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Sandia National Laboratories

Surety Technical Basis Development: Abnormal Mechanical Environments

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Motivation

Sandia National Laboratories

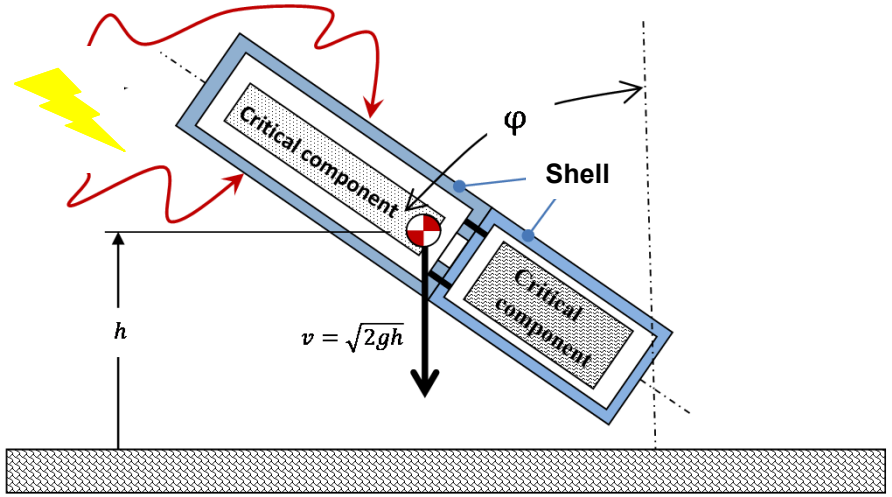
The Weapon Analysis Department provides customers with a **technical basis** for making surety decisions based on fundamental physics by combining expert knowledge with computational and physical analyses

Examples

- Abnormal environments
  - Abnormal Mechanical: High speed impact with a immovable barrier
- Insults/hazards encountered during assembly/disassembly
  - Probe impact: Falling/tripping man carrying a tool
- Safety assurance support for design
  - Pre-test prediction of component responses to abnormal environments

Problem

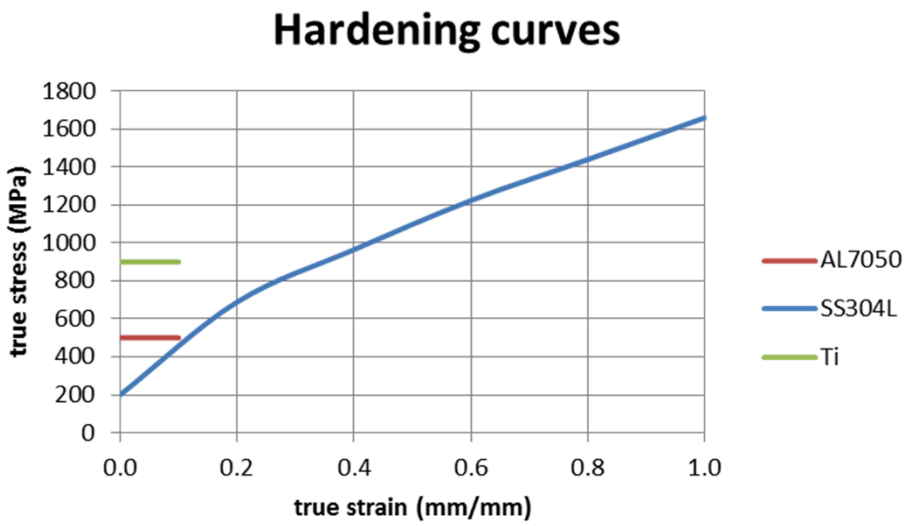
- Select a material for a container with constant mass that maintains its integrity (e.g., water tight or electrically isolated) after being dropped
  - Two shells joined together with 3/8” diameter bolts



