Research on the Relation of Airbag Effectiveness and Occupant Position

Shang Enyi，Qiao Nai，Yang Zhongwei，Gao Jingdang

JinZhou Jinheng Automtive Safety System Co, Ltd.

Abstract： Provided that it has been qualified that a sled has a same effectiveness with a car ， based on the sled test which a 50Th Dummy is placed at forefront, midway and rearmost position of the seat and a 95Th dummy and a 5Th dummy on a sled, analyzed the time of airbag touched dummy and the position of airbag touched dummy through high speed film tool, also comparatively analyzed all collected test results，concluded that the time when the protection effectiveness of a well designed airbag after deployed is optimal is not at a certain time point but is a time course when occupant head touched the airbag how many milliseconds after or before it reached its maximum volume, at the same time we concluded that there is no strict requirement on occupant seated position.

Keyword： airbag； sled test； optimal protection effectiveness； occupant seated position

1 Introduction

At present，national safety regulations are continually perfected and the consciousness of people is strengthened gradually, as supplement equipment to safety belt, airbag system has been installed on more and more cars. But not all occupants know how to use airbag system correctly, and there are some wrong viewpoint even in some open published articles, for example, Driver should move seat rearwards, so that there is enough room for airbag to reach its better effectiveness when a crash happens; driver should not drive with its body moved forwards, should have a correct posture and should lean on seat back closely and under the constraint of seat belt, etc.

2 The principle of airbag system and gist of airbag system development

2.1 The principle of airbag system

In a high-speed car crash event, generally there are two impacts happened. The first impact happened when the car begin to impact another car or barrier; after the first impact, the car was destroyed and changed moving state——decelerated and stopped even rebounded, at this moment, the occupants in the car would still keep its forwards motion state because of inertia, as a result, the occupants impacted the inner structures in the car ,such as steering wheel, instrument panel, windscreen ,etc, and this crash is named the second impact. Airbag system starts work after the first impact and before the second impact, there will be a airbag full of gas opened quickly between occupant and car's inner structures, then the occupants will impact the airbag, a hole on the airbag can absorb occupants' kinetic energy though the damp function generated by exhausted air, and will avoids or reduce injury to occupant.

Airbag system is composed of sensor, controller, inflator and airbag. Airbag work principle is: sensor senses crash signal, and sends it to controller, then controller receives and calculates the signal from sensor. If controller judges that it is necessary to open airbag, it will send a "Fire" signal to inflator, inflator is fired and generates a large amounts of gas, then airbag is open and full of gas.

2.2 The gist of airbag system development

At present, the development on airbag system is according to DESIGH REGULLATON WITH

Contact: E-mail shangenyi@sina.com

REGARD TO THE PROTECTION OF THE OCCUPANTS IN THE EVENT OF A FRONTAL COLLISION－CMVDR 294. The tests of airbag system development, both base tests and validation tests are conducted according to this regulation. As for the adjustment to occupant's chamber , the regulation indicates in its section 1.4.3.11.1：For the seat which can be adjusted along longitudinal direction, the "H" point of the seat shall be placed with the locking device engaged in the position that is nearest to midway between the foremost and rearmost positions; and it should be located in the altitude position specified by the manufacturer (if the seat can be adjusted along altitude direction singly).

That is to say, during airbag system development, the standard position of occupant is in midway position (H point is located in midway position), airbag design is optimized based on that, so the optimal effectives of airbag system is provided that the occupant is located in midway position of the seat when an event happens.

So we can have a conclusion, from the view of airbag system development, " drivers should move the seat backwards, so that there is enough room for airbag to reach its better effectiveness when a crash happens; driver should not drive with its body moved forwards, and should have a correct posture and lean on seat back closely", which is not right.

