Low Risk Deployment Passenger Airbag – CAE Applications & Strategy

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Abstract

Occupants who were out-of-position (OOP) in the vehicles would increase the risk of airbag induced injuries in the crash event. The punch out forces resulting from the airbag deployment act on the occupant and would cause potential injuries. To evaluate the OOP performance of the airbag system, FMVSS208 requests a series of test loadcases. In passenger side OOP, it includes test loadcases with rear-facing child seats, 3yld and 6yld in two different occupant positions.

Design of low risk deployment passenger airbag system requires balanced considerations of in-position occupant protection performance and out-of-position performance. A research project has been conducted to investigate those relationships in great details.

In this paper, the development of CAE capability to predict low risk deployment passenger airbag behaviors is presented. Using validated CAE mode a series of studies have been conducted to define depowered inflator which can meet the needs of both in-position and out-of-position performances. This forms the key strategy for low risk deployment passenger airbag in design applications.

Introduction

Occupants who were out-of-position (OOP) in the vehicles would increase the risk of airbag induced injuries in the crash event. The punch out forces resulting from the airbag deployment act on the occupant and would cause potential injuries. To evaluate the OOP performance of the airbag system, FMVSS208 requests a series of test loadcases. In passenger side OOP, it includes test loadcases with rear-facing child seat, 3yld and 6yld, as shown in Figure 1.

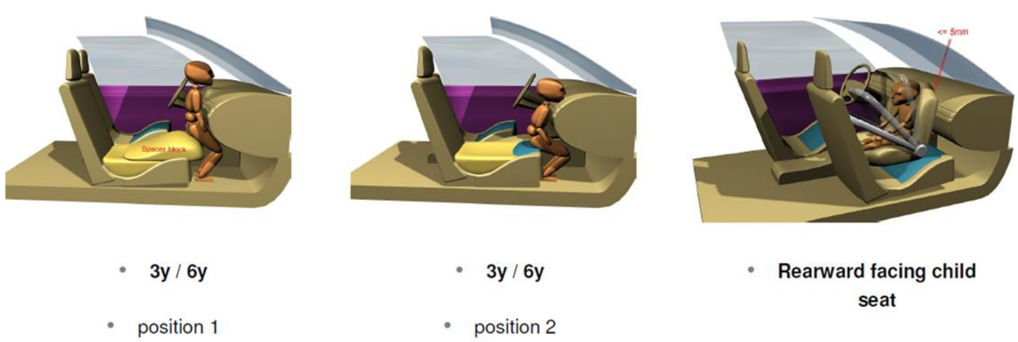


Figure 1, FMVSS208 Passenger Airbag OOP Test Loadcases

There are two different ways to demonstrate low risk of airbag related injuries:

(1) Airbag system is designed to be low risk for airbag deployment against children in those test loadcases.

(2) Advanced sensing system is implemented to identify child seated in the passenger seat and suppress the airbag system.

It is clear that design of low risk deployment passenger airbag has both real-life benefit and cost-saving over expensive sensing system. Design of low risk deployment passenger airbag system requires balanced considerations of in-position occupant protection performance and out-of-position performance. A research project, which was targeting development of low risk deployment passenger airbag system against 3yld and 6yld test loadcases, has been conducted to investigate those relationships in great details. In the project, the virtual CAE analysis has played important role to define the depowered airbag system and then physical tests have been conducted to confirm such depowered airbag system can meet the requirements of both in-position and out-of-position performances.

In this paper, the development of CAE capability to predict low risk deployment passenger airbag behaviors is presented. Using validated CAE mode a series of studies have been conducted to define depowered inflator which can meet the needs of both in-position and out-of-position performances. This forms the key strategy for low risk deployment passenger airbag in design applications.

Passenger Airbag OOP

As mentioned above, there are two positions associated with both 3yld and 6yld dummies (four loadcases in total): position 1 is the dummy sitting in front of the instrument panel (IP); position 2 is the dummy head on the IP. The major injury of OOP associated with 3yld and 6yld dummies are the neck related Nij. Statistically, within those four OOP loadcases, position 2 for both dummies is the most challenge loadcase, which often causes occupant high Nij injury. The injury is strongly related to following three key aspects in the airbag design: airbag inflator power, airbag folding pattern and vehicle IP geometry.

