Pressure Vessel Enclosure Penetration Energy Prediction

Jonathan McConnell and Andrew Hicks

Mentors: Kimberly Haulenbeek, Neal Hubbard, Thomas Ivanoff

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SAND2022-10345 PE

Overview

- About us
- Description and goals
  - Motivation
  - Mesh setup
  - Goals
- Model
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  - Johnson-Cook
- Simulations
- Results and conclusions

About us

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Jonathan McConnell

University of Central Florida
PhD candidate, Mechanical Engineering

Current research:

Tethered autogyros

Andrew Hicks

Louisiana State University
PhD candidate, Mathematics

Current research:

Liquid crystals, numerical PDEs

Our rivalry

LSU meets UCF on Jan. 1, 2019 (source: ESPN)

Description & Goals

Motivation

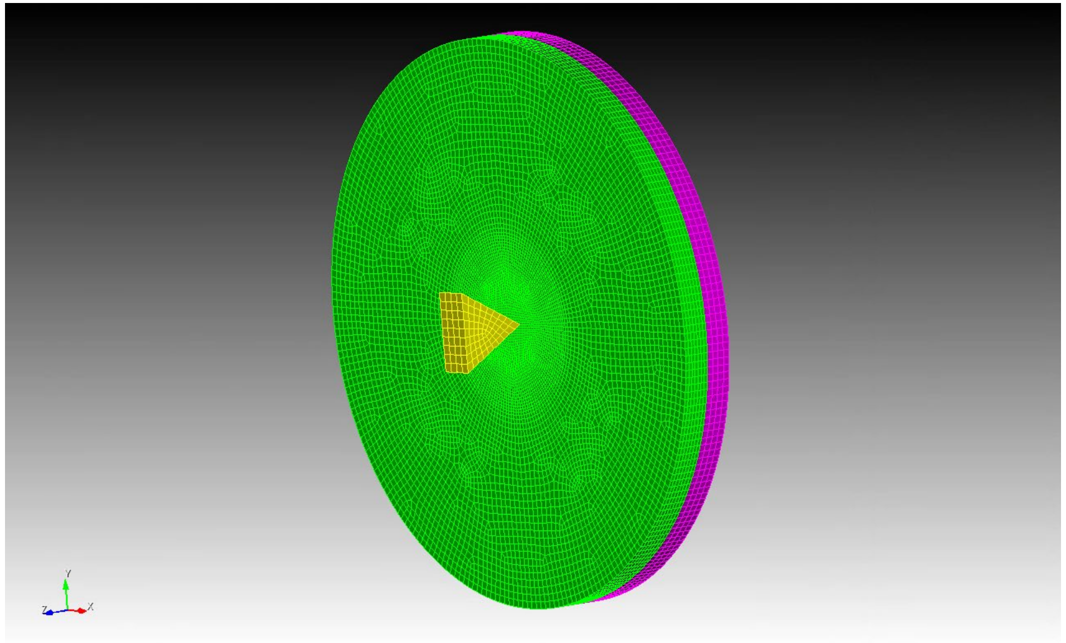
- Pressure vessels failure poses significant risk to surrounding people/equipment
- Study of pressure vessel failure poses similar risk to experimentalists/equipment
- Proper safety enclosure design is necessary
- Simulation of high energy shrapnel collision can give insight into enclosure design

Mesh setup

- Components of model:

  Projectile | Barrier | Gasket

- Projectile shot into barrier at initial velocity
- Gasket present in half of simulations
- Gasket may help absorb some energy



Goals

- Simulate with various enclosures to find projectile kinetic energy (KE) required to either penetrate barrier or launch a “plug” projectile out of barrier
- Two barrier materials: A36 steel (bulk of barrier) and polycarbonate (viewing window)
- One gasket material: neoprene
- Three steel barrier thicknesses:
  - 6.35 mm (0.250 in)
  - 9.53 mm (0.375 in)
  - 15.88 mm (0.625 in)
- Three polycarbonate barrier thicknesses:
  - 12.70 mm (0.500 in)
  - 19.05 mm (0.750 in)
  - 31.75 mm (1.250 in)

