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Research on the Test and Assessment Method for Roof Crush Resistance

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Abstract: The detailed analysis of the standards of roof crush resistance was presented in this paper. Based on the comparison of GB 26134-2010, FMVSS 216 and FMVSS 216a, come to the conclusion about the trend of roof crush resistance standard-stronger crush resistance and less injury potential in rollover accidents. In this paper the test machine, test process and requirements were described in detail. It's significant for expanding FMVSS 216a test item in China and certification for domestic vehicles which would be exported to America.

Keywords: Roof Crush Resistance, Standard, FMVSS 216a, Test procedure, Rollover

1Introduction

According to the vehicle accident statistics, the death rate is high during rollover accidents. The critical factors which make occupants dead and hurt seriously include occupants' head and neck extruded because of the displacement of door and roof and that occupant is thrown out of the passenger compartment. The rollover accident is of low occurrence rate and high death rate [1].

The original FMVSS 216 standard, roof crush resistance, was established by National Highway Traffic Safety Administration (NHTSA) in 1971 to decrease the likelihood of a vehicle roof collapsing in the event of a rollover. The standard had been revised several times and the final rule, FMVSS 216a, was established in 2009. The original load requirement is 1.5 times unload vehicle weight (UVW) and the load requirement is 3 times UVW in FMVSS 216a. At the same time, FMVSS 216a is expanded to include vehicles with a gross vehicle weight rating between 2722kg and 4536kg. What's more, head room maintenance is monitored by head position fixture (HPF) which represents a 50th percentile male seated in the front occupant positions [[2][3]. The requirements of roof crush resistance become stricter and stricter. In order to decrease the likelihood of occupants' hurt or death in the event of a rollover, roof crush resistance of passenger cars, GB 26134-2010, is implemented on January 1, 2012 [4]. It's significant to decrease the likelihood of occupants' hurt or death in the event of a rollover and put the performance of occupant protection a new high.

2 Evaluation methods of roof crush resistance

Usually, the vehicle roof collapsing is regarded as the critical cause of occupants' head and neck hurt. Based on a large number of experiments, it's concluded that strong roof is good for occupant protection and decreasing the death rate in the event of a rollover by Insurance Institute for Highway Safety (IIHS) [5]. In order to decrease the occupants' death rate in event of rollover caused by vehicle roof collapsing, many evaluation methods are put forward, such as the static loading test and vehicle inverted drop test.

2.1 Static loading test for vehicle roof

The static loading test is put forward in GB 26134-2010, FMVSS 216 and FMVSS 216a. First, the vehicle is fixed to the test plate. The loading device maintains the angle specified in the loading process (see Figure 1). At last, record the displacement of loading device and the load of loading device and HPF.

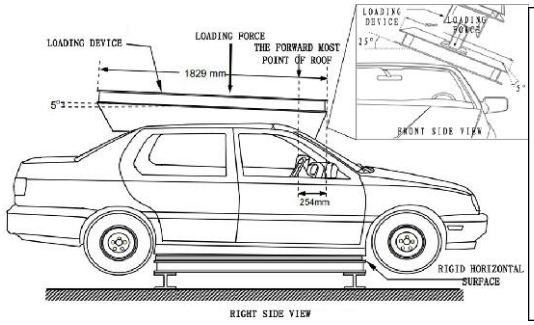

Figure 1. Static loading test of vehicle roof

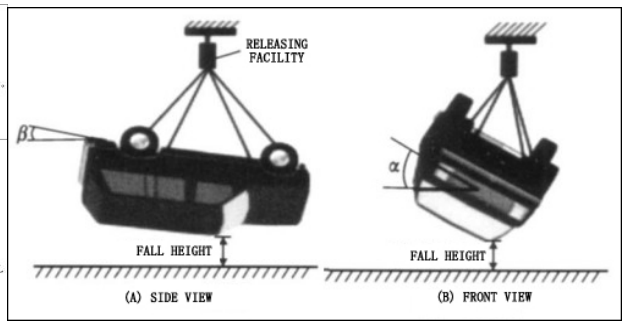

Figure 2. Vehicle inverted drop test

2.2 Vehicle inverted drop test

The dynamic test method is used for measuring roof crush resistance of vehicle roof in SAE J996. The vehicle inverted (roll angle is 25 °and pitch angle is 5 °) falls free in the height of 500mm. Then measure the displacement of the vehicle roof. See Figure 2, the sketch map of vehicle inverted drop test. This paper researches on the static loading test which is popular in the world.

3 research on the standards of roof crush resistance

Test procedure of GB 26134-2010, FMVSS 216 and FMVSS 216a is almost the same. The requirements of FMVSS 216a are stricter. The stricter requirements in FMVSS 216a are present as follow.

