COE CST Eleventh Annual Technical Meeting

Task 377: Nitrous Oxide Composite Case Testing

PI: Bin Lim. Ph.D
Co-PI: Andrei Zagrai. Ph.D

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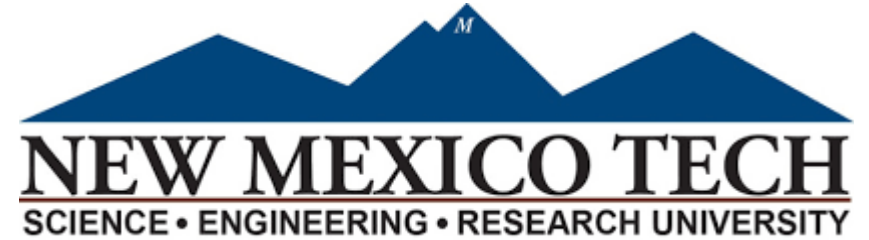Commercial Space Transportation

Agenda

- Team Members
- Task Description
- Goals
- Background information
- Results
- Future Work

Team Members

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

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

- Organization: New Mexico Institute of Mining and Technology

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

- Construction of analytical approach to predict such behaviors (completed)
- 1D Molecular Dynamic code simulation to understand the fundamental mechanism (completed)
- Application of the theory to a series of experiments (in progress)

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Goals

- Construction of 1D extreme tension wave theory: completed

- Task1: Expansion of the theory from 1D to 2D configuration: in progress

- Task 2: Understanding of the wave propagation details during the sample expansion hoping to deliver the clue to understand the fragmentation distribution: in progress