Model

Model choice

- Two models were chosen: elastic/plastic and Johnson-Cook

- Elastic/plastic:
  - Simple linear relationship between stress and strain
  - Neglects effect of temperature and strain rate

- Johnson-Cook:
  - Requires more test data
  - Requires curve fitting
  - Incorporates temperature and strain-rate effects
  - More accurate representation of damage and fracture

Johnson-Cook model

- Stress-strain relationship:

The von Mises tensile flow stress σ is expressed by

$$\sigma = (A + B\epsilon^n)(1 + C \ln \dot{\epsilon}^*)(1 - T^{*m})$$

where A, B, C, m, and n are constants, ϵ is the equivalent plastic strain, $\dot{\epsilon}^*$ is the nondimensionalized strain rate, and T^* is the homologous temperature [1]

Johnson-Cook model

- Damage model

The damage D to an element is expressed by

$$D = \sum {}^{\Delta\epsilon}/_{\epsilon^f}$$

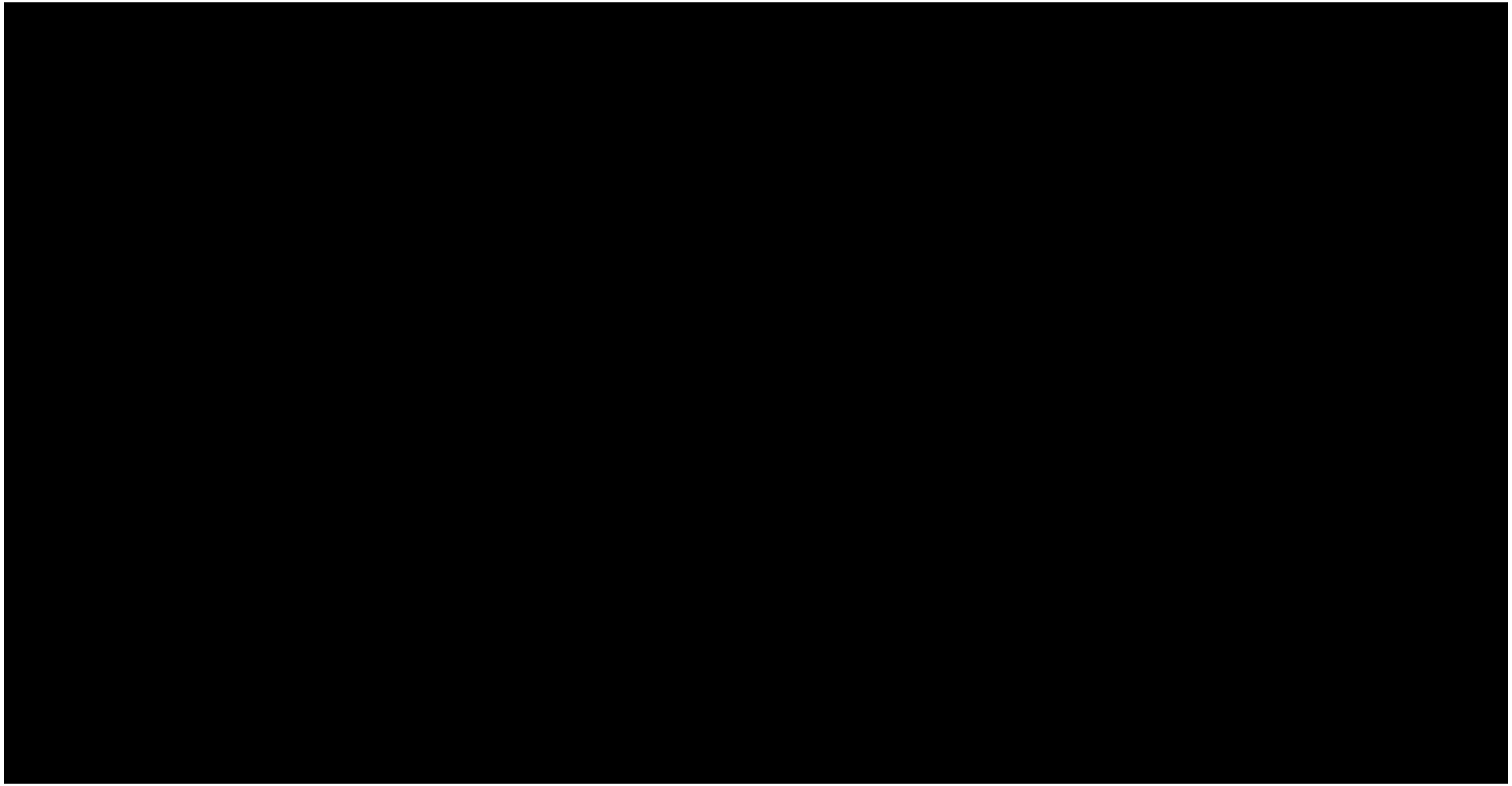
where $\Delta\epsilon$ is the increment in equivalent plastic strain, and ϵ^f is the strain required to fracture, defined by

