Study of Neck injury evaluation and improvement method for US NCAP 5% Dummy

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ABSTRACT

NHTSA has carried out a lot of New US-NCAP tests became effective from MY2011. Injury probability of New US NCAP test is more severe than previous NCAP test. The Hybrid III 5th %ile dummy in front passenger position is used instead of 50th %ile dummy. 5th %ile dummy gets lower points than 50th %ile dummy in many tests. One of the main cause is Nij. Especially neck extension moment value is main factor to improve Nij.

US NCAP frontal test data was reviewed to know tendency of neck extension moment value. The object of the study is to find out how neck moves and neck extension moment occur. Furthermore, CAE test with new concept of passenger airbag is conducted to improve extension moment based on analysis result.. New concept of passenger airbag has two main vent holes that can be closed to retain inner pressure of airbag. Retaining inner pressure of airbag can decrease relative motion between head and neck to improve Nij.

INTRODUCTION

It's not easy to get high point for US-NCAP for passenger because New assessment method is more severe than previous one. New US-NCAP adopted HIC 15,Nij, Chest Deflection,Femur for 5%ile dummy on passenger. Especially Nij(Neck injury) is of great importance from other injury. An effort is being made to improve neck injury in many method.

This paper analyse neck injury characteristic of MY2012 ~ MY2013 test car and suggests neck injury improvement with concept keeping inner PAB pressure.

Neck Injury Analysis

50 crash test car of model year 2012 ~ 2013 were analyzed for data collection. Passenger overall rating is lower than driver. Passenger gets 5star rating less than about 25% comparing to driver getting 5star more than about 50%. Main cause of lower rating of passenger is neck injury. Neck injury is calculated as equation 1.

Equation 1. $$Nij = \frac{Fz}{Fzc} + \frac{Mocy}{Myc}$$

If driver and passenger get the same moment and force value, each Nij value is different because of different Myc (Moment Y Constant) as table 1.

Table 1.
Neck Injury Critical Value

Dummy	Fzc(N) Tension	Fzc(N) Compression	Moment Yc(Nm) Flexion	Moment Yc(Nm) Extension
HIII 50%	6806	-6160	310	-135
HIII5%	4287	-3880	155	**-67**

The most extension moment y(-My) have great effect on Nij. Nij has 4 type of injury as NTE, NCE, NTF, NCF. But only Nte and NCE occurred among almost 50 cars. This simply means that the bigger the extension moment Y, the worse neck injury as table 2. So improving extension moment y is the most important work for getting good overall point.

Table 2.
Passenger Result According to Neck Injury

Passenger Rating	Nij	Extension Moment Y (-My)
★★	0.79	47.1
★★★	0.53	30.9
★★★★	0.46	25.3
★★★★★	0.33	17.9

Neck Motion Analysis by Using Other Sensors

Generally moment y pulse is as figure.1 In part 1, belt pretention is working before dummy contact on PAB. Dummy head is going upward and forward. – force x, - moment y, + force z are occurred. In part 2, after head contact on PAB, dummy head reaction is occurred to rearward. + force x, + moment y occurred. In part 3, before head rebounding, force x and moment y are steady downward curve. In this part, the most important work is how to decrease downward curve.

In all part, force x and moment y curves are similar at the same time as figure 1. This means dummy neck force and moment y are associated.

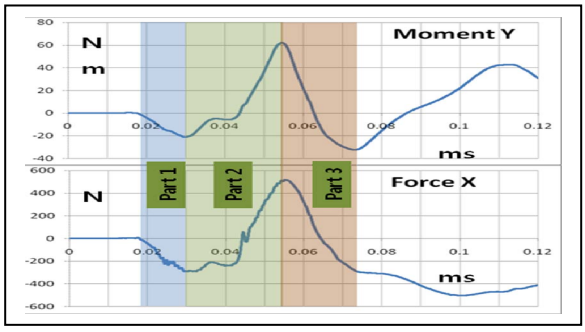

Figure 1. Neck Moment Y and Force X Curves

Neck sensor is located on top of neck. So neck itself motion cannot be analyzed through the video. To know neck sensor how to work, two angle sensors are used. One is attached on top of neck and the other one is attached on head C.G. Relative angle between head and neck can be known comparing moment y as figure 2.

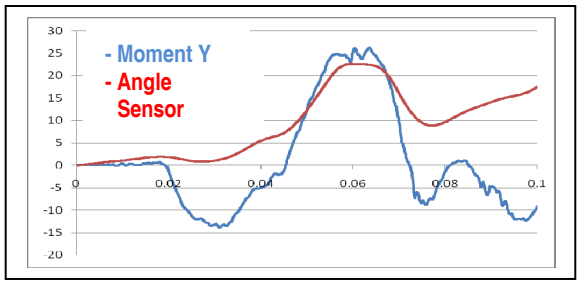

Figure 2. Relative Angle Between Neck and Head.

This means that neck motion can be known by two curves. When force x and moment y are minus sign, head moves toward from the top of neck(joint) and head is extension motion as figure 3. When force x and moment y are plus sign, head moves reward from the top of the neck(joint) and head is flexion motion as figure 4.