Table 1.Analysis of GB 26134-2010、FMVSS 216 and FMVSS 216a vehicle roof crush resistance

Standards		FMVSS 216	FMVSS 216a	GB 26134-2012
Application		Passenger cars, and to multipurpose passenger vehicles, trucks and buses with a GVWR of 2722 kilograms	Passenger cars, and to multipurpose passenger vehicles, trucks and buses with a GVWR of 4536 kilograms	M1, except the convertible car
Requirements	Loading device	Required load 1.5 times UVW or 22240N whichever is less, while the displacement of loading device is less than 127mm	Required load 1.5 times UVW(GVWR of 2722kg or less) and 3 times UVW(GVWR 4536kg or less), while the displacement of loading device is less than 127mm	Required load 1.5 times UVW or 22240N whichever is less, while the displacement of loading device is less than 127mm
	HPF	Not required	When the displacement of loading device is 127mm, if contact occurs the load on the headform cannot be greater than 222N	Not required
Loading position		Roof of driver or passenger side	Roof of driver and passenger side	Roof of driver or passenger side
Loading device		a rigid unyielding block whose lower surface is a flat rectangle measuring 762 millimeters by 1829 millimeters		
Loading velocity		≤13mm/s		
Positioning loading device		the longitudinal axis of loading device is at a forward angle (in side view) of 5 degrees and the transverse axis is at an outboard angle, in the front view projection, of 25 degrees		

(1) The range of application is expanded to include more kinds of vehicles. GB 26134-2010 applies to M1. FMVSS 216 and FMVSS 216a apply to passenger cars, and to multipurpose passenger vehicles, trucks and buses. FMVSS 216 applies to vehicles with a GVWR of 2722 kilograms or less. However, FMVSS 216a applies to vehicles with a GVWR of 4536 kilograms or less. FMVSS 216 and FMVSS 216a do not apply to school buses and convertibles or vehicles that conform to dynamic rollover test requirements S5.3 of FMVSS 208,"Occupant Crush Protection." It also does not apply to vehicles manufactured in two or more stages, other than chassis cabs, that conform to the roof crush requirements of FMVSS," School Buses Occupant Protection."

(2) The requirement of maximum applied load is stricter. GB 26134-2010 requires that the passenger compartment roof structure resist up to a maximum applied load equal to three times UVW of the vehicle M1. FMVSS 216 requires that a maximum applied load equal to 1.5 times UVW of the vehicle and 2.5 times later after the standard is revised. However, FMVSS 216a requires that a maximum applied load equal to 3 times UVW for vehicles weighing less than 2722kg and 1.5 times UVW for vehicles weighing between 2722kg and 4536kg.

(3) Head room is required. The lower surface of the loading device moves 127 millimeters. The interior of the roof

structure contacts the headform of HPF when positioned at the location for a 50th percentile male occupant as specified in S7.2, and if contact occurs the load on the headform cannot be greater than 222 N.

(4) FMVSS 216a requires that both sides of vehicle should be tested.

Analysis of GB 26134-2010、FMVSS 216 and FMVSS 216a vehicle roof crush resistance, see Table1.

4 Research on static loading test

4.1Test equipment

(1) Static loading device

The test device is a rigid unyielding block whose lower surface is a flat rectangle measuring 762 millimeters by 1,829 millimeters. Its longitudinal axis is at a forward angle (in side view) of 5 degrees below the horizontal, and is parallel to the vertical plane through the vehicle's longitudinal centerline. Its transverse axis is at an outboard angle, in the front view projection, of 25 degrees below the horizontal. The angle of loading device must be maintained throughout the loading process. The rate of loading is not more than 13 millimeters per second. The static loading device will have the capability of traveling a minimum of 153 millimeters after initial contact with the roof. See Figure 1.

(2) H-point Position Machine (HPM) and Head Restraint Measuring Device (HRMD)

The SAE J826 HPM is used for measuring the position of H-point and the angle of the seat back. HRMD is a separate head-shaped device used with the HPM to measure the static geometry of a vehicle head restraint. HRMD is equipped with two probes to measure head restraint height and backset, see Figure 3.

Figure 3. HPM and HRMD

(3) Head Positioning Fixture (HPF)

Figure 4. HPF

The surface of HPF headform is rigid hemispherical with a diameter of 165mm. HPF headform is mounted on a

3-axis load cell and attached to a fixture that is capable of being rigidly affixed to the test vehicle's floor pan area of the driver and front outboard passenger seat. To protect the load cell from damage, the fixture shall have the capability of collapsing after withstanding a minimum of 350N of compressive resultant force as measured on the headform. The fixture shall also be designed to adjust vertically or laterally to achieve the proper head form position. See HPF affixed to the test vehicle in Figure 4.

