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Simulation of Cylinder Expansion Tests Using an Eulerian Multiple-Material Approach

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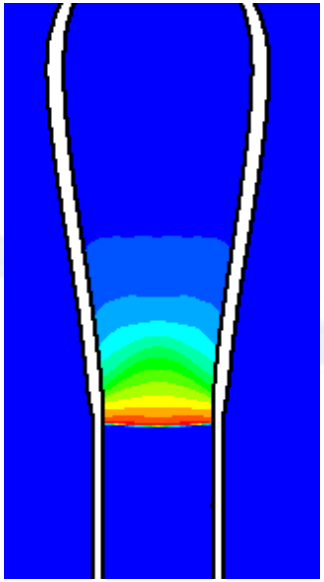
Outline

- Introduction
- Numerical Models
- Preliminary Calculations
- Cylinder Expansion Test Simulations
- Discussion
- Future Work



Introduction

- Cylinder Expansion (CYLEX) tests conducted to determine explosive performance
  - New conventional explosives
  - Non-standard mixes
- Explosive cased in a copper cylinder is detonated
- Resultant expanding wall velocities recorded
- Explosive energy can be determined
- Allows for determination of parameters for detonation product gas equation of state

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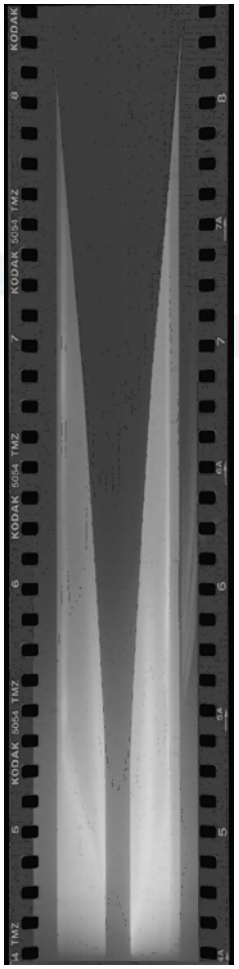
Cylinder Expansion Test



time

Images Courtesy of DRDC Suffield

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Objectives

- Simulation of cylinder expansion tests for three increasingly energetic explosives:
  - Nitromethane
  - TNT
  - Composition B3 (60 wt% RDX, 40 wt% TNT)
- Validation of Chinook CFD code
  - Multiple-material model
  - Reaction model

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Background

- Multiple-material model previously applied to (non-reactive) underwater explosion and landmine simulations
- One of earliest calculations after implementation of advanced energetic material modelling capability in Chinook
- Calculations performed using Eulerian formulation

Model Theory

- Continuum approach – mixed cells with uniform pressure and velocity
- Allows for several equations of state to be used in a calculation
  - Mie-Gruneisen (HOM) for condensed explosive and tube wall
  - JWL for explosive products
  - Ideal gas for air
- One-step Arrhenius reaction model converts reactants into products
  - User-specified heat of reaction

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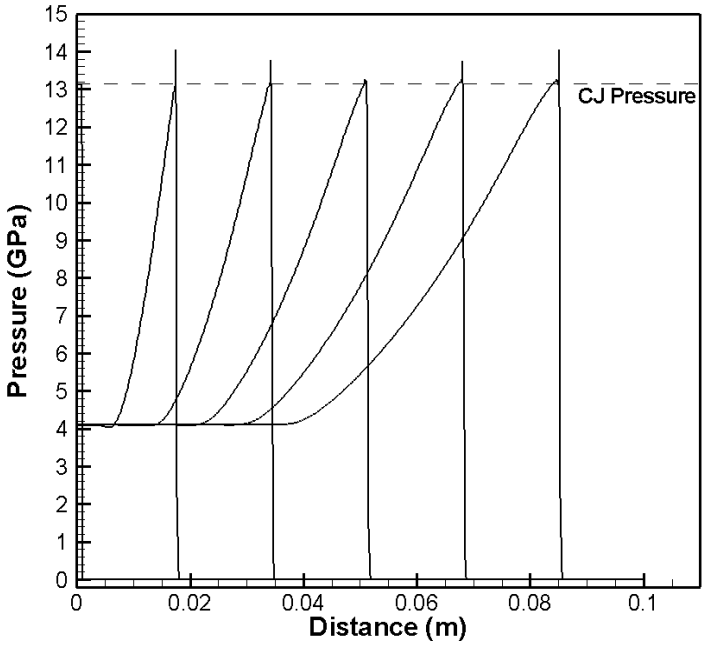
Preliminary Calculations



