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 files 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 function of the time for the pyrotechnic initiator. After initial delay time (~10ms), the external rupture film breaks and initiates the discharge of the product gas from the inflator to the discharge tank, indicating that the density, temperature, and pressure begin 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 require 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.](image1.png)

![Figure 2 Schematic of the Cross view of a typical passenger-side heated gas inflator for simulation model.](image2.png)

![Figure 3 Thermodynamic properties of discharge gas for the inflators.](image3.png)
(a)Keyword file
*TITLE
Pyrotechnic_inflator
$

*CHEMISTRY_PROPPELLANT_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  N2
$

*CHEMISTRY_CONTROL_PYROTECHNIC
$Infletr_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.

$Infletr_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  0.25

$Infletr_airbag_card
  $  comp_id  Volume4  P4  T4
  11  0.51  101325.  295.

$Infletr_output_file
  $Infletr_outputfile

$Infletr_model
  $model_id  erlim
  10  0.0

  inflator1.inp
  therminf.dat


(b)Input file
ELEMENes
N  Na  0  Fe
END
SPECIES
N2  O2  Na20(a)  Fe(a)  Na20(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