3 Research on sled test

3.1 Sled test can take place of car crash test

Table1 The injury value comparison between X car crash test and sled test

Item		Limited value	Sled	Car
Driver	HIC	1000	150.5	131.3
	Chest deformation (mm)	75	19.6	25
	Chest acceleration 3ms index (g)	/	45.7	50.9
Passenger	HIC	1000	370.8	321.3
	Chest deformation (mm)	75	26.8	27.7
	Chest acceleration 3ms index (g)	/	49.5	77.2

Before test，install the white body of the car on sled to take place of car，and dispose according to car。During sled test, take use of a energy absorbing device to amortize energy ， it can make moving sled with a speed stop, and get a reversible deceleration same with the car crashed, and that is to say the sled can have a deceleration same with the car crashed. In general , B "pillar" isn't deformed during crash test, so we can think that the data collected on B "pillar" is the deceleration of the car crashed.The laboratory of JinZhou JinHeng Automotive Safety System Company has been qualified by CNAL(China National Accreditation Board for Laboratories) 。As shown in Table 1, after the research on the airbag system of X car finished, we compared the result of the car crashed with the result of the corresponding sled test, and the result indicated that sled test can take place of car to research on the protection effectiveness of airbag system.

3.2 Research on sled test

As for airbag system design, it is generally considered that the protection effectiveness of airbag is optimal when head contacts the airbag as soon as it is full of gas. But in fact, in true events, the condition maybe very different from test environment , so that it is difficult to realize the optimal time point, so in concept we should consider that the optimal effectiveness of a airbag when it is deployed is not happened at a certain time point but happened in a time course, i.e we can consider that the optimal time course is the time when occupant head touches airbag how many milliseconds

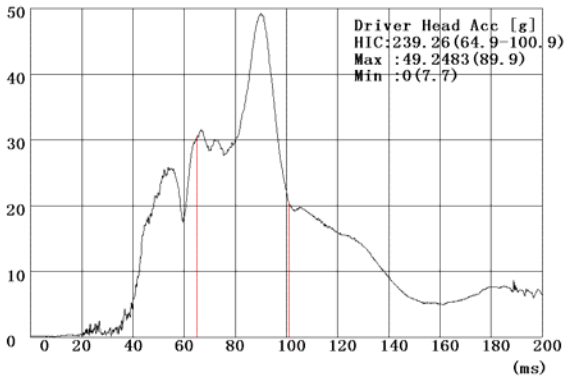
after or before it reached its maximum volume 。

Table 2 Sled test matrix

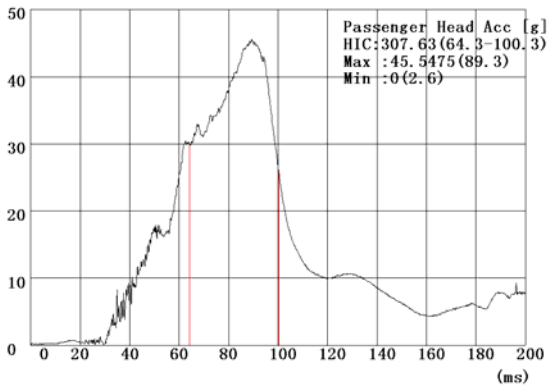
No.	Test content
1	Both driver and passenger are50th Dummy placed in midway
2	Both driver and passenger are50th Dummy placed in forefront
3	Both driver and passenger are50th Dummy placed in rearmost position
4	Both driver and passenger are50th Dummy placed in midway, and Fire time of ECU is delayed by 4ms.

To research the relation between optimal effectiveness of airbag and occupant position, during the process of one car type development, we have done a lot of sled tests. The test matrix is shown in Table 2, we did test analysis on different fire time and cases when occupant is installed on forefront, midway and rearmost position.

