CAE Analysis of Passenger Airbag Bursting through Instrumental Panel Based on Corpuscular Particle Method

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Jaguar Land Rover

1 Background

Passenger airbag (PAB) has been widely used in automotive industry and passenger airbag bag deployment test is an important safety test for occupant protection. The safety regulation requires that passenger airbag deploys into working position in time without causing any fragmentation of its surrounding structure (Fig.1). Due to the significant load of airbag deployment and its complex unfolding process, it is always a challenge to design a system which enables passenger airbag safely bursting through instrumental panel. Traditionally the development of such system is experience-based and heavily reliant on physical tests, which are very expensive and time consuming. Hence, it is highly desirable to have a low cost but efficient method to design the PAB system.

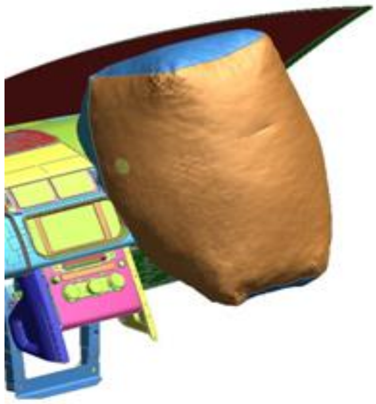


Fig.1: Passenger Airbag Deployment Test

At Jaguar Land Rover, A CAE based approach has reshaped the design process of passenger airbag system (Figure 1), and enabled the system design to be assessed in the virtual environment at its very early stage. The CAE analysis can verify the design and identify the potential failure modes. Moreover, it optimises the design and ensures the design to be error-free for tooling. The approach has significantly reduced the development time and cost at JLR. The approach consists of detailed FE modelling of passenger airbag and instrumental panel parts, as well as the correlation work.

One of the critical steps of the CAE analysis is to simulate airbag behaviour of its early deployment. Control volume (CV) model has been widely applied in CAE for airbag in-position simulation, however it is recognised that CV model is less effective for simulating airbag early deployment application such as OOP simulation [1]. Arbitrary lagrangian-euleria

(ALE) model is able to capture the dynamics of airbag initial deployment, but it is CPU intensive and complex to set up [2]. Recently corpuscular particle method (CPM) has gained popularity in simulation of airbag early deployment. It has similar simulation accuracy as ALE model, but needs much less CPU resources [3, 4].

2 Airbag bursting through process and CPM model

The safety regulation requires that passenger airbag bursts through the instrumental panel surfaces without causing any fragmentation and sharp edge. It is a significant challenge for engineers. The violent power of airbag often causes damage to its surrounding parts if they are not designed properly (Fig. 2).

