




**Application of gas dynamic method in development of airbag modules**



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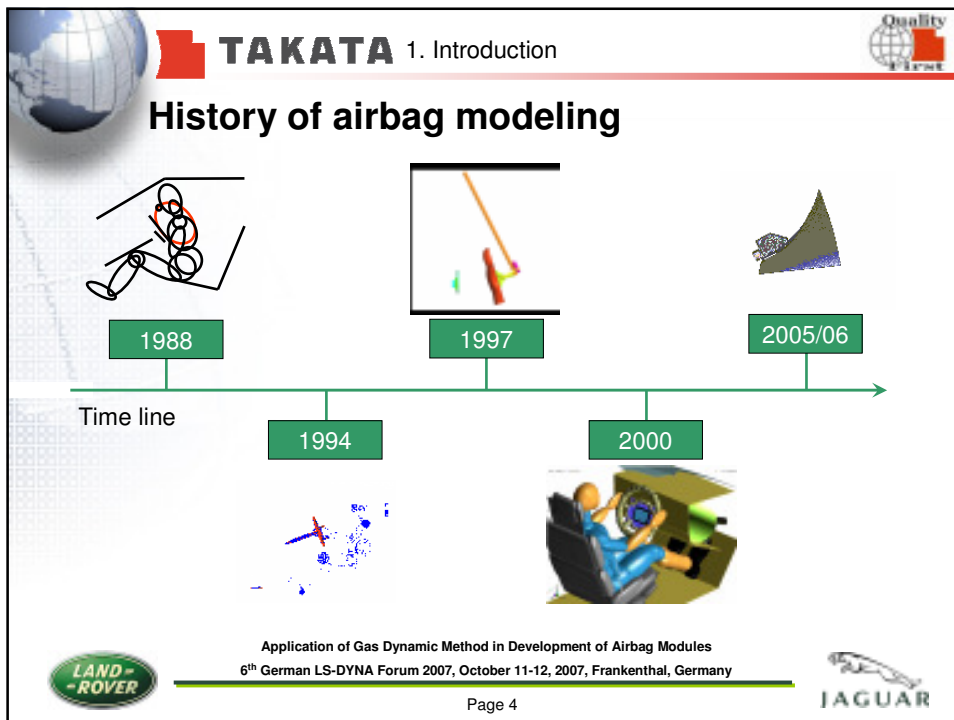
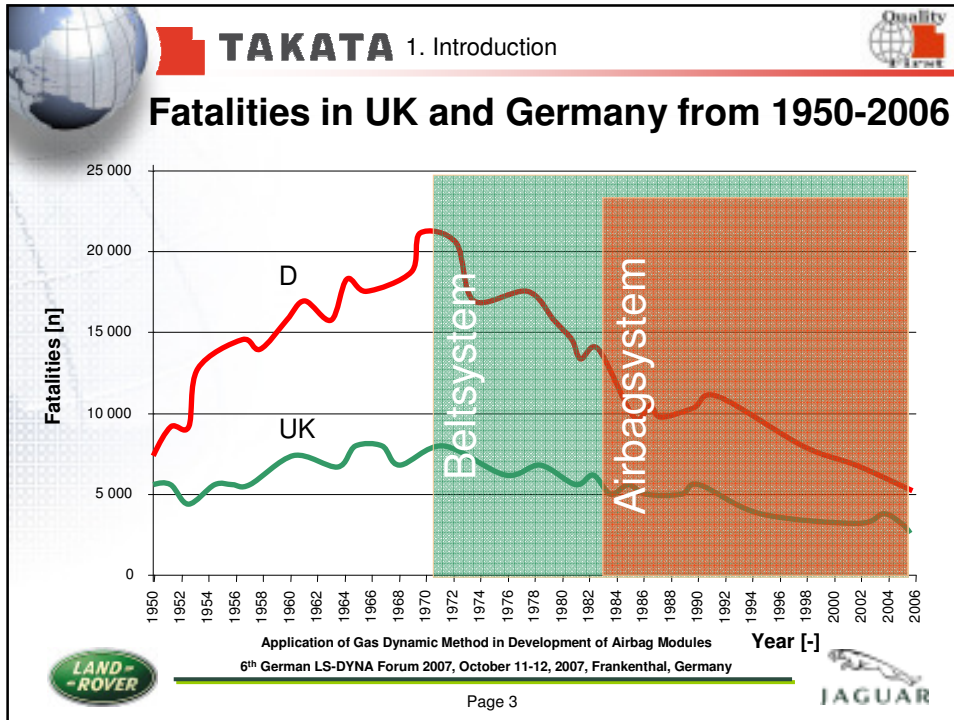




