Finite Element Simulation of a Blast Containment Cylinder Using LS-DYNA

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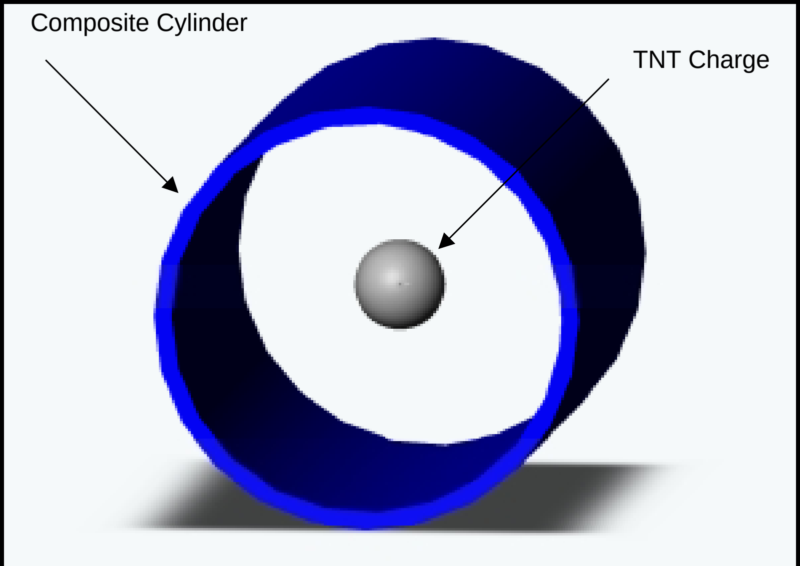
Abstract

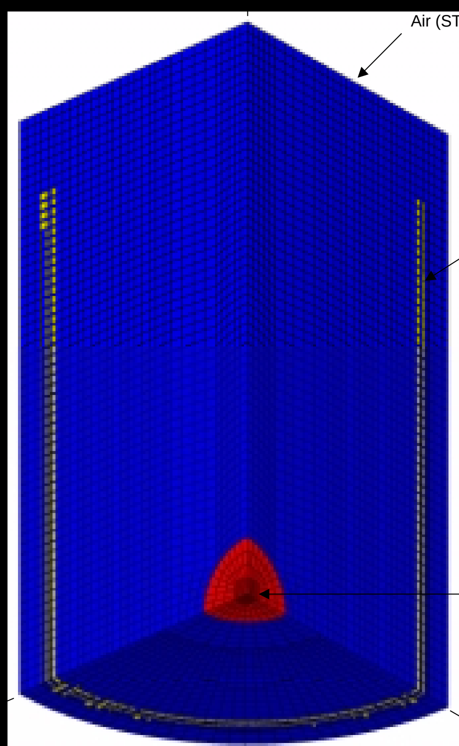
- Several computational models and mesh geometries were created to study blast loading in a containment cylinder.
- To reduce the complexity of the model, Titanium Boride was used as the material for the cylinder instead of a composite material.
- ALE multi-material was used to simulate TNT and air interaction with the cylinder

