area, see formula (3):

$$\text{Head final score} = \frac{\text{Total score for all grid points or districts}}{\text{The highest score for all grid points or districts}} \times 12 \quad (3)$$

III. HEAD TYPE IMPACTOR

3.1. Child and adult head impactor

The C-NCAP head collision uses two kinds of head-type impactors for children and adults, as shown in Figure 5 and Figure 6. The specific parameters are shown in Table 2.

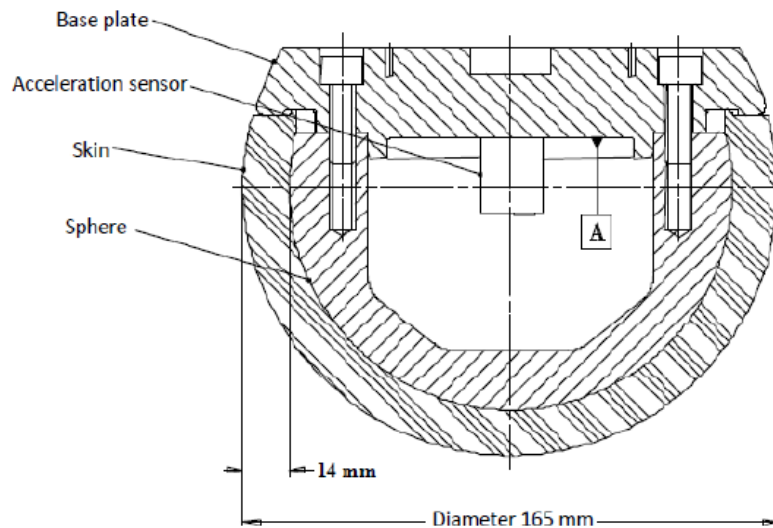


Figure5 Diagram of child headform impactor

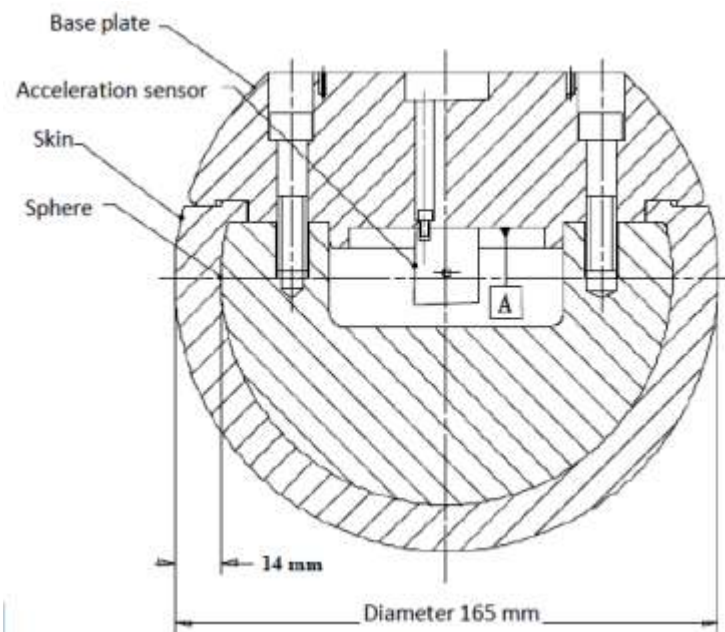


Figure6 Diagram of headform impactor

Table2 C-NCAPChild and adult head parameters

Head type parameters	Child head type	Adult head type
Spherical diameter(mm)	165±1	165±1
Quality(kg)	3.5±0.07	4.5±0.1
Moment of inertia(kgm ²)	0.008-0.012	0.010—0.013
Skin thickness(mm)	14±0.5	14±0.5

3.2. Head-type impactor calibration

During the calibration test, the head-type impactor is dropped from a prescribed height. The drop-out method shall ensure that the head-type impactor is instantly released and dropped onto a rigidly supported horizontal steel plate, and the head-type impactor shall be suspended in such a way that the head-type impactor is not rotate during the fall, as shown in Figure 7.