In general, the inflator used in for OOP solution has dual stage powers. When both stage powers come out together (with given delays), the inflator generates its full power. The required amount of full power is defined by in-position restraint performance, such as loadcase of unbelted 50%-ile occupant in 25mph rigid barrier test. Then the power of the first stage of the inflator is mainly controlled by the inflator production – the ability of stage power split. The commonly used pyro-tech inflator has its split of 70% (first stage) and 30% (second stage). The first stage power can be used for OOP tests as long as it is used in 16mph belted occupant in the sensing decision.

Airbag folding is also a very important design parameter in the OOP. The ideal folding pattern should allow the airbag warp around the dummy head with its main panel acting on occupant face during the airbag deployment without local loading on head. However, airbag folding often has certain variations; it can produce inconsistent deployment in repeat tests, which often cause so-called robustness issue for OOP. The figure 2 illustrates two repeat tests with different airbag deployment characteristics.

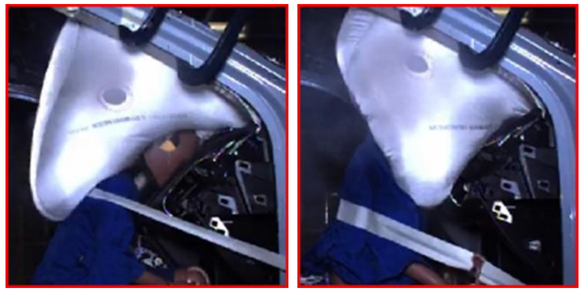


Figure 2, Folding variation leads to different deployment characteristics

CAE Capability on Passenger Airbag OOP

1. CAE capability on passenger Airbag Deployment

It has become industry common consensus that in order to model airbag deployment, one should model the airbag system "as made". This means the correct folding pattern, detailed IP door, and gas dynamic simulation method must be implemented in the CAE model. With those details modelled, CAE can model airbag deployment correctly. Figure 3 shows the folded passenger and detailed IP system used in the project.

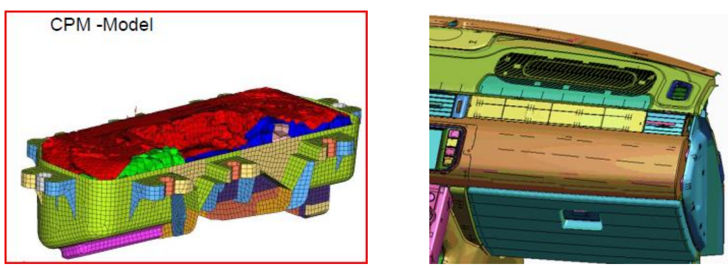


Figure 3, Correct folding pattern, detailed IP and gas dynamic

The challenge or bottle-neck of CAE application in the airbag OOP development is the time-consuming CAE airbag folding process, and its ability to model variations of physical airbag folding. Therefore, in the project, the strategy of developing low risk passenger airbag system is to validate CAE models against a set of physical OOP tests and then using the validated CAE model to conduct a series studies to define boundaries for robust low risk passenger airbag deployment.

2. CAE capability on dummy setup

Dummy position in OOP has significant effects on how airbag and dummy interact. Therefore, CAE capability to predict dummy positioning is a key enabler of CAE OOP prediction. FMVSS208 test protocol provides detailed dummy setup procedures. For 3yld position 1and 2, and 6yld position 1, there is no major challenge as one can follow the protocol to setup the dummy position with reasonable accuracy. However, for 6yld position 2 (head on IP), just following the protocol one can hardly setup the same dummy position in CAE to compare with physical dummy position. This is because physical dummy setup on 6yld position 2 involves pushing dummy back to achieve head-IP contact. By pushing dummy back, the physical dummy lumber spin deforms, while in CAE this process is difficult to achieve without “pre-simulation”.

Setting up a multiple pre-simulations according to protocol to setup CAE dummy position is also time-consuming process and has no double added another layer of complexity of virtual CAE OOP prediction. Instead, in this project, a simple and quick virtual CAE method has been developed. Using this method, the predicted 6yld dummy position 2 is very close to the physical dummy setup measurement.

The principle of the method is to conduct a pre-simulation on 6yld by pushing the back and generate a series of dummy positions with different back angles. Those dummy positions are saved as CAD images in standard database. In different vehicle platforms and environments, follow the protocol, and from those dummy positions, pick up the dummy position (red arrow) with which the dummy head is in contact with IP as shown in Figure 4. The CAE predicted dummy setup in such method has been proven to be very close to physical measurement (FARO lines) as shown Figure 5.