Introduction



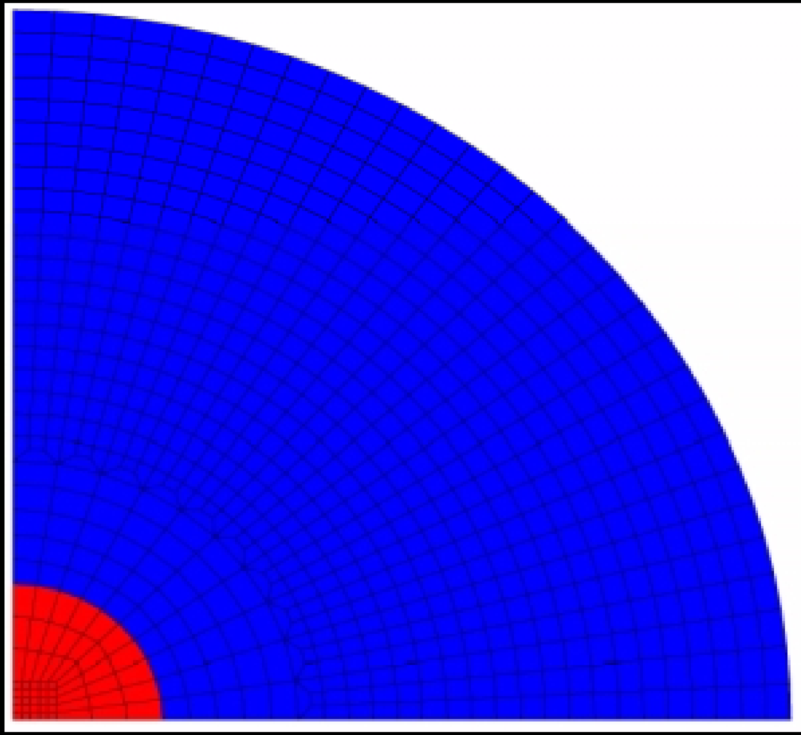
- Cylinder Material, Titanium Boride with an inner radius of 75mm and an outer radius of 81.1mm. The cylinder is 300mm in length
- TNT charge equivalent to 37.4 grams of 50:50 by weight trotyl-hxogen centered in cylinder

Modeling Procedure



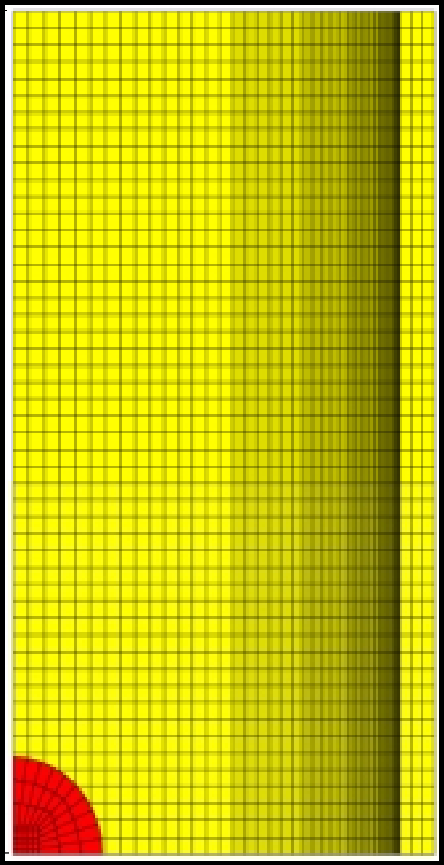
- LS-DYNA was used as the non-linear finite element solver
- TrueGrid was used to generate the mesh
- HyperMesh was implemented to generate the input deck