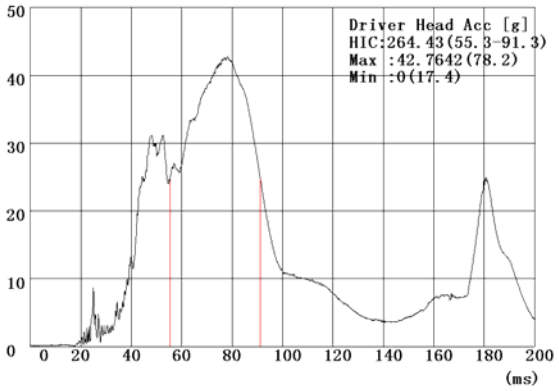
3.2.1 Comparison on Head acceleration peak values and Head injury values



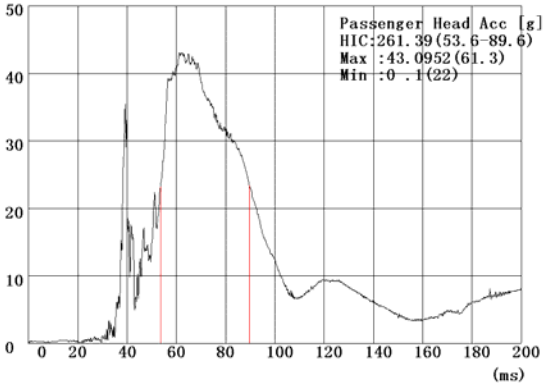
Curve1 No.1 driver head resultant acceleration



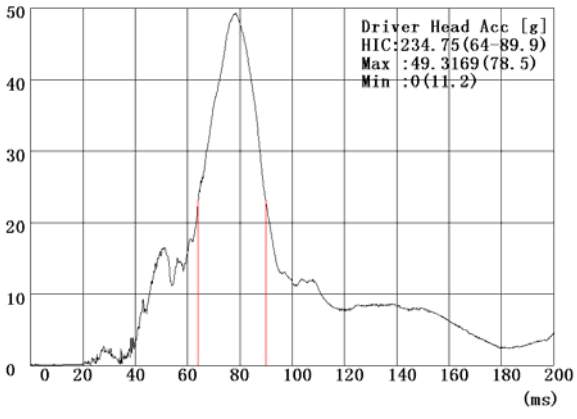
Curve2 No.1 passenger head resultant acceleration



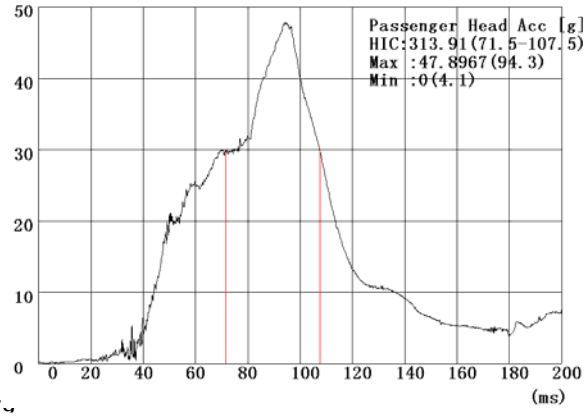
Curve3 No.2 driver head resultant acceleration



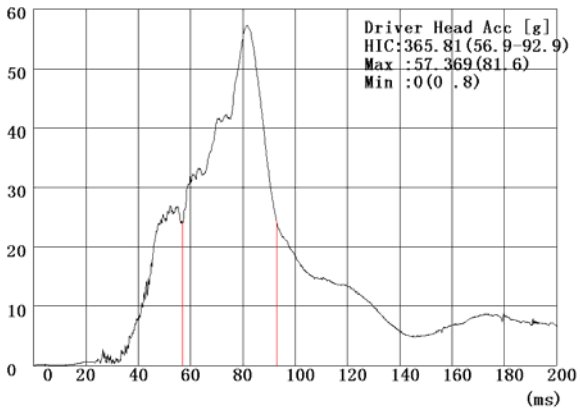
Curve4 No.2 passenger head resultant acceleration