$$\epsilon^f = (D_1 + D_2 \exp(D_3\sigma^*))(1 + D_4 \ln \dot{\epsilon}^*)(1 + D_5 T^*)$$

where $D_1, \ldots, D_5$ are constants and σ^* is the nondimensional pressure-stress ratio. [1]

Simulations

Simulations



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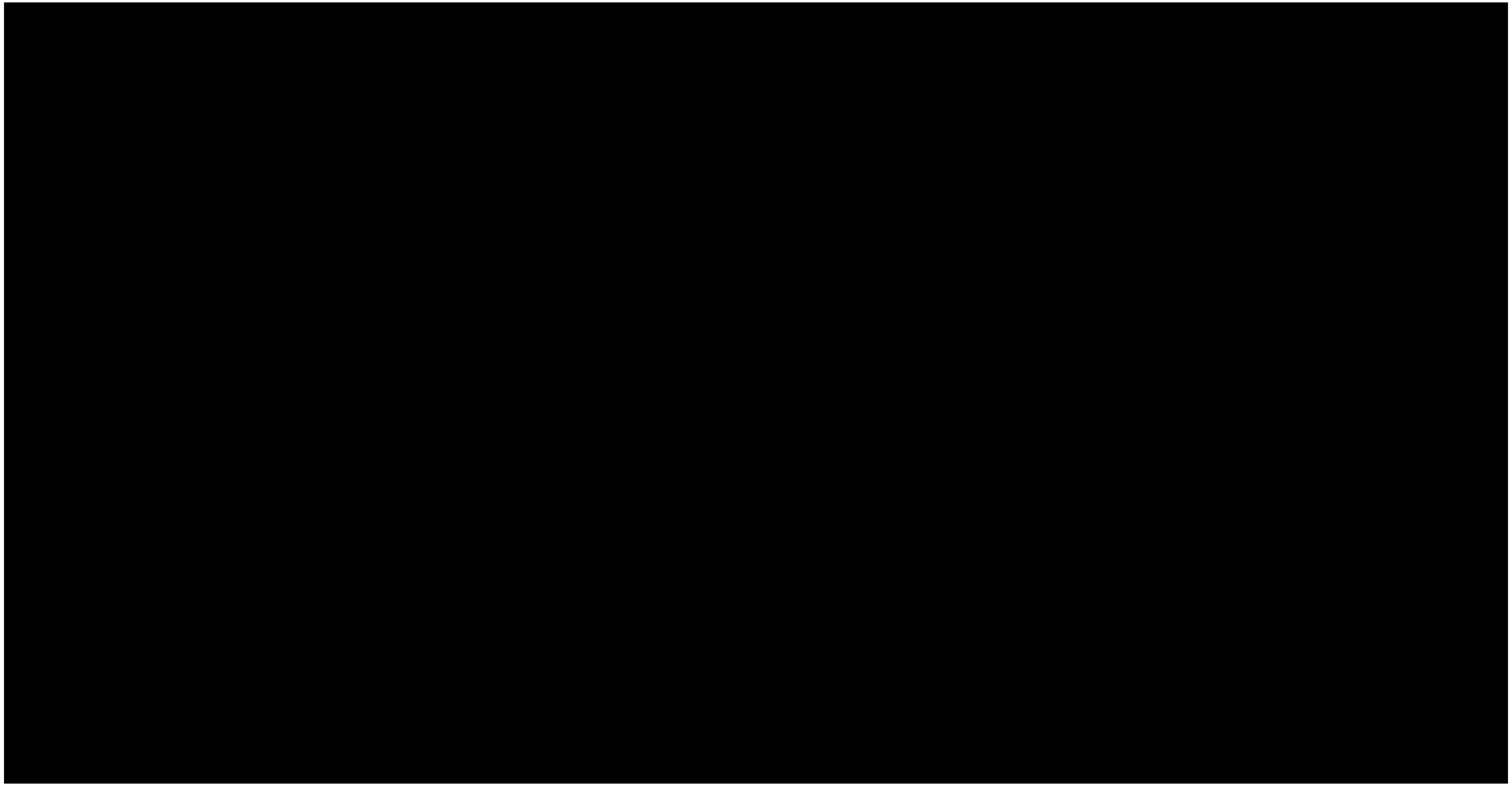