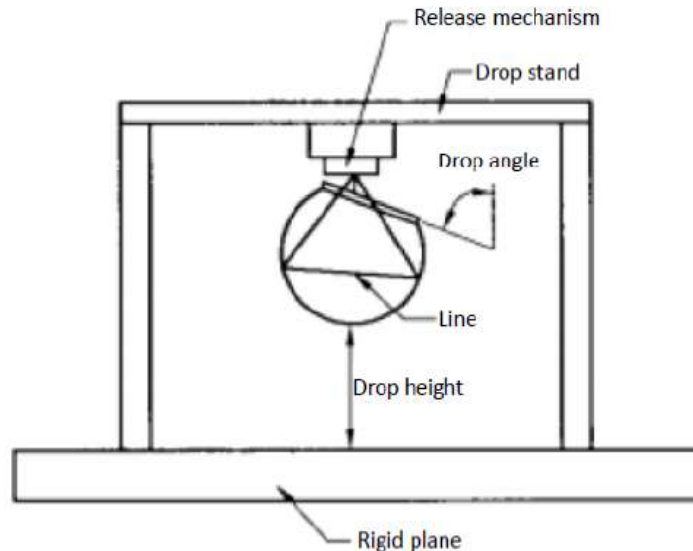


Figure7 Schematic diagram of headform dropping test

The peak acceleration of the composite acceleration measured by the acceleration sensor installed in the head impactor shall satisfy:

- (1) For children's head impactors, not less than 245g and not more than 300g.
- (2) For adult head impactors, not less than 225g and not more than 275g.

IV. MAIN FACTORS AFFECTING HEAD INJURY

According to the requirements of the C-NCAP on the head type test, the head model was established through the simulation software^{[6][7]}, and the strength and rigidity of the hood were respectively expressed using the yield strength of the material and the length of the cover plate. According to the bonnet of a certain model, the yield strength, length, thickness and tilt angle of the model are analyzed. It is concluded that the length of the bonnet has the greatest impact on the head injury index HIC₁₅, and the impact of the visor strength is the smallest. In other words, stiffness>thickness>inclination angle>intensity, which means that the length of the engine hood is properly reduced, the pedestrian head protection will have a better effect.

V. THE APPLICATION AND DEVELOPMENT TREND OF PEDESTRIAN PROTECTION TECHNOLOGY

Through the statistical study of collision accidents between people and vehicles, the head and lower limbs are the most injured parts of pedestrians^[8]. The current domestic and foreign pedestrian protection technologies mainly include: improvement of the front-end structure of the automobile, improvement of the engine hood, pedestrian airbag system and active vehicle safety system.

5.1 Improvement of front-end structure of car

The front-end structure of the car includes parts such as a bumper face shield, a buffer device, a bumper beam, and a bracket, and is an automobile part that first comes into contact with people in a collision between a person and a car. Studies have shown that the smooth and rounded shape of the nose is not only beautiful, smooth lines, reduce wind resistance, but also increase the contact area of the legs when the collision, reducing leg injuries. The gentle slope formed by the windshield with a large dip angle can effectively buffer the impact of pedestrians, reduce the chance of front windshield glass breakage, and will use flexible glass materials in the future. Reduce front surface protrusions such as the front wiper arm shaft to prevent the bottom corner screws from damaging pedestrians in the event of a collision.

In order to reduce the collision, the bumper will cause damage to the pedestrian's legs^[9]. On the one hand, it adopts lighter weight, better energy absorbing materials, on the other hand, it improves the bumper design, lifts the collision point, and integrates the bumper into the car's front face. It has been proved that this design has a large contact area with the human body during a collision, which can reduce the degree of injury.

5.2. Hood improvement

According to the research data of the IHRA (International Harmony Research Prevention), heads accounted for 30.9% of the entire pedestrian body injury area. In the cause analysis of pedestrian deaths, head injuries accounted for 62%. The main components that cause head injuries are the hood and the front windshield^{[10][11]}. If the engine compartment has ample space, the hatch can be opened during a collision, and at

the same time the front of the hood can be moved backwards, then the damage caused by pedestrian impact can be greatly reduced.