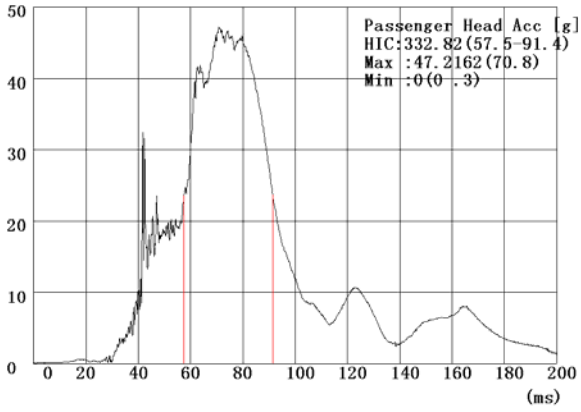
Curve5 No.3 driver head resultant acceleration



Curve6 No.3 passenger head resultant acceleration



Curve7 No.4 driver head resultant acceleration



Curve8 No.4 passenger head resultant acceleration

Test Item	Driver		Passenger	
	Peak value of resultant head acceleration（g）	Time (ms)	Peak value of resultant head acceleration（g）	Time (ms)
1	49.2	89.9	45.5	89.3
2	42.8	78	43.1	61.3
3	49.3	78.5	47.9	94.2
4	57.4	81.6	47.2	70.8

Table 3 Comparison on resultant acceleration after test

Test Item	Driver head HIC	Passenger head HIC
1	239	308
2	264	261
3	235	314
4	366	333

Table 4 Comparison on HIC after test

The total peak value of head resultant acceleration data and occurrence time in each test are shown in table 3，the injury values after test are shown in table 4。

For driver side，from table 4 we can find that the HIC value in test 1、2、3 varies a little，from the table 3 we can find that the peak value of the resultant acceleration is almost same。While for the test 4，because on the driver side the distance between the driver and steering wheel is short，ignition of ECU delays 4ms，it will lead to the contact time between airbag and driver head is prior to the maximal time of airbag deployment，and the airbag will contact the dummy head when the inside pressure of airbag is creasing，so，it will reduce the protective effect to driver head，but from table 4 we can find that though the protective effect is reduced，the protective effect is still not bad。

For passenger side，from table 4 we can find that the HIC value in four test varies a little，from table 3 we can find that the peak value of resultant acceleration varies a little。It is obvious that because the passenger is far from the instrument panel，and the volume of this side is more far，the four test condition effect the result a little。

3.2.2 The analysis of contact point and contact time between dummy and airbag during crash test

In order to analyses the test result further，now show the picture of the contact time between airbag and dummy head in each test below：