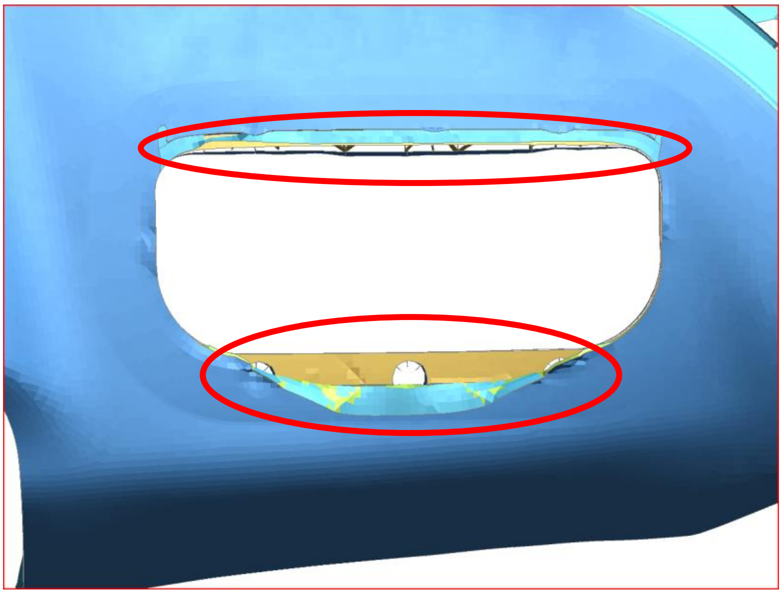


Fig.2: The damage caused by airbag

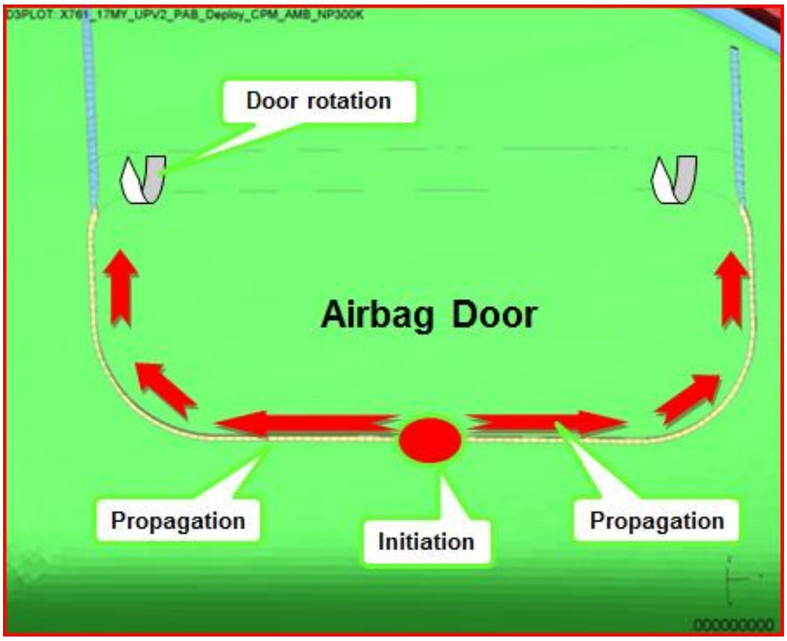


Fig.3: A desirable PAB bursting through sequence – initiation – propagation- opening

In passenger airbag deployment test, most failure modes happened during the airbag bursting through process. The typical failures were airbag door cracking, fracture of its surrounding parts and door hinge failure. All these failure modes were linked to the interaction between airbag and its neighboring parts. Therefore, in order to predict any potential failure mode and identify the design shortcomings, it is the key to have a good understanding of airbag bursting process. Generally speaking, the bursting through process can be divided into stages of initiation, propagation and opening. As shown in Fig. 3. A correct initiating position and smooth propagation allow the passenger airbag opening quickly, that enables airbag to release its energy properly. Any delaying of the bursting process increases the pressure on airbag container, chute and door and causes the structure parts to absorb extra energy and expose the system to great risk of integrity failure. The traditional design verifying method is based on test and it takes long time and incurs high cost to validate a design.

3 CAE simulation of passenger airbag bursting through

The PAB bursting through sequence has significant impact on the loads applied to the structure surrounding the airbag. It is important that CAE simulation catches the airbag deployment behavior representatively, so that the loading path in the simulation matches the physical tests. To achieve this goal, the FE model need to have detailed features of all important area of passenger airbag system, such as airbag environmental structure, airbag folding and airbag gas flow.

3.1 Modeling of structure around passenger airbag

The passenger airbag surrounding structures usually consists of airbag chute, topper pad substrate and airbag door and door hinge etc., shown as Fig. 4. Often these parts are made of plastic material. In order to predict the structure integrity of those parts, it is important to control the model building quality as well as to correlate material property for the plastic parts.