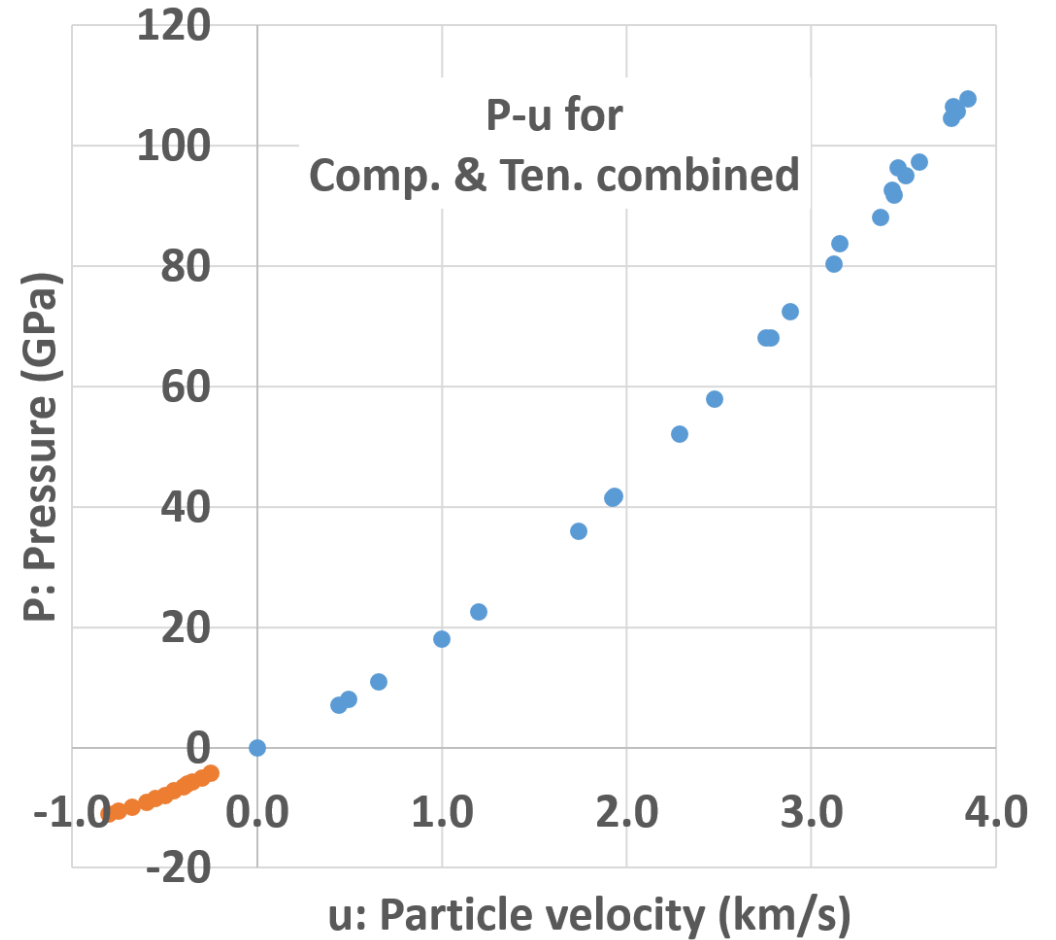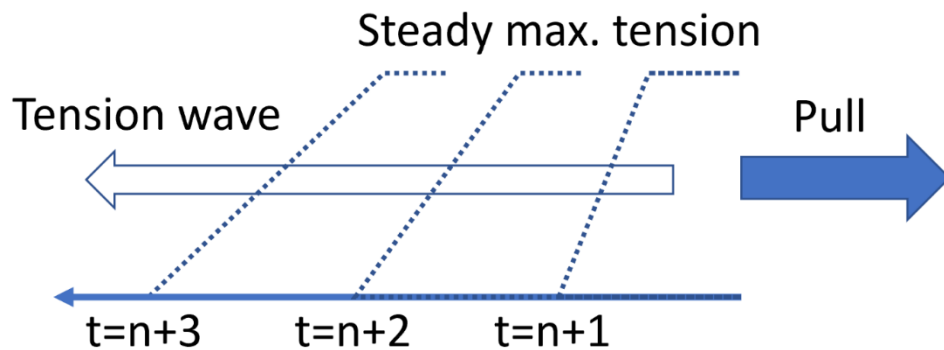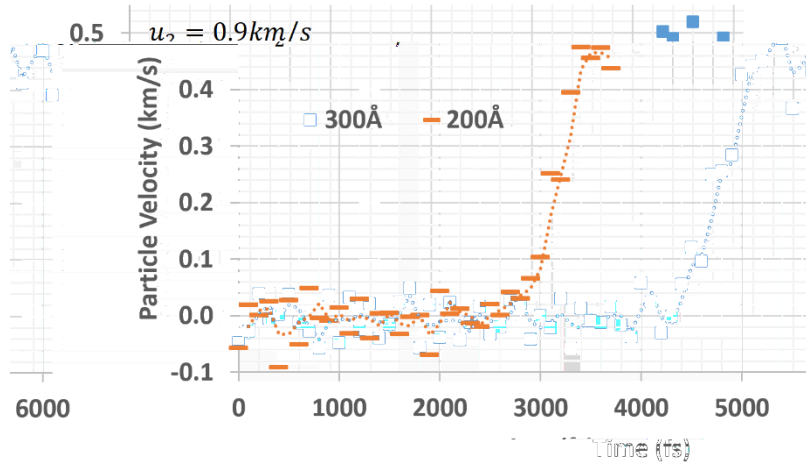# Background Information (Previous work, LAMMPS)
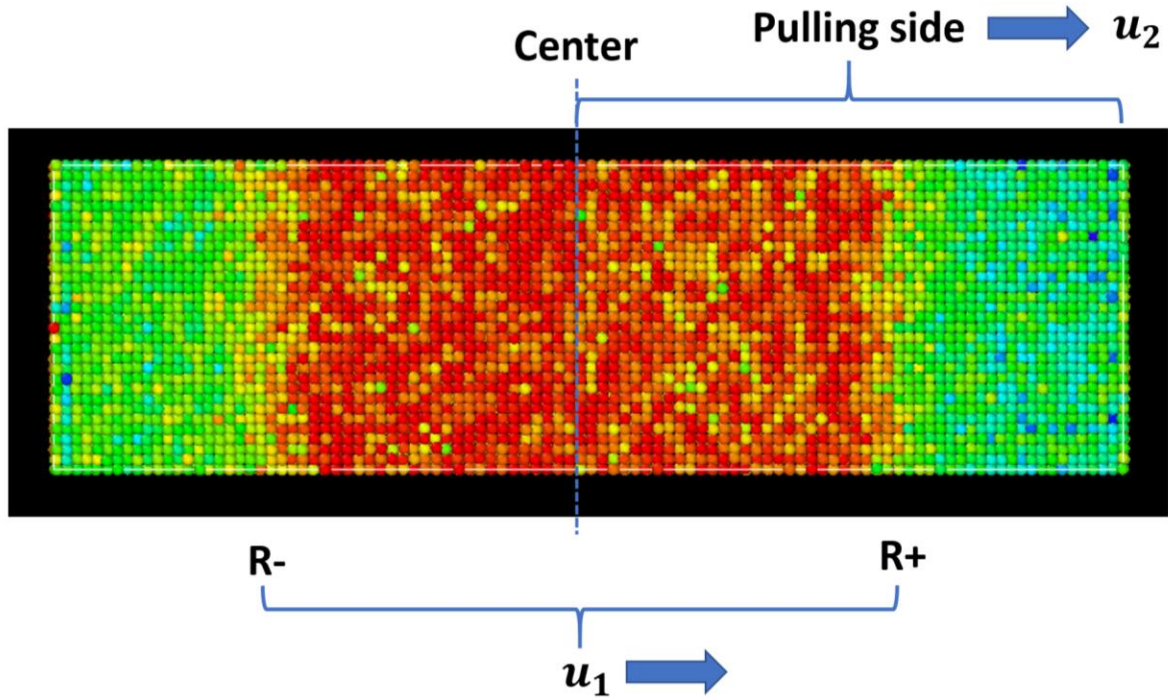
Al 6061

