

CAE Applications for Balanced Curtain Airbag Design Meeting FMVSS226 and System/Component Performance

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Abstract

In the curtain airbag design during the vehicle programme, following requirements dominate the design. FMVSS226 Ejection Mitigation (EjM) requires curtain airbag provide adequate protection for rollover event. Restraint system performance for legal and consumer tests, such as FMVSS214 and NCAPs, requires good occupant head protection in the first impact. TWG Out-Of-Position (OOP) requires low risk deployment of curtain airbag for the occupants seating in out-of-position. In addition, curtain airbag design should ensure the integrity of surrounding trims, such as pillar trims, during the deployment at different environmental conditions. This paper outlines the CAE applications for balanced curtain airbag design which meets all the requirements as mentioned above.

Introduction

Curtain airbag is a key restraint component to protect occupants in the events of side impact (referred as First Impact) and rollover (referred as Second Impact). The design of curtain airbag has to meet the requirements of not only restraint system performances (e.g. occupant protections in side impact and rollover), but also component performance (e.g. low risk deployment for OOP and component integrity).

In 2011, NHTSA introduced the new regulation for rollover protection, FMVSS226 Ejection Mitigation. The requirement demands increased occupant containment in rollover and side crashes for belted/unbelted occupants and third rows of seating. The rule requires the linear impact tests at two energy levels and two inflation times (e.g. 278J@1.5s and 178J@6s). The results of this requirement are the introduction of larger curtain airbag with higher power inflator for longer inflation. Since then, FMVSS226 EjM has become a key loadcase to define the curtain airbag inflator selection and curtain airbag design.

However, the introduction of larger curtain and larger inflator has great challenge to the integrity of curtain airbag and surrounding trims, and OOP performance as well. Therefore, it is important that balanced performances between restraint system requirements and component requirements during the process of curtain airbag design and inflator selection.

In this paper, CAE applications and studies have been conducted to gain the understanding of energy requirements and managements for balanced curtain design airbag to meet the multiple requirements on restrain system performance, EjM, OOP and component integrity.

Management of Curtain Airbag Inflator Power

In the vehicle programme, restraint suppliers are responsible for the inflation selection and curtain airbag design, while OEM ensures that the inflation selection is chosen in the balance for all requirements. Figure 1 illustrates the inflator power preference of the key requirements.

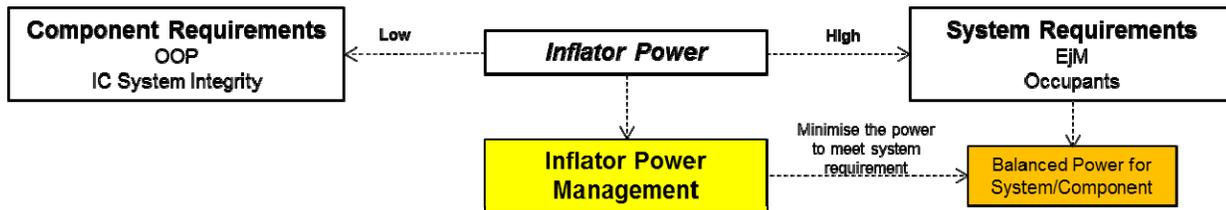


Figure 1. Inflator power preference of key requirements

From system requirements point of view, higher inflator power selection is preferred. For example, for EjM this means the chamber pressure at 1.5s and 6s would be higher in the same design condition with lower power inflator. On the other hand, less power inflator would make OOP and curtain integrity requirements easier to meet. The conflict requirement for the inflator power requires OEM carefully manage the inflator power and onset rate selection in curtain airbag design. Essentially, the inflator power should be minimised to meet system requirements (occupant restraint system and EjM) in order to provide better design condition for OOP and component integrity.

In the occupant restraint system requirements, the key loadcases include legal and consumer tests from different countries, such as FMVSS214, USNCAP, EuroNCAP and ChinaNCAP. In all the loadcases, study shows that EuroNCAP pole (50%-ile) test and FMVSS214 50%-ile pole test show the highest energy absorption requirement and curtain peak pressure in the occupant protection. Therefore, pole test loadcase is the control loadcase to define the inflator power and maximum curtain chamber thickness for the Frist Impact.