Materials

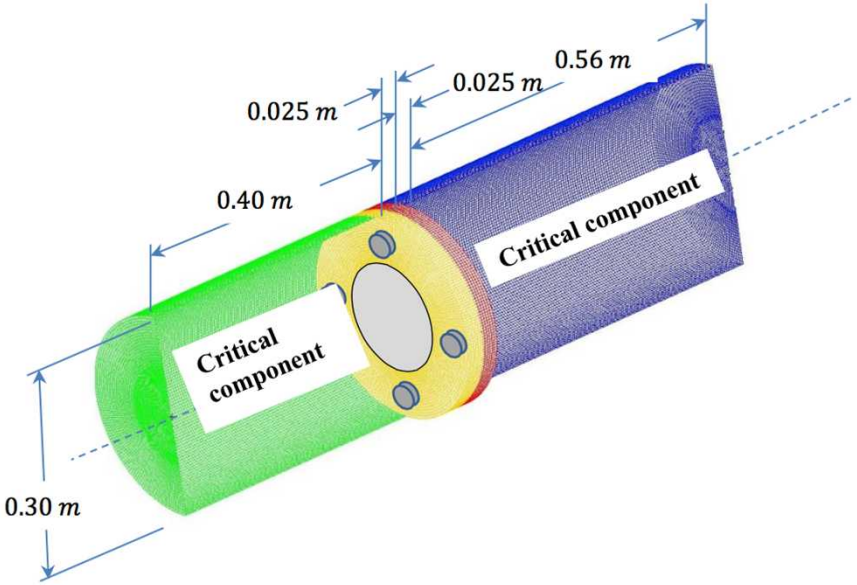
- Aluminum (Al7075)
  - Brittle, Low Toughness
- Titanium (Ti)
  - Brittle, Medium Toughness, Highest Yield
- Stainless Steel (SS304L)
  - Ductile, High Toughness

Material	Density (kg/m^3)	Elastic modulus (GPa)	Poisson ratio	Yield (MPa)	Failure strain
Al7050	2810	70	0.33	500	0.1
SS304L	7860	200	0.28	200	1.0
Ti	4430	114	0.32	900	0.1



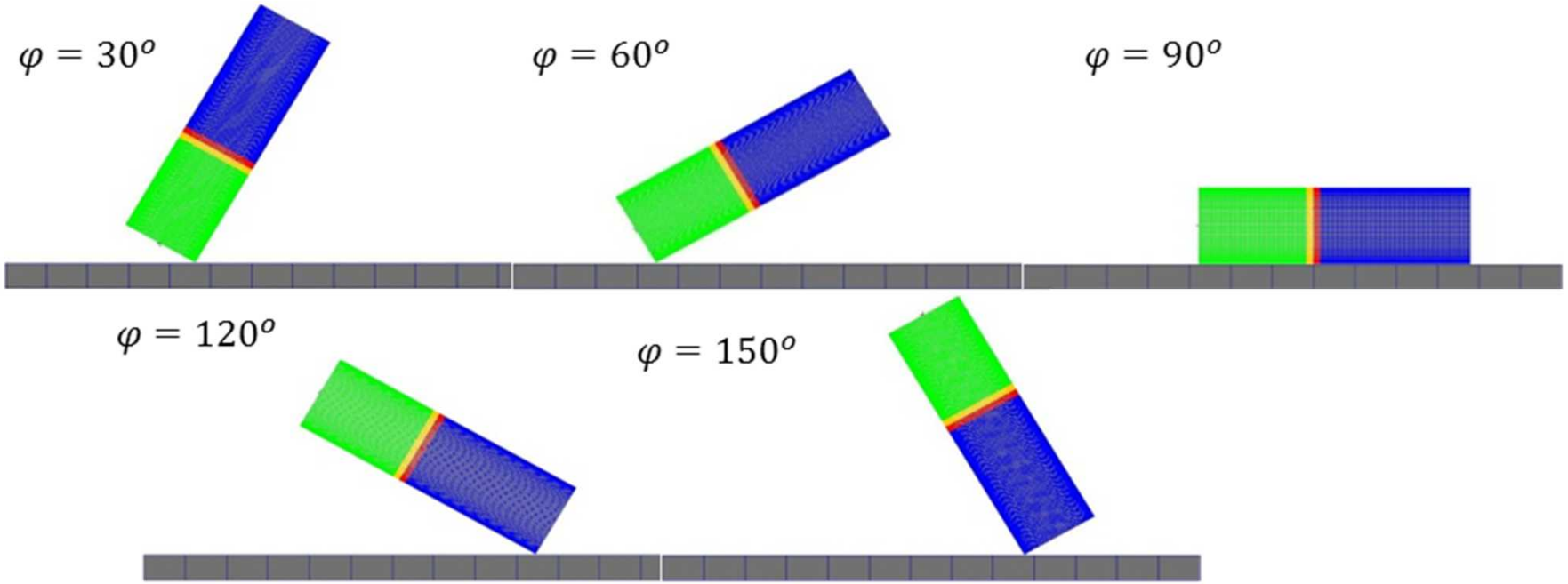
Model

- Container shell meshed using shell elements
  - Shell thickness was modified according to the material
- Bolts modeled using simple beam elements and spiders
- Contact surface meshed using hex elements
- To facilitate an environment search use < 200k elements