Fig.1 Test 1 The contact status between passenger and airbag

Fig.2 Test 2 The contact status between driver and airbag

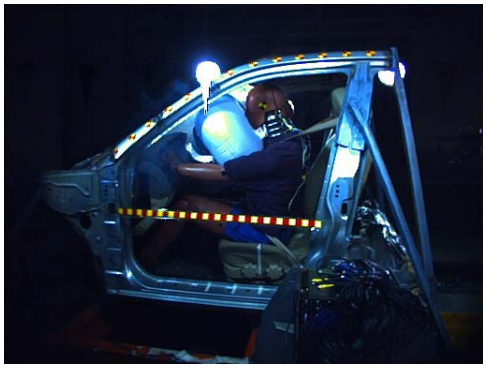


Fig.3 Test 3 The contact status between driver and airbag

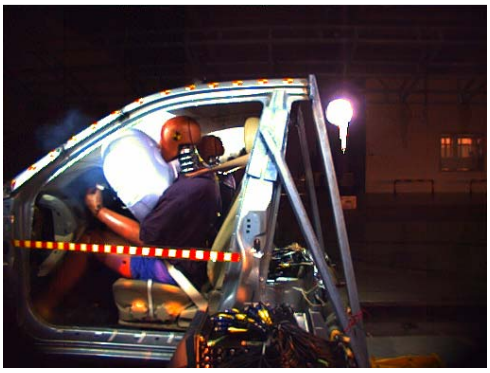


Fig.4 Test 4 The contact status between driver and airbag

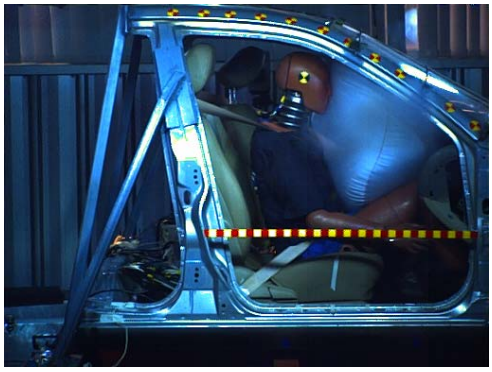


Fig.5 Test 1 The contact status between passenger and airbag

Fig.6 Test 2The contact status between passenger and airbag

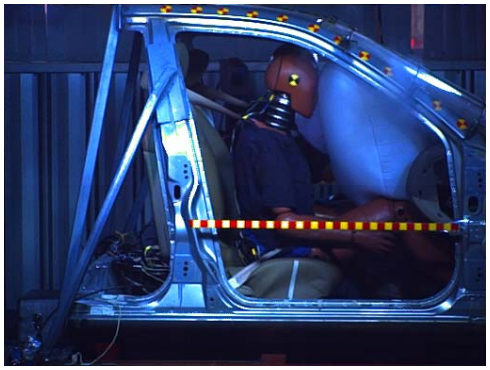


Fig.7 Test 3 The contact status between passenger and airbag

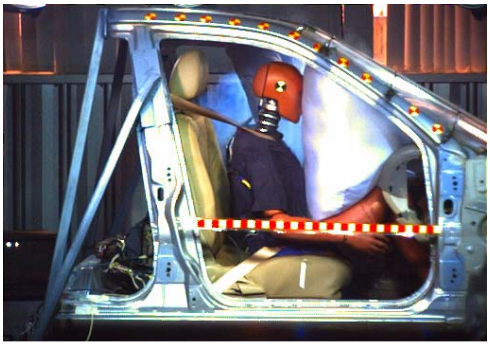


Fig.8Test 4 The contact status between passenger and airbag

Test Item	Driver side				Passenger side			
	Tearing time (ms)	Full time (ms)	Contact time (ms)	Time difference of contact & full (ms)	Tearing time (ms)	Full time (ms)	Contact time (ms)	Time difference of contact & full (ms)
1	17	45	49	4	27	58	55	-3
2	18	44	41	-3	28	58	36	-12
3	19	48	56	8	27	59	61	2
4	22	50	46	-4	30	61	52	-9

Table 5 Airbag working status in each test

In order to be convenient for the analysis of picture， roughly determined the cover tearing time, airbag filled fully time, the contact time between head and airbag in each test through the video analysis，shown in table 5。

From each picture we can find that，the contact between head and airbag，whether to driver or passenger，the position in each test should almost same。The only difference is the airbag is located between full、be able to be full、be able to be blow-by。

From Table 5 we can find that，when the seat of the driver and passenger is different ,and time to fire of ECU is different，the time difference between head and airbag is big，but from Table 4 we also can find that，the difference of injury value for dummy is small。

3.2.3 Resultant analysis

In the rule CMVDR 294 Annex 4，in the 1.2 section：during the test, there is a contact between the head and any vehicle component，a calculation of the value of HPC is made ,on the basis of the acceleration（ɣ）,measured according to annex 3,paragraph5.2.1,by the following expression:

$$\text{HPC}=(t_1\text{-}t_2)\ \left[\frac{1}{t1-t2}\int_{t1}^{t2} rdt\right]^{2.5}$$

In which ：（in 1.2.1 section）If the beginning of the head contact can be determined satisfactorily，t_1 and t_2 are the two time instants, expressed in seconds, defining an interval between the beginning of the head contact and the end of the recording for which the value of HPC is maximum；（in 1.2.2 section） If the beginning of the head contact can not be determined satisfactorily，t_1 and t_2 are the two time instants, expressed in seconds, defining an interval between the beginning and the end of the recording for which the value of HPC is maximum。

Test Item	Driver side		Passenger side	
	Contact time (ms)	t_1-t_2(ms)	Contact time (ms	t_1-t_2(ms)
1	49	64.9-100.9	55	64.3-100.3
2	41	55.3-91.3	36	53.6-89.6
3	56	64-89.9	61	71.5-107.5
4	46	56.9-92.9	52	57.5-91.4

