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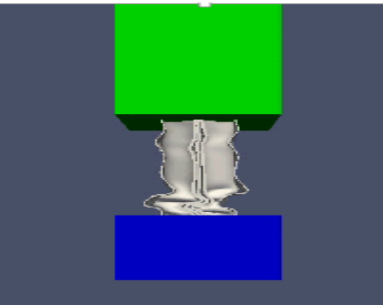
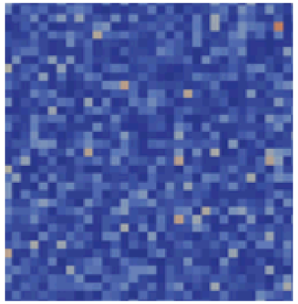
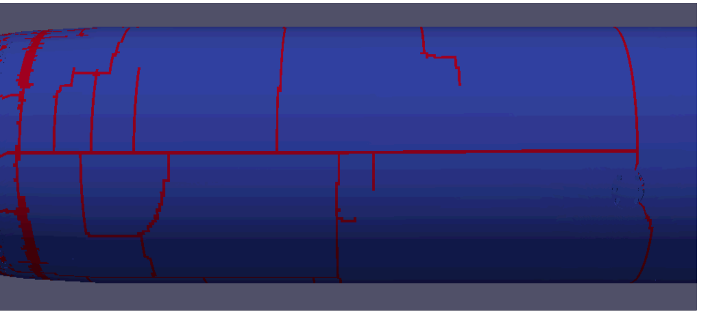

Sandia National Laboratories

Exceptional service in the national interest

Improved Material Representations for More Predictive Modeling

Nick Kerschen (Mentor: Chris Hammetter)

1554 Technical Exchange

7/25/2016

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Overview

- Background
- Technical Problems
- Technical Approach
- Weibull Distribution
  - Description
  - Implementation
  - Results
- Aluminum Characterization
  - Fitting material model
  - Use in simulations
  - Results
- Conclusion

Background

- Graduated May of 2016 with a B.S. in Mechanical Engineering from N.M. State
- Will attend Purdue University in the Fall of 2016 as a Master's student under Dr. Wayne Chen
- Master's research will involve shocking energetics using a gas gun
- Third summer at Sandia (second in 1554)
- Native of Albuquerque
- Love sports (especially baseball), and living an active lifestyle

www.nbc15.com

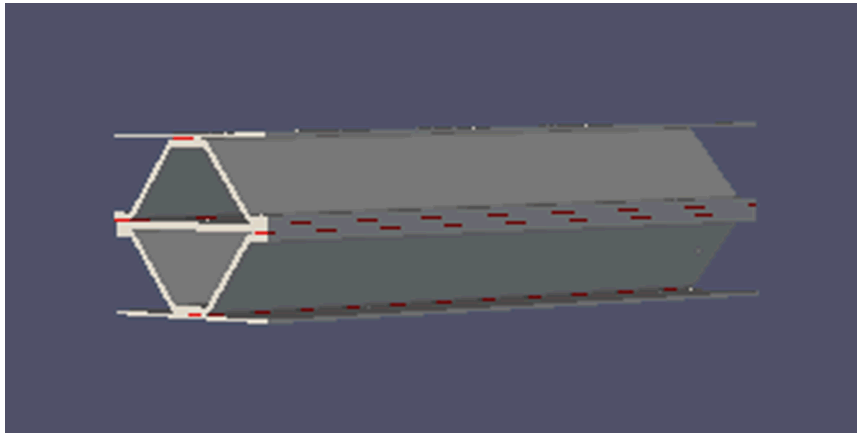
en.wikipedia.org

Technical Problems

- Weibull Distribution
  - Crack sensitivity in aluminum case is too high
  - Will change behavior based on number of processers, small change in unrelated component
  - Ability to obtain consistent cracking behavior is desirable

www.keyword-suggestions.com

- Aluminum Characterization
  - Al-5052 used in honeycomb structure for energy absorption
  - Need better simulation match to gas gun material characterization experiments



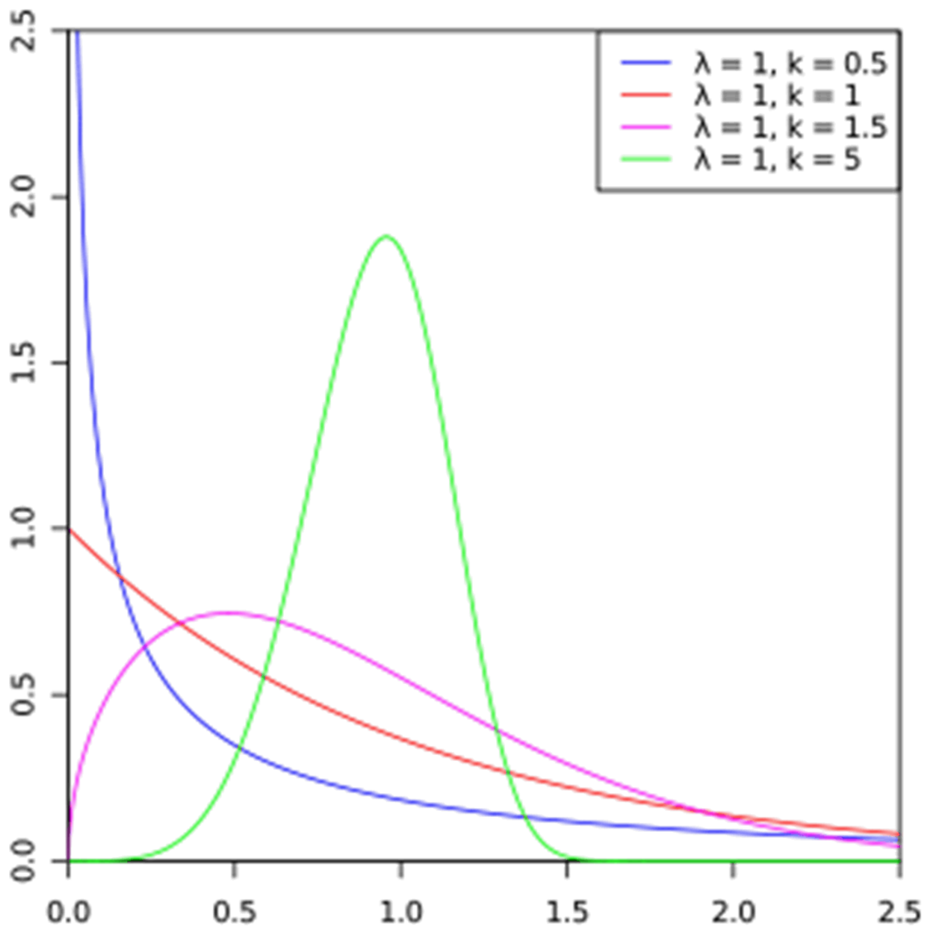
Technical Approach

- Weibull Distribution
  - Hasn't been implemented for aluminum case material models
  - Explore what material models will accept a Weibull Distribution
  - Use the distribution to try and desensitize cracking behavior