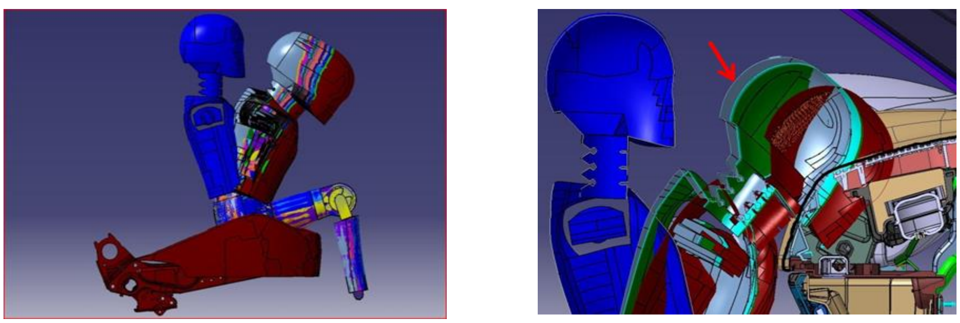


Figure 4, Pre-simulation to generate a series of dummy position

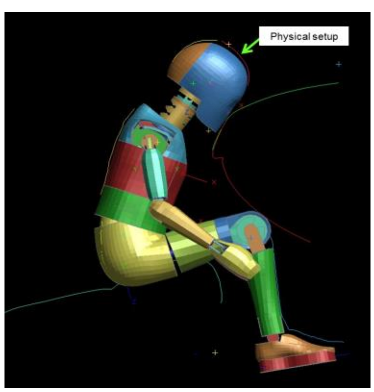


Figure 5, Comparison between CAE predicted dummy position and physical measurement

3. CAE validation to physical OOP tests

With implementation of all CAE modelling method mentioned above, CAE correlates the physical tests well.

Figures 6-7 show the 6yld position 1 and 2 correlations. In two repeat position 2 tests, one had the airbag deployed over the dummy head (over-shot), and one had the airbag warped-around the head (warp-around). This inconsistent airbag deployment characteristic is mainly due to folding variations as mentioned before. The Nij in over-shot situation is in general less than the Nij in warp-around, which means the warp-around condition would be worse case for Nij in Position 2.

The baseline CAE model represents over-shot condition and predicts well in both kinematics and Nij (Figure 7a). For the warp-around condition, it is decided to use airbag jetting method to mimic airbag warp-around the head without refolding the airbag. This is very effective and correlation can be achieved once the warp-around condition is achieved, as shown in Figure 7b.