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

Background Information (Previous work)

$u_2 = 0.9\,km/s$

300Å — 200Å

Particle Velocity (km/s)

Time (fs)

Steady max. tension

Tension wave

Pull

t=n+3   t=n+2   t=n+1

P-u for
Comp. & Ten. combined

P: Pressure (GPa)
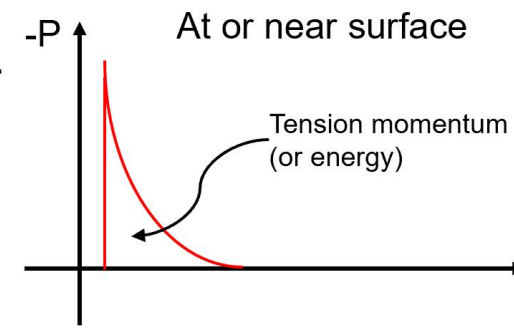
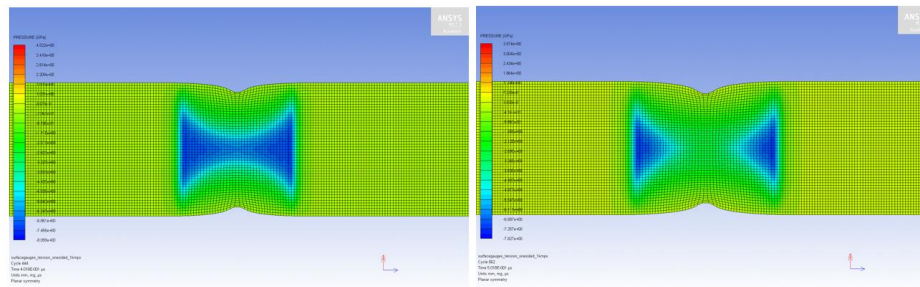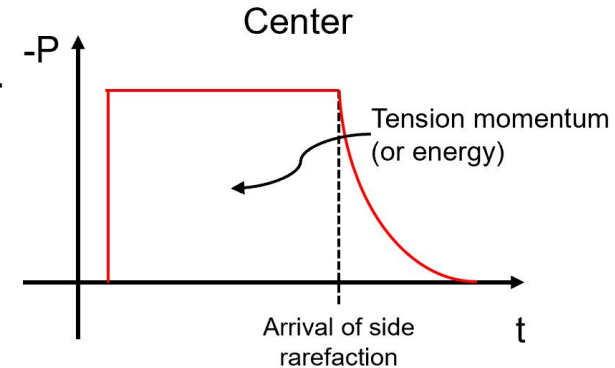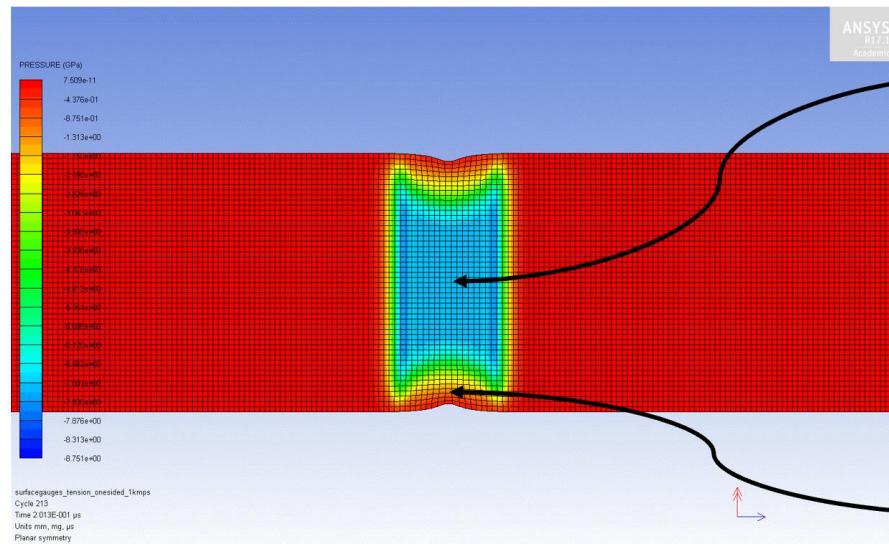u: Particle velocity (km/s)