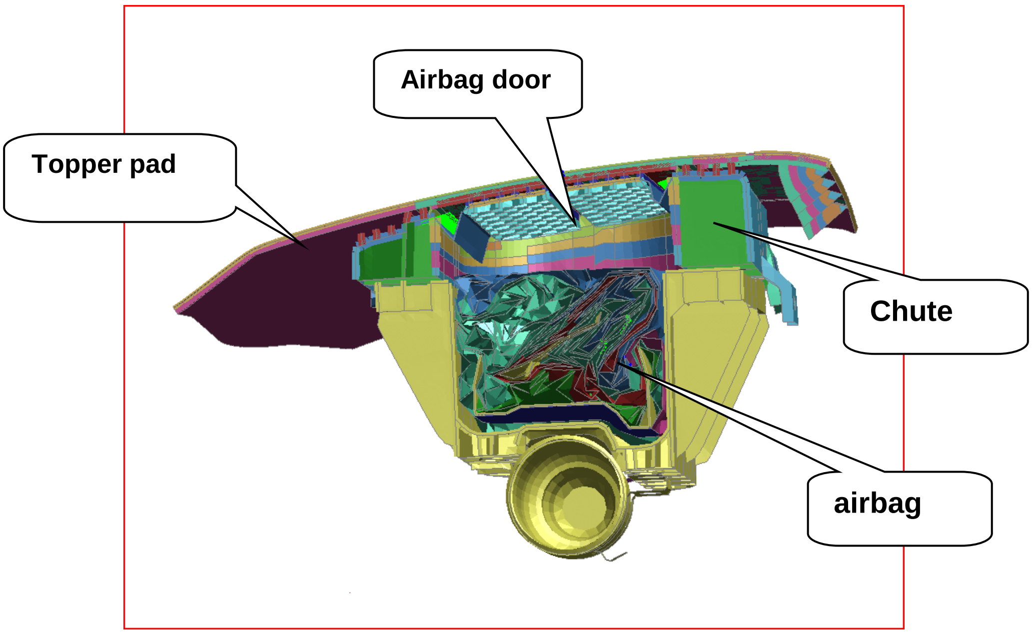


Fig.4: FE model of airbag, chute and door

3.2 Modeling of airbag cushion folding

While it is relatively straight forward to model the structure around the passenger airbag, it is more complicated to build a representative airbag model. Airbag behavior is determined by two main factors: airbag folding and inflator gas flow. To simulate the airbag bursting through process, an airbag model has to catch these two features. Although it is a complex and time consuming process, a folded passenger airbag model can be achieved thanks to the latest CAE folding technique, show as in Figure 5.

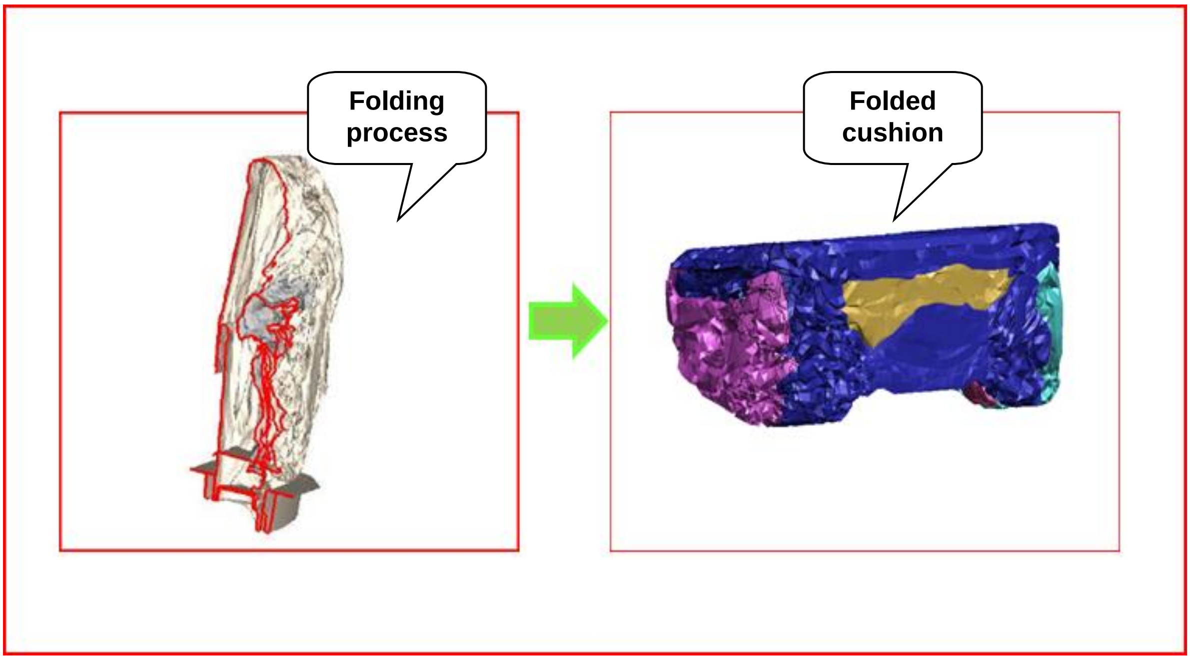


Fig.5: Passenger Airbag Folding

3.3 Modeling of airbag gas flow

Airbag inflator gas flow generates the impacting load on the PAB system. It determines the loading condition. There are different ways to model inflator gas flow. The conventional method is the controlled volume method, which assumes a uniform pressure inside airbag chamber. While this assumption is fairly valid after airbag gets in its working position, it has its limitation at early stage of airbag deployment. During the airbag cushion unfolding process, the gas is fast flow through the gaps of folded fabric cushion. It is unlikely an uniform pressure can be reached.

In order to simulate the passenger airbag cushion's early unfolding behavior, CPM (corpuscular particle methodology) has been introduced to model the airbag gas flow. CPM is based on the kinetic molecular theory, the molecules of gas and air in the airbag are modeled as particles, and gas particles are released from the inflator into airbag chambers. The gas particles flow is able to mimic the inflator gas jetting and generate a representative early stage loading condition for the airbag door. A comparison of passenger airbag unfolding behavior between CV and CPM method is presented below (Fig. 6 and 7)).