- Aluminum Characterization
  - Desire a better representation of Al-5052 Stress/Strain behavior
  - Used a Ductile Fracture model
  - Implement calibrated material model into Honeycomb Crush sim

General Weibull Distribution

- What is Weibull?
  - Used most commonly in failure analysis
  - Two critical parameters
    - Shape (k)
    - Scale (λ)
  - $f(x;\, \lambda, k) = \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} e^{-\left(\frac{x}{\lambda}\right)^{k}};\, x \geq 0$
- How it is used in SIERRA
  - Use to assign different values for a certain material property
  - Can change Weibull parameters to change distribution
  - Same Weibull parameters and mesh will produce repeatable distribution of properties

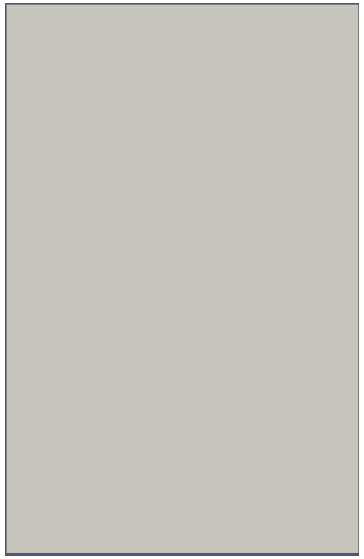


en.wikipedia.org

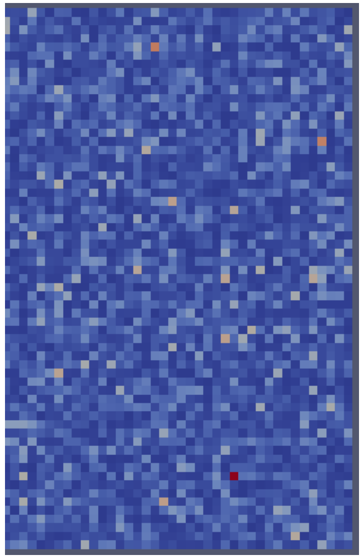
Implementing a Weibull Distribution

- Start with Johnson-Cook model to get Weibull distribution implemented correctly in SIERRA
- Switch over to ml_ep_fail model using same Weibull code
- Run multiple simulations to examine crack behavior sensitivity

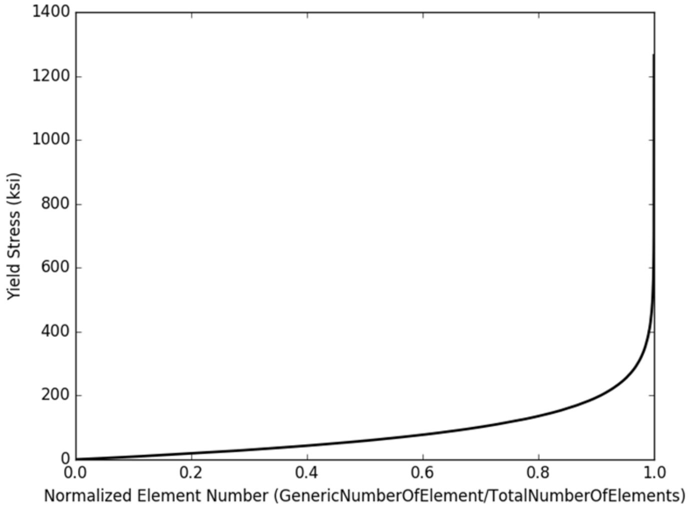
```
BEGIN INITIAL CONDITION Weibull_YieldStress
   block = block_200
   initialize variable name = yield_stress
   variable type = element
   weibull median = {yield_stress}
   weibull seed = 123456
   #weibull scale =5
   weibull shape = 1
END INITIAL CONDITION  Weibull_YieldStress
```



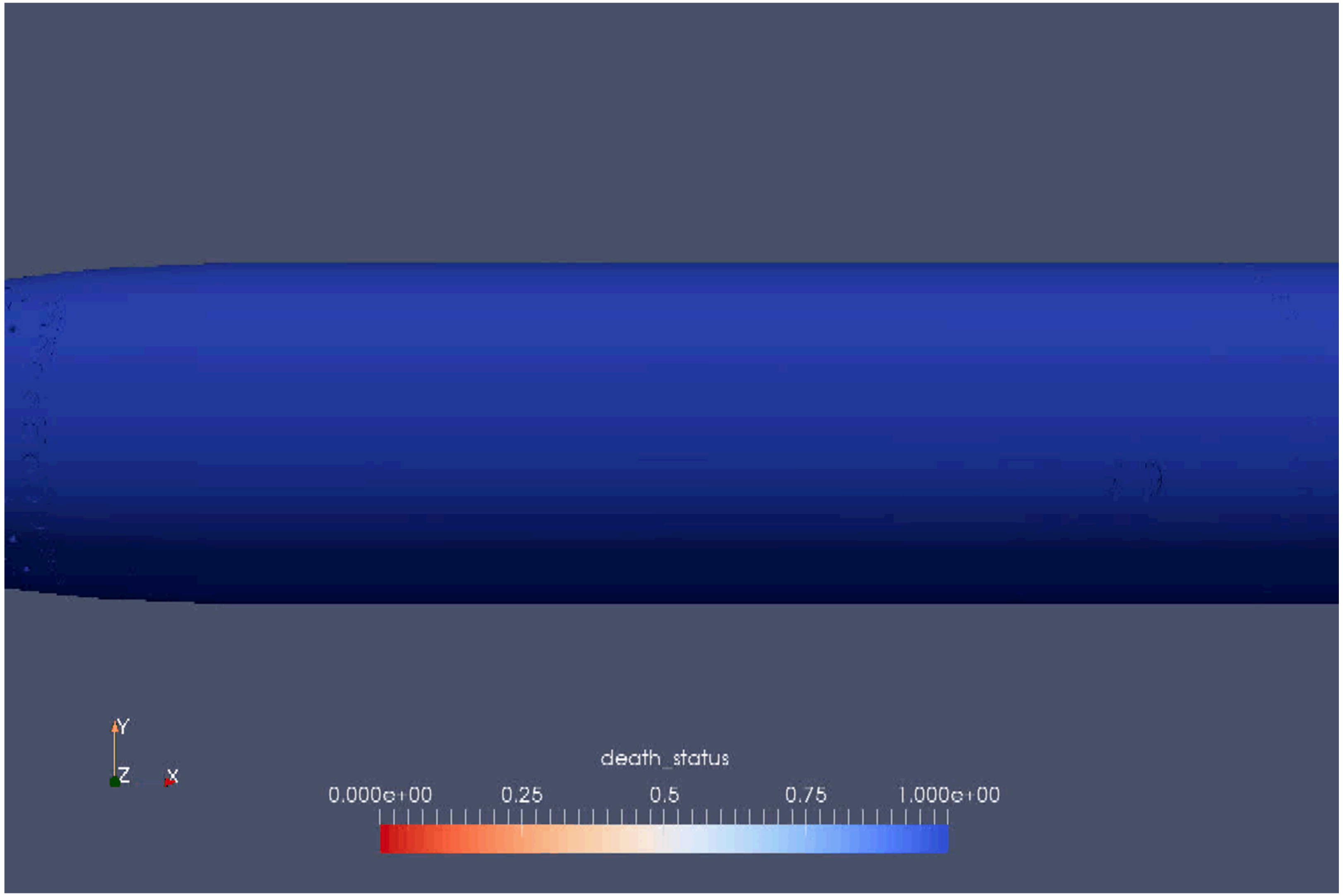
Block with uniform yield stress distribution