- 0.1 m long 1D domain
- Small initiation region at CJ state
- 0.2 mm cell size
- CJ pressure and detonation velocity extracted for each explosive

Explosive	Detonation Velocity (m/s)	CJ Pressure (GPa)
Nitromethane	6800 (2.8%)	13.27 (0.84%)
TNT	7280 (1.3%)	19.97 (-1.8%)
Comp B3	8400 (3.1%)	27.03 (-0.66%)

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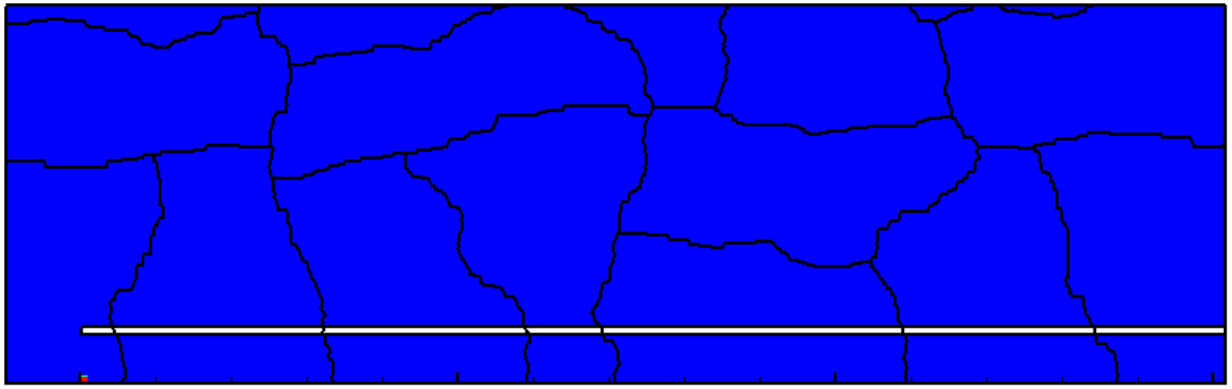
Cylinder Expansion Simulations

- 2D axi-symmetric analysis of cylinder tests
- 30 cm long by 2.54 cm diameter copper tube
- 0.2 mm cell size (structured quads)
- Expanding grids eliminate boundary reflections
- Approximately 1.1 million total cells
  - Utilize parallel computing



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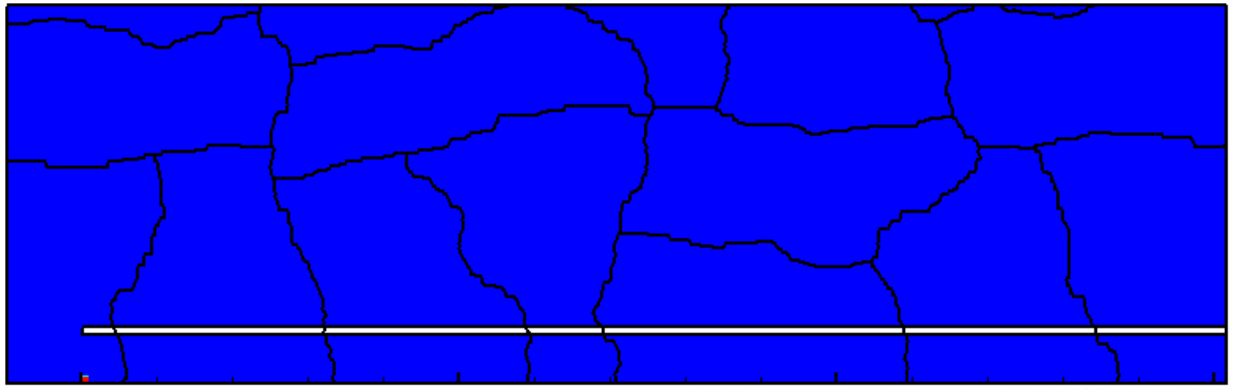
Cylinder Expansion Simulations