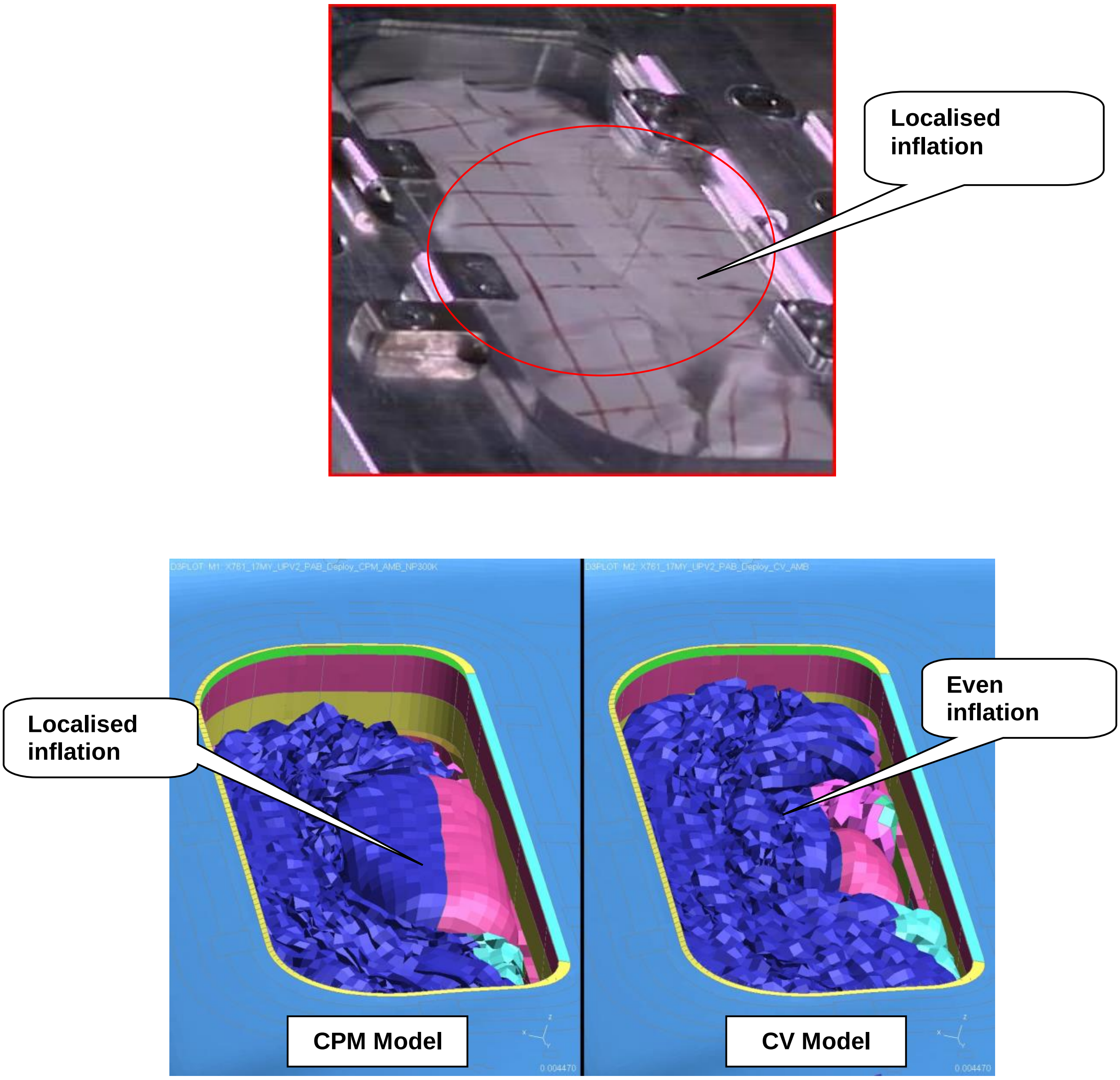
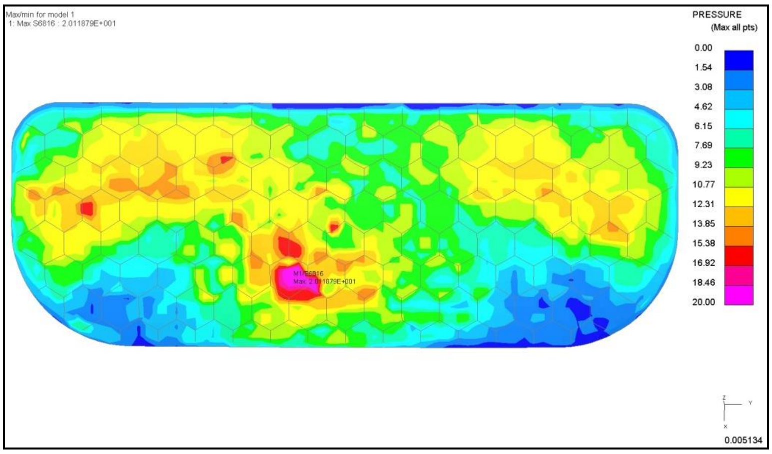
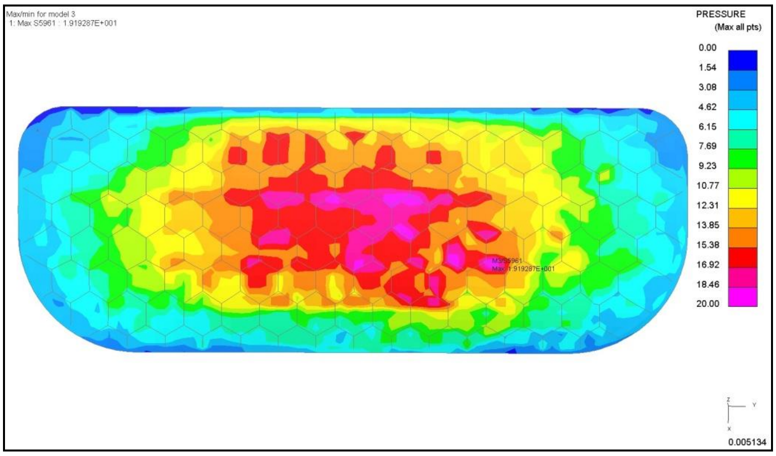