1. Introduction
2. Comparison of gas dynamic methods
3. Predictability of Corpuscular Method
4. Application of gas dynamic airbag models
5. Conclusions

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**TAKATA** 1. Introduction Quality First

### Todays tasks of airbag models

The diagram illustrates the various components and tasks involved in airbag modeling. It features a central 3D model of an airbag, with ten green ovals connected to it by lines, each representing a specific task or component: EA, Housing, Seams, Cover, Diffuser, Folding, Shape, Vents, Fabric, and Inflators.

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**TAKATA** 2. Comparison of gas dynamic methods Quality First

### Gas dynamic methods used for diffuser

The diagram shows the 'Set up of model' for gas dynamic methods used for a diffuser. It includes a 'Plate', 'Diffuser', and 'Inflator'. Below this, three methods are compared: CFX (Computational Fluid Dynamics), ALE (Arbitrary Lagrangian-Eulerian), and Corpuscular (Particle-based simulation). Each method is represented by a small 3D visualization of the diffuser setup.

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**TAKATA** 2. Comparison of gas dynamic methods

**CFX results for diffuser model**

Pressure distribution plate      Pressure distribution inflator "nose"

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**TAKATA** 2. Comparison of gas dynamic methods

**ALE results for diffuser model**

ALE

ALE half model of diffuser      Examples of modified parameter to improve model stability

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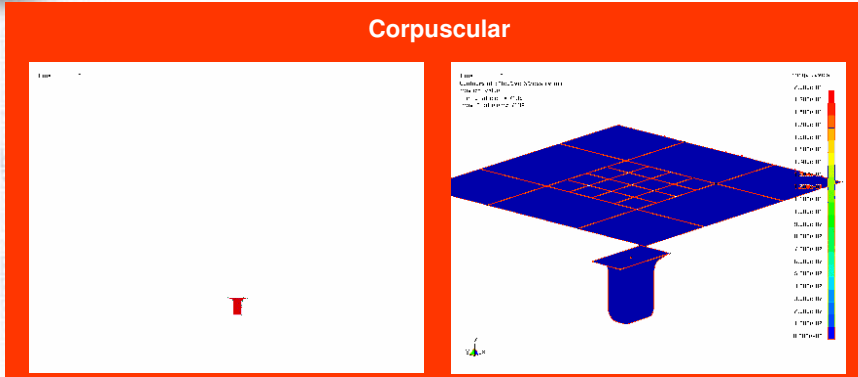
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**TAKATA** 2. Comparison of gas dynamic methods

### Results of corpuscular method

**Corpuscular**



Corpuscular model of diffuser      Distribution of stress (VM)

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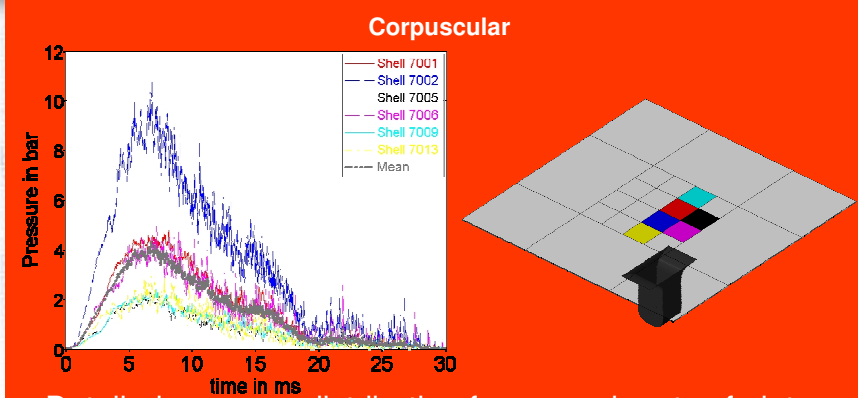
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**TAKATA** 2. Comparison of gas dynamic methods

### Results of corpuscular method

**Corpuscular**



Pressure in bar


time in ms


Detailed pressure distribution for several parts of plate

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**TAKATA** 3. Predictability of Corpuscular Method




## Inflation tests with a triangle bag




- A triangle bag is sensitive to parameter modifications (e.g. pressure or direction of wrap and weft).
- Therefore this bag is used instead of a standard bag to verify predictability of Corpuscular method