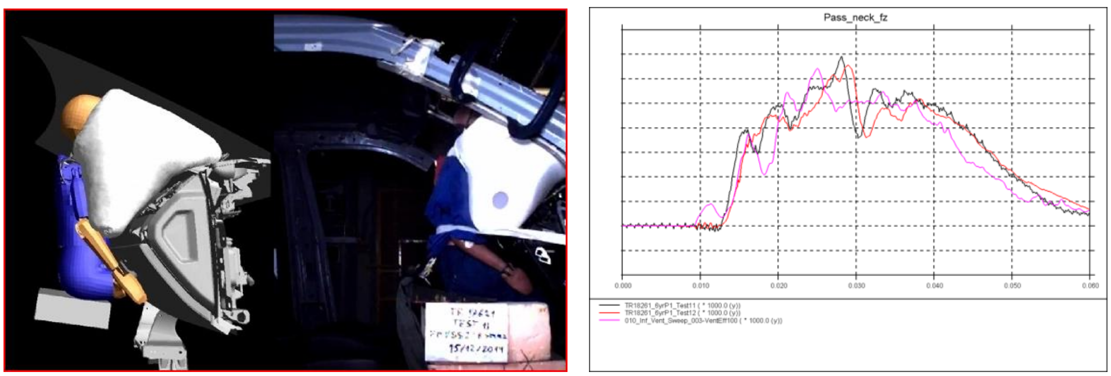


Figure 6, 6yld position 1 CAE correlation

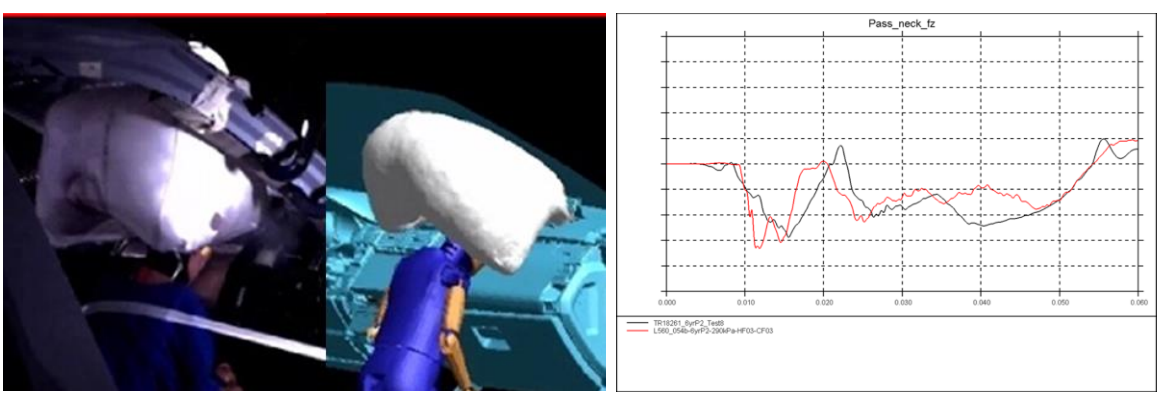


Figure 7a, 6yld position 2 CAE correlation – Over-shot

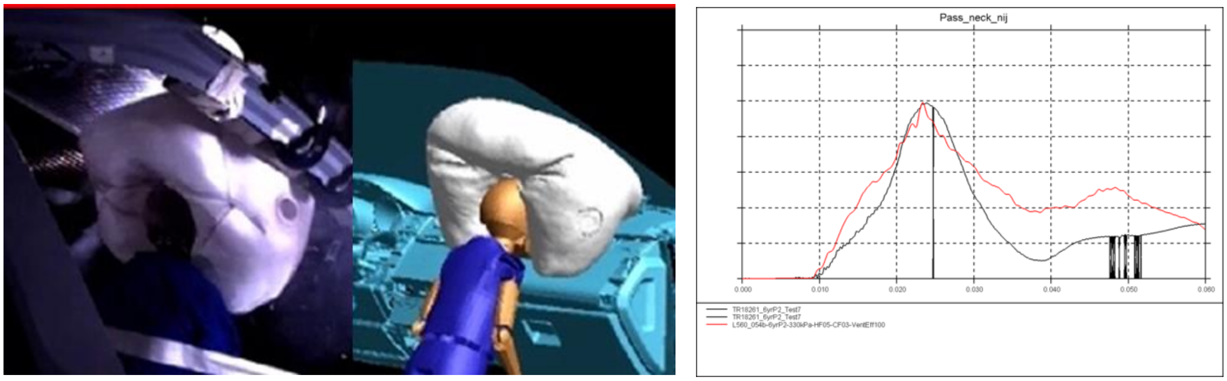


Figure 7b, 6yld position 2 CAE correlation – warp-around

Figures 8-9 show the 3yld position 1 and 2 correlations.