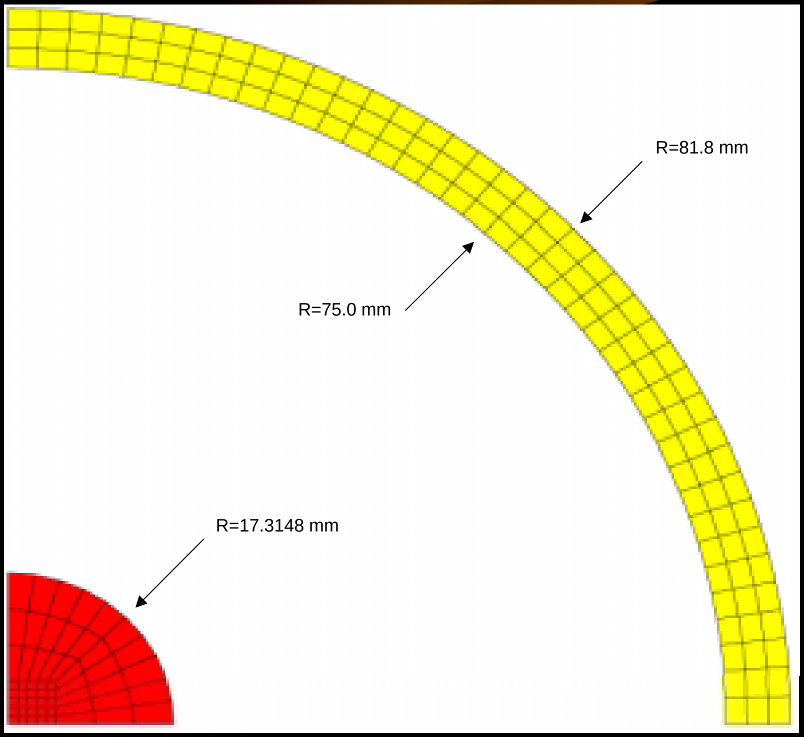
Mesh Geometry



- Element sizes were targeted for 3±2mm with an aspect ratio of 1:1
- To achieve the 3mm target the mesh was transition close to the TNT charge

Side and Bottom Profile





JWL

The Jones-Wilkins-Lee (JWL) equation of state (EOS) model for explosive detonation products is given by

$$P = A\left(1 - \frac{\omega}{R_1 V}\right)e^{-R_1 V} + B\left(1 - \frac{\omega}{R_2 V}\right)e^{-R_2 V} + \frac{\omega E}{V}$$

where *A*, *B*, *C*, R_1, R_2, and ω are constants to be calibrated experimentally, $V = \frac{v}{v_0}$ is the product volume relative to the initial explosive volume, *E* is the energy per unit volume, and *P* is the pressure. Values for these constants can be developed experimentally or can be found in the literature.

Linear Polynomial

The Linear Polynomial EOS for linear internal energy is given by

$$P = C_0 + C_1\mu + C_2\mu^2 + C_3\mu^3 + \left(C_4 + C_5\mu + C_6\mu^2\right)E$$

where $C_1 \cdots C_6$ are polynomial coefficients, $\mu = \frac{\rho}{\rho_0} - 1$ with $\frac{\rho}{\rho_0}$ being the ratio of current density to the initial density, and E has units of pressure. For the modeling of gasses, the gamma law equation of state can be used. This implies that

$$C_0 = C_1 = C_2 = C_3 = C_6 = 0$$

and

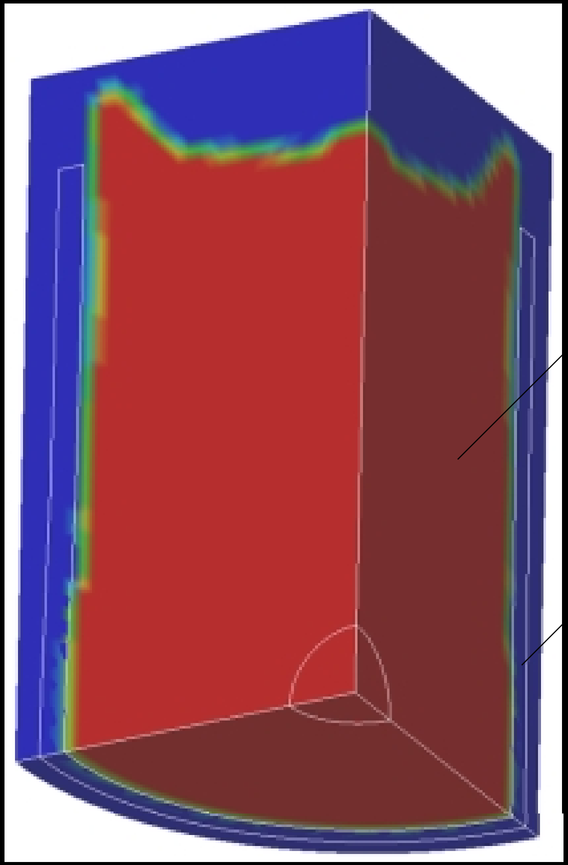
$$C_4 = C_5 = \gamma - 1$$

where γ is the ratio of specific heats. Thus for air the pressure equations is given by