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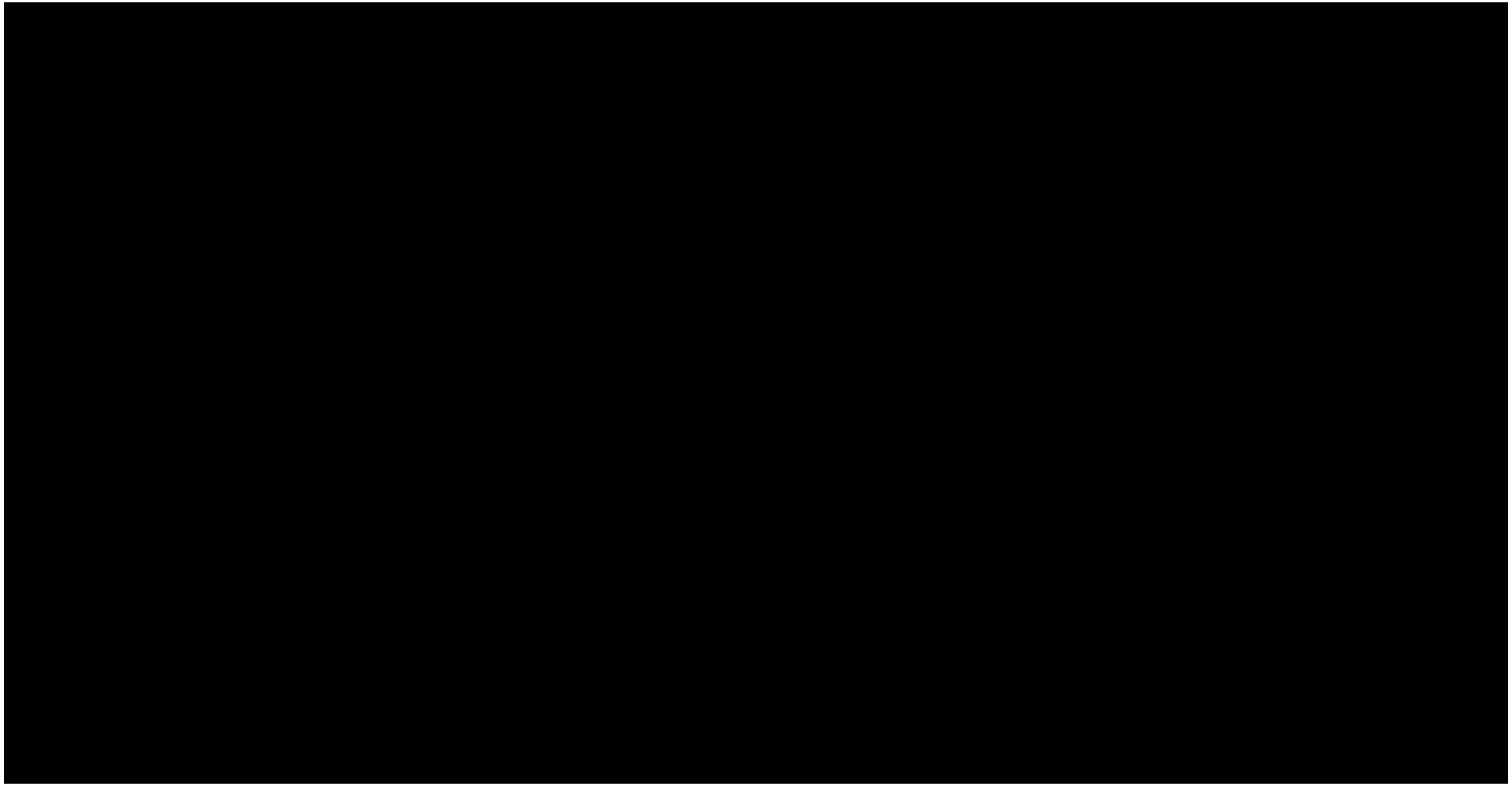
