COE CST Tenth Annual Technical Meeting

Task 377: Nitrous Oxide Composite Case Testing

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Students: Chris Rood, Matt Hirsh, Angel Chavira, Steven Palmer

Agenda

- Team Members
- Task Description
- Goals
- Theoretical Approaches
- MD Code simulations
- Conclusions and Future Work

Team Members



- PI: Seokbin (Bin) Lim (NMT)
- Co-PI: Andrei Zagrai (NMT)

- Grad Student: Matt Hirsh
- Undergrad Student: Christopher Rood, Angel Chavira, Steven Palmer

- COE CST Program Manager: Ken Davidian (FAA)
- Technical Monitor: Ken Davidian (FAA)

Task Description

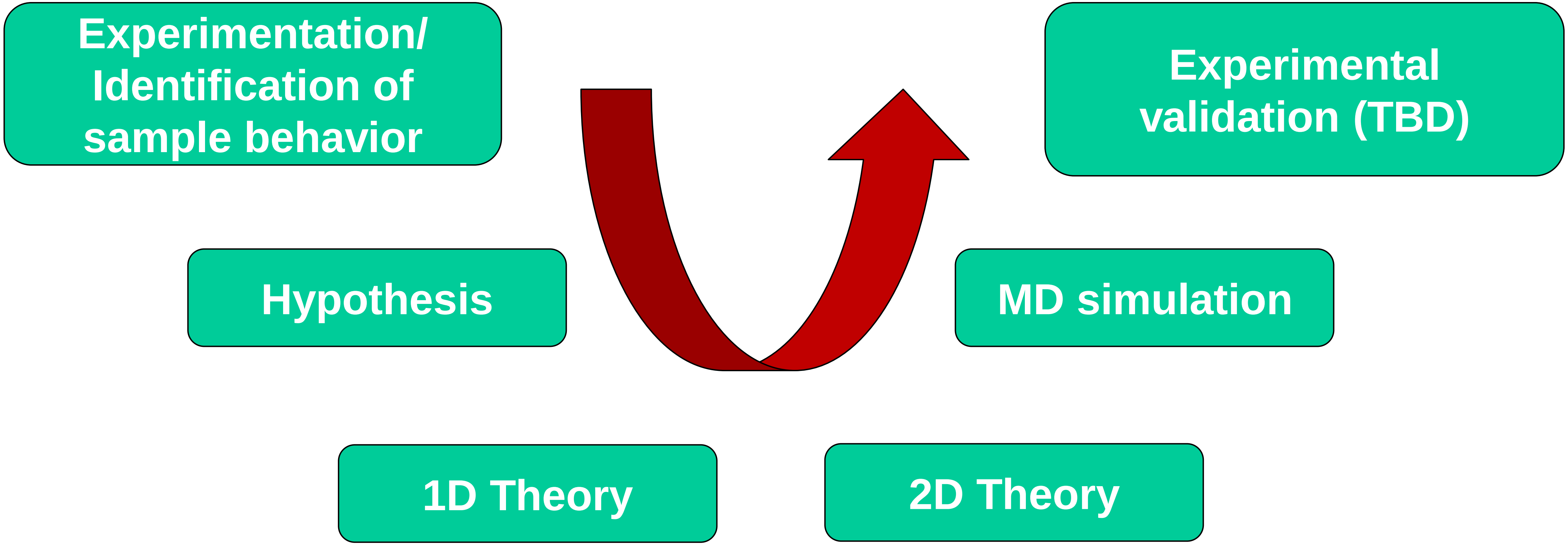
Objectives

- Develop an understanding of fragmentation hazards from composite and Al tanks used for fuel/oxidizer storage
- Construction of hypothesis and numerical validation of how cracks form in test samples

Tasks

- Develop methods/hypothesis to predict the crack formation behavior (completed)
- Construction of analytical approach to predict such behaviors (completed)
- 1D Molecular Dynamic code simulation to understand the fundamental mechanism (in progress)

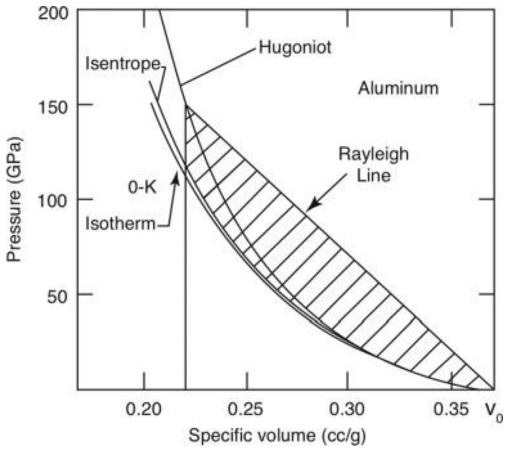
Task Description



Goals

- Construction of 1D extreme tension wave theory (Al 6061)
- Expansion of the theory from 1D to 2D configuration
- Understanding of the wave propagation details during the sample expansion hoping to deliver the clue to see the fragmentation

