EX216

Lagrange Gun

The sudden blast of a Lagrange gun is simulated in this example. The blast forces a piston to move rapidly in response to a large pressure differential. FLUENT simulations are done using both a real gas law and the standard ideal gas law. The real gas simulations are shown to be in excellent agreement with analytical predictions for all aspects of the system response.

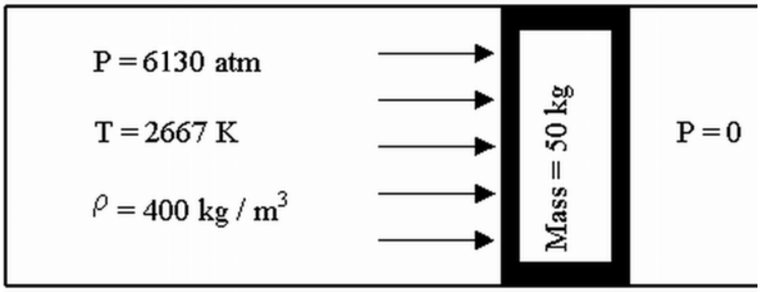

Figure 1: Schematic of the Lagrange gun

The Lagrange gun simulation is a classical problem in ballistics [1], and is particularly relevant to the gun and missile industries. Here, a simplified Lagrange gun is modeled as a two-dimensional axisymmetric case with the use of the dynamic mesh (DM) model and the user-defined real gas model (UDRGM) in FLUENT 6.1. The results are compared with analytical solutions from the literature [2].

A 50 kg projectile (piston) resides in a chamber with a charge of cordite gas (a propellant, with density 400 kg/m^3) at 6130 atm of pressure and a temperature of 2667°K. The projectile is free to move axially depending on the differential pressure force acting on its two surfaces. The moving mesh capabilities of FLUENT 6 are used to capture the motion by providing an updated piston position and corresponding grid at each time step of the transient calculation. The piston motion versus time is computed by a user-defined function (UDF), which uses Newton's second law. The only force considered is due to the pressure, which is integrated at each time step. Although friction forces are not considered, they could easily be added.

As the projectile moves, new layers of quadrilateral cells are added to the mesh adjacent to the base of the projectile. The coupled implicit solver is used, assuming an inviscid flow. The initial gas conditions are patched onto the solution domain, and the thermodynamic properties of the gas are calculated using the UDRGM, through which the Abel-Nobel equation of state (ANEOS) is implemented. The charge mass is assumed to be constant with time (i.e., there is no leakage around the piston). Adaptive time stepping is used, so that the piston movement in each time step is restricted to a fraction of the user-specified ideal cell width.

A schematic of the model setup is shown in Figure 1, with the axisymmetric grid used shown in Figure 2. The cylindrical chamber is bounded by rigid walls on all sides except one, where a movable piston is located. The piston position versus time (up to the shot exit) as computed by FLUENT is shown in Figure 3, together with the analytical solution of Love and Pidduck [1]. The agreement is strikingly accurate. Figure 4 illustrates the pressure acting at the projectile base as a function of time as computed by FLUENT and as predicted by theory [1]. The kink

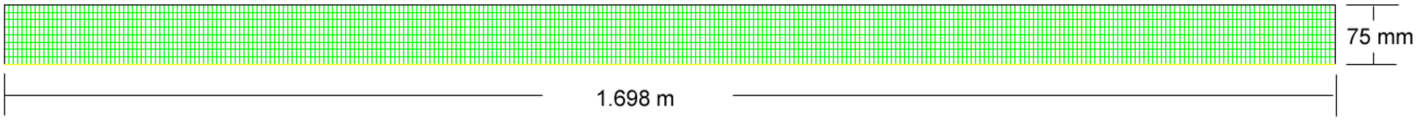

Figure 2: Overview of the length and radius of the solution domain, along with the grid at t=0