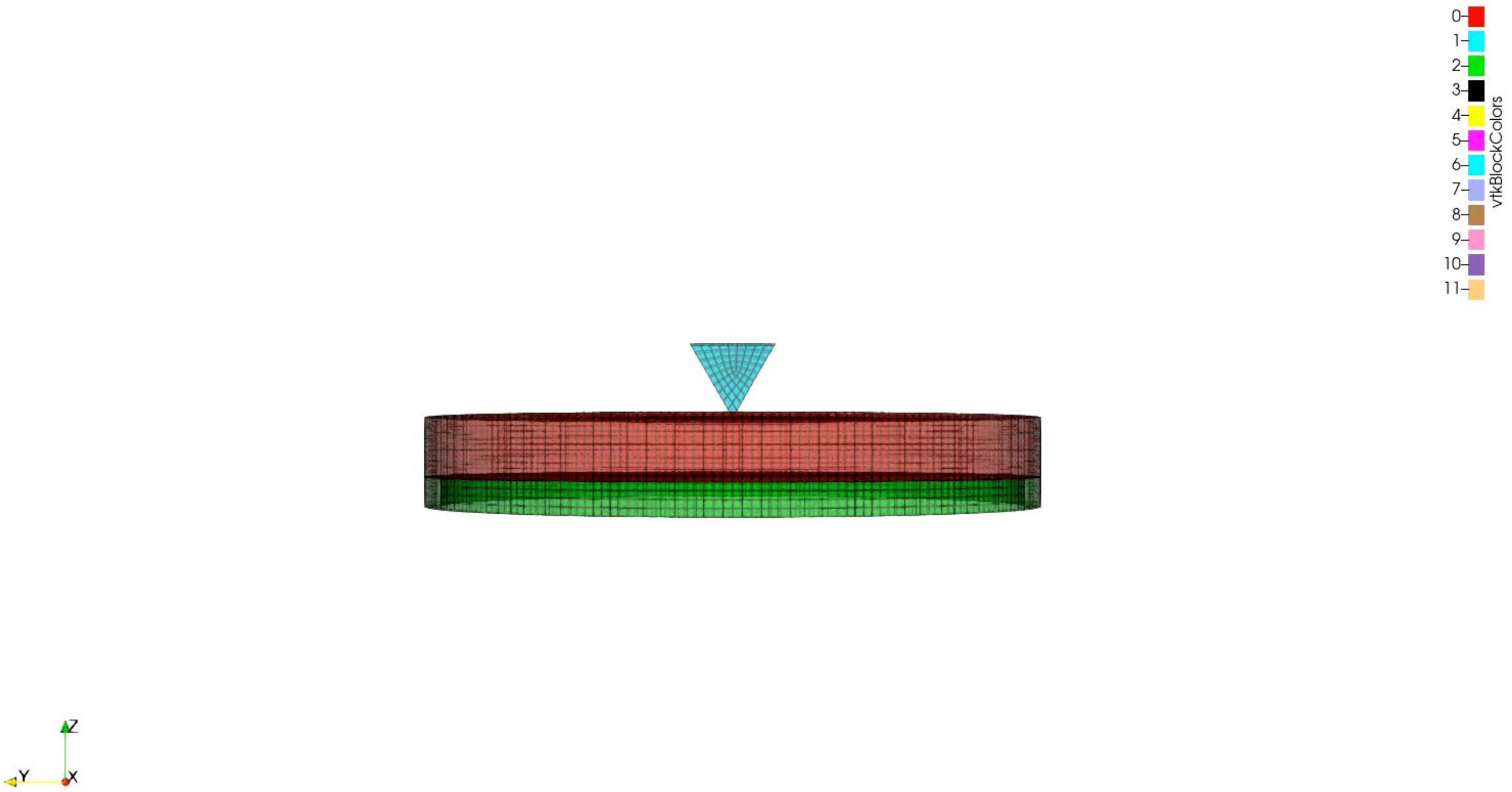
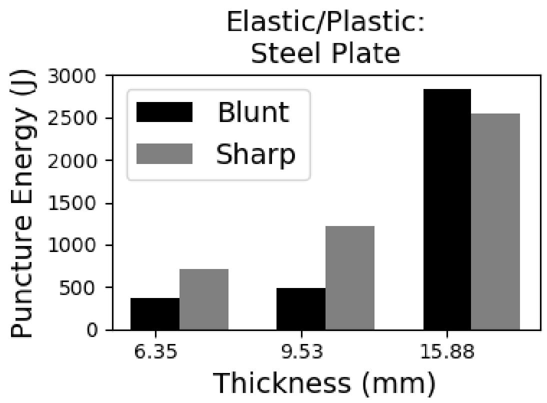