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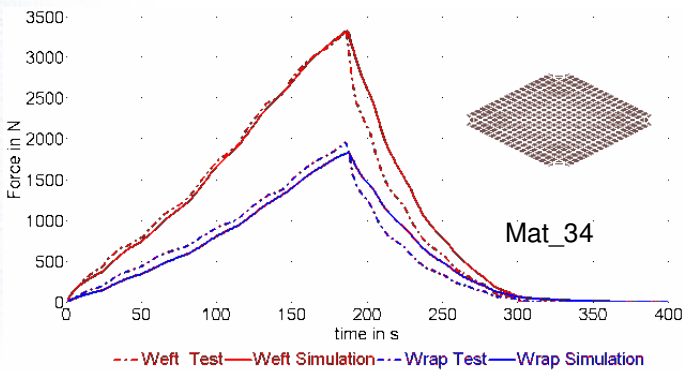





**TAKATA** 3. Predictability of Corpuscular Method




## Validation of fabric model



- One of the most important basics for predictable airbag models are validated fabric material data



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**TAKATA** 3. Predictability of Corpuscular Method

**Inflated triangle bag with different weft directions**

The image shows two side-by-side comparisons. The left side has a green background and is labeled 'Weft direction 45°'. It features a 'Simulation' image of a triangle bag with diagonal hatching and a 'Test' image of a white inflated triangle bag. The right side has a red background and is labeled 'Weft direction 90°'. It features a 'Simulation' image of a triangle bag with horizontal hatching and a 'Test' image of a white inflated triangle bag. Both simulation images have the word 'Simulation' written in red, and both test images have the word 'Test' written in red.

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**TAKATA** 3. Predictability of Corpuscular Method

**Comparison of inflation kinematics**



The image shows two side-by-side comparisons. The left side has a red background and is labeled 'Flat'. It features a video frame showing a flat airbag module inflating. The right side has a green background and is labeled 'Leporello Folding'. It features a video frame showing a Leporello folding airbag module inflating. Both video frames show the airbag against a blue grid background.

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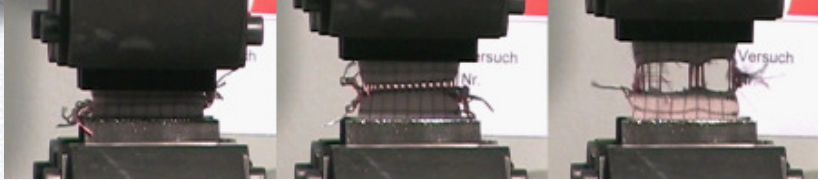
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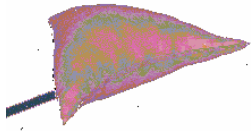
 **TAKATA** 3. Predictability of Corpuscular Method 

### Rapture model for airbag seams





Tensile tests of seams to validate numerical modell

$p = 7 \text{ bar}$





Integrated seam model of airbag inflated with corpuscular method

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 **TAKATA** 3. Predictability of Corpuscular Method 



### Conclusions

- Corpuscular method is the right way for effective, stable and predictable airbag models especially regarding OoP.
- Positive features already to mention are the simple transformation of existing LS-DYNA airbag models and reasonable computing times.




Our mission - your safety


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**TAKATA** 4. Application of Gas Dynamic Model




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- ⇒ Gas dynamic ALE method has been successfully and widely used in curtain airbag development within JLR, where airbag venting is normally not present and the only leakage is simulated through fabric.
- ⇒ Our experience shows that ALE method is not very stable and difficult to be applied in driver and passenger airbags where open vents need to be simulated.
- ⇒ Compared with ALE method the corpuscular particle method is more stable and much easier to deal with open vents in the airbag.
- ⇒ Following example is the application of the particle method in passenger airbag of a JLR project.





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**TAKATA** 4. Application of Gas Dynamic Model




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⇒ In LS-DYNA, there are two gas dynamic methods are available at the moment. Both methods have their own advantage and disadvantage. Following table gives JLR's opinion.