Block with Weibull yield stress distribution

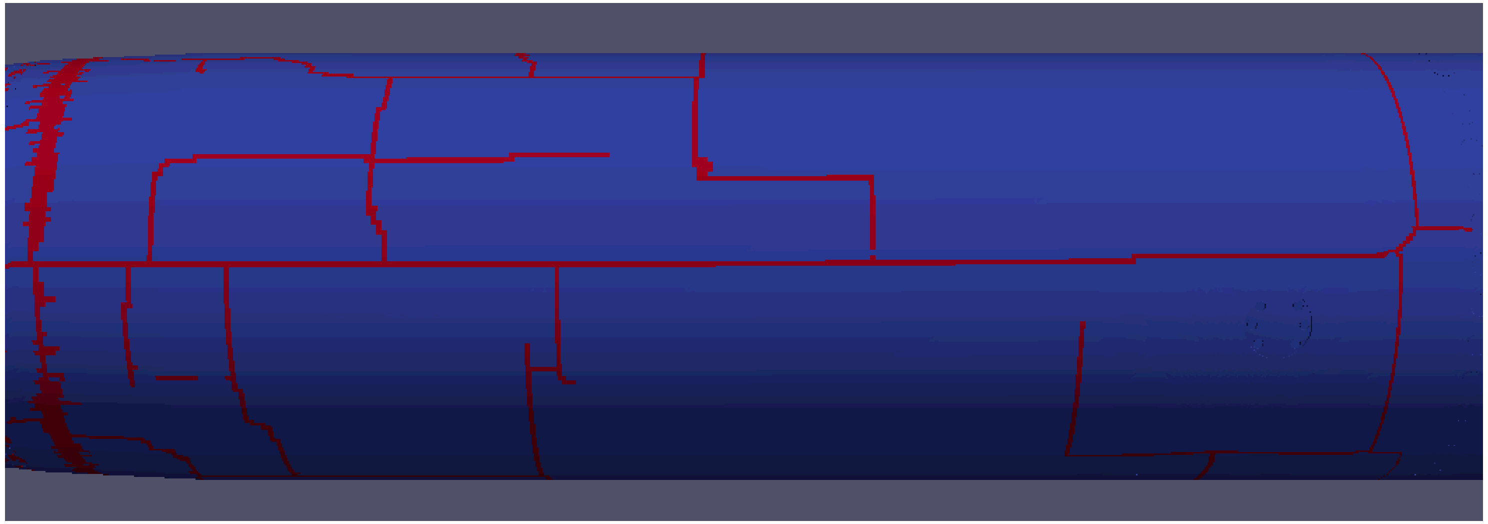


Results



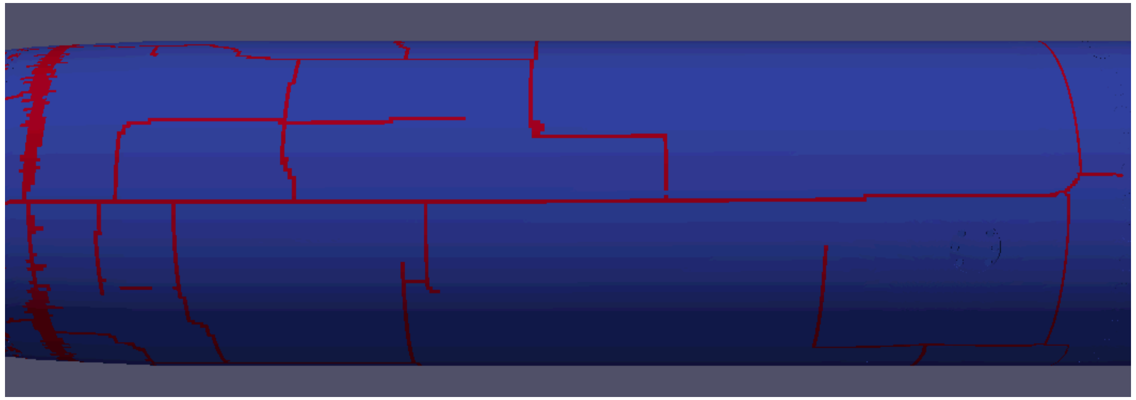
Results (Baseline)

- Uniform aluminum case yield stress distribution
- Filler concrete yield stress at 4000 psi