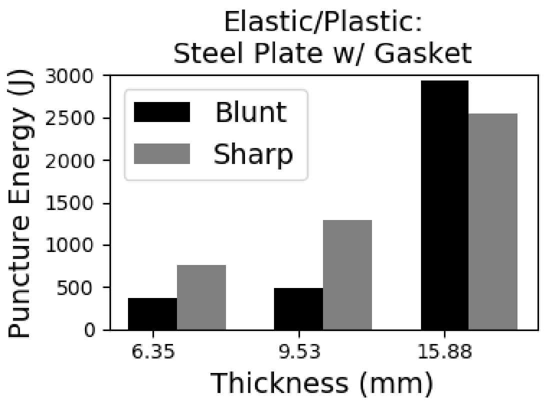
Simulation – Polycarbonate 0.75 in w/ Gasket at 275 m/s



Results and conclusions

Results


Elastic/Plastic:
Steel Plate
Blunt
Sharp
Puncture Energy (J)
0
500
1000
1500
2000
2500
3000
6.35
9.53
15.88
Thickness (mm)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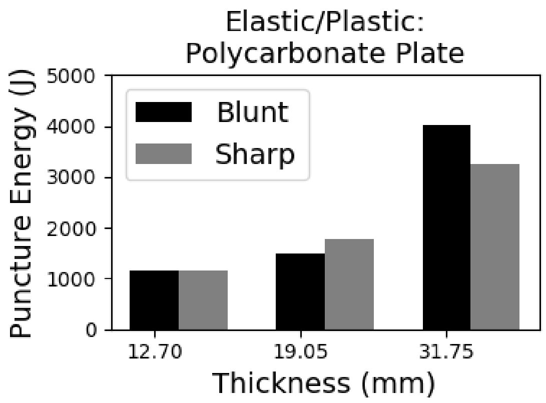
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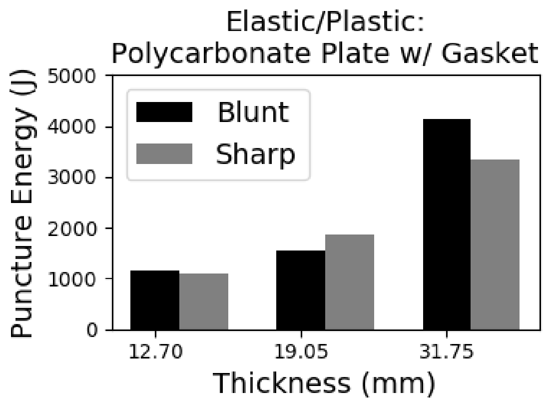
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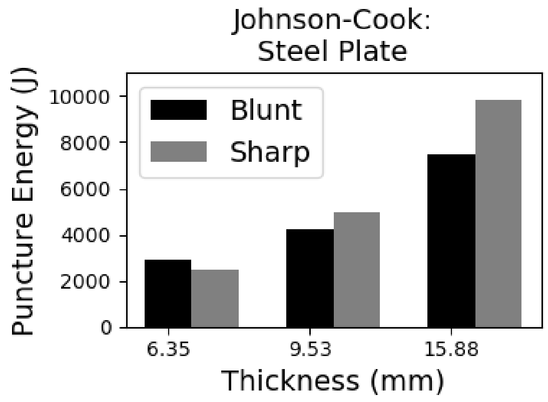
Johnson-Cook:
Steel Plate
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Sharp
Puncture Energy (J)
0
2000
4000
6000
8000
10000
6.35
9.53
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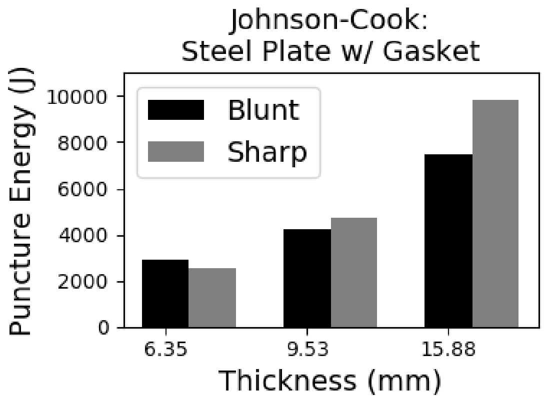