In reality, under the premise of reducing the hardness of the engine cover^[12], a collision sensor is installed in the front bumper. If a collision with a pedestrian is detected, the engine cover lift control module is started, and the engine cover can be instantly increased by the ejection device. Avoid the collision of pedestrians with hard objects in the engine compartment^[13], as shown in Figure 8. In fact, this technology has appeared very early. Many cars have adopted this technology and achieved very good results in the European NCAP test. With the emphasis on pedestrian safety, this technology will be more and more used by models.

There are two main types of gun lift systems: gunpowder type and mechanical type. Honda's "Mileage", French Citroen "C6", British Jaguar's "XK" and "XF", Nissan's "Skyline Coupe" and "Fair lady Z" have adopted the boom-type bonnet. In addition to the gunpowder type C6, C6 uses the power of the spring to lift the engine hood and unlock it with gunpowder. In addition, the Daimler E-Lift can be used to lift the engine hood. After unlocking, the engine hood can be opened and closed again. The spring can be retracted to its original state.

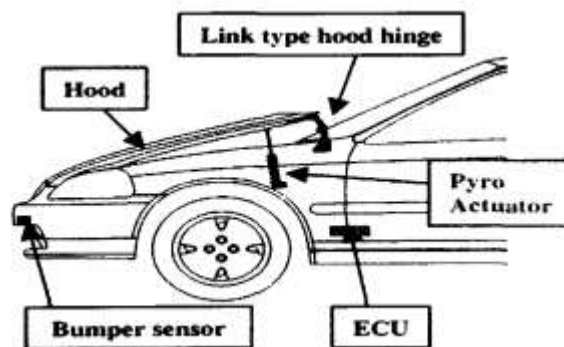


Figure 8 The schematic diagram of active hood lift system

5.3. Pedestrian airbag system

Pedestrian airbags mainly include hood airbags and front airbags. The airbag prevents the human body from hitting the front windscreen of the car, so as not to cause more damage to people and passengers in the vehicle in a violent collision. For example, the hood airbag begins to deploy on the bumper above the bumper. The folding mode and section design of the airbag ensure that the airbag deploys with the contour of the front of the vehicle to ensure the safety of the child's head and adult legs^[14]. The role of the front airbag is to provide secondary collision protection to prevent pedestrians from being thrown onto the hood and being injured by the bottom of the front window. Since the impact sensors used in the front airbags are relatively simple, it is expected to be put into production earlier than the hood airbags, and the collision warning detection of the latter is quite complicated. Currently foreign manufacturers are conducting extensive research to determine the best way to start two airbag systems.

4.4 Vehicle active safety system

The development of the vehicle intelligent security system ensures the active protection of pedestrians and promptly informs the driver before the accident to avoid accidents and minimize the damage of the accident. The active safety system utilizes sensors, laser radar, infrared rays, ultrasonic sensors, blind spot detectors, etc. around the vehicle body to detect the front and rear, left, and right road conditions, respectively, to provide drivers with timely avoidance of operating instructions, and to remind the driver to maintain a safe distance from vehicles. Frontal, rear-end and side-to-side collisions between vehicles and vehicles, vehicles and other objects or vehicles and pedestrians.

VI. CONCLUSION

Pedestrian protection laws and regulations in developed countries have been successively promulgated and continuously improved. China's pedestrian safety regulations "C-NCAP Management Rules (2018 Edition)" have been promulgated and will be formally implemented on July 1, 2018. This will further Promote human protection research and development. We must continue to learn from the experiences of developed countries, accumulate a large number of test data of domestic vehicles under the current safety regulations, conduct a large number of studies on road traffic conditions and traffic accident statistics in China, and combine our own automobile safety technology standards and the characteristics of our pedestrians. Research to promote the development and application of China's pedestrian protection technology for automobiles.

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