In the curtain airbag design process, minimum energy absorption capability required by curtain airbag for different loadcases can be estimated through running vehicle level CAE models without the curtain airbag presented in the vehicle. The relative head velocity at the time of head-to-pole or barrier contact can be used to calculate the minimum energy, which should be absorbed by curtain airbag to prevent the contact. In practice, a factor of safety margin should be applied to the minimum energy as curtain airbag requirement. This process provides relatively accurate energy levels for curtain airbag design in component level. Therefore, the chamber pressure and thickness of the curtain airbag can be optimised and then the curtain volume and inflator power can be minimised. Figure 2 shows the head velocity in the situation without the curtain airbag.

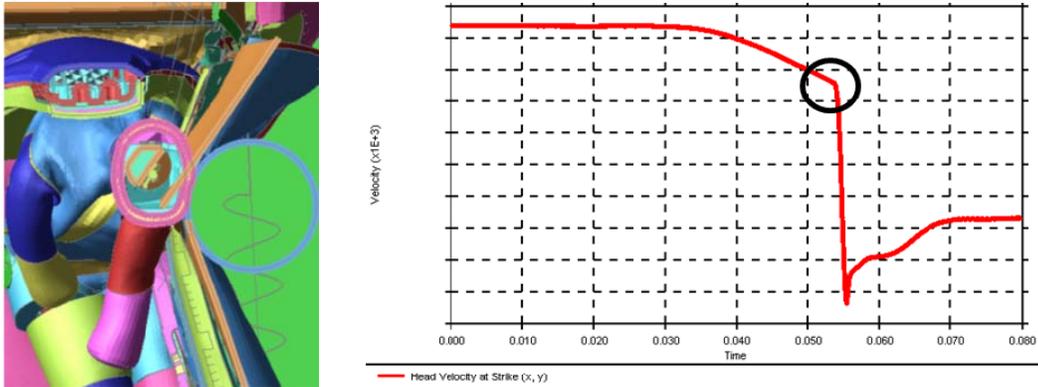


Figure 2. Minimum energy absorption calculation – Pole Test

To meet E_jM requirement, there are a number of key elements in the curtain airbag design, such as chamber pressure at 1.5s and 6s, chamber thickness, tether tension and chamber support, etc. Among those key measures chamber pressure is the most important design parameter, which is strongly related to the inflator power and sealing techniques.

There are two types of commonly used inflator for ejection mitigation curtain airbag, cold gas inflator and hybrid inflator. The both inflators have their advantages and disadvantages in the performance and product. The major advantages of the cold gas inflator for the rollover application are its low exit gas temperature and longer inflation time. Therefore, cold gas inflator is less-affected by the environmental temperature and allows the curtain airbag to stay deployed for a longer time. Figure 3 shows a typical curtain airbag inflation test for the cold inflator. The left plot in Figure 3 shows curtain airbag pressure in the first 150ms, and right plot shows the pressures at 1.5s and 6s. In contrast, Figure 4 shows a typical curtain airbag inflation test for a hybrid inflator in the first 100ms.