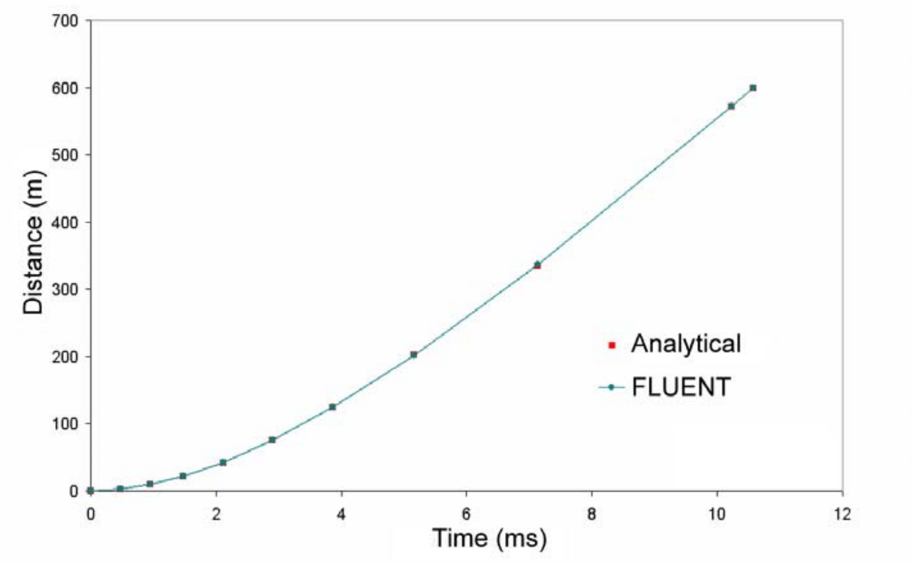

Figure 3: Piston position as a function of time

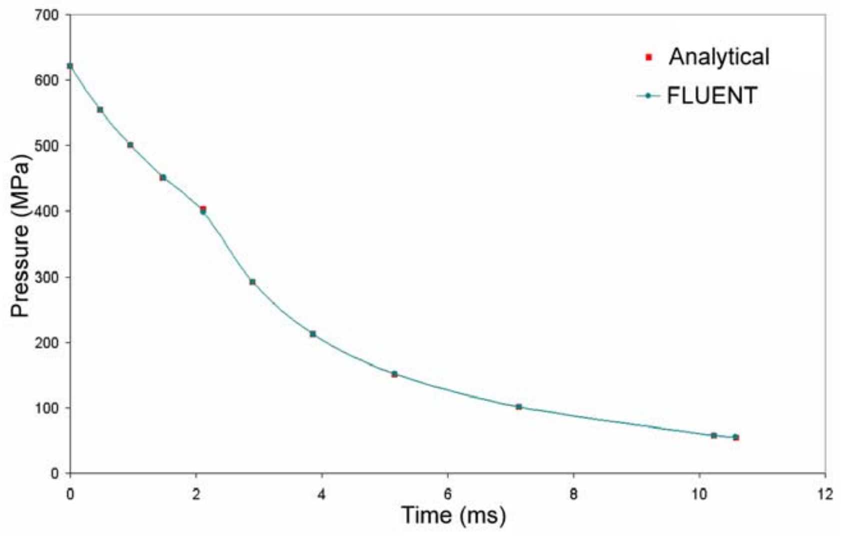

Figure 4: Piston base pressure as a function of time

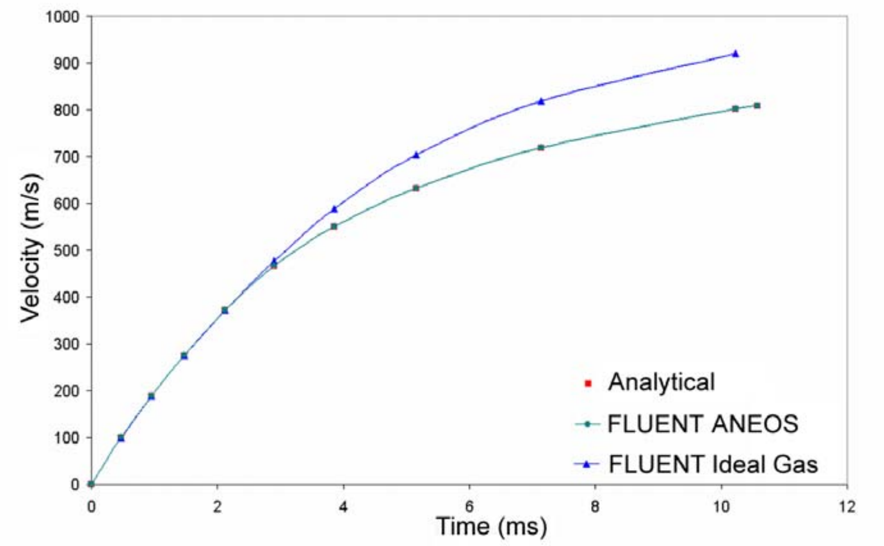

Figure 5: Piston velocity as a function of time, comparing the real and ideal gas laws in FLUENT to experiment

in the profile is the result of a rarefaction wave, propagating to the left of the moving piston. After it reflects off the left cylinder wall and travels back to the piston, it acts to equalize the pressure in the chamber. Thus while the chamber pressure continues to fall, it does so with less of an axial gradient once the wave reflection occurs. FLUENT predictions for the velocity of the piston as a function of time are compared with the analytical result in Figure 5. The CFD calculations using both the real and standard ideal gas law are shown to demonstrate the importance of real gas effects. It can be observed that as the piston moves to the right at higher speeds, the deviation between the ideal gas prediction and theory increases. This underlies the limitations of using the ideal gas law under very high-pressure conditions.

The projectile exit time is predicted by FLUENT to within 0.049% of the analytical value. The excellent agreement for all aspects of the Lagrange gun case using the UDRGM forms a basis for other dynamic mesh applications requiring high temperature and pressure, conditions for which the standard ideal gas model is not adequate.

References:

1. A. E. A. Love and F. B. Pidduck, Phil. Trans. Roy. Soc., **222**, p. 167-226, 1921-22.

2. F. W. Robbins, Memorandum Report ARBRL-MR-03299, US Army Arm. Res. and Dev. Com., Bal. Res. Lab., July 1983.