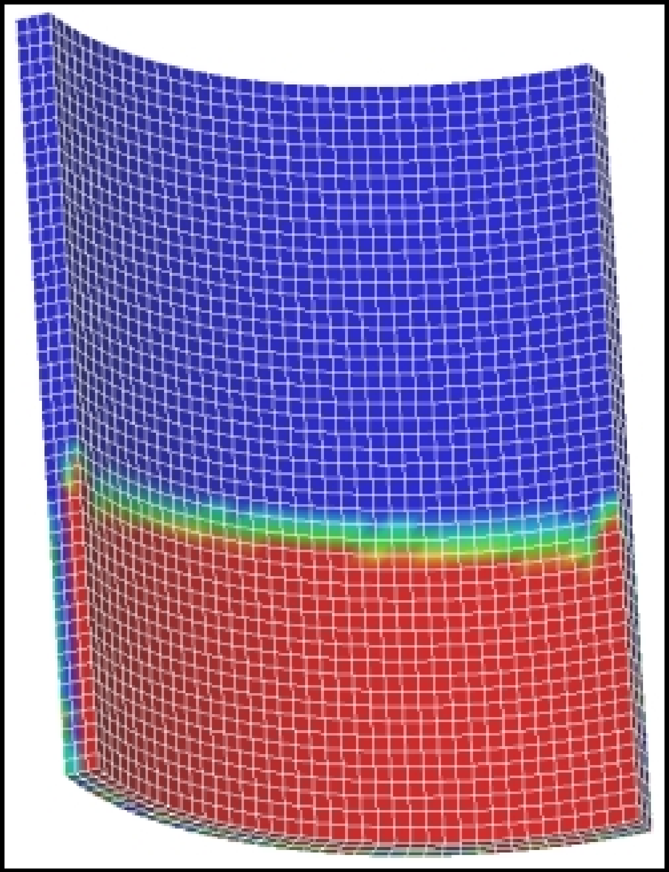
$$p = (\gamma - 1)\frac{\rho}{\rho_0}E$$

It should be noted that for an ideal gas it may be incorrect to assume $C_4 = C_5 = \gamma - 1$ and $C_0 = 0$. The EOS equation should be used in its entirety to check the pressure value.