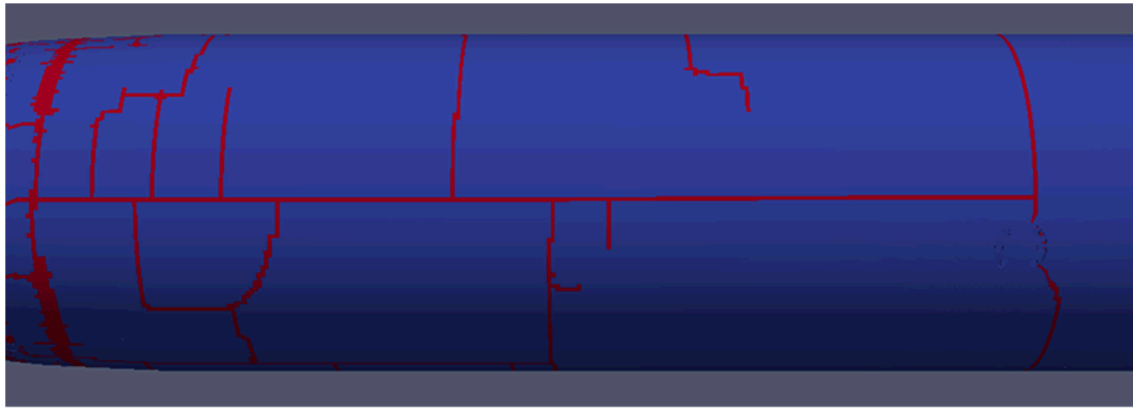


No Weibull ; YS = 4000

Results



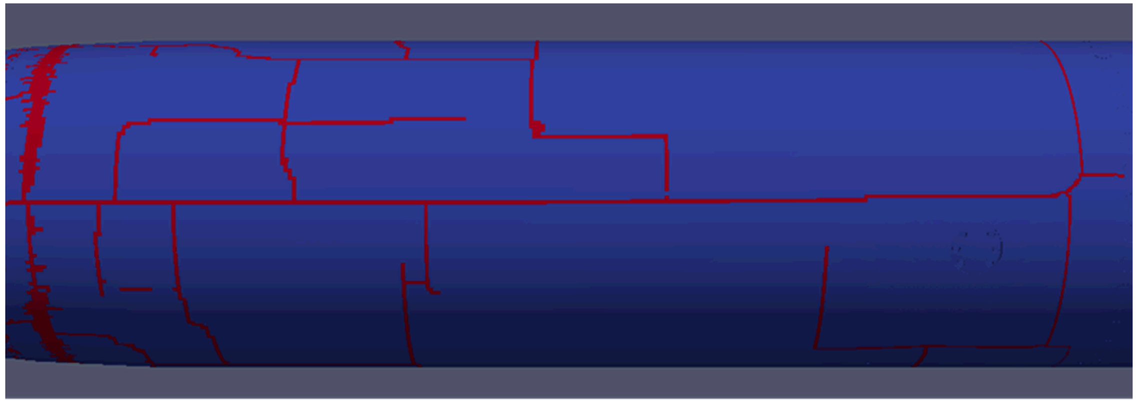
No Weibull; YS = 4000



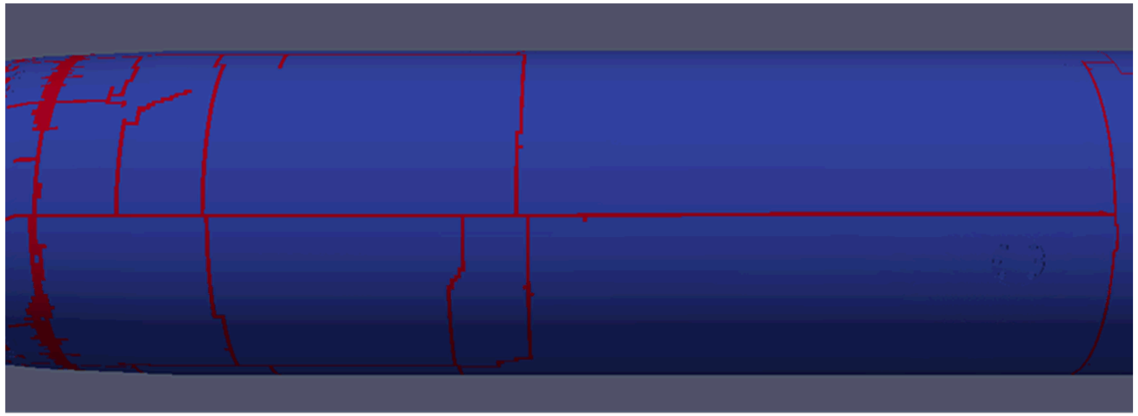
Weibull Implemented; YS = 4000

- Implemented Weibull distribution for aluminum case yield stress
- Kept filler concrete yield stress at 4000 psi
- Expected different crack pattern from baseline simulation

Results



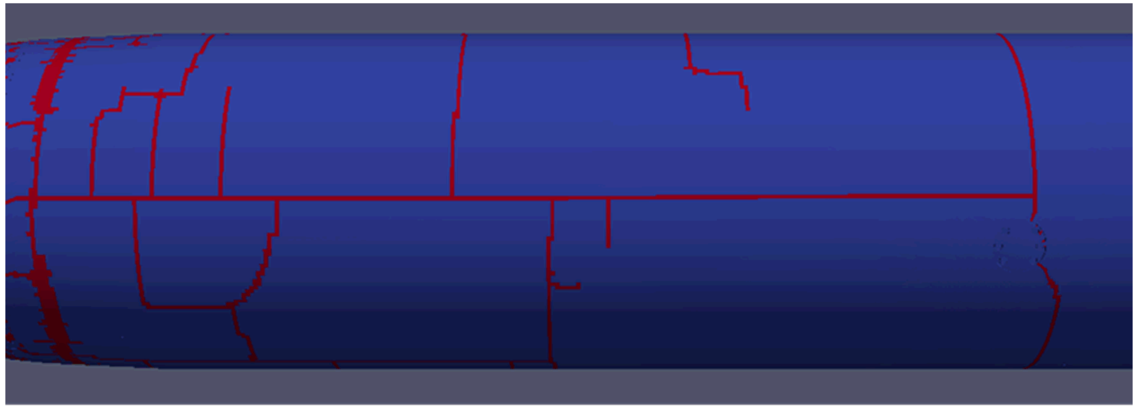
No Weibull; YS = 4000



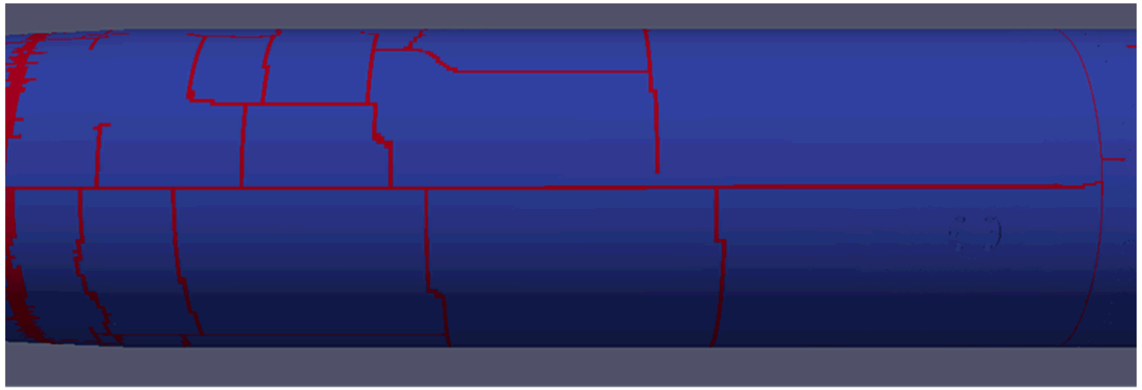
No Weibull ; YS = 4010

- Increased filler concrete yield stress to 4010 psi (increase of .25%)
- Both simulations have uniform distribution of aluminum case yield stress
- Expected different crack patterns

