Modeling of Automotive Airbag Inflators using Chemistry Solver in LS-DYNA®

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Abstract

Airbags are part of an important vehicle safety system, and the inflator is an essential part that generates a specific volume of gas to the airbag for a short duration of time. Recently, we have developed numerical models of automotive airbag inflators in conjunction with the LS-DYNA® chemistry solver. In this presentation, we will demonstrate two different models: a conventional pyrotechnic inflator and a compressed, heated gas inflator. Detailed and comprehensive descriptions for constructing the keyword flies will be given and the results for the two models will be discussed. Limitations of the currently available models and future directions for coupling with the existing LS-DYNA® solvers, i. e., ALE and CESE solvers will also be presented. In addition, more advanced models will be proposed and discussed in detail.

1. Pyrotechnic Inflator

Figure 1 represents the cross-sectional view of a pyrotechnic airbag inflator. The modeling zones of the pyrotechnic inflator generally consist of the propellant, combustion chamber, gas plenum, and discharge tank [1-3]. Propellant grains including igniting material are contained and confined to the combustion chamber, which is completely sealed from the rest of the inflator by a thin rupture disk, so that the pressure of the combustion chamber is maintained until it reaches a desired value. With the rapidly increasing pressure and temperature by combusting propellant grains, the high pressure in the combustion chamber opens up the rupture disk. Then, the filter screen between the combustion chamber and the gas plenum captures the condensed phase slag and also cools the hot gas by permeating through the wide surface area heat sink. When the combustion gas is filled in the gas plenum and the pressure in it exceeds a certain specified value, another rupture disk opens and the product gases are then exhausted into the discharge tank. Since the pressure, temperature and mass flow rate in the discharge tank caused by the performance of the inflator characteristics is the crucial factor in designing an airbag, the purpose of the simulation model is to provide accurate information on the combustion gas.

2. Heated Gas Inflator

Recently, O'Loughlin et al.[4] published a US patent for the heated gas inflator (HGI) to avoid a several drawbacks for the conventional pyrotechnic inflator; 1) variable performance depending on the ambient condition, 2) disposal of un-burnt propellants, and 3) toxicity of the combustion products. Figure 2 illustrates the schematic of the cross-sectional view of such inflators, which have cylindrical shapes and are initially filled to very high pressure with a gaseous mixture of fuel and oxidizer. The HGI consists of an igniter, pressurized initial mixture chamber, and a discharge tank including exit nozzle. The common fuel is hydrogen with oxygen and the diluting gases are typically helium, nitrogen and argon. Initially, the canister chamber of a HGI is filled with pressurized fuel and mixture gases. By triggering an electric signal, the igniter initiates the combustion, which propagates through the canister and eventually generates a strong detonation waves downstream. Then, a burst disk having the same purpose as a pyrotechnic inflator opens and allows the gas into the discharge tank or airbag.

3. Results and Discussion

Figure 3 shows the simulation results of the density, temperature, and pressure profiles as a funcition of the time for the pyrotechnic initiator. After initial delay time(~10ms), the external ruture film bereaks and initiates the discharge of the product gas from the inflator to the discharge tank, indicating that the density, temperature, and pressure begine to increase.

4. Keyword and Chemistry Input File

Figure 4 shows the keyword files needed to simulate the pyrotechnic inflator and HGI. The chemistry input files are designed to be unchanged since they requires the equilibrium compositions of the propellant products and also need to control the condensed phase thermodynamics data. However, a user who has experience in combustion could design his own HGI model using a full combustion model with the chemistry solver.

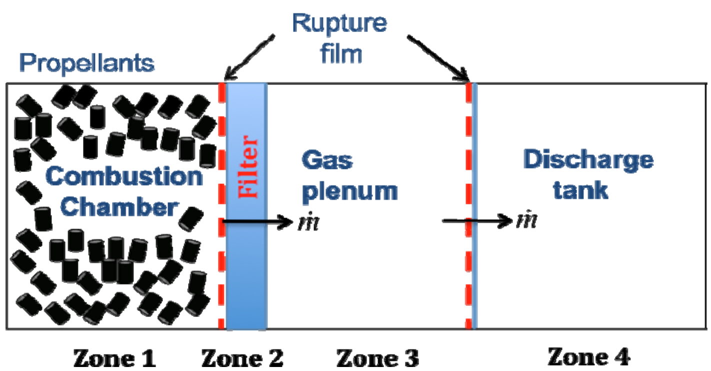


Figure 1 Schematic of the cross-section of pyrotechnic airbag inflator for simulation model.