Method	Gas flow visualisation	Stability	Run time	JLR applications
ALE method	good		long	Side airbag, curtain airbag, others which need clear gas flow visualisation (such as diffuser design)
Particle method	poor	better	better	Driver/passenger airbag



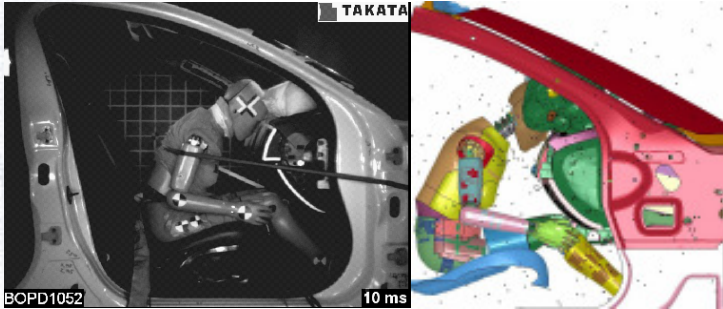
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 **TAKATA** 4. Application of Gas Dynamic Model 

### Passenger OOP





Model Correlation/Prediction: particle method has been used in passenger airbag OOP development

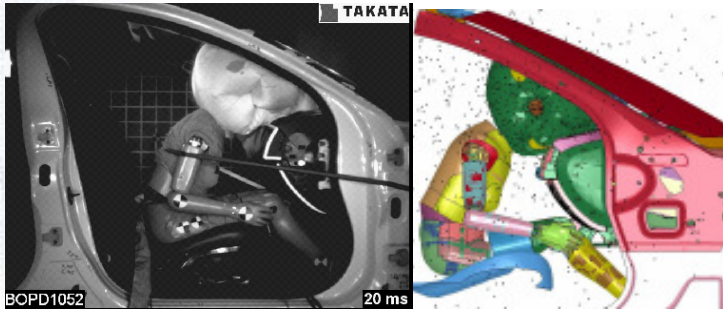
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 **TAKATA** 4. Application of Gas Dynamic Model 



### Passenger OOP



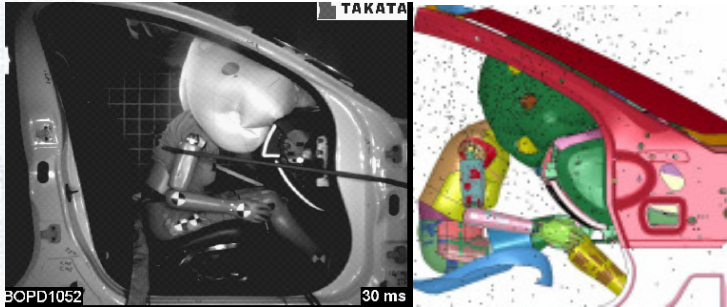
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### Passenger OOP



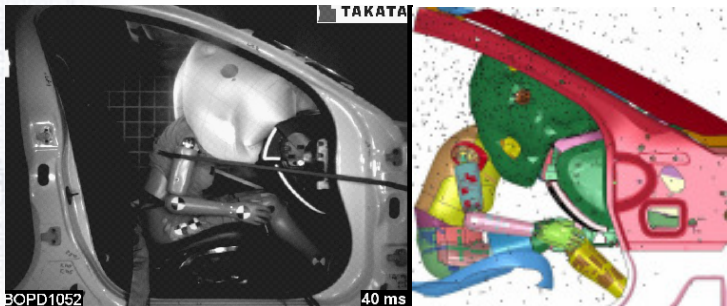
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 **TAKATA** 4. Application of Gas Dynamic Model 

### Passenger OOP




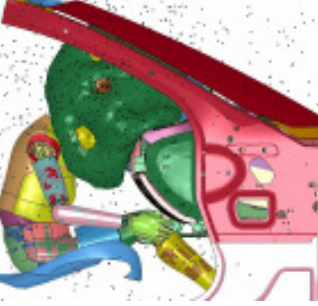
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**TAKATA** 4. Application of Gas Dynamic Model Quality First

### Passenger OOP

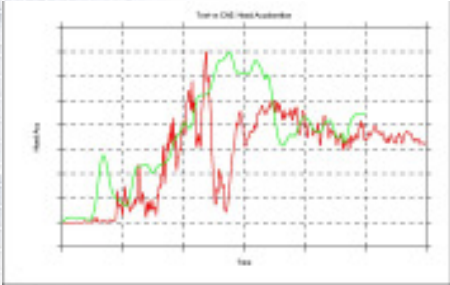
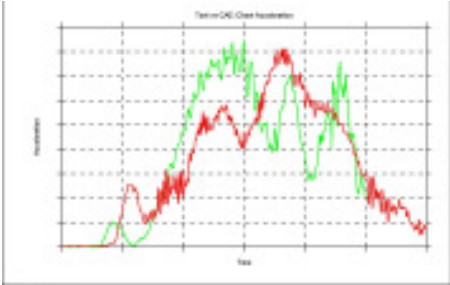
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**TAKATA** 4. Application of Gas Dynamic Model Quality First