Results



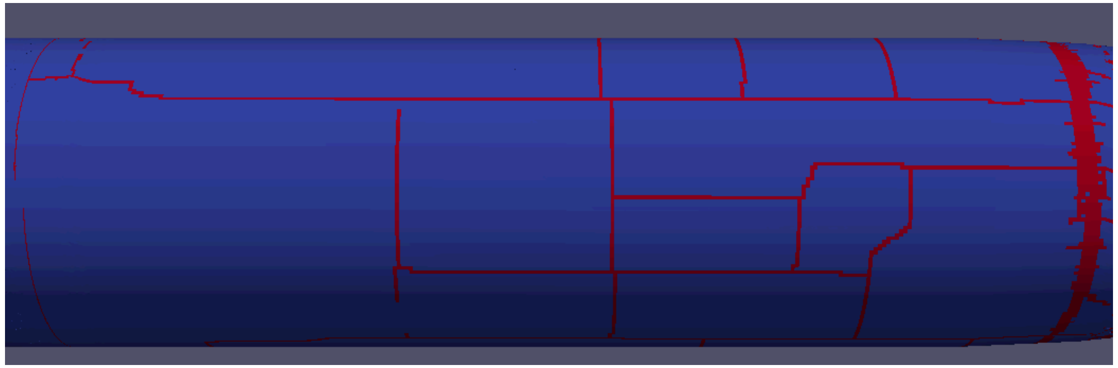
Weibull Implemented; YS = 4000



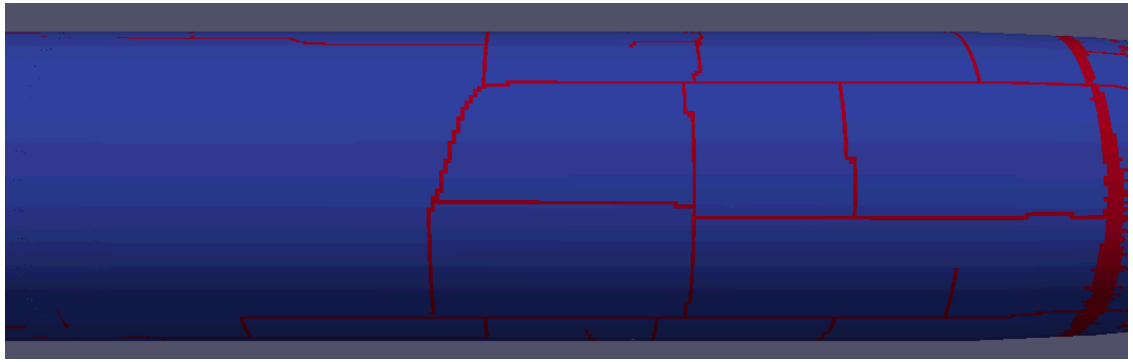
Weibull Implemented; YS = 4010

- Increase filler concrete yield stress to 4010 psi (increase of .25%)
- Both simulations have Weibull distribution of aluminum case yield stress
- Hoping for same crack pattern

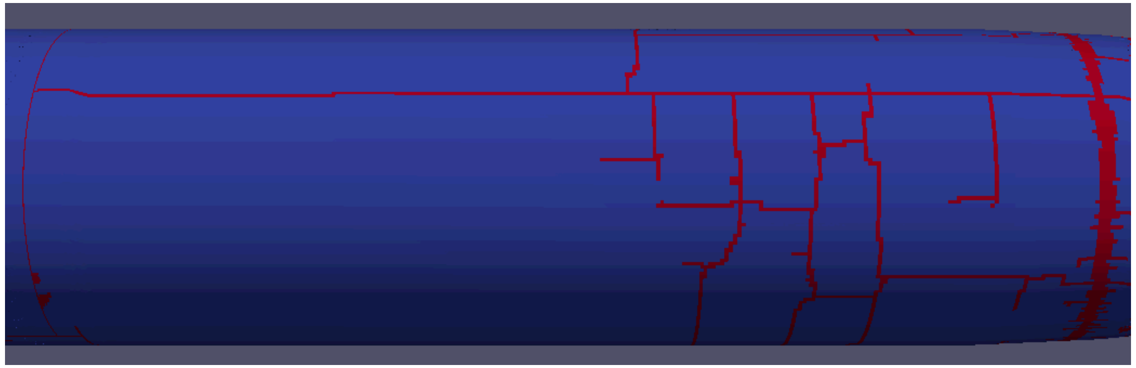
Results (Side 2)



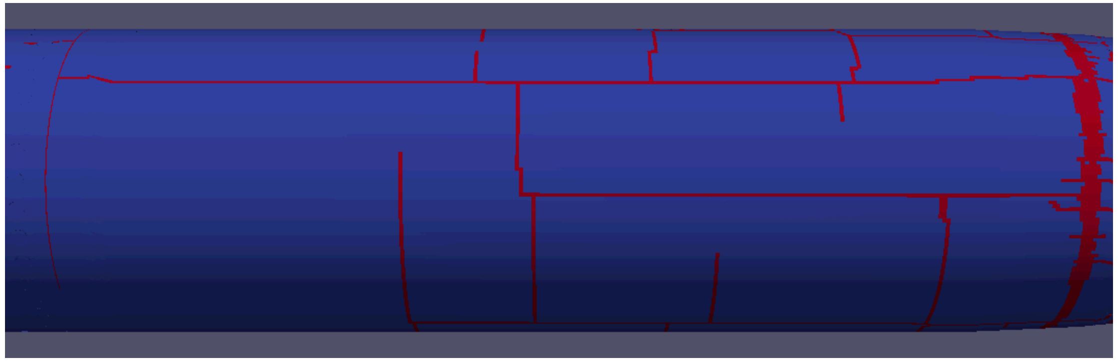
No Weibull ; YS = 4000



Weibull Implemented ; YS = 4000



No Weibull ; YS = 4010



Weibull Implemented ; YS = 4010

Progress and Future Work

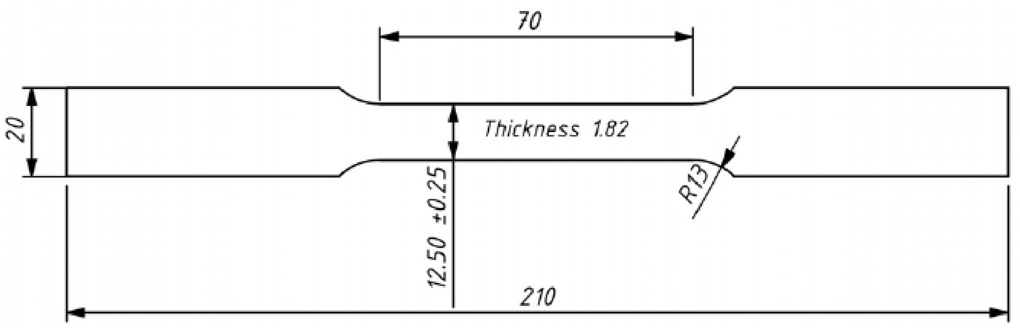
- Reproduced randomness in aluminum case cracking
- Successfully implemented Weibull distribution
- Try another distribution or method to desensitize cracking behavior
- Get more ideas from the SIERRA team

Al-5052 Characterization

- Approach
  - Model experimental setup from literature
  - Come up with a better representation of Stress/Strain behavior for Al-5052
  - Implement new material model into honeycomb simulations
  - Compare Photo Doppler Velocimetry (PDV) data with old and new simulations to determine success