Theoretical Approach I



Conservation equations (Tension Hugoniot)

R- Mass $$\rho_1 = \frac{\rho_0 R^-}{R^- + u_1}$$

R+ Mass $$\rho_1 = \rho_2 \frac{R^+ - u_2}{R^+ - u_1}$$

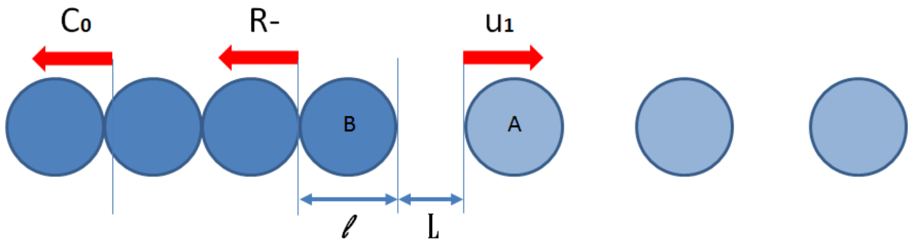
R- Momentum $$P_1 = \rho_0 R^- u_1$$

R+ Momentum $$P_1 = \rho_2 (R^+ - u_2)(u_1 - u_2)$$

Combination of those equations $$u_1 = \frac{1}{2} u_2$$

From the conservation equations and the speed of tension wave

$$P_1 = -\rho_0 s u_1^2 \quad (\text{or } P_1 = -\rho_0 R u_1)$$



Assume, $s = \frac{\rho_1}{\rho_0 - \rho_1}$

then, $R^- = -s u_1$

Theoretical Approach II

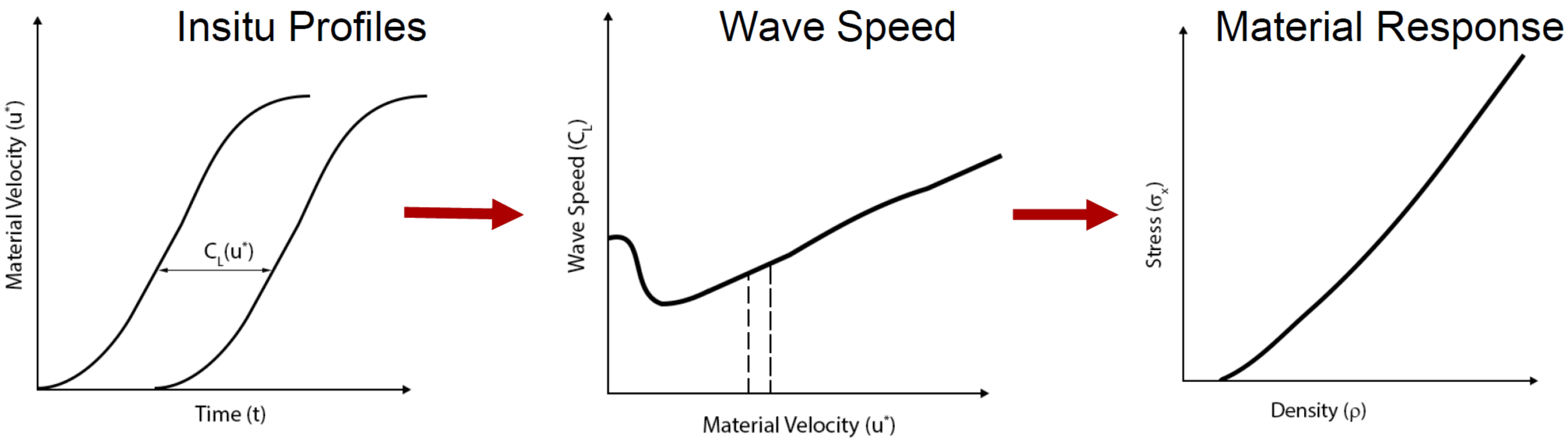
Quasi-Isentrope

- Quasi-isentrope can be easily determined by the measuring the in-situ particle velocity in two different time steps
- Simple and Steady wave propagation assumption