Fig.6: Passenger airbag early unfolding behaviour

From the test photo in figure 6, it was clear that passenger airbag started to load the middle section of the door. However, the CV passenger airbag model generated an even pressure distribution on the door (Fig. 7), which was different to the test condition. The CPM airbag model generated a pressure pattern that concentrates on the middle part of the door (Fig. 7), it was very similar to the real test condition. Therefore, CPM provides a feasible approach to simulate loading condition for passenger airbag deployment test. Compared to CV and ALE methods, CPM is a practical approach with good accuracy but relatively low CPU cost.



CV model pressure distribution



CPM model pressure distribution

Fig.7: Pressure distributions on the door

4 CPM airbag model correlation

The correlation process of CPM airbag model was based on a conventional airbag correlation process - impact tests. Compared to CV model, CPM airbag model achieved better correlation in terms of initial stage cushion deployment. As shown in figure 8, the CV airbag cushion deployed much slower than the physical test but the CPM airbag cushion had a fast cushion deployment similar to the test. Regarding to airbag in position performance, both CV and CPM model can achieve a good correlation to the physical test (Fig. 9). It has been noticed that porosity and venting function of CPM model need to be defined differently compared to CV model, this will be discussed later in the paper.

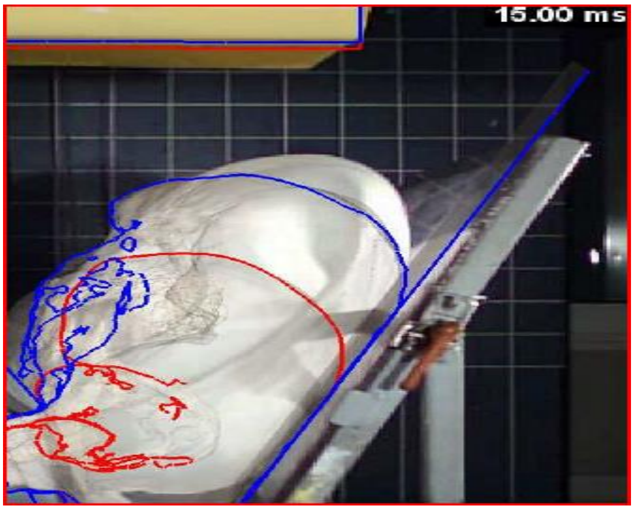


Fig.8: Airbag impact test

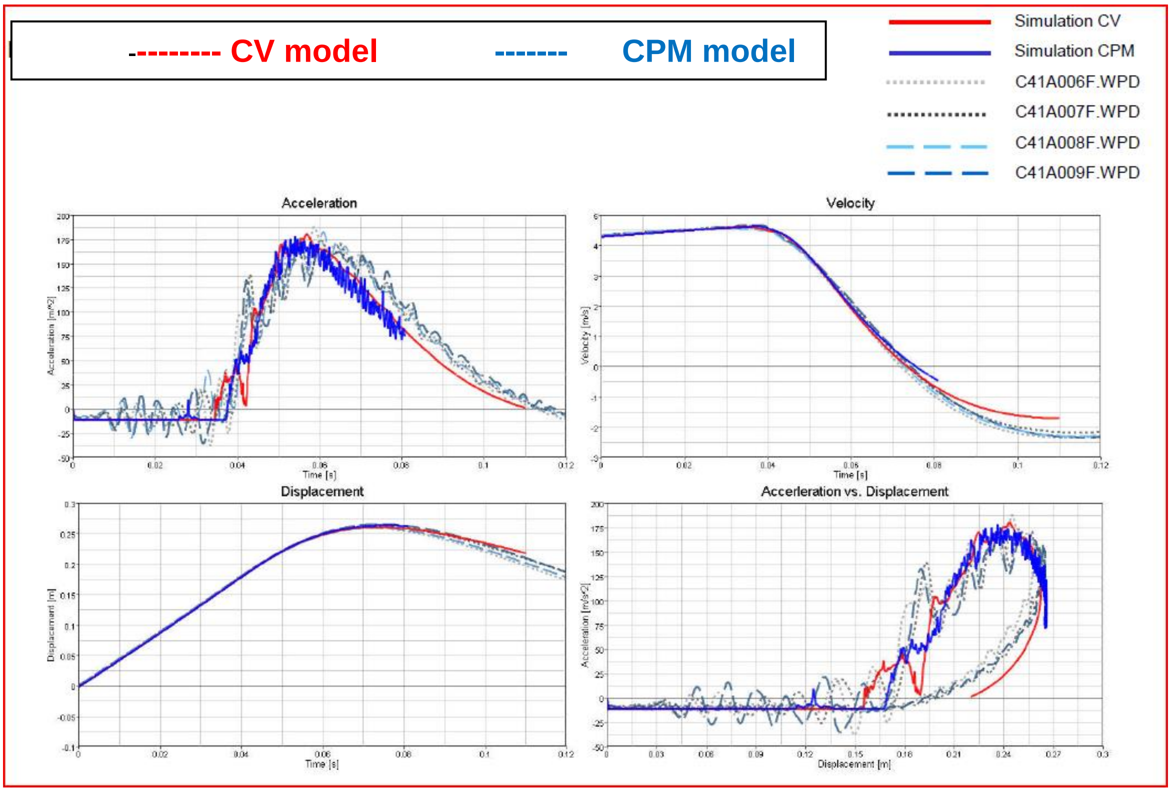