Simulating the Experiment

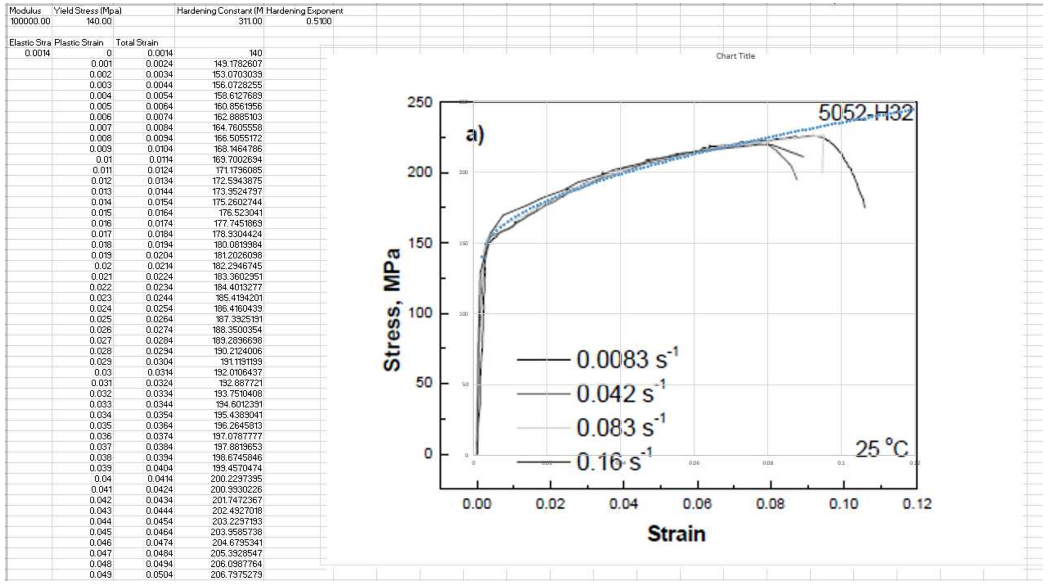
- Dogbone specifications came from Ozturk et al.
  Ozturk F, Toros S, Kilic S. Evaluation of tensile properties of 5052 type aluminum-magnesium alloy at warm temperatures. Arch Mater Sci Eng 2008;34:95–8.
- Modeled one quarter of experimental setup
- Used a Ductile Fracture material model in the tensile test simulation



Dogbone specifications from experiment

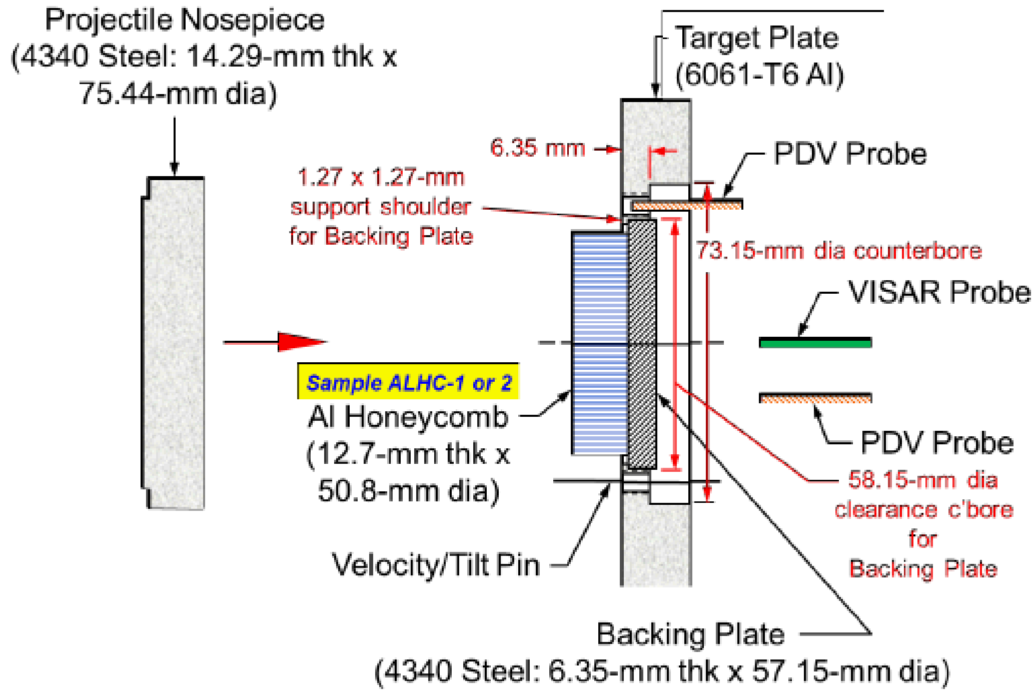
Fitting the Aluminum Material Model

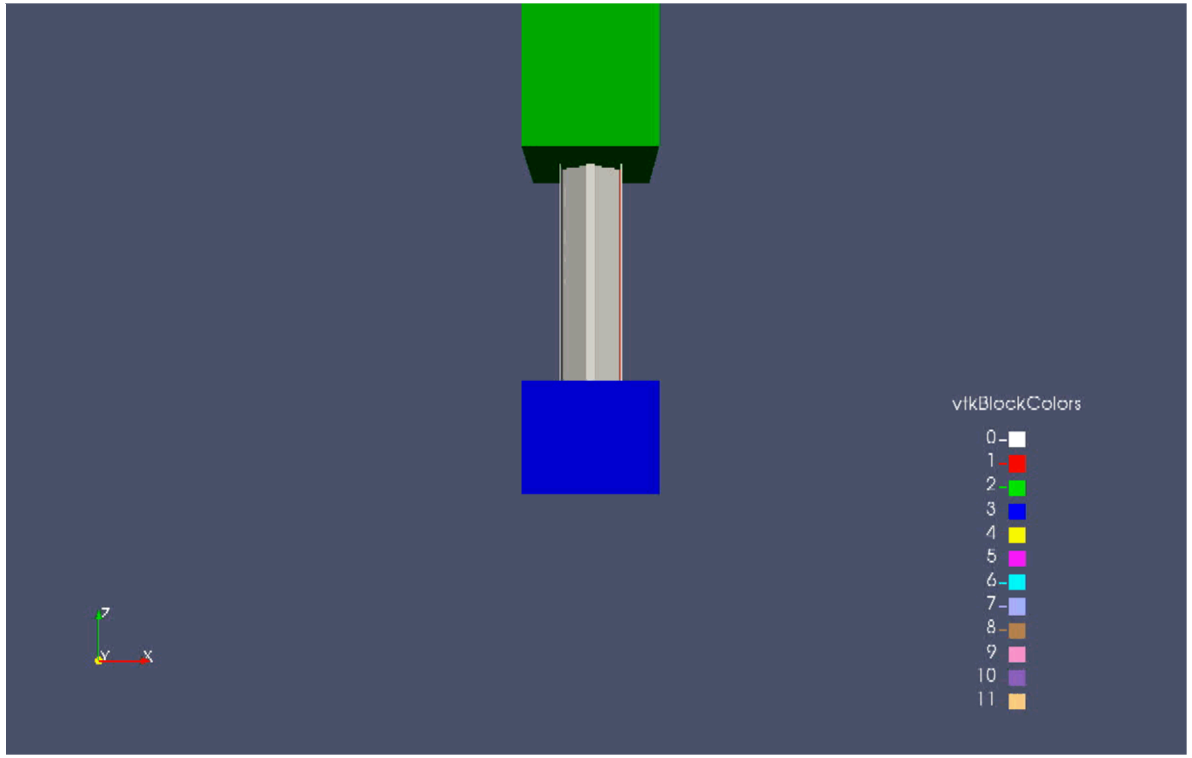
- Experimental data came from Ozturk et al.
  Ozturk F, Toros S, Kilic S. Evaluation of tensile properties of 5052 type aluminum-magnesium alloy at warm temperatures. Arch Mater Sci Eng 2008;34:95–8.
- Elastic region fit well with yield stress and Young's modulus
- Took a few iterations to obtain acceptable hardening behavior
- Utilized critical tearing parameter for failure criterion
- Used Excel and the Stress/Strain curve from the literature to fit Power Law Hardening
- $\sigma = \sigma_y + K\epsilon_p^n$ (K and n are the independent variables)