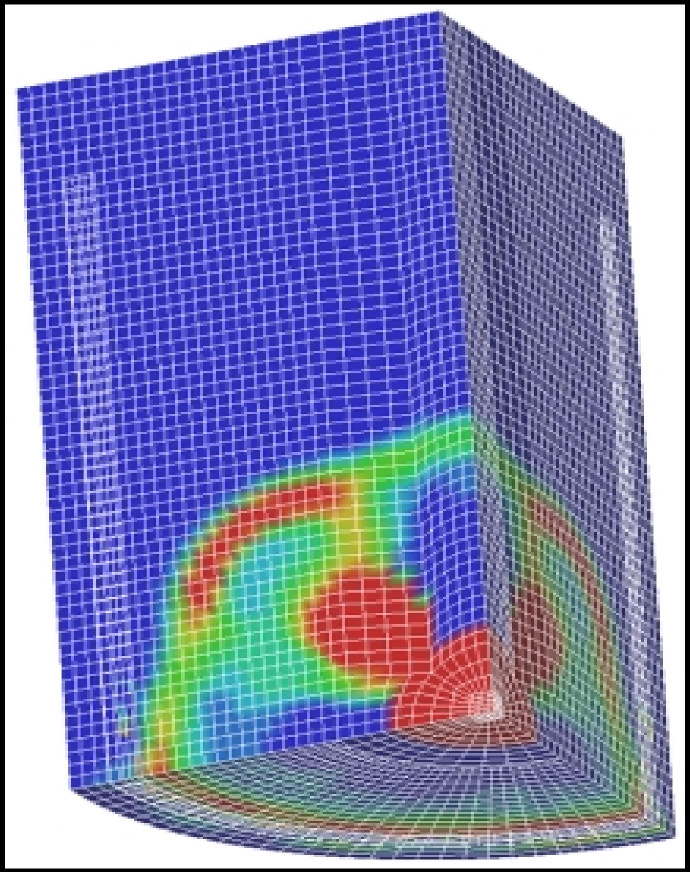
Results



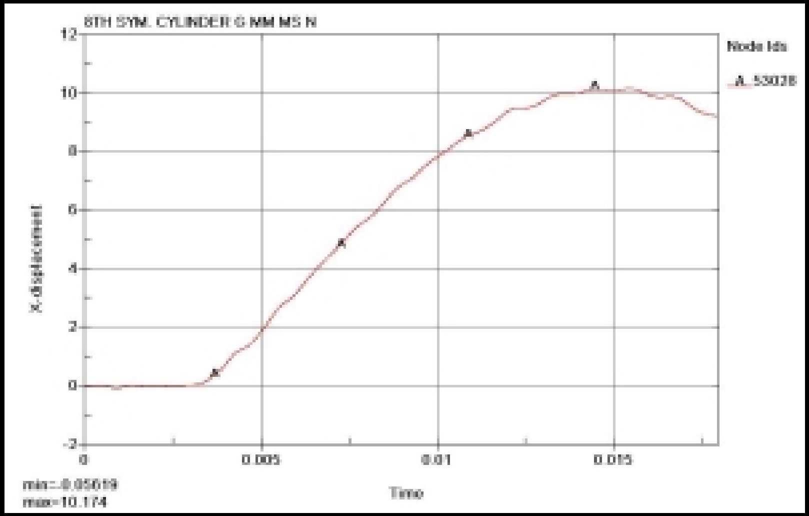
- By changing the penalty factor (PFAC) in the Constrained Lagrange In Solid input card the penetration of the TNT/Air volume fraction into the cylinder mesh can be controlled



- By using different meshes an even pressure loading on the cylinder can be obtained

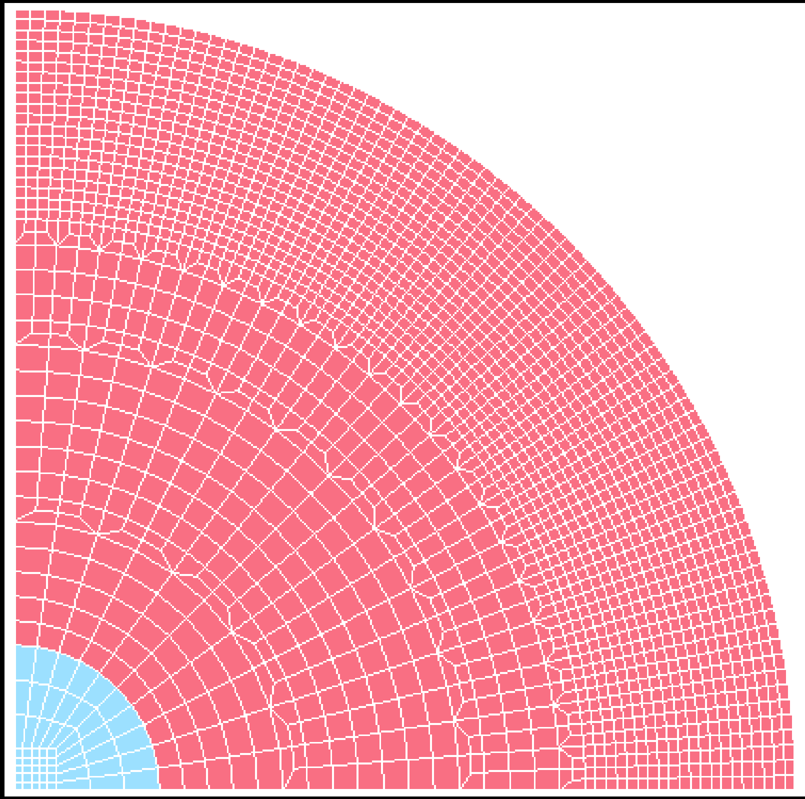


- Transition from spherical to square mesh produces a faster moving and more concentrated pressure wave