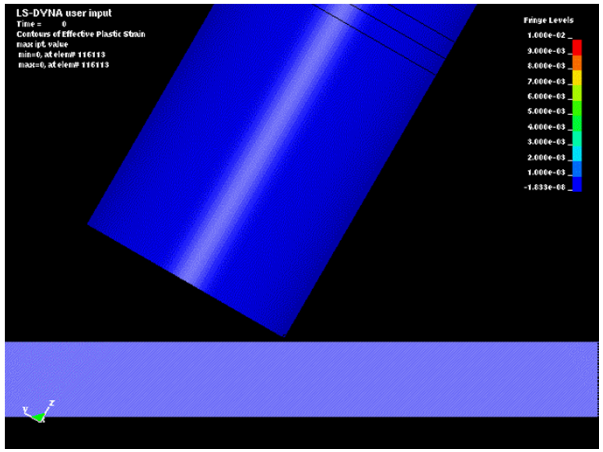


Environment Search

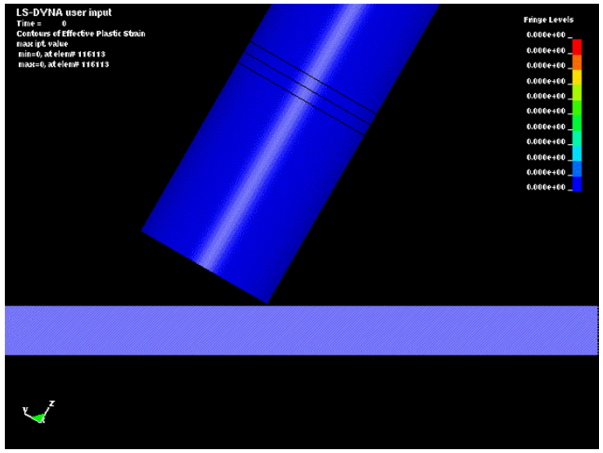
- Drop simulations were performed at five different angles
  - 30, 60, 90, 120, 150 degrees
- The varying drop heights were simulated by changing the impact velocity