Modulus	Yield Stress (Mpa)		Hardening Constant (M	Hardening Exponent
100000.00	140.00		311.00	0.5100
Elastic Stra	Plastic Strain	Total Strain		
0.0014	0	0.0014	140	
	0.001	0.0024	149.1782607	
	0.002	0.0034	153.0703039	
	0.003	0.0044	156.0728255	
	0.004	0.0054	158.6127689	
	0.005	0.0064	160.8561956	
	0.006	0.0074	162.8885103	
	0.007	0.0084	164.7605558	
	0.008	0.0094	166.5055172	
	0.009	0.0104	168.1464786	
	0.01	0.0114	169.7002694	
	0.011	0.0124	171.1796085	
	0.012	0.0134	172.5943875	
	0.013	0.0144	173.9524797	
	0.014	0.0154	175.2602744	
	0.015	0.0164	176.523041	
	0.016	0.0174	177.7451869	
	0.017	0.0184	178.9304424	
	0.018	0.0194	180.0819984	
	0.019	0.0204	181.2026098	
	0.02	0.0214	182.2946745	
	0.021	0.0224	183.3602951	
	0.022	0.0234	184.4013277	
	0.023	0.0244	185.4194201	
	0.024	0.0254	186.4160439	
	0.025	0.0264	187.3925191	
	0.026	0.0274	188.3500354	
	0.027	0.0284	189.2896698	
	0.028	0.0294	190.2124006	
	0.029	0.0304	191.1191199	
	0.03	0.0314	192.0106437	
	0.031	0.0324	192.887721	
	0.032	0.0334	193.7510408	
	0.033	0.0344	194.6012391	
	0.034	0.0354	195.4389041	
	0.035	0.0364	196.2645813	
	0.036	0.0374	197.0787777	
	0.037	0.0384	197.8819653	
	0.038	0.0394	198.6745846	
	0.039	0.0404	199.4570474	
	0.04	0.0414	200.2297395	
	0.041	0.0424	200.9930226	
	0.042	0.0434	201.7472367	
	0.043	0.0444	202.4927018	
	0.044	0.0454	203.2297193	
	0.045	0.0464	203.9585738	
	0.046	0.0474	204.6795341	
	0.047	0.0484	205.3928547	
	0.048	0.0494	206.0987764	
	0.049	0.0504	206.7975279	

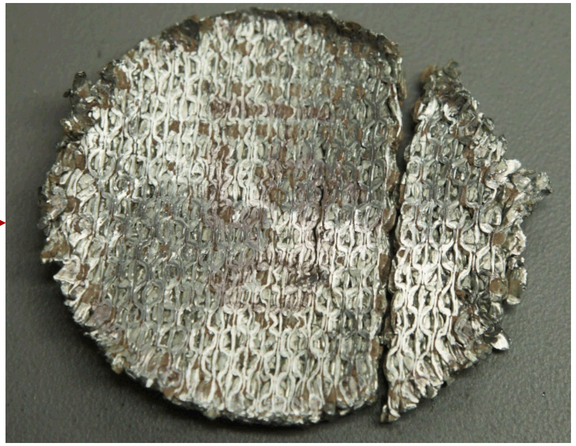
Crushing Aluminum Honeycomb





Results

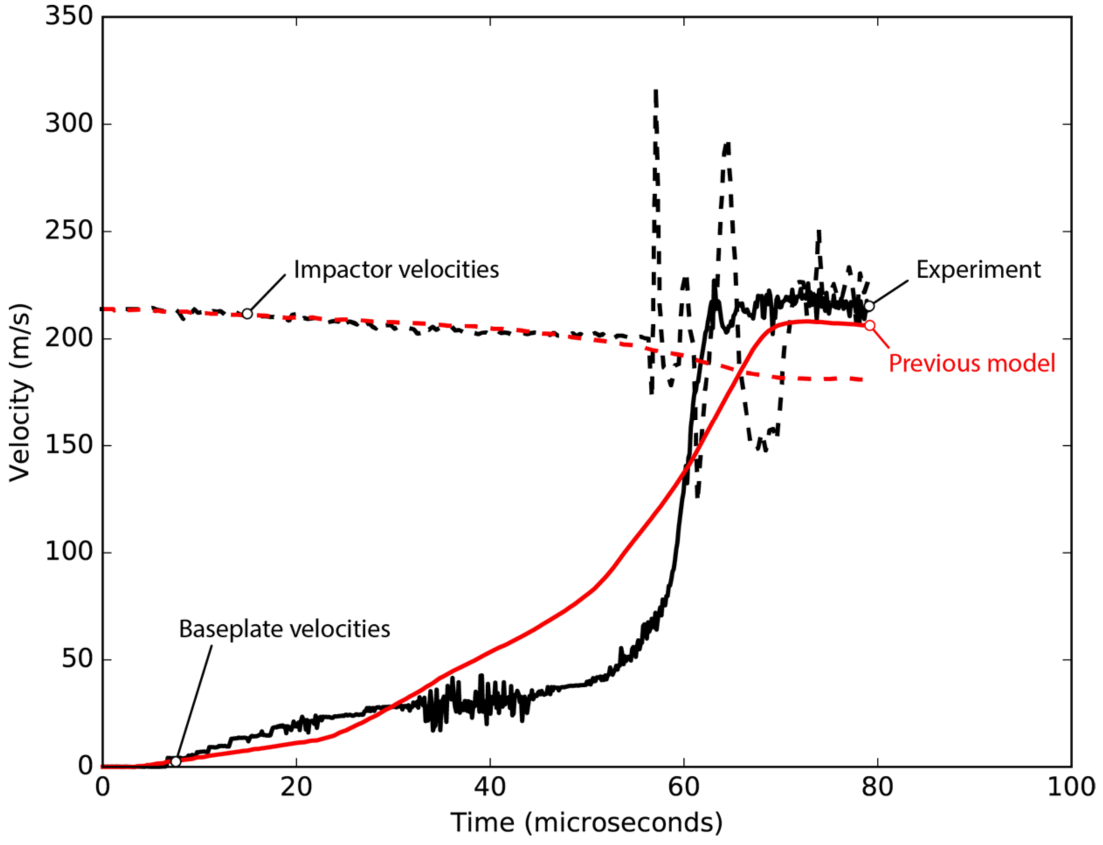
- Successfully implemented calibrated Aluminum 5052 model into honeycomb simulation
- Ran simulations at 702 ft/s and 541 ft/s
- Velocity vs Time for the impactor and base plate better align with experimental data