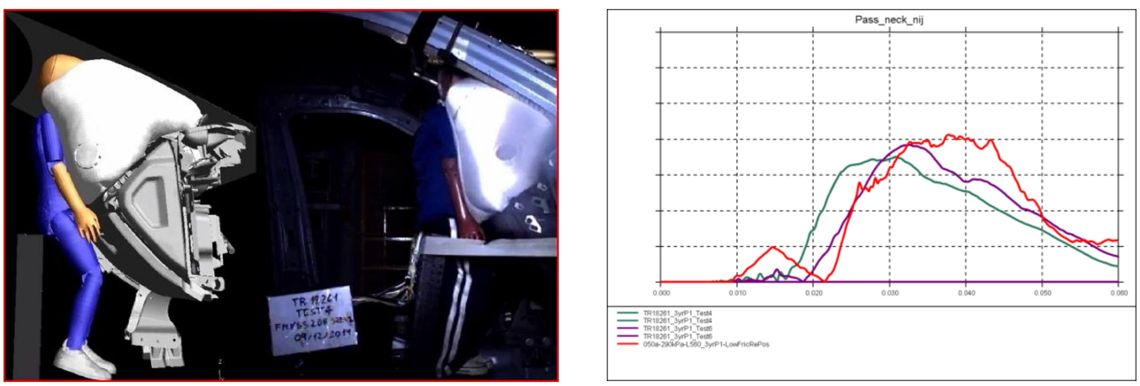


Figure 8, 3yld position 1 CAE correlation

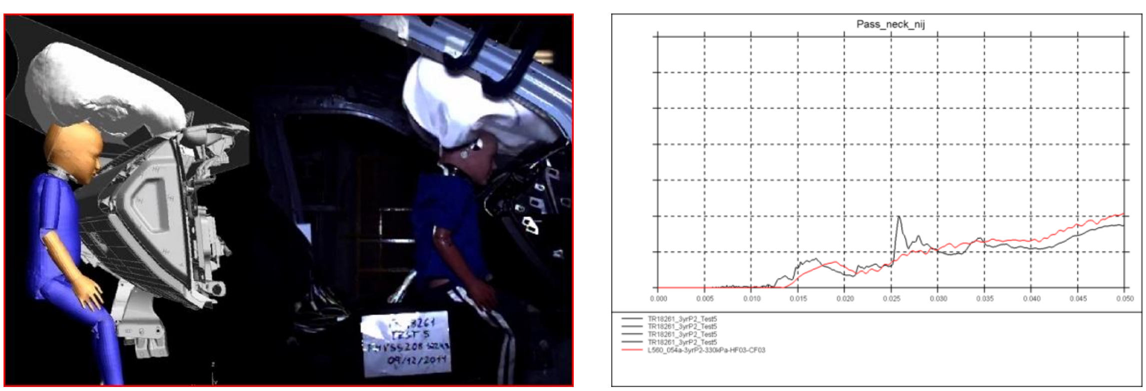


Figure 9, 3yld position 2 CAE correlation

Low Risk Deployment Airbag - Strategy

The validated CAE model has been used to conduct a series of studies to define depowered first stage power for robust low risk deployment airbag for OOP. The outcome from the study has tuned to the strategy of low risk deployment airbag design.

The study shows that the Nij is strongly proportional to the power of the inflator at a given system (folding and geometry). Figure 10 demonstrates that if at baseline with 100% first stage power the neck injury is around 100% target for both 3yld and 6yld position 2, in order to achieve robust OOP, the first stage power has to be depowered to 80% of baseline power for the given folding and vehicle geometry.