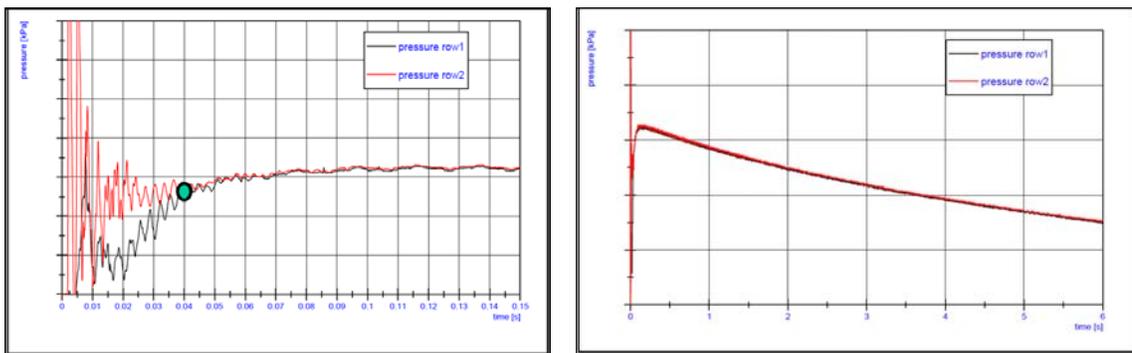


Figure 3. Cold gas inflator – inflation test

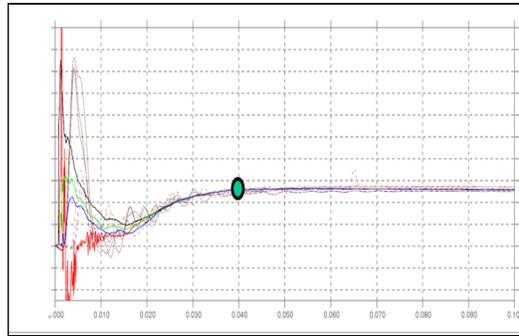


Figure 4. Hybrid inflator – inflation test

The dot point indicates the pressures at 40ms in both Figure 3 and 4. It is clear that the curtain airbag pressure powered by a hybrid inflator reaches its peak around 40ms and starts to flatten/decay over the time in Figure 4, while the curtain pressure powered by a cold gas inflator is still increasing after 40ms and has much longer inflation time before it starts to decay.

The advantage of hybrid inflator over cold gas inflator is the weight. As hybrid inflator has relatively higher exit temperature, for the same inflation flow IF, it requires less mole gas to compare with cold gas inflator. Therefore, the dimension and weight of the inflator are smaller.

Therefore, the management of inflator power for EjM requirements involves a number of design parameters, such as inflator types, peak tank pressure, sealing techniques. All those design parameters need to be carefully monitored and controlled.

CAE Studies for Balanced Curtain Airbag Design

To understand influence of inflator parameters (peak tank pressure and onset rate) on system and component performances, generic CAE studies have been conducted on pole test, OOP and curtain-trim integrity. Figure 5 shows the tank pressure and onset rate of two inflators from different restraint suppliers used in the CAE studies. Those inflators are proposed by the different restraint suppliers for the vehicle programmes which have the similar volume of the curtain airbag design. Inflator A is a cold gas inflator and Inflator B is a hybrid inflator.

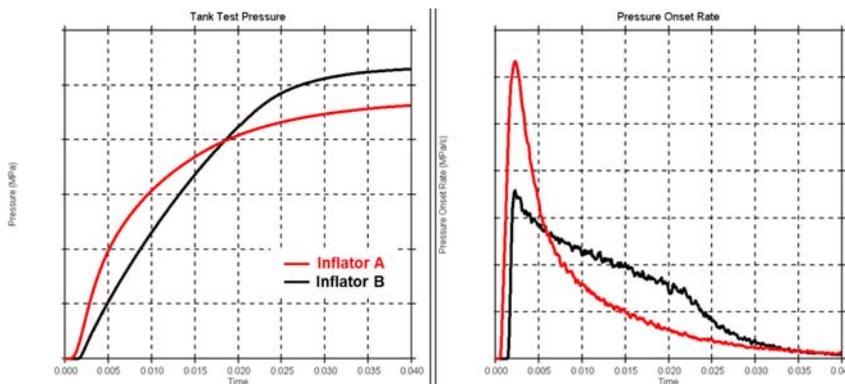


Figure 5. Two inflators proposed for the similar curtain airbag volume

Although the curtain airbag volumes are similar, it is clear that the inflators proposed by different restraint suppliers are very different in terms of inflator power (peak pressure) and onset rate. Inflator A has higher onset rate but lower peak pressure than Inflator B.

Those inflators have been used for the studies below in the same curtain airbag to demonstrate the requirements for the balanced curtain airbag design meeting all key requirements.

1. Restrain System Performance – FMVSS214 Pole

As FMVSS214 pole 50%-ile test is the control loadcase in the curtain airbag, this loadcase has been selected in the study. With higher onset rate and lower peak tank pressure of the Inflator A, one expects that the curtain airbag deploys quicker and is softer during the loading phase, therefore, lower occupant HIC.

Figure 6 shows the sequences of the curtain airbag deployments with those two inflators: early deployment, before loading and rebound. Figure 7 shows the head acceleration of the occupant.