Thickness (mm)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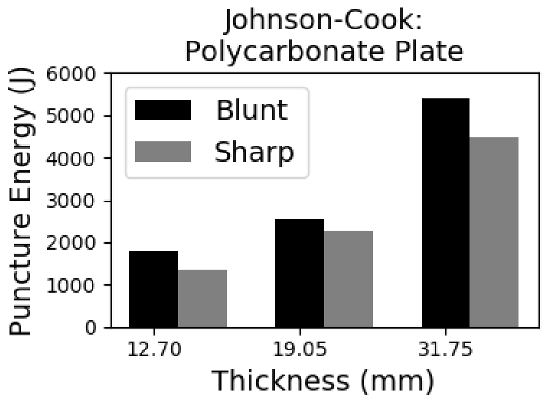
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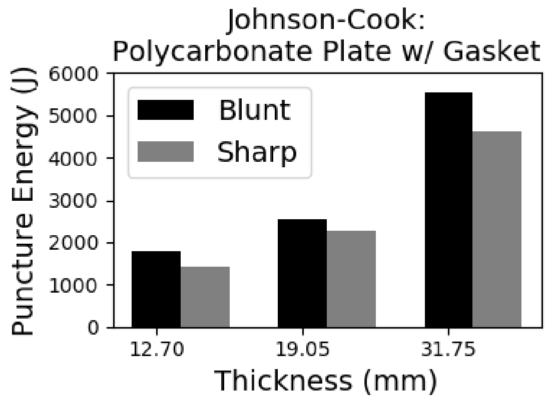
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Conclusions

- The effect of the gasket was negligible for most cases
- For steel plates, a switch is seen between which orientation punctures at lower energy as plate thickness increases
- For polycarbonate, sharp took less energy for all thicknesses
- The Johnson-Cook model required higher energies for penetration than the Elastic/Plastic
- For moderate wall thickness, viewing window area should be minimized
- The strength to stop a projectile does not guarantee safety from plugs

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Thank you!!! :D

Any questions?