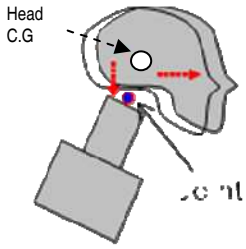

Figure 3. Neck Motion #1

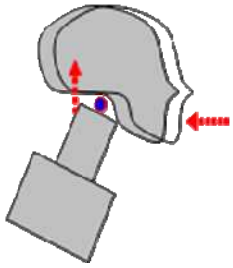

Figure 4. Neck Motion #2

In conclusion, relative motion between top of neck and head C.G should be decreased to improve moment y and force x. Especially, head moving toward from top of neck should be decreased.

PAB Vent Position

Vent hole size should be optimized for passenger injury because vent hole can control inner pressure of airbag. If vent hole is too big, head injury can be better. But neck injury can be worse because of relative motion between neck and head. If vent hole is too small, relative motion between neck and head can be decreased. But head injury can be worse. Here is a car shows how to control inner pressure of PAB.

Vent hole is much the same as other one before 60ms. But after 60ms, vent hole is blocked partially by a pillar, instrument panel and wind shield. This means that relative motion between head and neck can be decreased by controlling pressure of PAB. Refer to figure 5.

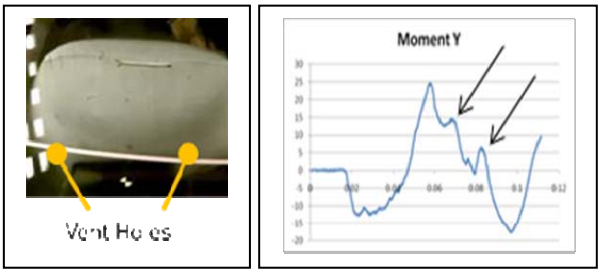

Figure 5. PAB Vent Holes Position and Moment Y Curve

Belt Load Characteristic

Belt load limiter can control relative motion between head and neck. High belt load made much relative motion and low belt load made small relative motion. Belt result of ★5, ★4 star cars are as table 3. Max belt load of good rating cars is lower than other cars. Belt Load area of good Nij cars before nij occurred lower than other cars. The smallest Nij of a car is 0.25 and belt load is the smallest.1.9kN.

Table 3.
Shoulder Belt Load Characeristic

	Nij	Max Load	Area just before Nij Time	Load at Nij Time
5star	0.33	3.1kN	570	1.3kN
4star	0.51	4.5kN	750	3.2kN

Time Gap Between Head and Neck Moment Y

This paper gives new concept of PAB. For this, time gap between head and neck moment y should be known. By controlling PAB pressure, neck moment y can be controlled. But head injury is also affected. If neck injury is getting better, head injury can be worse. This paper suggests to improve neck injury without making head injury worse.

The Head Injury, Hic15, is calculated with head resultant value. Normally, head resultant peak is occurred earlier than extension moment y peak. Refer to table 4.(40cars of 50cars are collected - some car's neck injury are so early as 30ms before head contacts on PAB, some car's neck injury cannot be collected because it's impossible to know when is the peak) After head peak, if PAB pressure is kept, neck extension moment y can be improved.

Table 4.
Head and Moment Y Peak Time Difference

	Head Peak	Extension Moment Y Peak
Time	64ms	87ms

Improvement Method for Neck Injury

Airbag – Main Vent Close Concept

To improve Nij(NCE, NTE), the most important work is to decrease extension moment y peak occurred after head resultant peak. The first suggestion is PAB inner pressure controller. Excessive PAB pressure can cause poor head injury and insufficiency PAB pressure can cause poor Nij injury. If these two factors are in harmony, head and neck injury can be improved at the same time.

The main concept is to close the vent hole that is main factor can control PAB pressure. Before head resultant peak time, main vent is open so that head injury can be improved. After head resultant peak, main vent is close so that extension moment y and force x down ward curves are decreased by decreasing head movement forward. Test is conducted by MADYMO sled test to know effectiveness of vent close concept as figure 6.

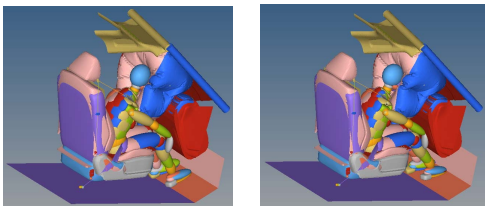

Figure 6. MADYMO Test

(Left : Vent Open / Right : Vent Close)

There are two 45mm main vents in the base test. Hic15 is 233 at 60ms and Nij is 0.46 at 80ms. Nij is not so good for good overall rating. Improvement test is conducted by closing two main vents by controlling vent close time. Closing only one vent test is also conducted as table 4.