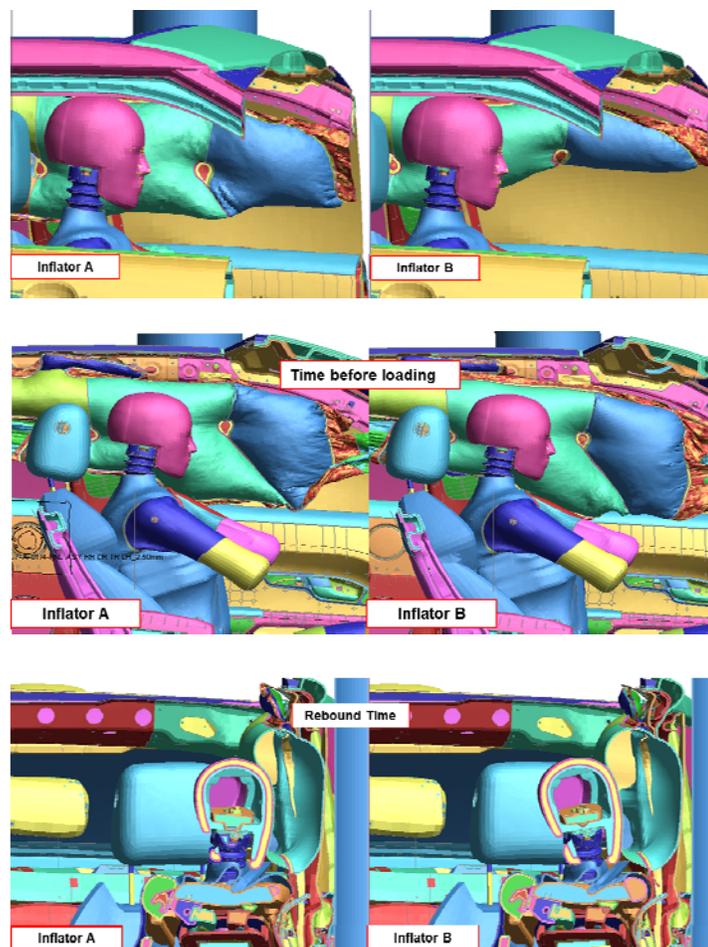


Figure 6. Curtain airbag deployments with two different inflators

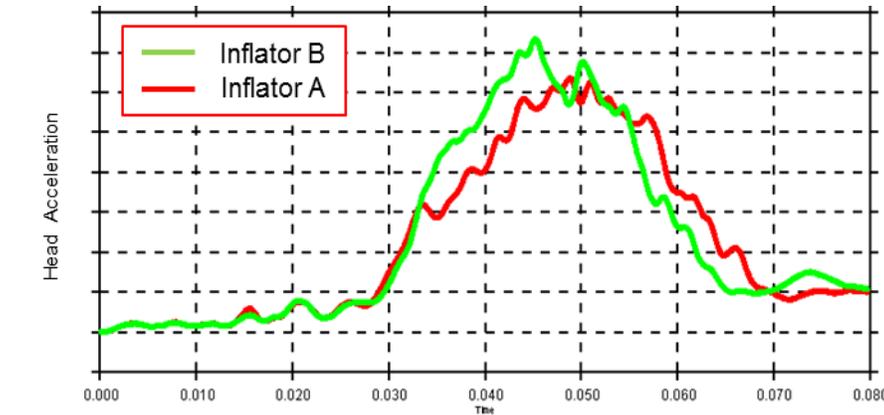


Figure 7. Head acceleration with two different inflators

Analyses and observations of animations and results draw following conclusions:

- a) **Onset rate:** curtain airbag powered by Inflator B with lower onset rate is able to inflate the curtain airbag in position in the right time; the quicker deployment from Inflator A with higher onset rate does not bring any extra benefits from restraint system performance point of view. This indicates that onset rate from Inflator A is over-specified.
- b) **Inflator power:** the occupant head acceleration is controlled by curtain airbag stiffness which is related to the inflator power. The less powerful Inflator A yields smaller head acceleration peak and HIC value to compare with high power Inflator B. The curtain airbag from Inflator A with less power has enough thickness at rebound time as safety margin. Therefore, more power from Inflator B is clearly unnecessary from restraint system performance point of view. This indicates that Inflator power from Inflator B is over-specified.

2. Ejection Mitigation Performance

For the same curtain airbag design, the EjM performance can be judged by its ability of pressure holdability at 1.5s and 6s. As mentioned above, the pressure holdability of the curtain airbag is related to both inflator power and sealing techniques.