Task 1 Results

- Preliminary simulation using Autodyn hydrocode to expand the 1D theory to 2D configuration (LAMMPS simulation is in progress)
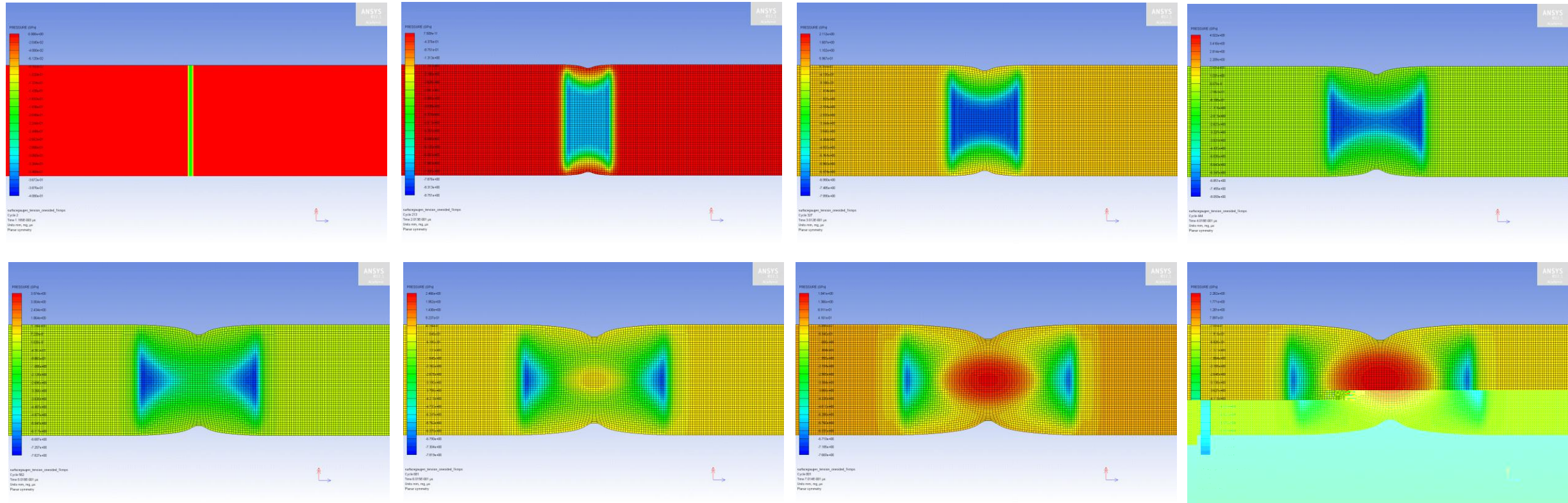
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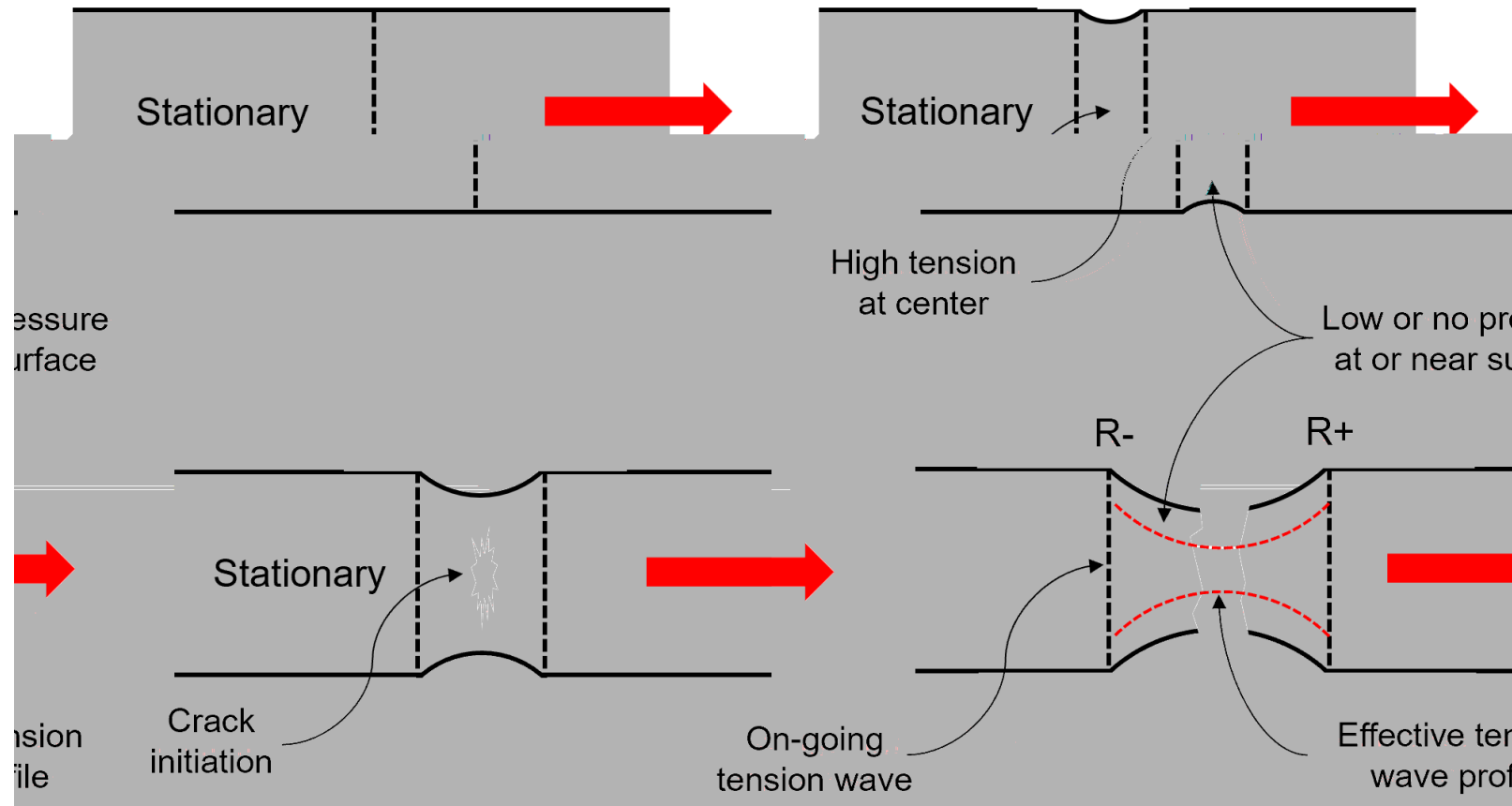