Table 4.
Test Matrix and Result

	Vent Size (mm)	Vent Close Time(ms)	HIC 15	Nij	Rating
1	45mmX2	N/A	233	0.46	4.76★
2	45mmX2	65ms	318	0.31	5.03★
3	45mmX2	75ms	244	0.41	4.90★
4	45mmX2	75ms(one vent close only)	244	0.46	4.76★
5	45mmX2	80ms	233	0.43	4.88★

Head g value is going up when vents close. The earlier vent close, HIC15 value gets higher. When vents at close at 65ms, Hic15 became 318 from 233. Although Hic15 becomes worse, extension moment y is improved greatly. Force x and moment y tend to move upward. This means that relative motion between head and neck is decreased as a result, Nij is 0.31.

When vents close at 75ms, Hic15 is almost not changed. Hic15 is increased from 233 to 244. Nij is improved from 0.46 to 0.41. HIC gets little bit worse and Nij gets better.

HIC15 and Nij injury are changed differently by vent close time. This means closing time of vents should be considered.

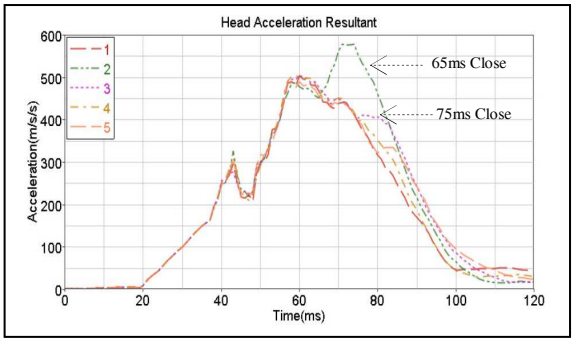

Figure 7. Head Acceleration

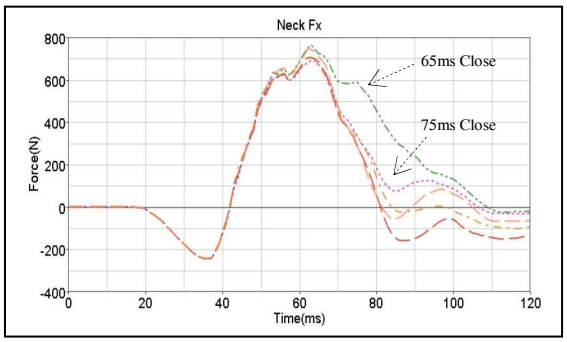

Figure 7. Neck Force X

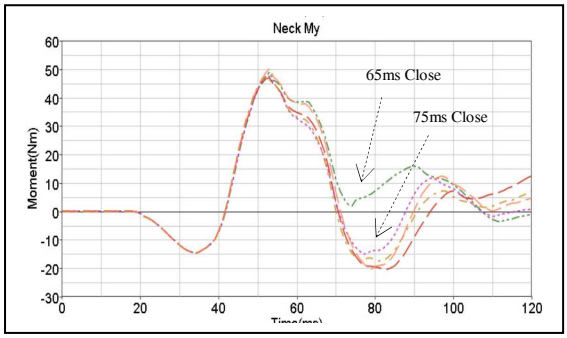

Figure 8. Neck Moment Y

When vent is close, head, neck force x, neck force y are going up at the same time. But if vent close time is optimized, only neck injury value can be improved only.

Belt Characteristic

For good result of head, neck, chest and femur as well, belt characteristic is one of main factor. As mentioned above, each car has different belt load characteristic. Belt can effect on head and neck injury. High belt load makes big motion and low belt load makes low motion. For improving neck injury, belt and airbag should be considered at the same time.

CONCLUSIONS

Neck injury should be improved for good overall rating in passenger 5%ile dummy. For this, understanding cause why and how neck injury occurred by the time should be done. A factor is suggested to improve neck injury by closing main vent holes.

1) Neck motion through the video analysis is not exact. In other word, neck sensor is not located on middle of neck. Neck sensor is on top of neck. So relative motion between neck and head to should be analyzed to know how sensor works. Force X and angle sensor are used to analyze neck motion. When head moves toward from the top of neck, force x and moment y are negative curves. At this time, relative angle between head and top of neck is worked as force x and moment y. To improve extension moment y, head movement forward should be decreased.

2) This paper suggests vent close concept. After head resultant peak passed, main vent holes are close to keep inner pressure of PAB. It can prevent that relative motion increasing between head and neck. The time when vent close is main factor to improve Nij. It can be one factor to improve dummy injury.

※ By using this concept, main vent holes can be larger to improve HIC in full frontal test, LRD regulation test, unbelt regulation test before vent close. After vent close, Nij in full frontal test, head bottom out in unbelt regulation test can be improved.

3) Belt characteristic, PAB shape, car characteristic and such should be considered at the same time to improve dummy injury, especially neck injury.

4) The plan with actual sled test would be come to action

REFERENCES

[1] NHTSA, NCAP Final Decision Notice, NHTSA-2006-26555, 2008.

[2] H.K. Beom “Statical Review for USNCAP Front Crash Result in MOMENT Y2011, KSAE, Conference Proceedings

[3] Matthew R. Maltese “Neck Pendulum Test Modifications for Simulation of Frontal Crashed”, SAE World Congress, 2008