- Monitoring array placed 20 cm down tube
- Wall velocities extracted at 6 and 19 mm
- Wall position taken at 0.5 mass fraction copper



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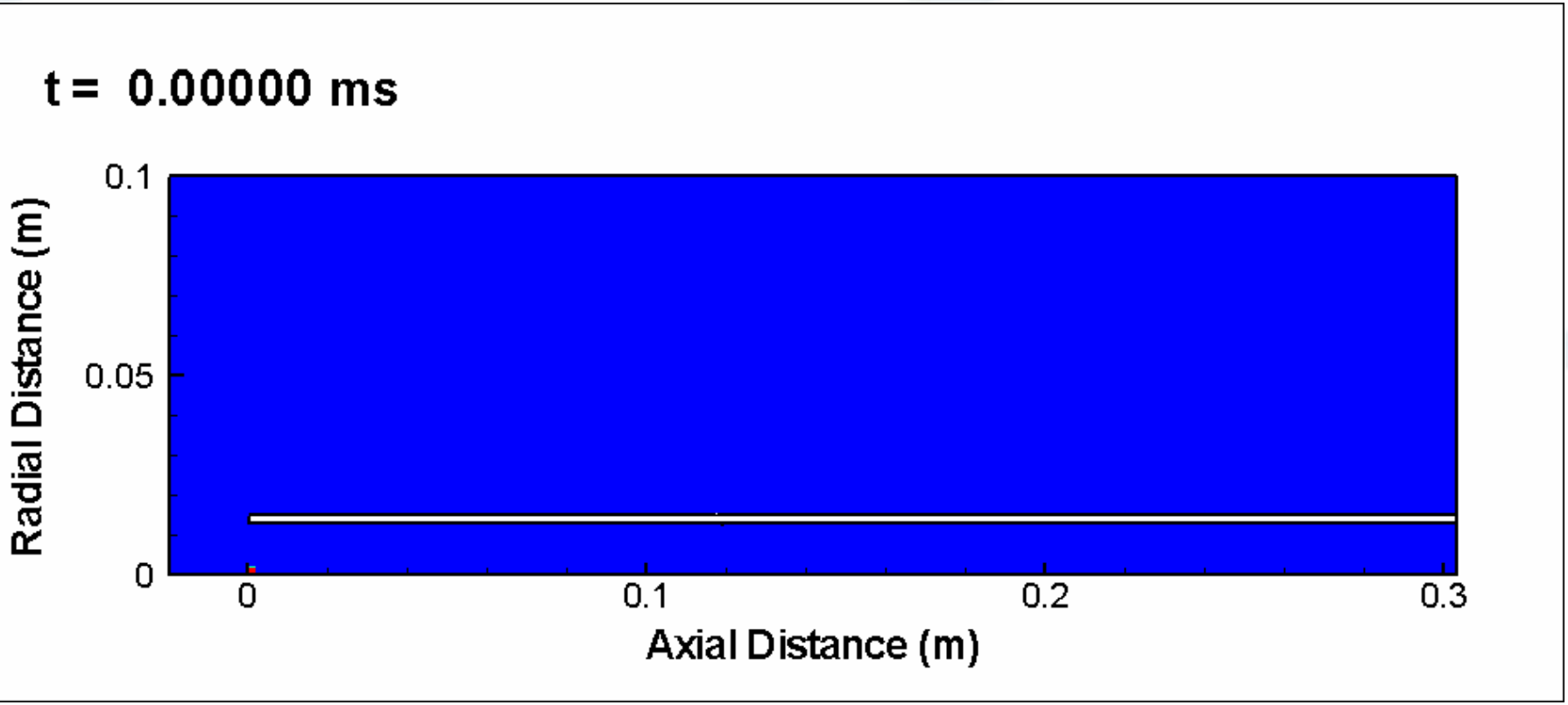
Wall Displacement