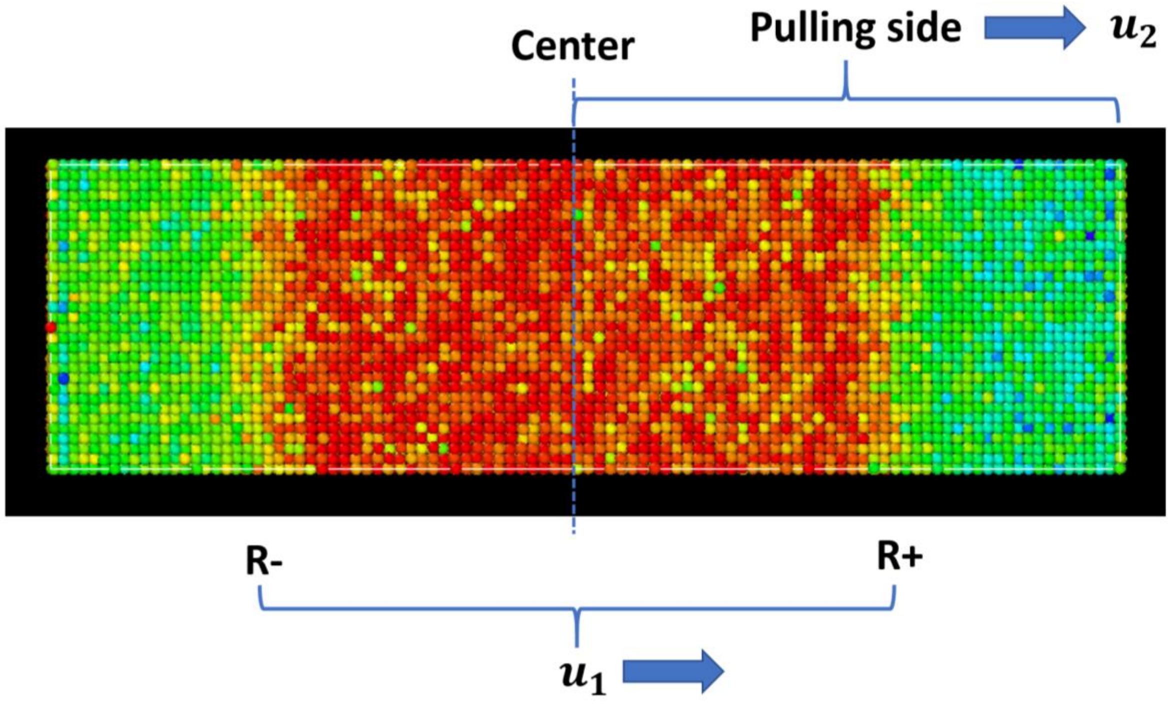
Quasi-Isentropic Compression of Free-Machining (C36000) Brass
Paul E. Specht and Seth Root, SNL, NM USA
PETER 2016 New Models in Hydrocodes, Le Grand Large, St. Malo, France, 2016