Fig.9: CPM passenger airbag correlation

5 CPM model parameter discussion

LS-DYNA introduced a new airbag card for CPM model (*AIRBAG_PARTICLE). A few dedicated airbag parameters were needed for CPM method. It is important to set up these parameters carefully as they influence the simulation accuracy and robustness (Fig. 10).

5.1 Number of particles.

Number of particles (NP) decides how many particles are used for CPM model. It is an important parameter and should be high enough to enable sufficient particles impacting airbag cushion generating a smooth pressure distribution on fabric elements. However, too high NP increases CPU cost. The recommended NP value is 200,000, but in our passenger airbag simulation practice, 250,000 NP seems to give more consistent unfolding behavior and resulting smooth airbag cushion shape (Fig. 11).

5.2 Porosity and vent

Airbag cushion porosity and vent can have a significant impact on its performance. Because CV is still the most frequently used method for airbag models, a common practice to create CPM model is to convert a CV airbag model into CPM model. However, it is vital to understand that the airbag porosity and vent need to be re-correlated to the test after the model conversion due to their different algorithms for porosity. Extra attention is also needed for setting vent for CPM model. For a relatively small vent size (it is usually the situation for most passenger airbags), CPM model has difficulty to vent enough particles through the vent aperture. Hence, It is necessary to activate the “enhanced venting” (by setting ENH_V=1), so that a representative vent can be achieved.