Pressure Contours

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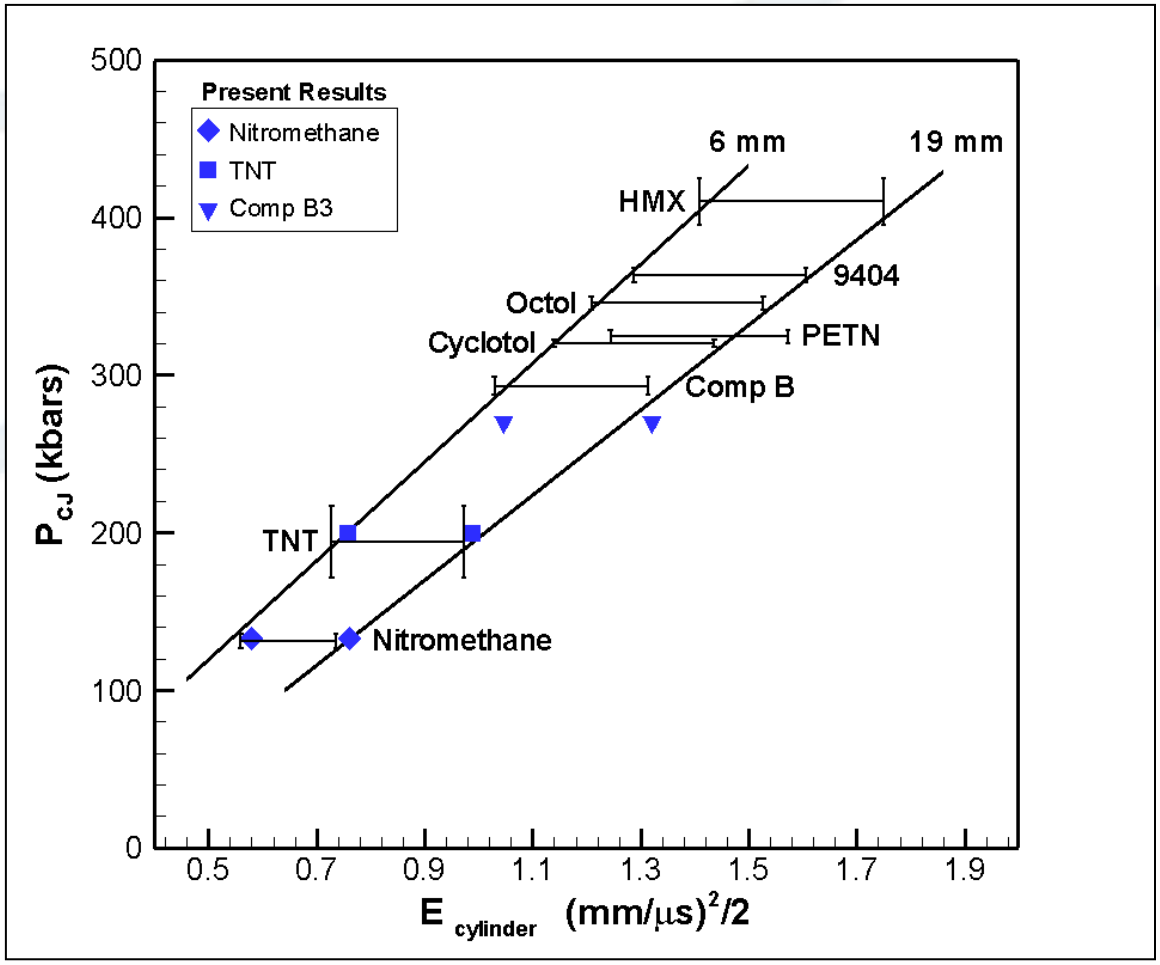
Comparison of Results



Discussion / Future Work

- Reasonable agreement with experimental results
  - CJ pressure / detonation velocity
  - Wall velocities
- Higher mesh resolution ?
- Eulerian approach results in some numerical diffusion
  - Adaptive mesh refinement
  - Material interface tracker
  - Lagrangian or moving mesh
- Next Step: Revisit this study and investigate explosives with higher reaction rates

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