$$d\sigma_x = \rho_0 \cdot C_L(u_p) \cdot du_p$$

$$dv = \frac{du}{\rho_0 \cdot C_L(u_p)}$$



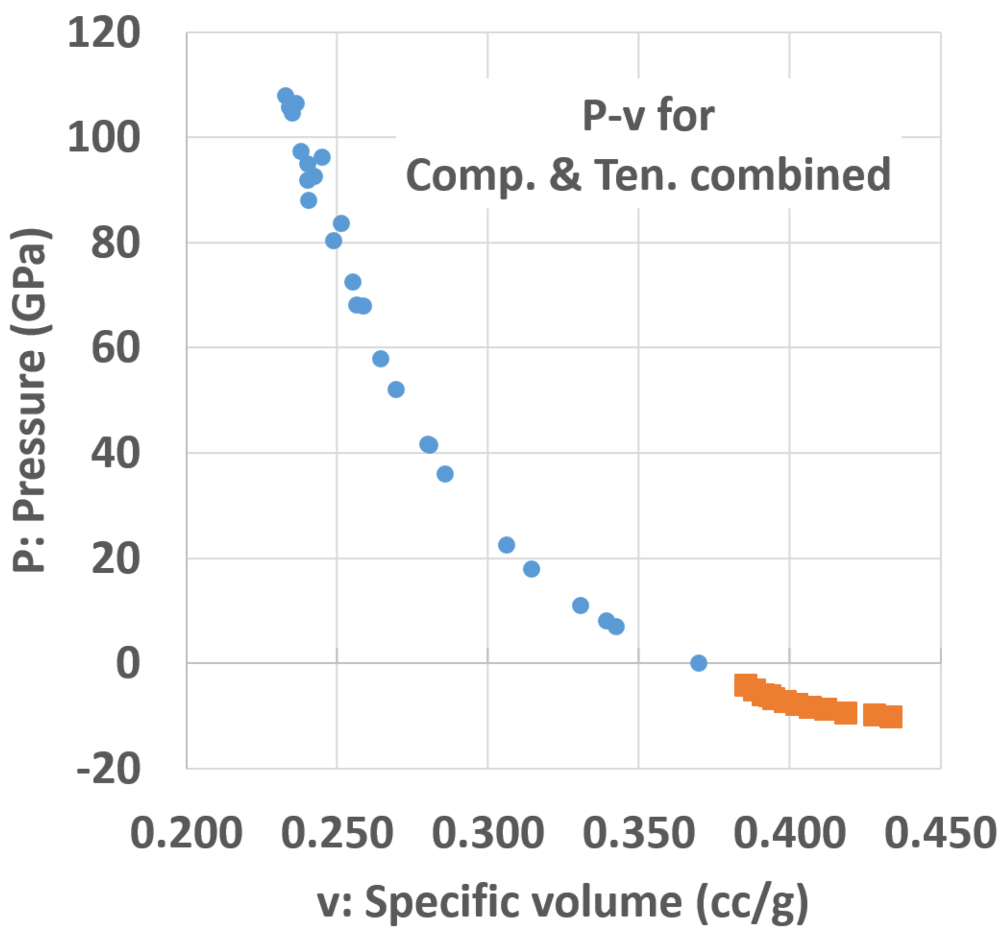
MD Code simulation (LAMMPS)