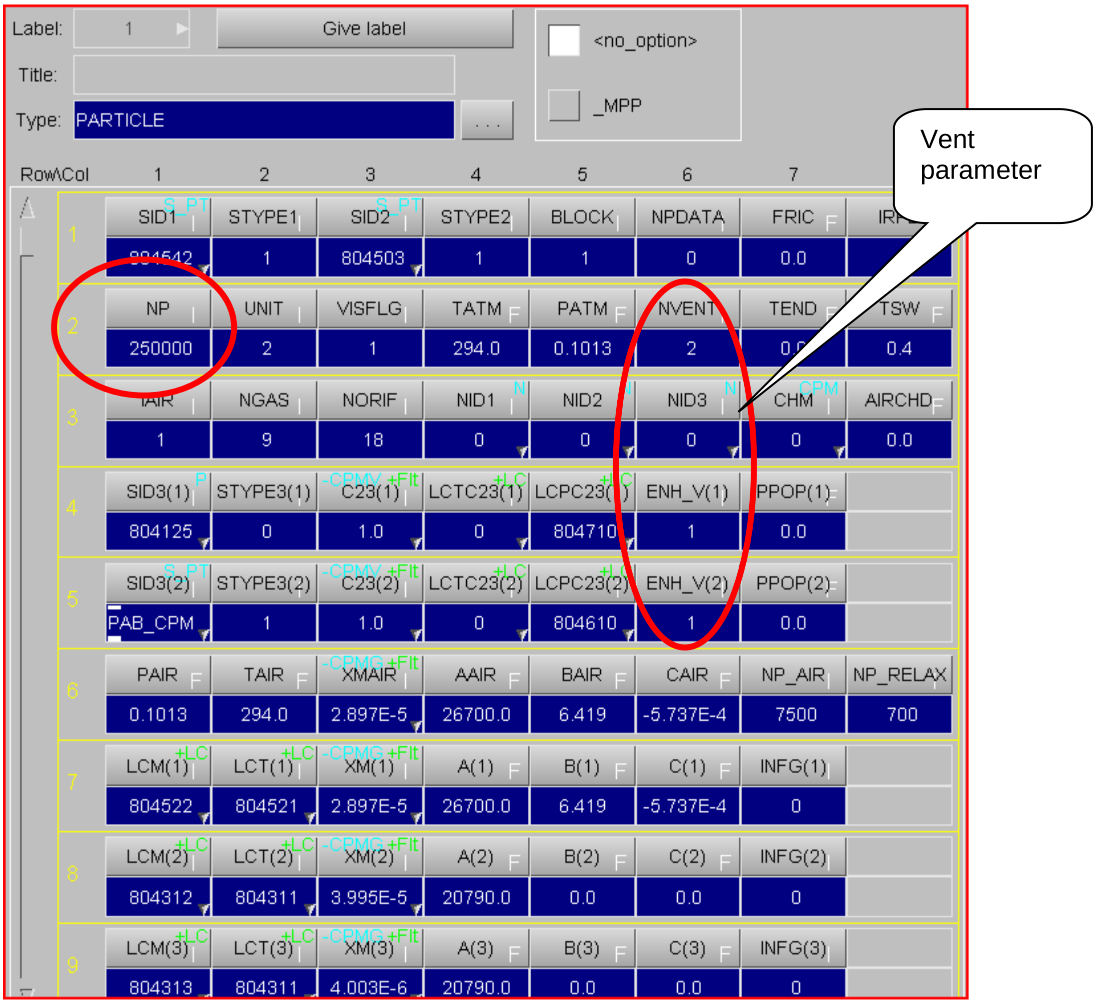


Fig.10: CPM parameter setting

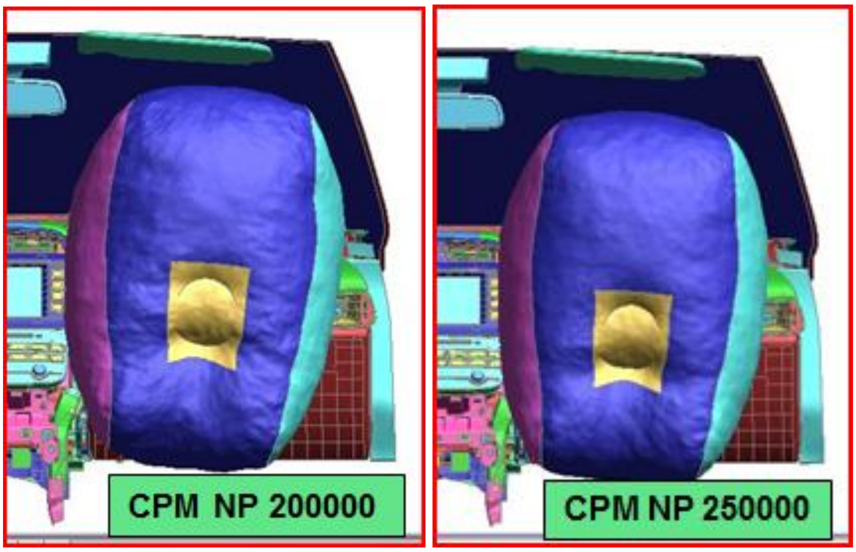


Fig.11: Number of Particle affects the pressure smooth distributions

6 A passenger airbag deployment simulation

A CPM airbag model was applied to CAE analysis of passenger airbag bursting through instrumental panel. The simulation reproduced the process of airbag door initiation, propagation and opening, and the CPM airbag model loaded representatively to its surrounding structures such as chute, door and topper pad, etc (Fig. 12). Based on the simulation results, the weak design areas were identified (Fig. 13) and design modifications were proposed accordingly. The improved design was verified by the CAE simulation again and tooling process started with CAE approved design.