### Passenger OOP


Head Acceleration


Chest Acceleration


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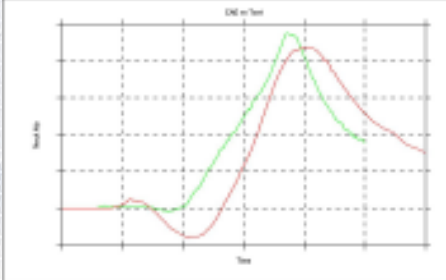



**TAKATA** 4. Application of Gas Dynamic Model



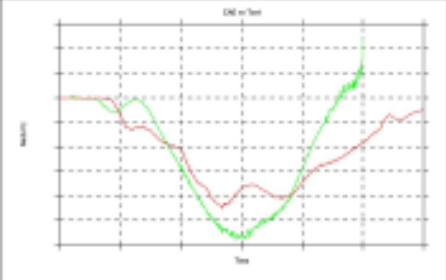
### Passenger OOP

- For passenger OOP, the neck injuries are the most interested injuries.
- Gas dynamic Particle method has been used in the correlation and good level of correlation to the neck injury is achieved.




Legend: — GM - Neck My, — Test - Neck My

**Neck Bending My**




Legend: — GM - Neck Fz, — Test - Neck Fz


**Neck Force Fz**





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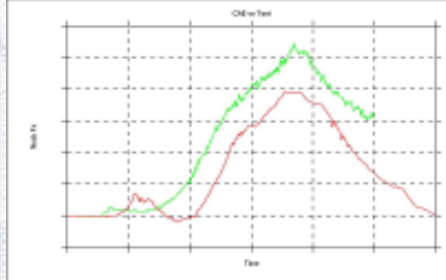
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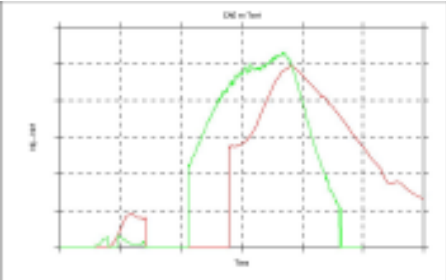


### Passenger OOP




Legend: — GM - Neck Fx, — Test - Neck Fx


**Neck Force Fx**



Legend: — GM - Neck Fz, — Test - Neck Fz





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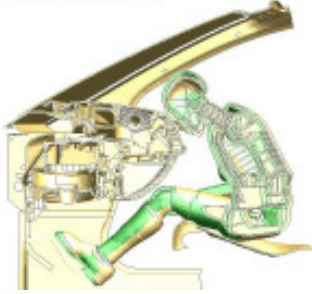
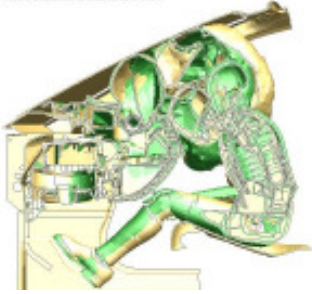

**TAKATA** 4. Application of Gas Dynamic Model




### Passenger OOP

Sensitivity Studies 1 - Dummy Positions (12mm in Z)


**How Kinematics Changes**


Dummy position is sensitive to the dummy kinematics. With 12mm difference of head position, the neck bending moment changes from extension-control to flexion-control in this case





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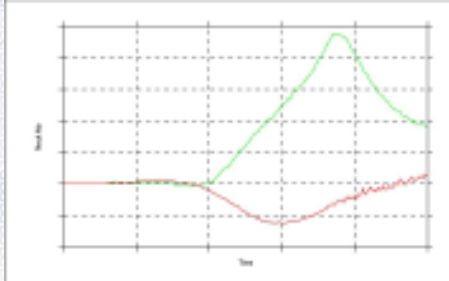

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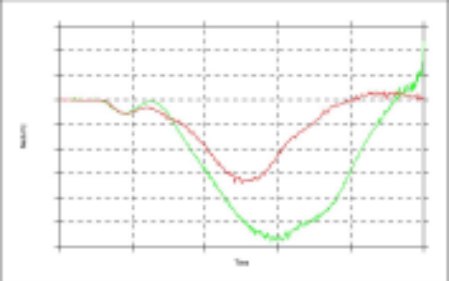
### Passenger OOP