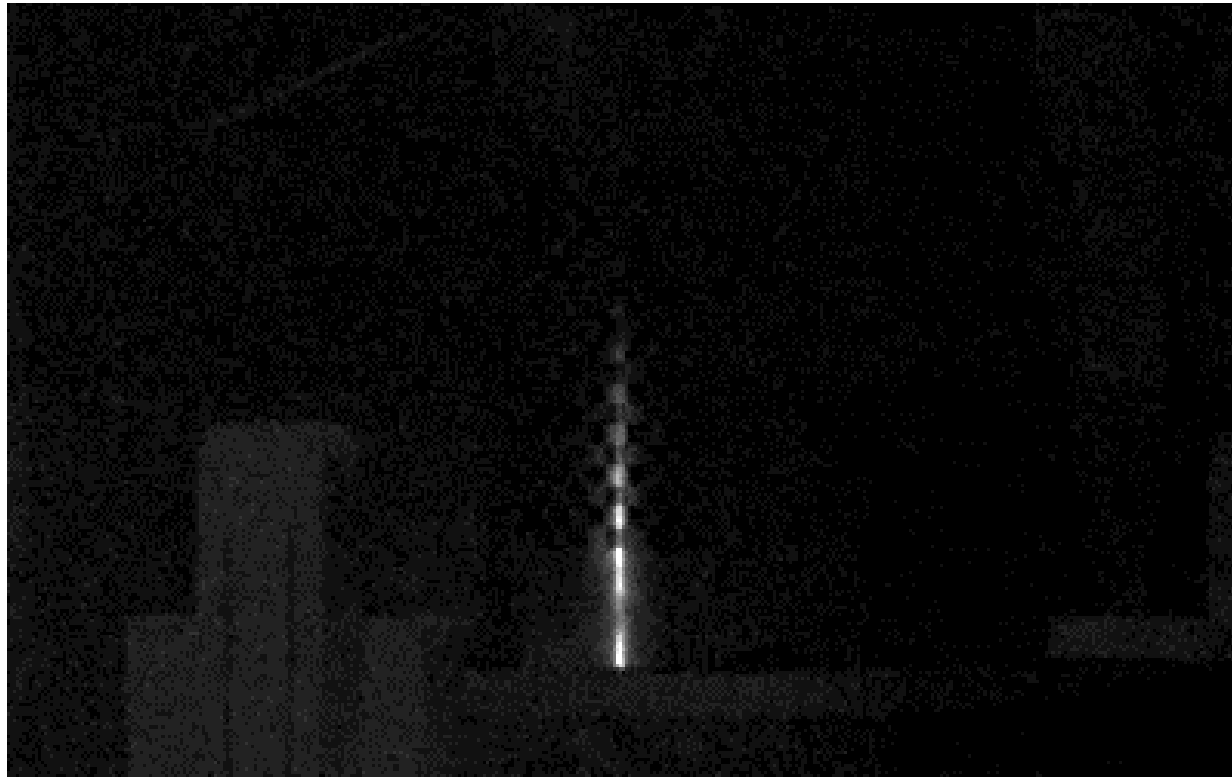
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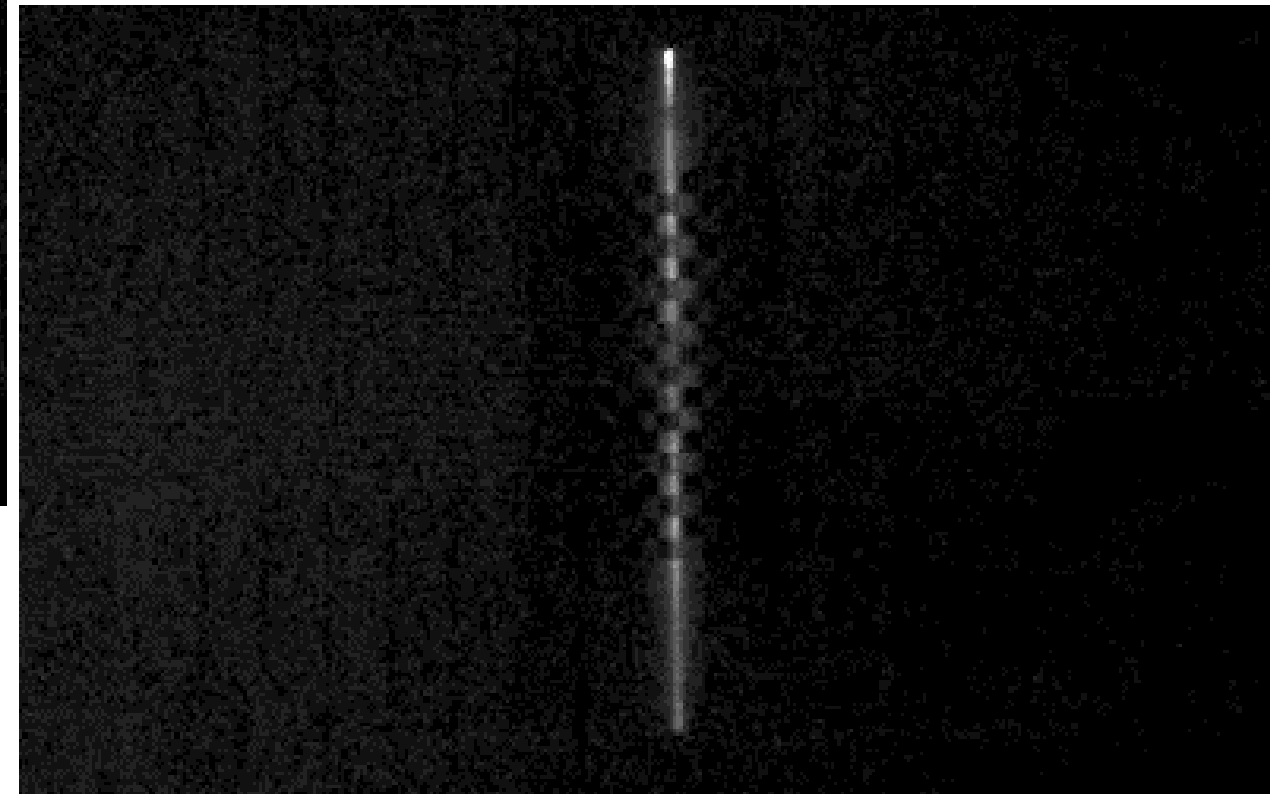
Task 2 Results and Progress