In the inflation tests carried out by the suppliers in the similar curtain airbag volume, both inflators achieve similar pressures at 1.5s and 6s. The result would be due to the benefit of cold gas inflator of Inflator A and sealing techniques used by the supplier.

3. Out-Of-Position Performance

Encouraged by NHTSA, Technical Working Group (TWG) has set up a number of occupant positions to assess occupant injury risk for side airbag out-of-position (OOP). Among those test loadcases, two key loadcases which are related to the curtain airbag are studied:

- a) 3.3.5.1 6 year old inboard facing
- b) 3.3.5.3 SID2s 5%-ile inboard facing

The CAE model used in the study was developed in gas dynamic airbags and validated through the physical tests. Figure 8 shows the validation results of neck moment and force.

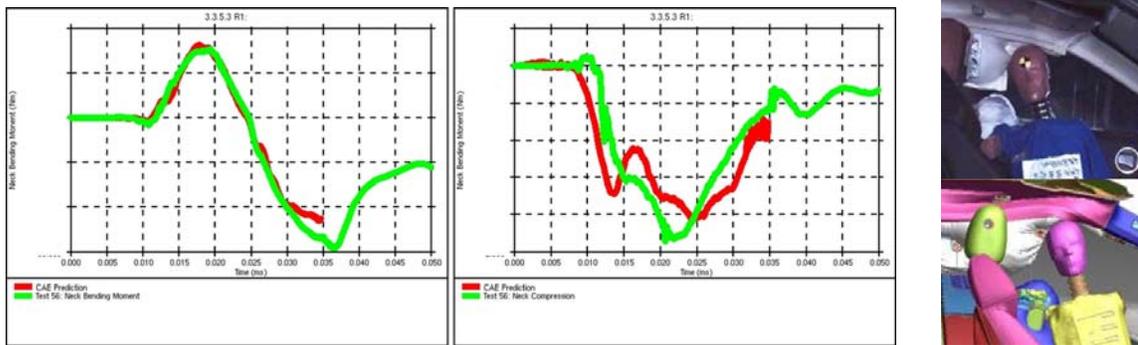


Figure 8. Validated CAE model for OOP

Using validated CAE model, two inflators are applied in the above loadcases to understand the injury risk in the OOP.

a) 3.3.5.1 - 6 year old inboard facing

Figure 9 shows the neck compression force for those two inflators. The results show that with higher onset rate of Inflator A the compression force almost 50% higher than Inflator B in the first strike around 10ms. However, higher inflator power of Inflator B generates similar higher compression force to Inflator A in later event around 25ms. Therefore, from OOP point of view, both inflator onset rate and inflator power need to be controlled.

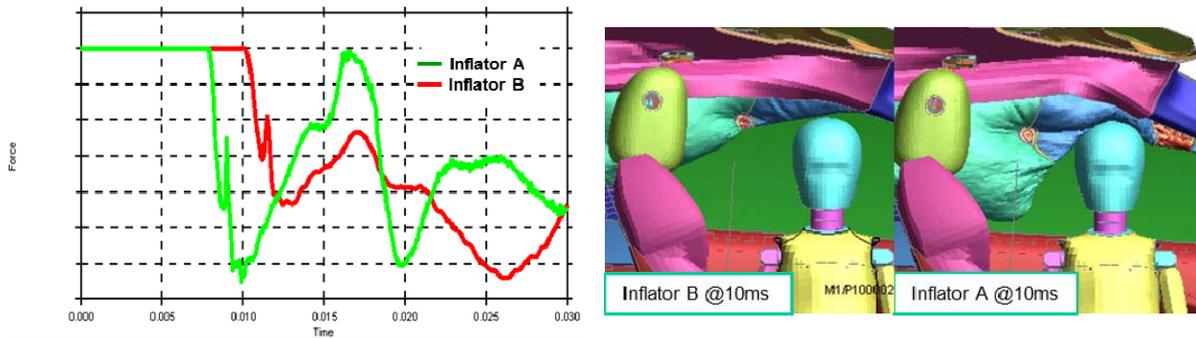


Figure 9. 3.3.5.1 – 6 year old inboard facing OOP

b) 3.3.5.3 – SID2s 5%-ile inboard facing

Figure 10 shows the neck compression force and neck moment for those two inflators. The similar conclusions can be drawn.

