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

Fatalities in UK and Germany from 1950-2006

- Fatalities in the UK and Germany from 1950 to 2006 are shown in the graph.
- The graph demonstrates a significant decrease in fatalities after the introduction of airbags in the 1990s.

History of airbag modeling

- The timeline of airbag modeling is shown, starting from 1988.
- Key developments include:
  - 1988: Initial airbag technology
  - 1994: Early use in vehicles
  - 1997: Improved airbag technology
  - 2000: Further advancements
  - 2005/06: Continued improvements and integration

Application of Gas Dynamic Method in Development of Airbag Modules

6th German LS-DYNA Forum 2007, October 11-12, 2007, Frankenthal, Germany
1. Introduction

Todays tasks of airbag models

- EA
- Housing
- Seams
- Inflators
- Cover
- Fabric
- Vents
- Diffuser
- Shape
- Folding

2. Comparison of gas dynamic methods

Gas dynamic methods used for diffuser

- CFX
- ALE
- Corpuscular

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2. Comparison of gas dynamic methods

**CFX results for diffuser model**

- Pressure distribution plate
- Pressure distribution inflator “nose”

**ALE results for diffuser model**

- ALE half model of diffuser
- Example of modified parameter to improve model stability
2. Comparison of gas dynamic methods

Results of corpuscular method

Corpuscular model of diffuser

Distribution of stress (VM)

Detailed pressure distribution for several parts of plate
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.

Validation of fabric model

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

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3. Predictability of Corpuscular Method

Inflated triangle bag with different weft directions

Simulation
Weft direction 45°
Test

Simulation
Weft direction 90°
Test

Comparison of inflation kinematics

Flat
Leporello Folding

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3. Predictability of Corpuscular Method

Rapture model for airbag seams

Tensile tests of seams to validate numerical model

\[ p = 7 \text{ bar} \]

Integrated seam model of airbag inflated with corpuscular method

• 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
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.

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.

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

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Model Correlation/Prediction: particle method has been used in passenger airbag OOP development.
4. Application of Gas Dynamic Model

Passenger OOP

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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.
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.

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.
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.

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

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

Neck Bending My  
Neck Force Fz
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.

Baseline design of diffuser shows the uneven gas flow from the mouth of the diffuser. This is proven by the test.
4. Application of Gas Dynamic Model

Diffuser Design

- Modified diffuser design shows much even gas flow

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.
Questions?