Uniform Crack Distribution
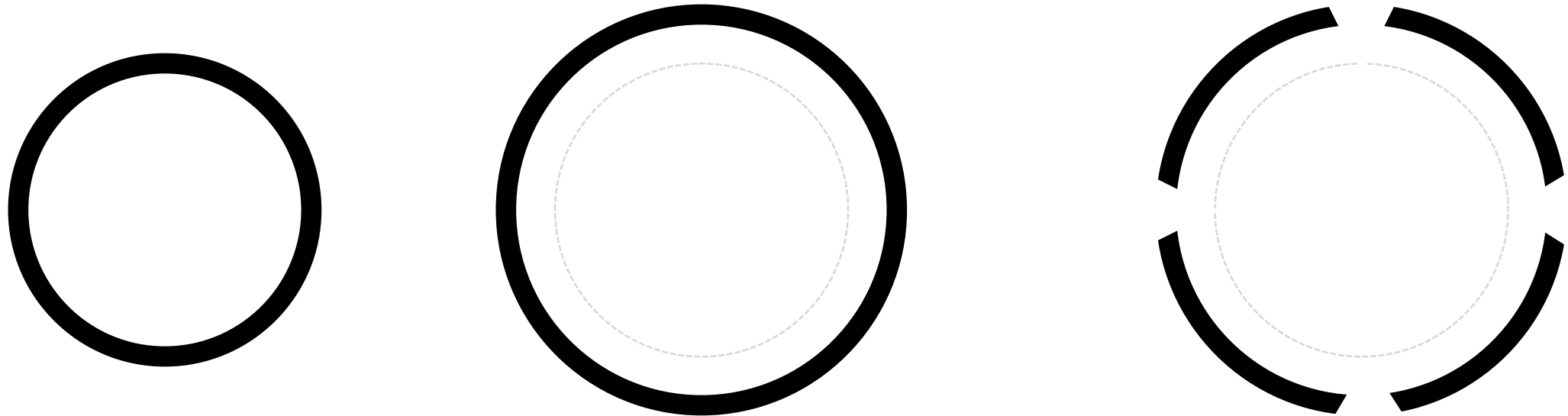Different Crack Distance