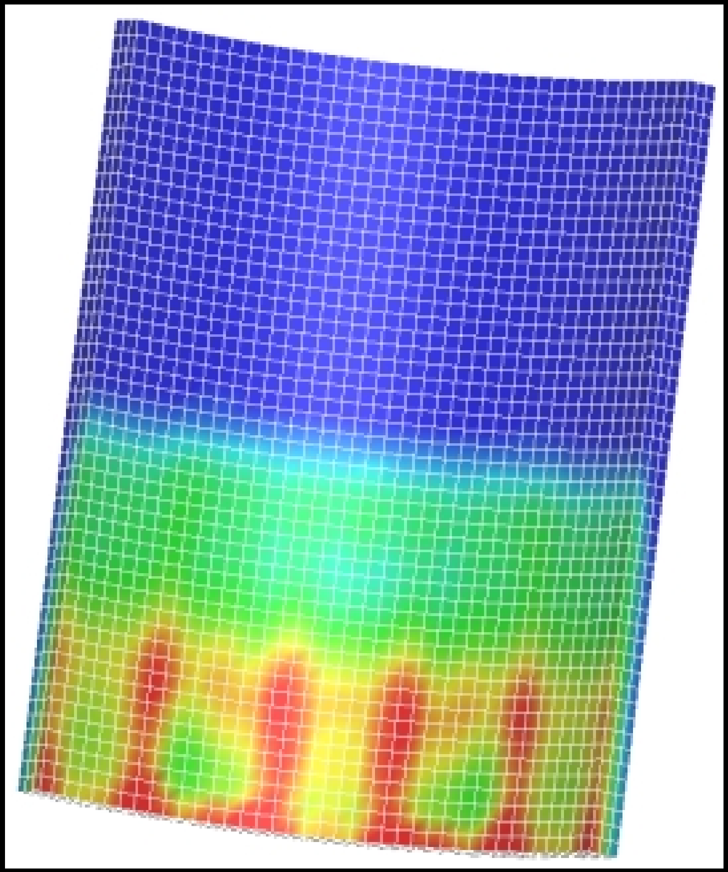


- Pressure wave oscillations can be seen in small oscillations in the displacement plot.

Other Mesh Models



- Multiple Mesh Transitions
- This mesh produces concentrated pressure loading on the cylinder



- Concentrated pressure loading, corresponds to the mesh transitions shown in the previous figure

Future Work

- Mesh geometry studies
- Compare JWL and JWLB peak overpressure for TNT
- Develop composite material models for cylinder
- Compare models with theoretical pressure calculations
- Compare models with experimental data

LS-DYAN Run Information

```
Memory required for explicit solution  :     19757935
 Additional dynamically allocated memory:       128903
                                  Total:     19886838

 T i m i n g   i n f o r m a t i o n
                       CPU(seconds)   %CPU  Clock(seconds) %Clock
  ----------------------------------------------------------------
  Initialization ....... 7.0000E+00    0.11     7.0310E+00    0.11
  Element processing ... 5.2730E+03   86.22     5.2727E+03   86.21
  Binary databases ..... 3.4000E+01    0.56     3.5167E+01    0.57
  ASCII database ....... 1.7000E+01    0.28     1.6758E+01    0.27
  Contact algorithm .... 7.8500E+02   12.84     7.8471E+02   12.83
  Contact entities ..... 0.0000E+00    0.00     0.0000E+00    0.00
  Rigid bodies ......... 0.0000E+00    0.00     6.4000E-02    0.00
  Implicit Nonlinear ... 0.0000E+00    0.00     0.0000E+00    0.00
  Implicit Lin. Alg. ... 0.0000E+00    0.00     0.0000E+00    0.00
  ----------------------------------------------------------------
  T o t a l s            6.1160E+03  100.00     6.1164E+03  100.00

 Problem time       =    2.0001E-02
 Problem cycle      =      9784
 Total CPU time     =      6116 seconds (1 hours 41 minutes 56 seconds)
 CPU time per zone cycle  =     13631 nanoseconds
 Clock time per zone cycle=     13632 nanoseconds

 Number of CPU's     2
 Start time   10/30/2003 12:08:48
 End time     10/30/2003 13:50:51
 Elapsed time     6123 seconds (   1 hours 42 minutes  3 seconds)
```

References

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