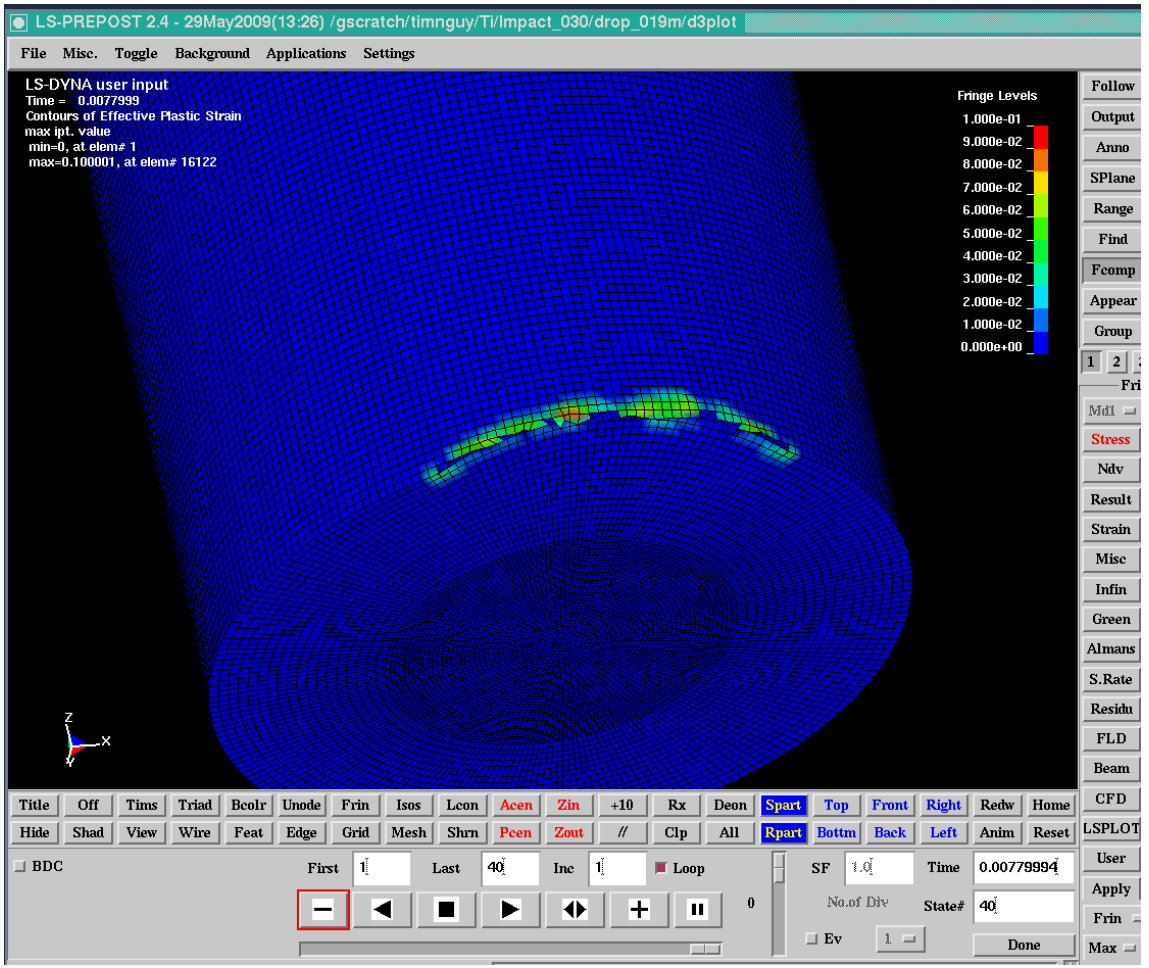
Impact Results



Aluminum (Al7075)



Stainless Steel (SS304L)



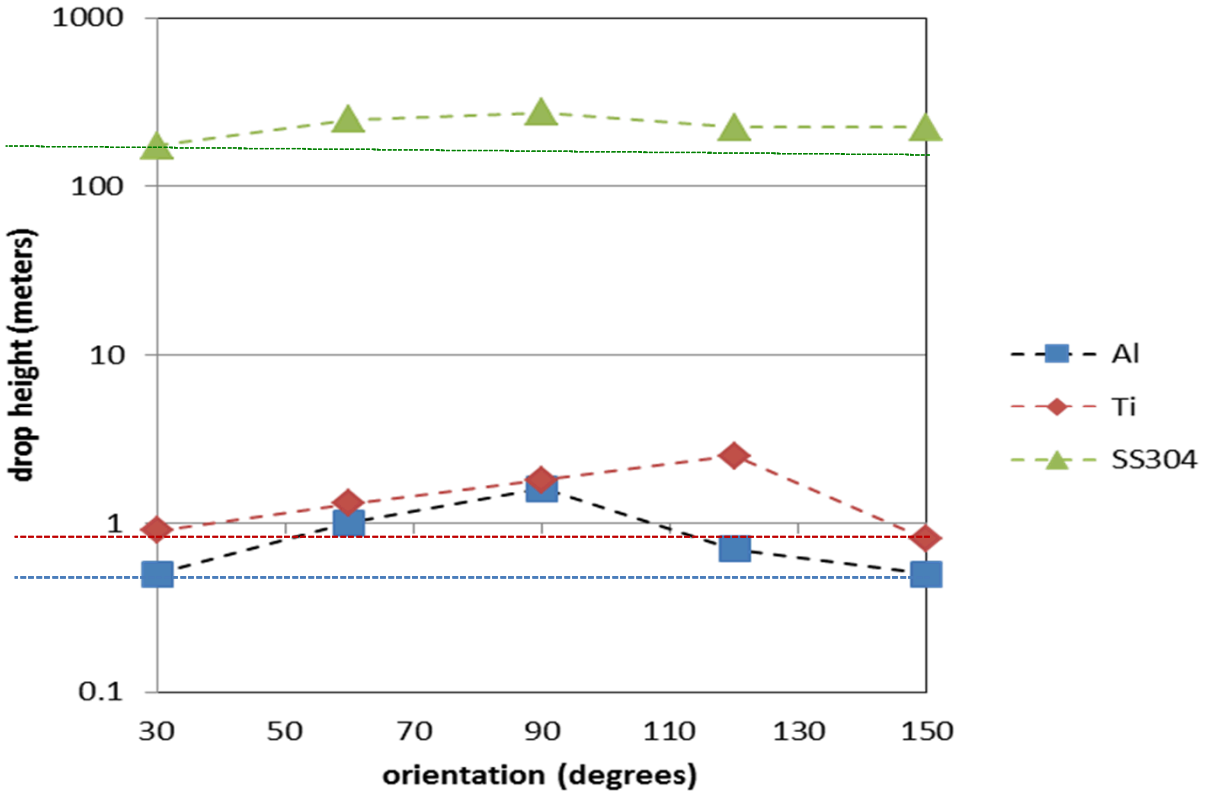
Ti

Results

- The baseline material Aluminum was the least effective
- Titanium was only marginally better than Aluminum
- Steel was by far the best material by two orders of magnitude