**How Key Injury Changes**


Dummy position is sensitive to the dummy kinematics. Head position with green curve is 12mm higher than that with red curve




**Neck Bending My**



**Neck Force Fz**





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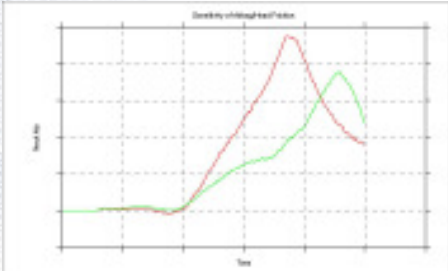
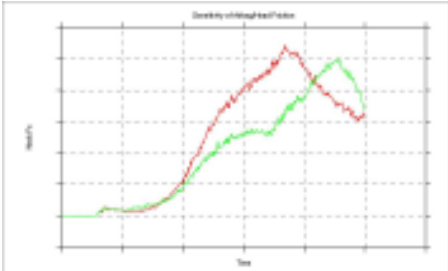
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## Passenger OOP


Sensitivity Studies 2 – airbag/dummy head friction

Airbag/dummy head friction is also sensitive to the neck injury. With smaller friction (green curve) less neck moment can be seen.








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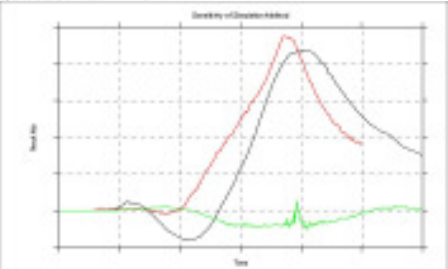
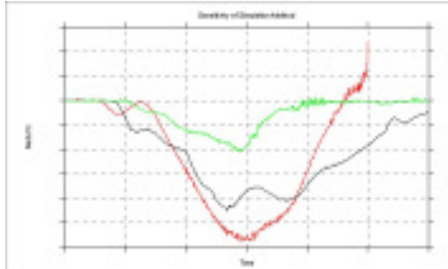
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## Passenger OOP


Sensitivity Studies 3 – simulation method (Control Volume vs Gas dynamic)

Black curve: Test data ; Red curve: Particle method; Green curve: CV method








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## 4. Application of Gas Dynamic Model

### Diffuser Design




- Diffuser can be used in PAB to generate even gas flow in order to have symmetrical airbag deployment
- Gas dynamic ALE method can be used as ALE method will provide clear gas flow visualisation. This enable use to study the flow vector coming out from the diffuser. By examining the gas velocity and its vector, it is able to find out if the design of diffuser can provide the symmetrical gas outlet.





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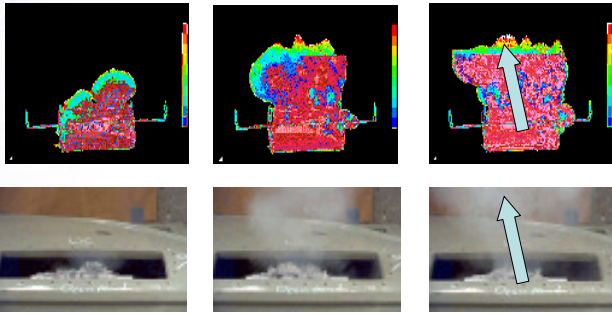



## 4. Application of Gas Dynamic Model

### Diffuser Design




- Baseline design of diffuser shows the uneven gas flow from the mouth of the diffuser. This is proven by the test.







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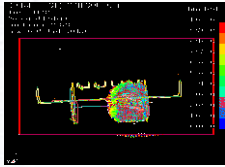
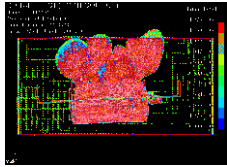
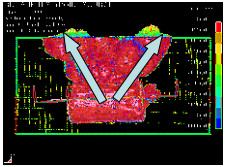



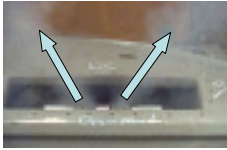
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### Diffuser Design




- Modified diffuser design shows much even gas flow








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## 5. Conclusions


### Conclusions



- Gas dynamic simulation is a critical CAE tool in OOP and airbag deployment through trims. It is important that software vendors develop the code to be robust, easy-to-use and possess quality gas flow visualisation.
- Restraint suppliers play an important role in airbag system development. JLR pays great attention to the collaboration work with our suppliers. This will encourage both sides to apply state-of-art CAE techniques into product development.



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