702 ft/s

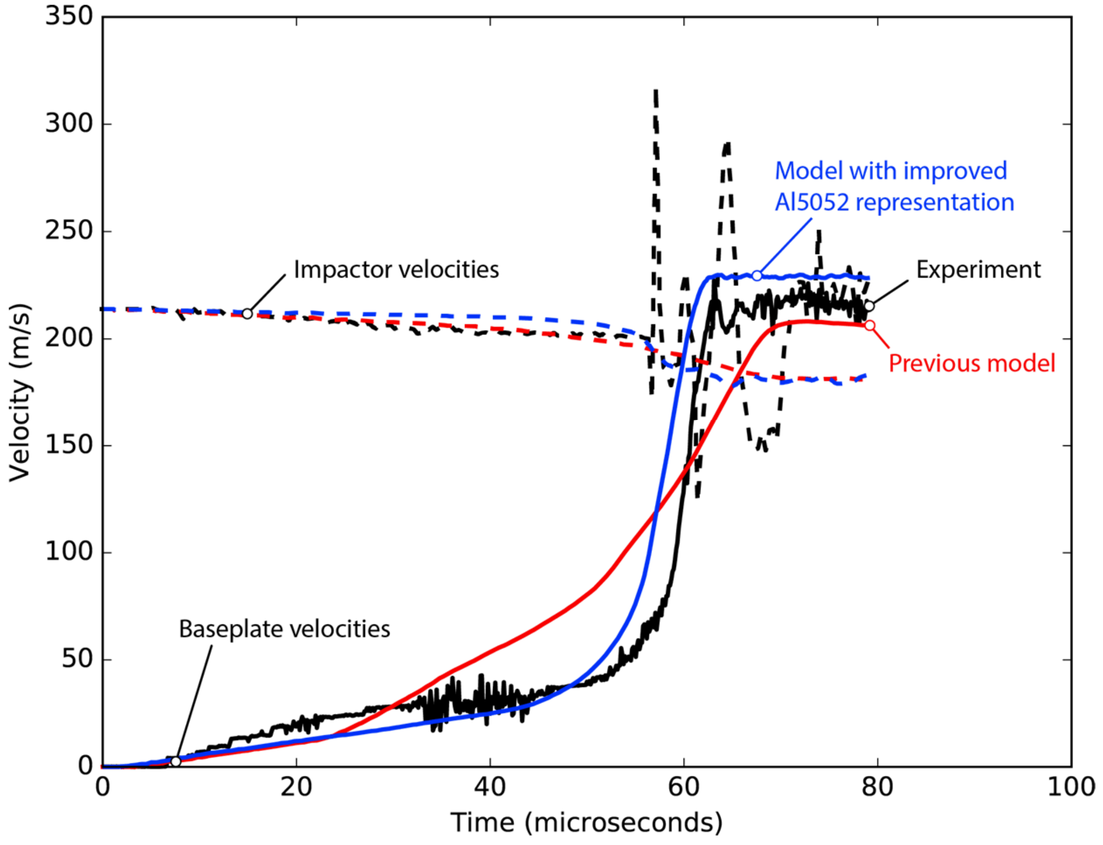
541 ft/s

Progress



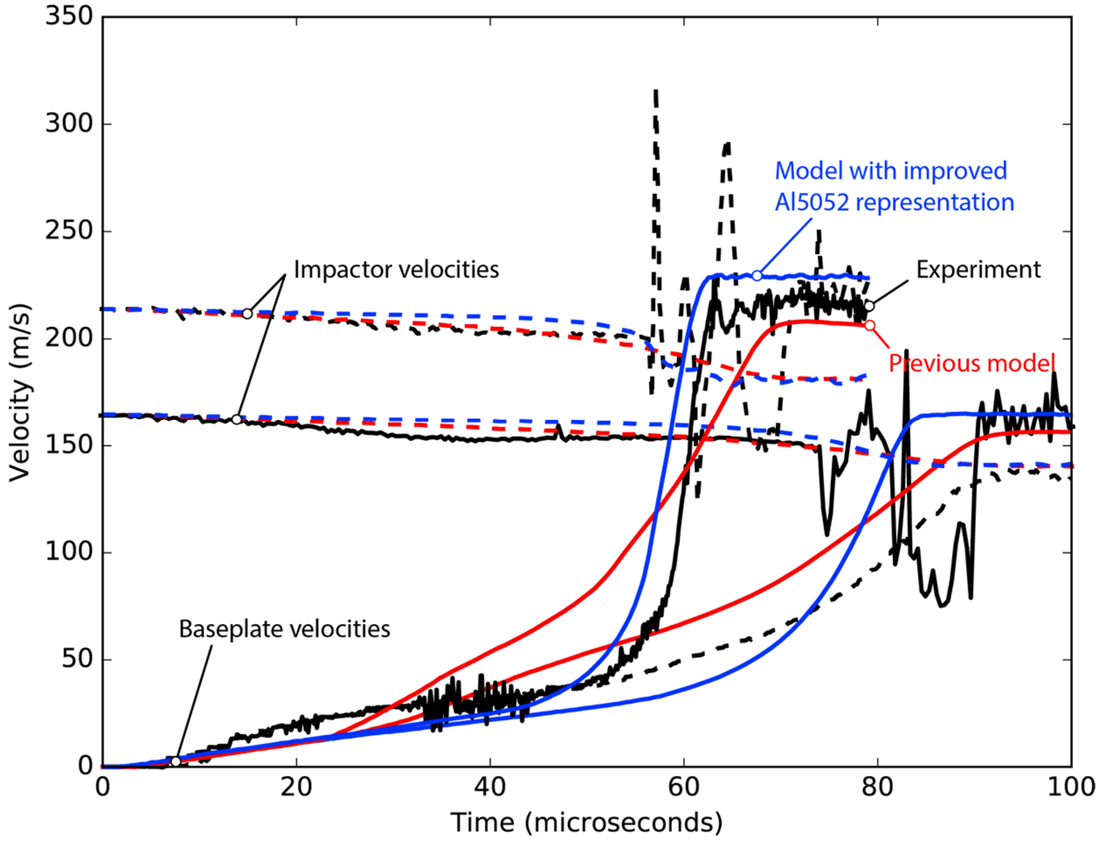
- Comparison using past simulation and material model
- Old material model is simple elastic plastic
- Investigation of new more complex model to try and improve results

Progress



- New material model is ductile fracture
- Comparison is at 702 ft/s
- Improvement

Progress



- Addition of comparison for 541 ft/s
- Clear difference in simulations at 541 ft/s
- Not a clear improvement at slower speed

Conclusion

- Weibull Distribution
  - Successfully implemented in aluminum case material model
  - Did not create repeatable cracking patterns
  - I learned about the Weibull Distribution, Workbench, and sometimes getting the wrong answer can be a success
- Aluminum characterization
  - Calibrated a ductile fracture material model for Al-5052
  - Successfully implemented this material model into honeycomb crush simulations
  - Closed the gap between simulation and experimental data (at least at higher speeds)
  - I learned about Power Law Hardening, gas guns, and a simple understanding of the basics can make objectives more attainable