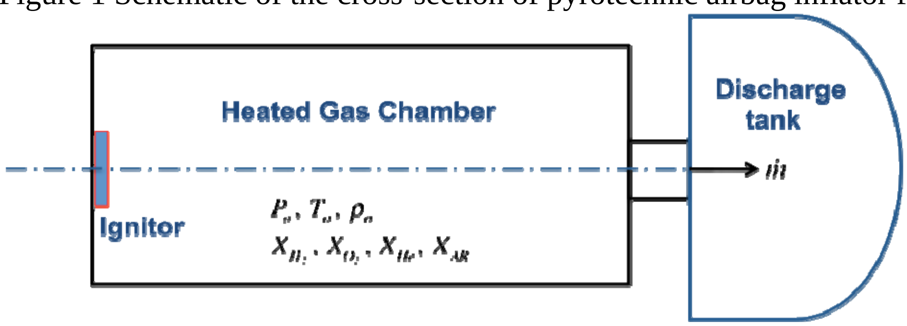
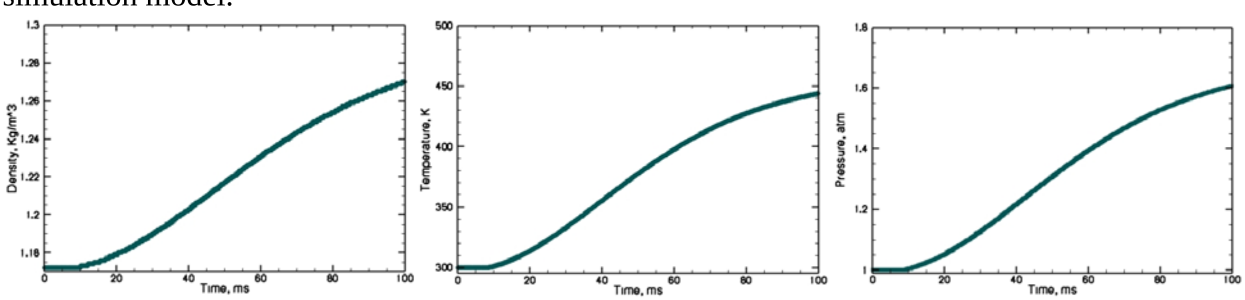


Figure 2 Schematic of the Cross view of a typical passenger-side heated gas inflator for simulation model.



(a) Density (b) Temperature (c) Pressure

Figure 3 Thermodynamic properties of discharge gas for the inflators.

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(a)Keyword file
*TITLE
Pyrotechnic_inflator
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
*CHEMISTRY_PROPELLANT_PROPERTIES
$    P_dia  P_height    P_mass   TP_mass
    0.0075    0.0045  0.451e-3      0.18
$       A0    Tdelay     Trise    Pindex
   4.45e-5     0.001     0.003      0.39
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
*CHEMISTRY_COMPOSITION
$  comp_id  model_id
        11        10
$  MoleNo.   Species
      3.76        N2
       1.0        O2
$
*CHEMISTRY_CONTROL_PYROTECHNIC
$Inflator_Combustion_Chamber_Card
$  comp_id   Volume1     Area1       Cd1        P1        T1   Rupt1_P   T_flame
        11   1.27e-4      0.01     0.049   101325.      295.  5.066e+6     1262.
$Inflator_Plenum_Card
$  comp_id   Volume3     Area3       Cd3        P3        T3   Rupt3_P R_time(S)
        11   5.56e-4  7.854e-5       0.8   101325.      295.  8.106e+6       .25
$Inflator_Airbag_Card
$  comp_id   Volume4        P4        T4
        11      0.61   101325.      295.
$Inflator_output_file
 inflator_outfile
$
*CHEMISTRY_MODEL
$ model_id    errlim
        10       0.0
 inflator1.inp
 therminf.dat

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
*END

(b)Input file
ELEMENTS
N Na O Fe
END
SPECIES
N2 O2 Na2O(a) Fe(a) Na2O(b) Fe(b) Fe(c) Fe(d)
END
```

Figure 4 Samples of the LS-DYNA keyword and the chemistry input files for the pyrotechnic inflator.

References

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[2] Robert G. Schmitt, P. Barry Butler and Jon J. Freemeier, "Performance and CO Production of a Non-Azide Airbag Propellant in a Pre-Pressurized Gas Generator," Combustion Science and Technology, 122:1-6, pp305-330 (1997).
[3] Young-Duk Seo, Suk Ho Chung, and Jack J. Yoh,"Automotive Airbag Inflator Analysis using the Measured Properties of Modern Propellants," Fuel, doi:10.1016/j.fuel.2010.12.042 (2011).
[4] J. P. O'Loughlin, and H. O. Stevens, "Heated Gas Inflator," US Patent0290108 (2006).