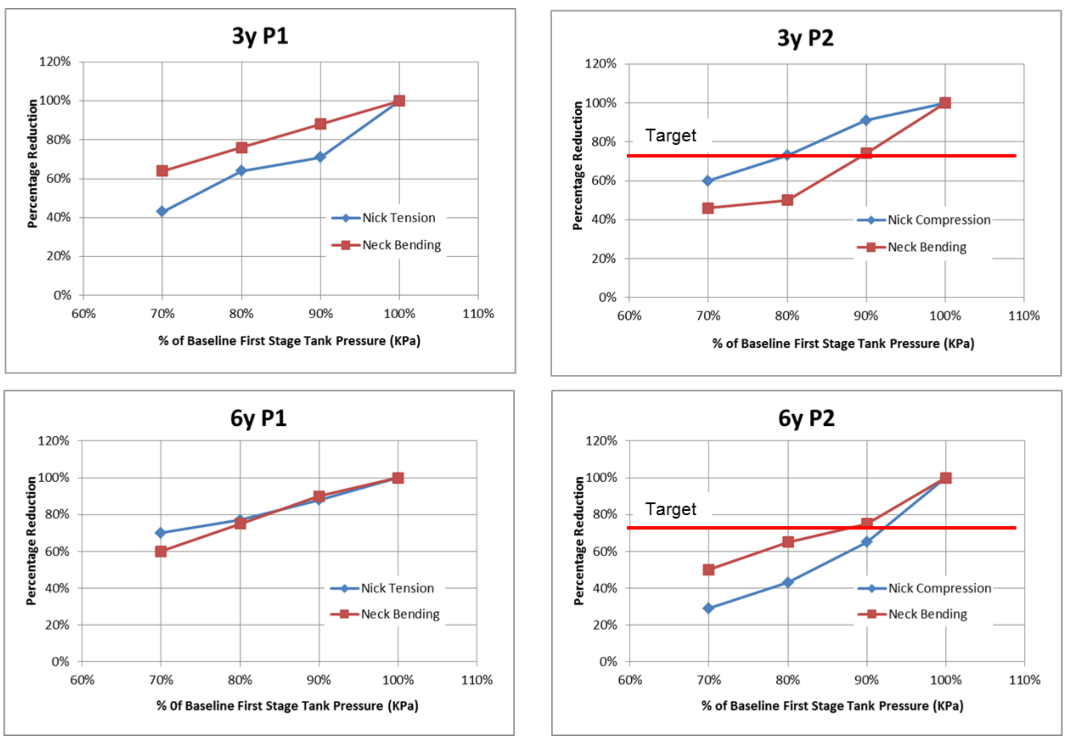
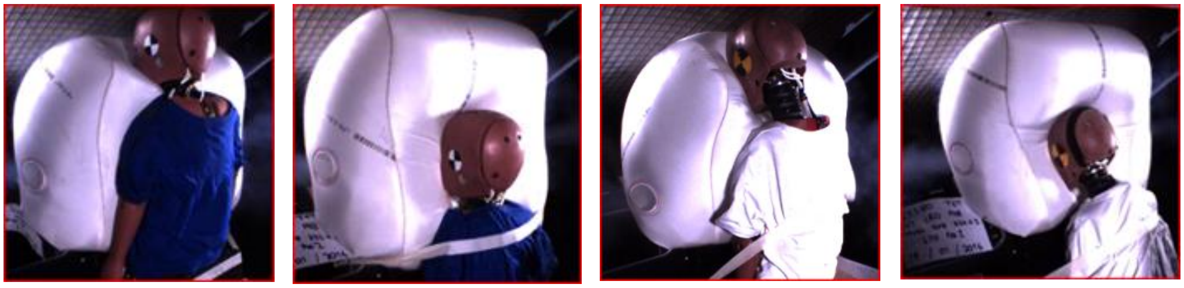


Figure 10, Neck injury is proportional to first stage power

To check in-position occupant restraint performance with depowered inflator, the CAE studies are conducted in unbelted occupants to confirm the performance.

The validated CAE model has also been used to conduct a series of studies on vehicle geometries / occupant positions. The results have led to better control on airbag folding and design rules of module locations

To validate the finding of this study, the inflators with depowered first stage power (80% baseline first stage power) have been ordered. Four test loadcases with three repeat tests have been tested in both Jaguar and Land Rover geometries. As predicted, the Nij results for all four loadcases are robustly below target. Figure 11 shows the airbag deployment and occupant kinematics.



3yld Position 1 3yld Position 2 6yld Position 1 6yld Position 2

Figure 11, OOP with depowered inflator

As a cross check, the depowered first stage power of the inflator is also used in sled tests with unbelted 50%-ile & 5%-ile with 19mph FFB crash pulse as shown in Figure 12. All injuries of the dummy meet the requirements.

Figure 12, Depowered first stage inflator in ub50%-ile and ub5%-ile sled test

Conclusions

With great efforts to model "as made" airbag and its environment, by using gas dynamic method one can model passenger airbag OOP reasonably well. The challenge on CAE OOP application is the time-consuming passenger airbag CAE folding process, which limits the CAE application in OOP development.

By using validated CAE and conducting parameters studies, design rules have been established on defining depowered first power, airbag folding and IP geometry controls. Those design rules enable the robust low risk deployment passenger airbag system can be achieved. Therefore, CAE can be used much more efficiently to check the injuries at key decision points rather than focus on modelling non-controlled events, such as variations of passenger airbag folding.

References

(1) Bill Feng, Challenge of airbag simulation for airbag deployment, Automotive CAE Grand Challenge 2015, Germany.
(2) Bill Feng, CAE applications for balanced curtain airbag design meeting FMVSS226 and system/component performance, 13th International LS-DYNA® User Conference, 2014.
(3) Bill Feng & David Coleman, "Gas dynamic simulation of curtain airbag deployment through interior trims", 10th International LS-DYNA User Conference, 2008.
(4) Bill Feng & S. Al-Samarae, "Application of gas dynamic method in development of airbag module", 6th LS-DYNA Forum, Germany, 2007.
(5) Jerry Longland & Bill Feng, "The practical and simulation development of low risk airbag system at Jaguar Land Rover", Airbag 2006, Germany.