

***MAT_GAS_MIXTURE, a new gas mixture
model for airbag applications**

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Abstract

Recent efforts to model fully coupled CFD-airbag processes have motivated the implementation of a gas mixture model in LS-DYNA.

The new model, *MAT_GAS_MIXTURE, allows the mixing of up to eight different gases. It is designed to conserve the total energy of the system. Kinetic energy dissipated in the ALE advection process is automatically transformed into heat.

The article serves as a description of the gas mixture model and of the accompanying keyword commands.

Introduction

Occupant safety groups are requesting better tools for airbag deployment simulations. A uniform pressure assumption is simply not accurate enough when analysing certain out of position situations.

To better capture the significant mechanisms in the incipient stage of the deployment process, one might need to explicitly model the gas flow and its interaction with the airbag fabric. LSTC is working on improving the necessary capabilities for such analyses to be carried out on a production basis.

The approach suggested by LSTC is to model the gas flow with an Eulerian or ALE formulation. The gas flow can be coupled to a Lagrangian airbag model through a fluid-structure interaction algorithm.

*MAT_GAS_MIXTURE has been developed for this purpose. It is a gas mixture model for explicit Eulerian and ALE simulations. The mixing is necessary for a good description of the gas when using hybrid inflators.

Theory

The only material property constants of *MAT_GAS_MIXTURE are heat capacities at constant volume, C_v^i , $i \in [1..N]$, and at constant pressure, C_p^i , $i \in [1..N]$. $N \leq 8$ is the total number of gas species in the mixture.

State Variables

The state variables are the densities of the different gas species, ρ^i , $i \in [1..N]$, and the specific internal energy, e .

Total Pressure

The static temperature, T , at a point is defined as

$$T = \frac{e}{\sum_{i=1}^N \rho^i C_v^i} \quad (1)$$

The total pressure, p , is defined as the sum of partial pressures from the different gas species in the mixture, p^i .

$$p = \sum_{i=1}^N p^i \quad (2)$$

where

$$p^i = \rho^i (C_p^i - C_v^i) T \quad (3)$$

Energy Conservation

The ALE solver in LS-DYNA is dissipative. The numerical schemes are designed to preserve the momentum, but not the kinetic energy. Some energy is lost in the advection.

By not keeping the energy balance, one can expect to finally end up with a too low gas pressure.

The amount of dissipated kinetic energy can be computed at each element. In *MAT_GAS_MIXTURE the dissipated kinetic energy is automatically transformed into heat. In this way the energy conservation is satisfied. It is a numerical trick and, depending on application, its legitimacy can be questioned.

Keyword Commands

*MAT_GAS_MIXTURE and *INITIAL_GAS_MIXTURE are used to define the gas properties and its initial state, respectively.

For airbag application, the idea is to model the inflators as sets of point sources. The point sources can be generated with the command *SECTION_POINT_SOURCE_MIXTURE. This keyword and its functionalities are still under development and it is not included in the official ls970 release.

*MAT_GAS_MIXTURE

Card 1 to 3

1	2	3	4	5	6	7	8
MID							
C_v^1	C_v^2	C_v^3	C_v^4	C_v^5	C_v^6	C_v^7	C_v^8
C_p^1	C_p^2	C_p^3	C_p^4	C_p^5	C_p^6	C_p^7	C_p^8

MID Material ID

$C_v^1 - C_v^8$ Heat capacity at constant volume for up to 8 different gases.

$C_p^1 - C_p^8$ Heat capacity at constant pressure for up to 8 different gases.

*INITIAL_GAS_MIXTURE

Card 1 to 2

1	2	3	4	5	6	7	8
SID	STYPE	MMGID	T_0				
ρ_0^1	ρ_0^2	ρ_0^3	ρ_0^4	ρ_0^5	ρ_0^6	ρ_0^7	ρ_0^8

SID Set ID
 STYPE Set type
 Eq.0 - part set
 Eq.1 - part
 MMGID Multi-material group ID that is to be initialized
 T_0 Initial static temperature of the gas mixture
 $\rho_0^1 - \rho_0^8$ Initial densities of up to 8 different gas species.

***SECTION_POINT_SOURCE_MIXTURE**

Card 1 to 2

1	2	3	4	5	6	7	8
SECID	LCT		LCV	NLC1	NLC2	NLC3	
LCM1	LCM2	LCM3	LCM4	LCM5	LCM6	LCM7	LCM8

Card 3, 4...

1	2	3	4	5	6	7	8
NID	VID	AREA					

SECID Section ID
 LCT Stagnation temperature load curve ID
 LCV Inlet flow velocity load curve
 NLC1- Node ID's defining a local coordinate system. If defined, the
 NLC3 vectors defining the inlet flow direction follow the rotation of
 this system.
 LCM1- Mass flow rate load curves for up to eight different gas species
 LCM8 (see *MAT_GAS_MIXTURE).
 NID Node ID defining the location of the point source
 VID Vector ID defining the inlet flow direction in a local coordinate
 system defined by NID1-NID3. If NID1-NID3 are not defined,
 the vector is assumed to be defined in the global coordinate
 system.
 AREA Point source orifice area

Tank Test

*MAT_GAS_MIXTURE has been benchmarked in a tank test simulation. The tank pressure time history was compared to results obtained with an *AIRBAG_HYBRID control volume approach.

The details of the models are not presented in this article. However, the complete input decks can be obtained from LSTC's ftp site. Please contact the author for downloading instructions.