The onset-rate-driven injury risk is a neck compression force around 10ms. The inflator-power-driven injury risk is both neck compression and moment in the later event around 25-35ms.

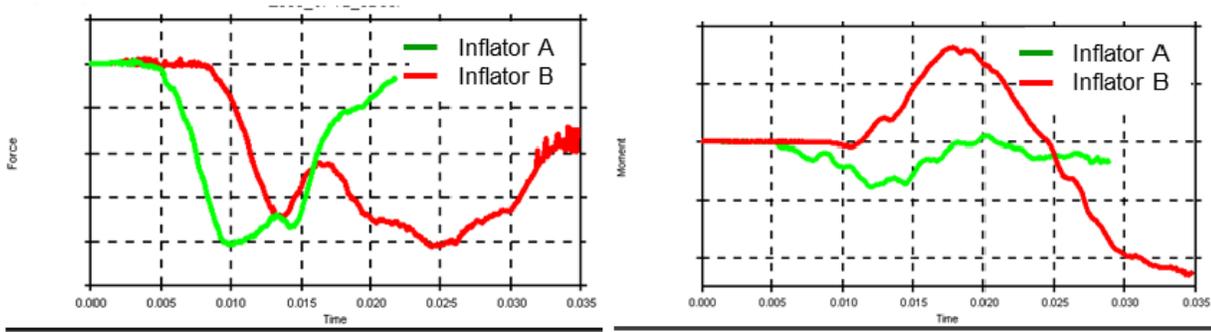


Figure 10. 3.3.5.3 – SID2s 5%-ile inboard facing

4. Curtain Airbag Component Performance

The fundamental requirement of curtain airbag design is that curtain airbag must have clean deployment without hanging up by the surrounding trims and damaging the surrounding trims, such as pillar trims and grab handle footer. The inflator selection has a big impact on curtain airbag component performance. In the CAE study, fully trimmed CAE model with gas dynamic curtain airbag has been developed.

a) Curtain airbag deployment

Figure 11 shows curtain airbag deployment with fully trimmed condition. It is clear that with higher onset rate in Inflator A, the curtain airbag has a clean deployment and gets in position quicker. Though in Inflator B the curtain airbag deploys slower, it also has clean deployment and can get in position within required time.

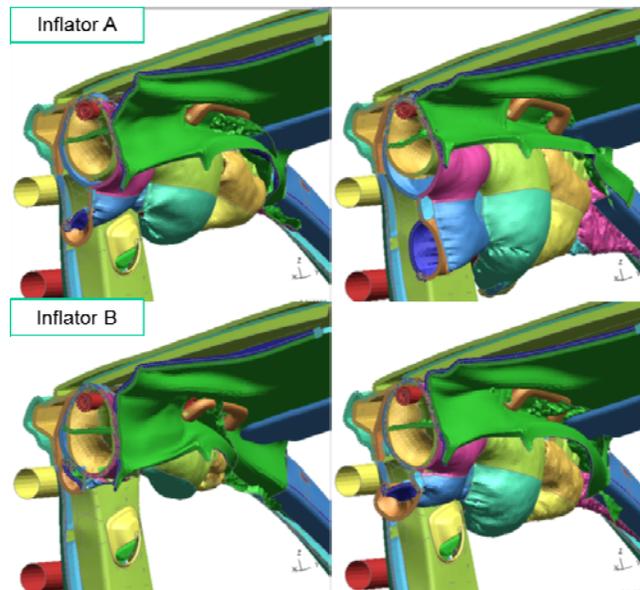


Figure 11. Clean curtain airbag deployment

b) Trim Integrity

In the trim integrity, the forces in grab handle footer and pillar fixings and pillar plastic strains have been investigated. Figure 12 shows the forces measured in the fixings.

It is clear that inflator with higher onset rate has greater impact on the components close to the inflator. In this example, the inflator is centre-mounted and the grab handle footer force is proportional to the inflator onset rate. The force is a shock-wave force with short duration around 5-10ms, as shown in left plot in Figure 12.

The results also show that at A-pillar fixing the onset rate effect is much less as the similar force magnitudes have been seen around 10-15ms for both inflators. This is probably because the fixing is far away from the inflator. But the second peak seen in the A-pillar fixing around 25ms in Inflator B is probably due to the higher power of Inflator B.