Table 6 The contrast between head & airbag contact time and t_1-t_2

In order to analyses the relation between beginning and the end of head contact and $t_1$and t_2，the data is shown in Table 6。

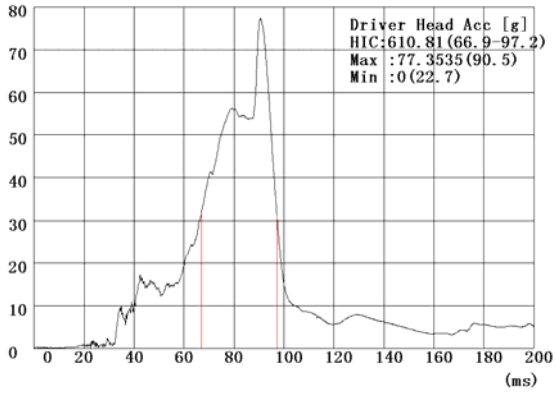
From table 6we can find that all the time difference between contact time and t_1 is around 10ms，with the help of wave analysis，we can see that the wave is small slope between contact time and t_1，that is active region of airbag，generally the calculative region of injury value is the contact process between passenger head and vehicle components when the inside pressure of airbag is

compaction or fully blow-by 。That is ，when the head contacts the airbag，the airbag is located between full、be able to be full、be able to be blow-by，it can not effect the HIC value。even if the airbag is not fully filled at the contact time, the shock injury to the driver and passenger is not the main injury at the second crash。For example passenger side in test 2 and 4，even if the contact time between airbag and driver head is prior to the maximal time of airbag deployment around 10ms，（table 5），it will occur the sweeping face status, this is not the main point causing the injury。

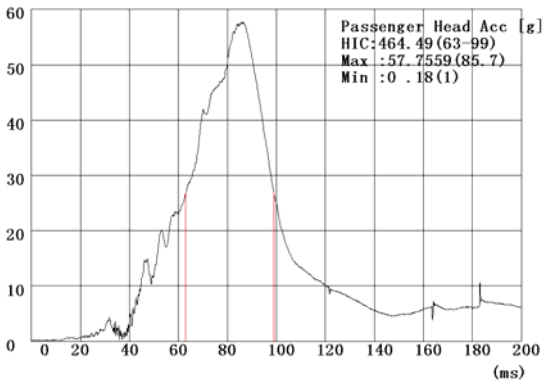
4. Dynamic OOP test

In order to validate the protective effect of airbag to high and female passenger, we install 95Th male dummy on driver side，and install 5Th female dummy on passenger side，Then conduct 48km/h sled crash test。The test result is shown in curve.9 and curve.10.

From the curve.9 and curve.10 we can find that，the HIC is obviously higher than 50Th dummy，but is far lower the rule limit value (1000), so，the developing airbag of this vehicle has a good protective effect to high and female passenger, too。



Curve9 95Th driver head resultant acceleration



Curve10 5Th passenger head resultant acceleration

4 Conclusion

In this article, through the analysis of airbag development and the test analysis that when the seat is located in the middle, forefront, rear, the delay time for ECU ignition, passenger is 95% male dummy, 5% female dummy. We can find the better-developed airbag, the contact time between head and airbag when the best effect occurred is a time quantum, the seat position is a zone. That is, the requirement to the passenger is not rigorous, when drives or gets on, the position should keep comfortable mainly, but they should tie the pretension belt。In addition，we should keep more relax because of the airbag，not add the fear.

References：

1 China Motor Vehicle Design Rules CMVDR 294.1999

2 Shang Enyi. Study for the absorbing energy during vehicle crash simulation test. Shanghai Automotive, 2003.Supplement, 2003.12

3 Huang, S.L., Zhang, J.H., Wang, X.D., Automotive crash and safety，Beijing：Qing Hua University Publishing Company，2000