Control Volume Model

A cubic 27dm³ tank was modeled with shell elements. The tank was filled with a mixture of three different inflator gases. The keyword input defining the inflator characteristics are listed below.

```
*AIRBAG_HYBRID
1, 1
293.0, 1.013E-04, 1.2E-09, 8.31, 1.0
0, 0, 0, 0, 0, 0, 0, 0, 0
0, 0, 4
$ Air
0, 0, 0, 0.029, 1.0, 27.27
0
$ Inflator gas 1
2, 1, 0, 0.045, 0.0, 30.00
0
$ Inflator gas 2
3, 1, 0, 0.018, 0.0, 45.00
0
$ Inflator gas 3
4, 1, 0, 0.028, 0.0, 30.00
0
$ Inlet temperature curve
*DEFINE_CURVE
1
0.0, 800.0
100.0, 800.0
```

```
$ Mass flow rate curves
*DEFINE_CURVE
2
0.0, 0.0
10.0, 3.0e-4
50.0, 0.0
*DEFINE_CURVE
3
0.0, 0.0
10.0, 0.0
20.0, 3.0e-4
50.0, 0.0
*DEFINE_CURVE
4
0.0, 0.0
20.0, 0.0
30.0, 3.0e-4
50.0, 0.0
*END
```

Eulerian Model

In the Eulerian model, the 27dm³ tank was embedded in a mesh of 30×30×30 Eulerian elements. The keywords necessary for the definition of the inflator characteristics are presented below.

```
$ Heat capacities of air and inflator gases
*MAT.GAS.MIXTURE
1
654.47, 482.00, 2038.30, 774.64
941.32, 666.67, 2500.00, 1071.40
$ Tank initially filled with air
*INITIAL_GAS_MIXTURE
1, 1, 1, 293.0
1.2E-09
```

```
$ Point sources
*SECTION_POINT_SOURCE_MIXTURE
2, 1, 0, 5
0, 2, 3, 4
100001, 1, 25.0
100002, 1, 25.0
100003, 1, 25.0
100004, 1, 25.0
$ Flow direction
*DEFINE_VECTOR
1, 0.0, 0.0, 0.0, 1.0, 0.0, 0.0
$ Location of point sources
*NODE
100001, 30.0, 180.0, 180.0, 7
100002, 30.0, 220.0, 180.0, 7
100003, 30.0, 180.0, 220.0, 7
100004, 30.0, 220.0, 220.0, 7
$ Flow velocity
*DEFINE_CURVE
5
0.0, 500.0
100.0, 500.0
```

Result

Figure 1 shows the tank pressure time histories obtained with the two different models. The difference in results is related to numerical errors in the fluid-structure interaction. The fluid-structure interaction algorithm tends to destroy the perfect energy balance. Ongoing development at LSTC is currently dealing with this problem.

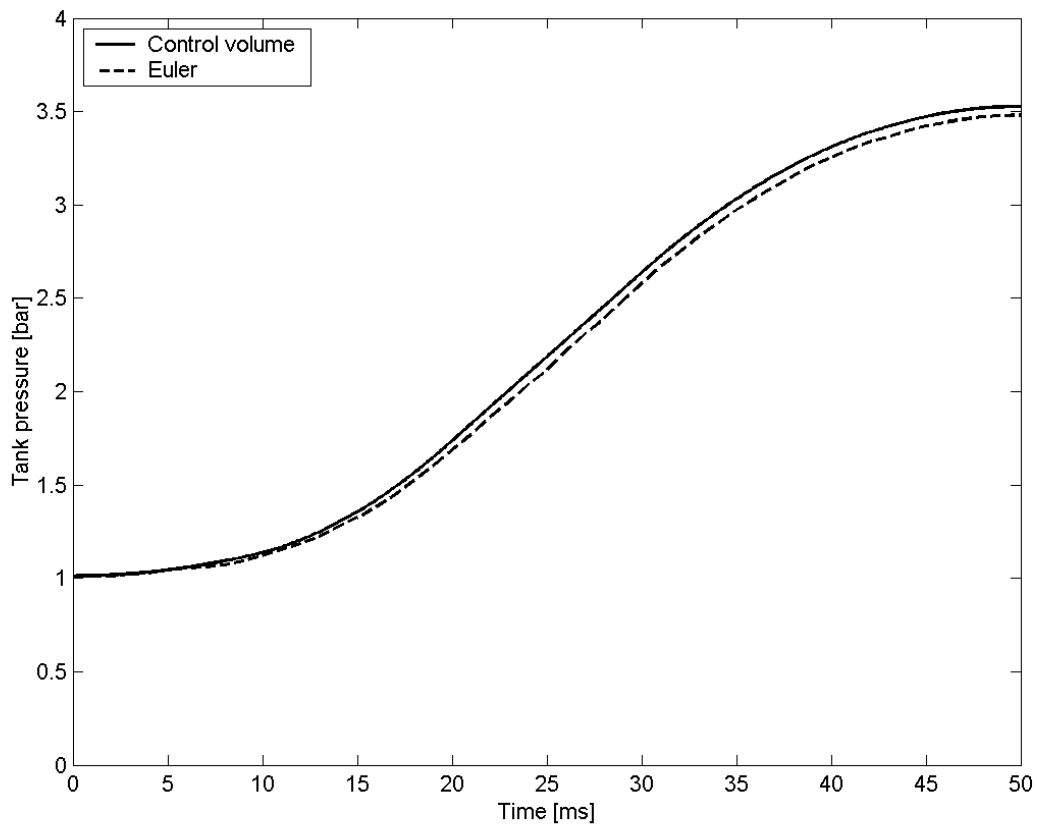


Figure 1: Pressure time history in two different tank test simulations.