The study concludes that onset rate of the inflator must be controlled for the trim integrity, while the peak pressure of the inflator needs to be optimised for both system and the trim integrity requirements.

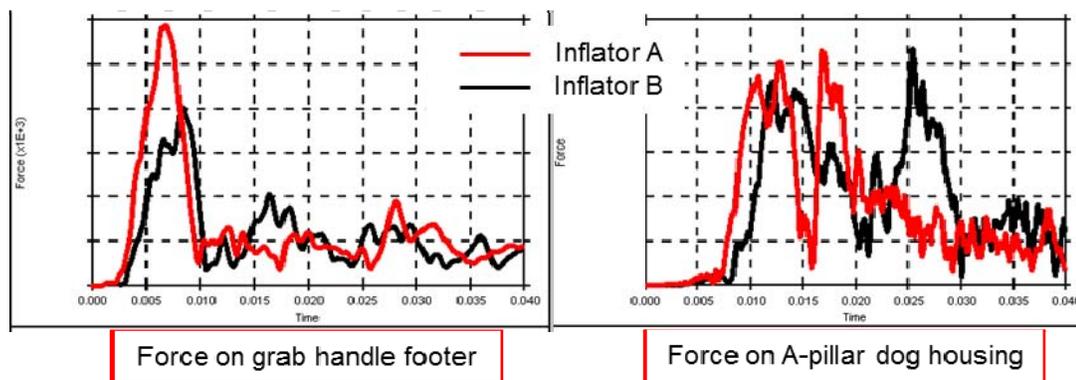


Figure 12. Trim integrity – forces measured in the fixings

Summary

In this paper, CAE applications and studies have been conducted for balanced curtain airbag designs. The effects of inflator performance (onset rate and peak tank pressure) on all key curtain airbag requirements have been studied. The results provide the clear guidance on the inflator selection for balanced curtain airbag design, as illustrated in Figure 13.

Balancing the different requirements, the inflator should be carefully selected with controlled onset rate and optimised peak tank pressure. For the onset rate, inflator suppliers should be challenged to provide the choice of onset rate in the same inflator family. In fact, Figure 14 shows the example of onset rate tuneability of the inflator, from which the optimised inflator with right power and onset rate can be selected during the vehicle programme.

For the peak tank pressure, the inflator power should be minimised to meet occupant restraint requirement through defining accurate energy absorption requirement for the curtain airbag. Therefore, adequate curtain airbag thickness and pressure can be selected and curtain airbag volume and tank peak pressure can be optimised. For the purpose of EJM, sealing techniques used in the curtain airbag should be carefully reviewed to improve curtain airbag pressure holdability to achieve target pressure with less power inflator.

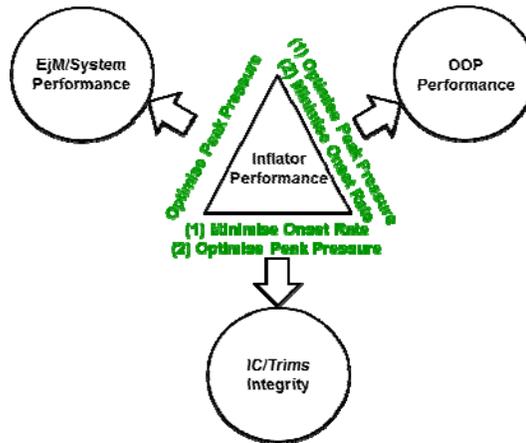


Figure 13. Inflator selection for balanced curtain airbag design

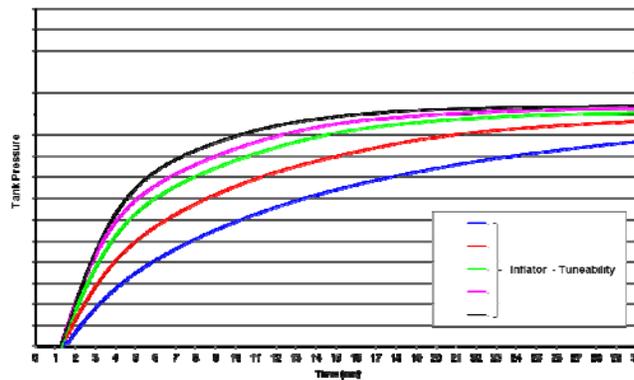


Figure 14. Inflator onset rate tuneability

References

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