$\min(h_{cr})$ = 175 m (58.6 m/s)

$\min(h_{cr})$ = 0.9 m (4.2 m/s)
$\min(h_{cr})$ = 0.5 m (3.1 m/s)

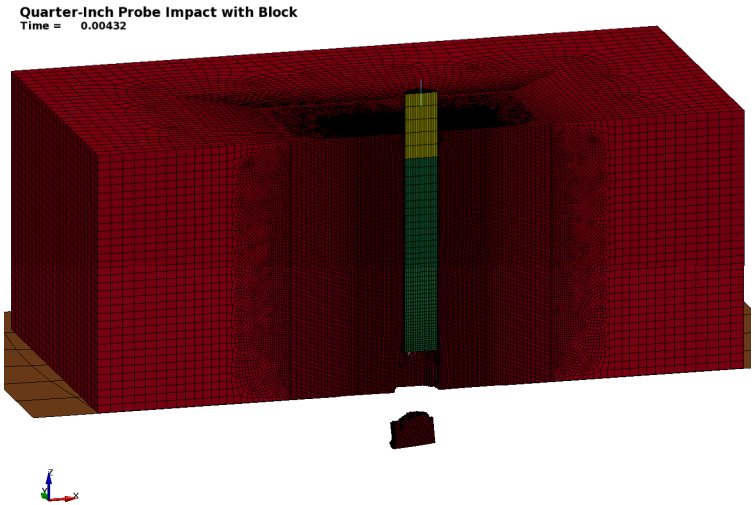


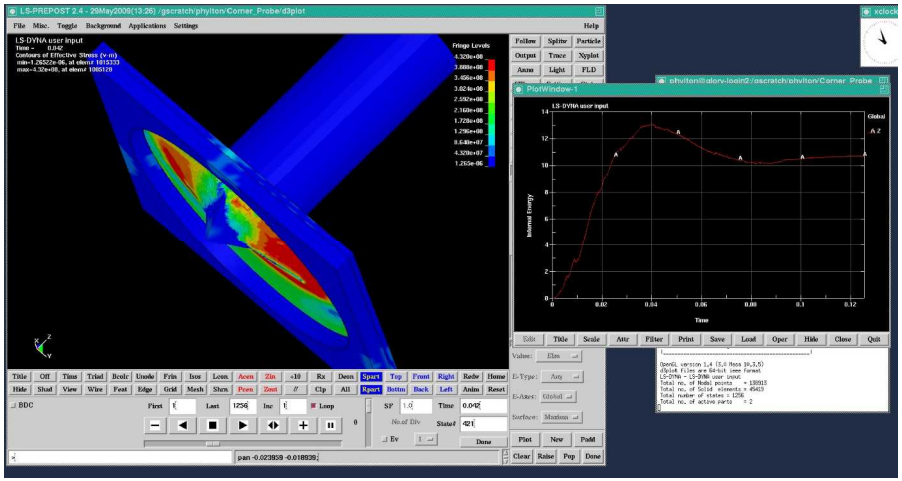
Acknowledgements

- This work was performed by mechanical engineering student intern Timothy Nguyen (sophomore MIT) over a period of 10 weeks under the guidance of Surety Analyst Jeff Dohner

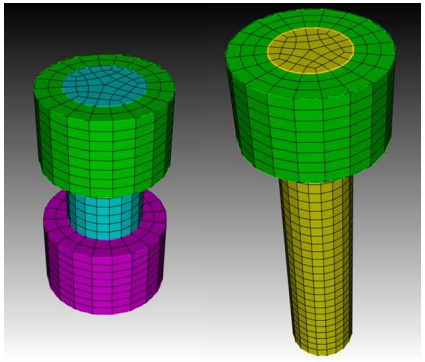
Additional Mechanical Analyses

Probe impact analyses of brittle and ductile materials





Bolt/Fastener modeling



Design assurance: Sled track pre-test prediction