New Inflator Models in LS-DYNA®

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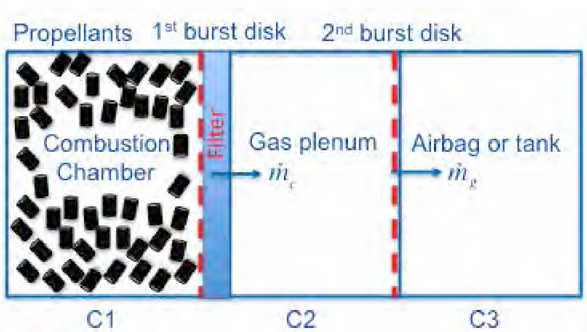
Abstract

Three new inflator models for the airbag simulation are developed, i.e., i) the pyrotechnic, ii) the cold flow hybrid, and iii) the heated flow hybrid models. In order to obtain the combustion product gas compositions and the combustion temperature, a PEP (Cruise,1973) program which is the propellant equilibrium combustion code is also provided. The inflating process is modeled by applying basic conservation laws: the continuity, the energy, and the species transport equations. Unlike other inflator models, here the combustion temperature in these new models is obtained by solving an implicit equation constructed via the thermodynamic relation after the total energy equation is solved. Thus, the new models will be more physical and can provide more accurate results. For user's convenience, three output formats are supported for LS-DYNA's ALE, CPM, and CESE solvers to continue the airbag simulations.

Introduction

The modeling zones of the pyrotechnic inflator generally consist of the propellant, combustion chamber, gas plenum, and discharge tank. 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. Once the propellant is ignited, pressure and temperature will increase rapidly due to combusting propellant grains, and this is followed by the rupture disk opening because of high pressure in the combustion chamber. Then, the filter screen between the combustion chamber and the gas plenum will capture the condensed phase slag, and this also cools the hot gas by permeating through the wide surface area heat sink. When the combustion gas fills in the gas plenum and the pressure in it exceeds a certain specified value, another rupture disk opens and the product gases exhaust into the discharge tank. Since the pressure, temperature and mass flow rate in the discharge tank caused by the performance of the inflator characteristics are the crucial factor in designing an airbag, it is very important for the inflator simulation models to provide accurate information concerning the propellant combustion process.



The schmatics of each zone in inflator model.

Model Descriptions

Available Inflator models:

- Pyrotechnic inflator (PI) model: basic model (gas is generated purely by propellant).
- Cold flow hybrid inflator (CFHI) model: inert gas stored in the gas chamber.

- Heated flow hybrid inflator (HFHI) model: the detailed reaction mechanism (currently only gaseous phase) required.

Basic Assumptions:

- Inflator is divided into several different discrete computational zones: combustion chamber, gas plenum, diffusers, and tank.
- In each zone, the gas and condensed phases are well mixed. Gas phase species are treated as ideal gas while the condensed phase species are incompressible.
- Gas and condensed phases are composed of multiple species with temperature dependent thermodynamics properties. For example, the specific heat for species *k* is a function of temperature only, given in terms of a polynomial as,

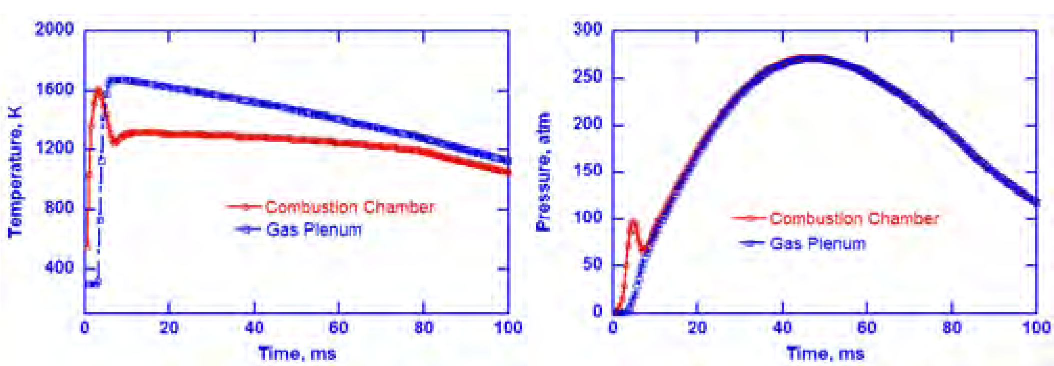
$$\frac{C^0_{pk}}{R} = a_{1k} + a_{2k}T_k + a_{3k}T_k^2 + a_{4k}T_k^3 + a_{5k}T_k^4, \quad C^0_{sk} = C^0_{pk} - R_k$$

- The burning rate of the propellant grain is approximated as a function of chamber pressure in time and is converted into the equilibrium compositions. Such compositions can be determined by either an equilibrium code or the stoichiometric combustion reaction.
- The mass flow rates from zone to zone are determined by the gas dynamic formula based on the isentropic flow assumption.

Calculations:

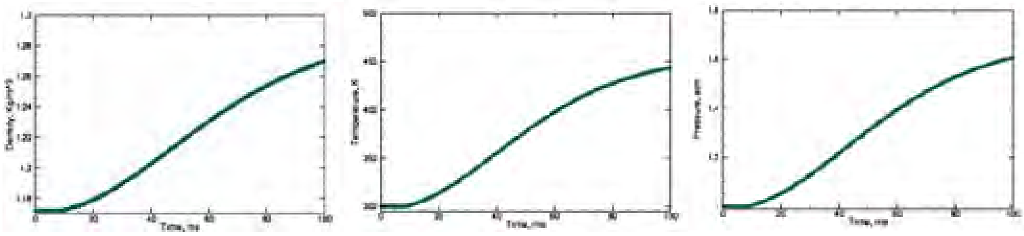
- In each zone, based on its initial conditions, the continuity, energy, and species transport equations are solved to find the species mass, total energy, chamber pressure, and chamber temperature. (see Fig. a) & b) for example)
- For HFHI model, a detailed mechanism of elementary reaction systems is required in order to compute the species production.

Fig. a) Combustion & Gas Plenum



(a) Temperature (b) Pressure

b) Discharge Tank



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

How to use:

1. Prepare the chemistry input file (*.inp) and thermodynamics data files (therminf.dat) for participating combustion species in the calculation.
2. Select the inflator model to run.
3. Specify the number of zones (currently, 3 zones only).
4. Set initial conditions for each zone (including the propellant card).
   a) The combustion chamber: initial conditions, propellant product composition, and chamber compositions.
   b) If the HFHI model is selected, make sure that the elementary reactions are included in the chemistry input file.
4. Run the code to get the load curve for flow properties.
5. Calibrate the input parameters using experimental data such as the combustion pressure and tank pressure curves.
6. Finally, use the necessary load curves and parameters to continue the airbag simulation

Remarks:

- The species compositions can be determined by either an equilibrium code or the stoichiometric combustion reaction.
- An LSTC variant of the PEP equilibrium code is provided as a separate code option from LS-DYNA to calculate the combustion species compositions (i.e. mole fractions) and the flame temperature.
- To obtain the accurate input values for the airbag simulation, the pressure curve must be calibrated through a tank test. If possible, it is recommended to conduct pressure curve calibration in the combustion chamber as well.

References:

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