The final physical test of airbag deployment proved that CAE based development process delivered a robust design for the project, with shorter cycle time and lower cost.

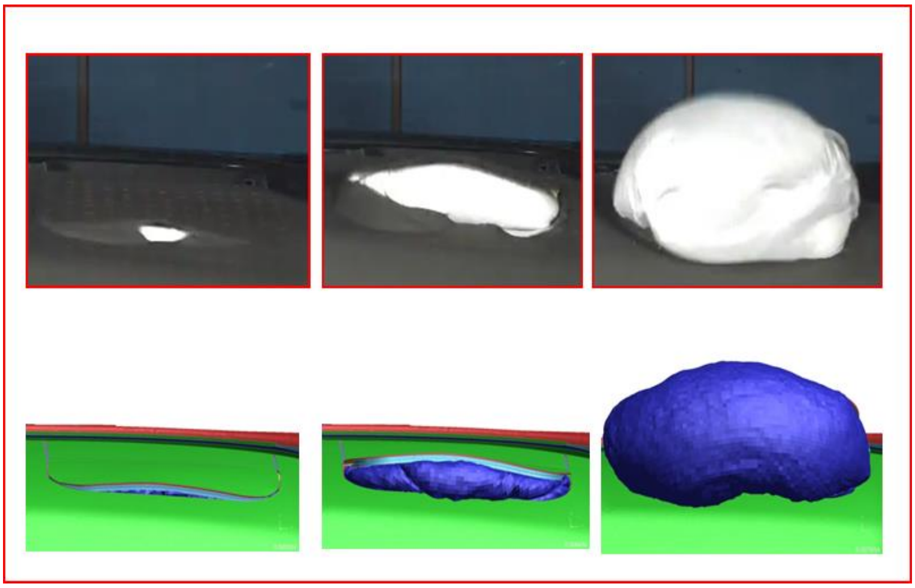


Fig.12: Simulation of airbag door opening process

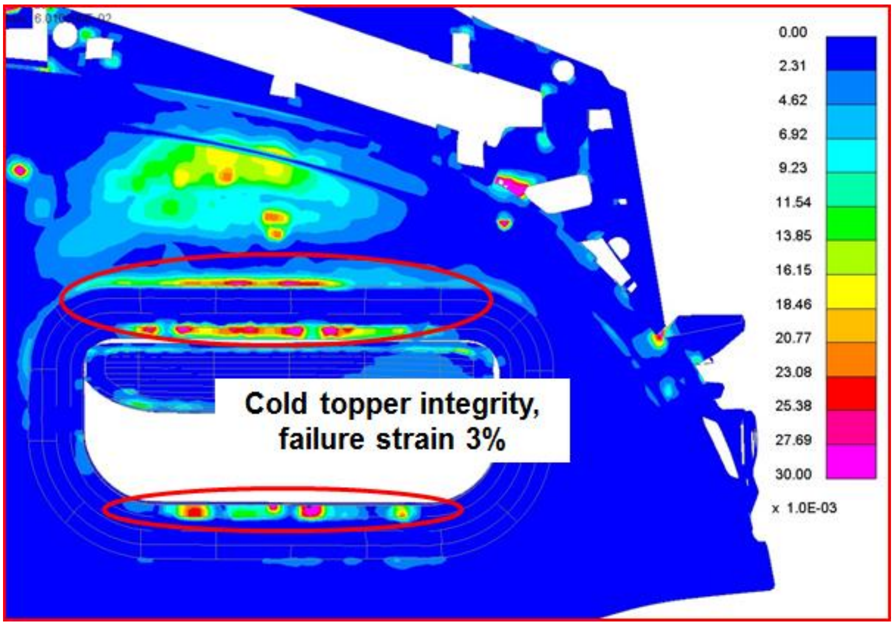


Fig.13: Simulation results of the plastic strain of the topper pad.

7 Summary

A CAE based design approach for passenger airbag and instrumental panel system has been developed at Jaguar Land Rover. The approach applies CPM method for passenger airbag modelling, which successfully predicted initial passenger airbag bursting load. The simulation results show that passenger airbag door opening kinematics achieved good correlation to the test result. More importantly, the CAE analysis highlighted the stress concentration area of the key components such as PAB chute, door, hinge and housing; identified the potential failure modes. Based on the CAE results, further design optimisation and verification had been conducted and the potential failure mode was corrected at the design stage. The approach has been applied to multiple projects and achieved great success in delivering robust designs with short cycle time and low cost.

8 Acknowledgements

This work was completed with the help and support from colleagues of JLR CAE team and the KSS CAE team. The authors would like to thank them for all their suggestions and discussions in the project work.

9 Literature:

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