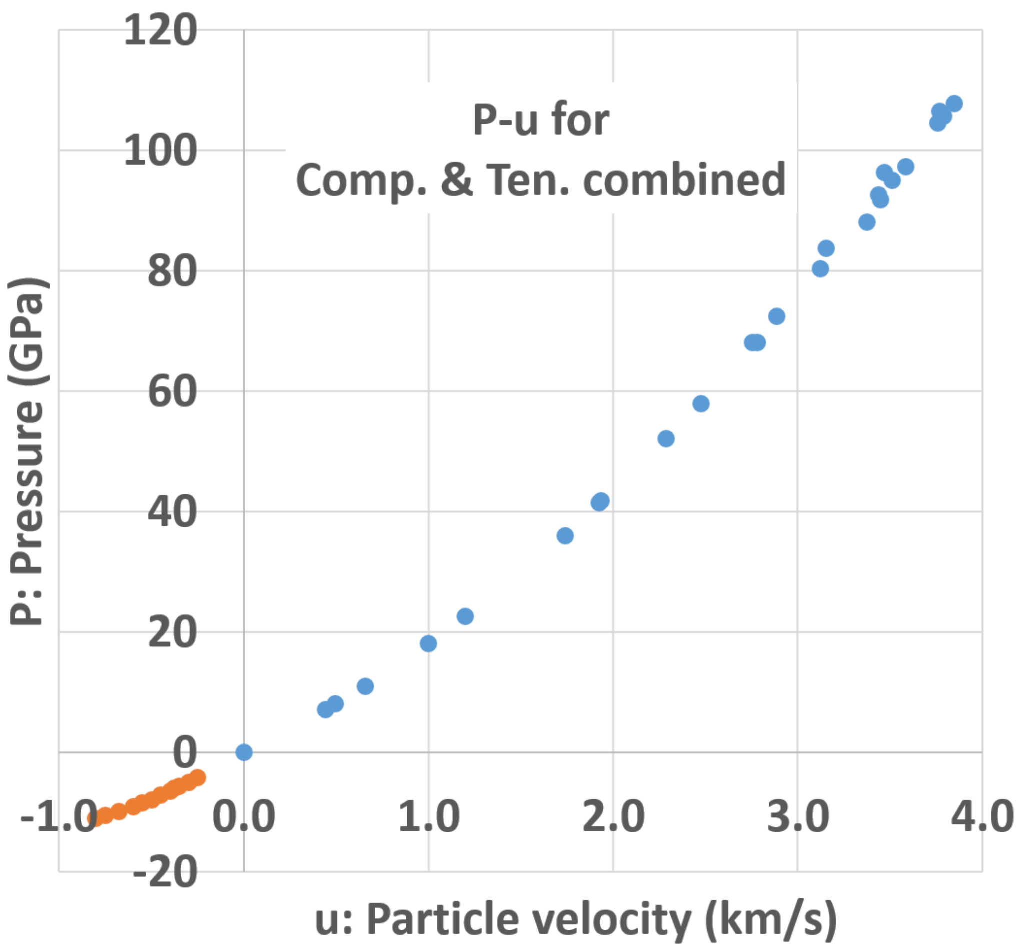


Al 6061

Pull speed (km/s)	Particle velocity (km/s)	LAMMPS results[1]				Theoretical calculation		
		Density (g/cc)	Tension wave velocity (km/s)	Pressure (GPa)		Density (g/cc)	Pressure (GPa)	Specific volume (cc/g)
u_2	u_1	ρ_1	R^-	P_1		ρ_1	P_1	v_1
0	0	2.700[3]	0	0		2.700	0	0.370
-0.50	-0.250	2.590	6.200	-4.200		2.595	-4.185	0.385
-0.60	-0.300	2.570	6.250	-5.000		2.576	-5.063	0.388
-0.70	-0.350	2.550	6.190	-5.750		2.556	-5.850	0.391
-0.75	-0.375	2.538	6.000	-6.100		2.541	-6.075	0.394
-0.80	-0.400	2.530	6.120	-6.500		2.534	-6.610	0.395
-0.90	-0.450	2.510	5.900	-7.200		2.509	-7.169	0.399
-1.00	-0.500	2.488	5.800	-8.000		2.486	-7.830	0.402
-1.10	-0.550	2.470	5.600	-8.500		2.459	-8.316	0.407
-1.20	-0.600	2.445	5.375	-9.100		2.429	-8.708	0.412
-1.35	-0.675	2.411	5.200	-9.900		2.390	-9.477	0.418
-1.50[2]	-0.750	2.373	4.800	-10.600		2.335	-9.720	0.428
-1.60[2]	-0.800	2.350	4.700	-11.100		2.307	-10.152	0.433

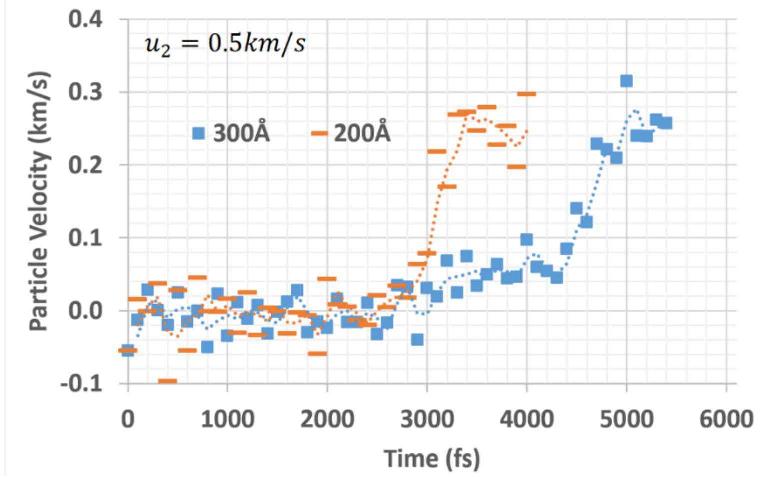
MD Code simulation (LAMMPS)