4.2Test procedure

(1) Loading position

The midpoint of the forward edge of the lower surface of the test device is within 10 mm of the transverse vertical plane 254 mm forward of the forward most point on the exterior surface of the roof, including windshield trim, which lies in the longitudinal vertical plane passing through the vehicle's longitudinal centerline.

If the roof of test vehicle is raised or altered, see Figure 5, and the initial contact point of the loading device is on the raised roof or altered roof to the rear of the roof over the front seat area, the loading device is positioned so that the midpoint of the rearward edge of the lower surface of the static loading device is within 10 mm of the transverse vertical plane located at the rear of the roof over the front seat area.

Figure 5. Loading position of the raised or altered roof vehicle

(2) Tie-Down of test vehicle

The test bench, a rigid horizontal (±0.25°) surface, must be capable of supporting the vehicle weight, the loads applied, and preventing movement of the vehicle during the test. The vehicle is fixed on the tie-down fixture by I-beam (see Figure 6). With the epoxy on the I-beam structures fully cured, place the test vehicle on the tie-down fixture and measure the vehicle's pitch and roll attitudes. Then fix the I-beam on the tie-down fixture.

(3) Positioning HPF

First, adjust the driver and front outboard passenger seats to the right position. The SAE J826 HPM is positioned in the seat with the lower leg segment set to 414mm and the thigh bar set to 401mm. Remove four HPM torso weights, two from the left side and two from the right side, and place the two larger HRMD torso weights on the hangers. Carefully, attach the HRMD headform to the HPM and adjust the HRMD to the right attitude. See Figure 7.

The 3-D space of the center of the HRMD headform is determined by 3-D coordinates measuring device. Then remove the HPM, HRMD and the seats, carpet and padding on floor. Attach the HPF to the floor and adjust the position of HPF headform to the HRMD's measured before (Figure 4).

Figure 6. I-beam and tie-down fixtureFigure 7. Installation of HRMD

4.3Prospect of static loading test

The vehicle needs stricter requirements of roof crush resistance in the future. At the same time, there are some problems in FMVSS 216a. FMVSS 216a requires that both sides of the roof should be tested. However, it's not specified which side should be tested first. During loading process, deformation of the A and B pillar, match-boxing effects to the roof and cracking of the windshield will affect the test results. Therefore, it's important to consider which side should be test first.

5 Conclusions

FMVSS 216a is the standard of phase-in and vehicles manufactured after September 1, 2015 must meet the requirements. The requirements of vehicle roof crush resistance are becoming stricter and stricter. At present, almost all the domestic vehicles meet the roof crush resistance requirements of GB 26134-2010. In order to improve the occupant protection performance in the event of rollover, the stricter standard should be put forward. Based on the comparison of GB 26134-2010, FMVSS 216 and FMVSS 216a, come to the conclusion about the trend of roof crush resistance standard-stronger crush resistance and less injury potential in rollover accidents. That introduction of test equipments, test procedure and requirements in FMVSS 216a is significant for revising the GB 26134-2010 and certification for domestic vehicles exported to America.

References

[1] National Highway Traffic Safety Administration. 2009. Traffic safety facts, 2008. Report no. DOT HS-811-170. Washington, DC: US Department of Transportation.

[2] 中国汽车技术研究中心. GB 26134-2010 乘用车顶部抗压强度[S].北京: 中国标准出版社, 2011.

[3] U.S DEPARTMENT OF TRANSPORTATION NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION. LABORATORY TEST PROCEDURE FOR FMVSS 216, Roof Crush Resistance [S]. Washington, DC: U.S.GOVERNMENT PRINTING OFFICE, 2001

[4] U.S DEPARTMENT OF TRANSPORTATION NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION. LABORATORY TEST PROCEDURE FOR FMVSS 216a. Roof Crush Resistance[S]. Washington, DC: U.S.GOVERNMENT PRINTING OFFICE, 2009

[5] Insurance Institute for Highway Safety. 2004. New rollover ratings reflect dynamic testing, but tests don't affect ratings very much. Status Report 39(3): 6-7. Arlington, VA.

[6] SAE International Surface Vehicle Standard, "Devices for Use in Defining and Measuring Vehicle Seating Accommodation, " SAE Standard J826[S], Rev. July 1995.

[7] Insurance Institute for Highway Safety, Crush worthiness Evaluation Roof Strength Test Protocol (Version I)[S], November 2009.