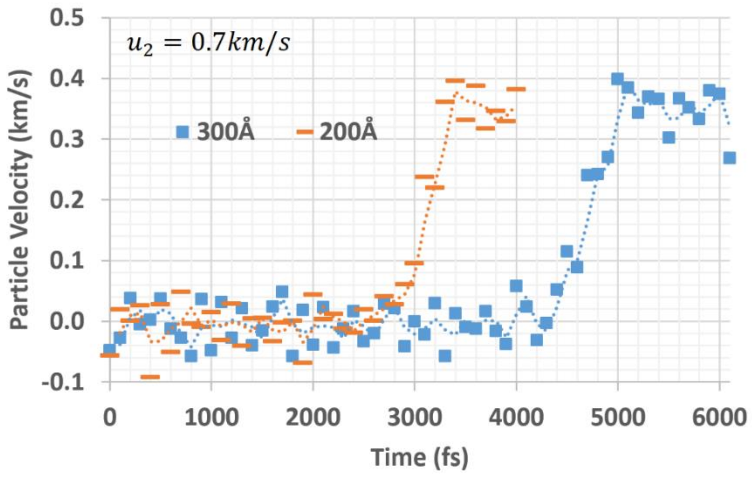


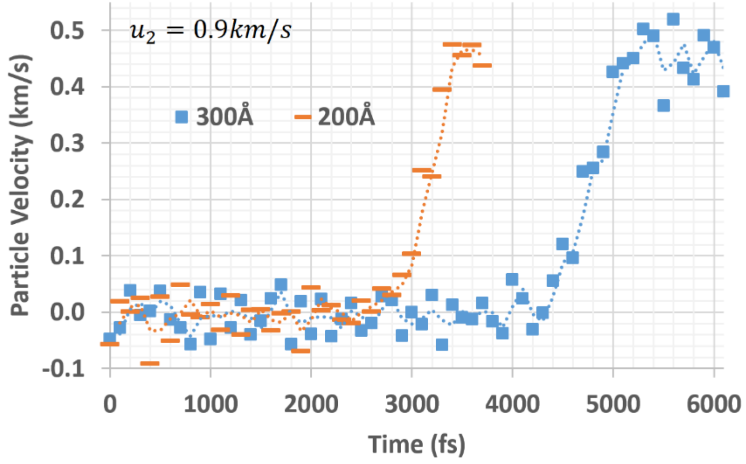


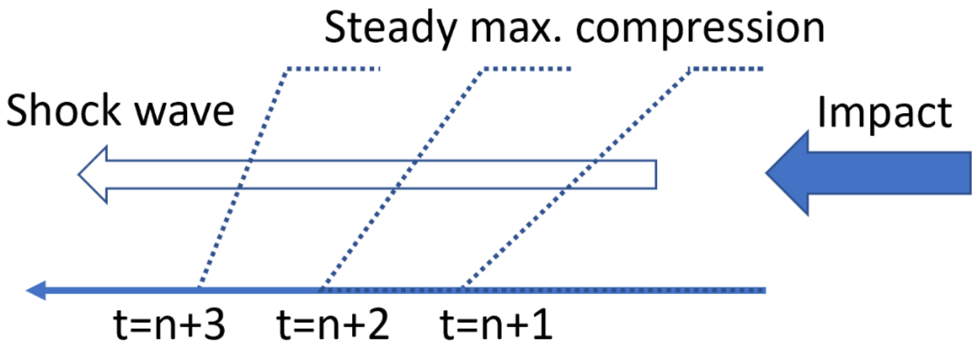
Al 6061 Hugoniot graph, LASL Shock Hugoniot Data, UC Press, 1980

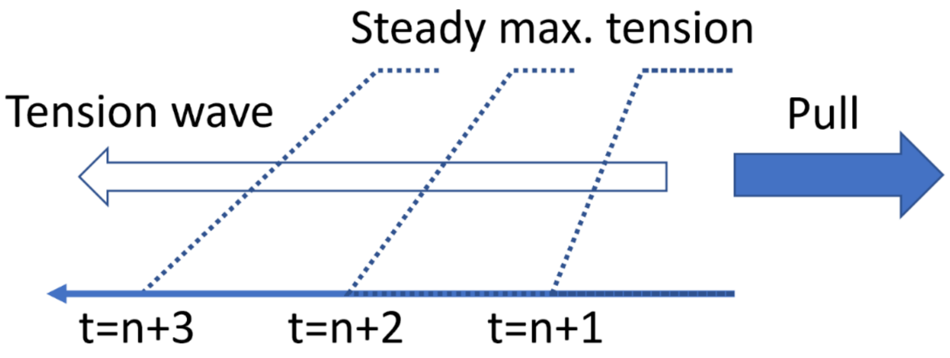
MD Code simulation (LAMMPS)











Publications, Presentations, Awards, & Recognitions

PUBLICATIONS

Seokbin Lim, et. al. ‘Extreme Dynamic Tension and the Profile of Tension Wave’, AIP Advances: in review

PRESENTATIONS

Seokbin Lim, Don Ryu, NASA EPSCoR ‘AutoCom’ Monthly Report, September 2020

Seokbin Lim, Philipp Baldovi, ‘Extreme Dynamic Tension: Preliminary Research’ APS March Meeting, SCCM, Denver (Online), March 2020

Conclusions and Future Work

Conclusions

- MD code reveals the wave profile of Al sample during tension
- It was able to plot a pressure-specific volume curve for tension
- Experimental validation is required

Next Steps

- Expansion of this 1D theory to 2D necking theory
- Understanding of the wave patterns and the crack formation