1/4in. thick, 4in outer diameter AL6061 tube with 0.68lbs HMX inside.

1/4in. thick, 4in outer diameter AL6061 tube with 0.24lbs HMX inside.

Task 2 Results and Progress

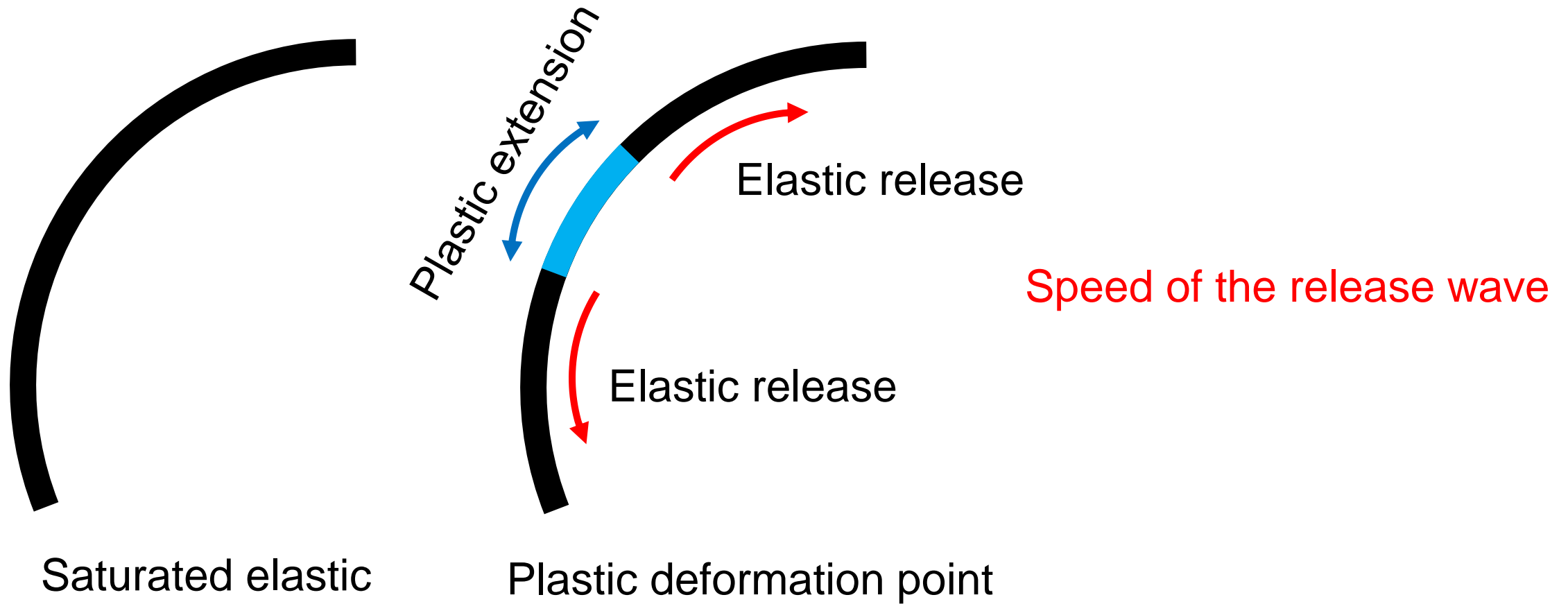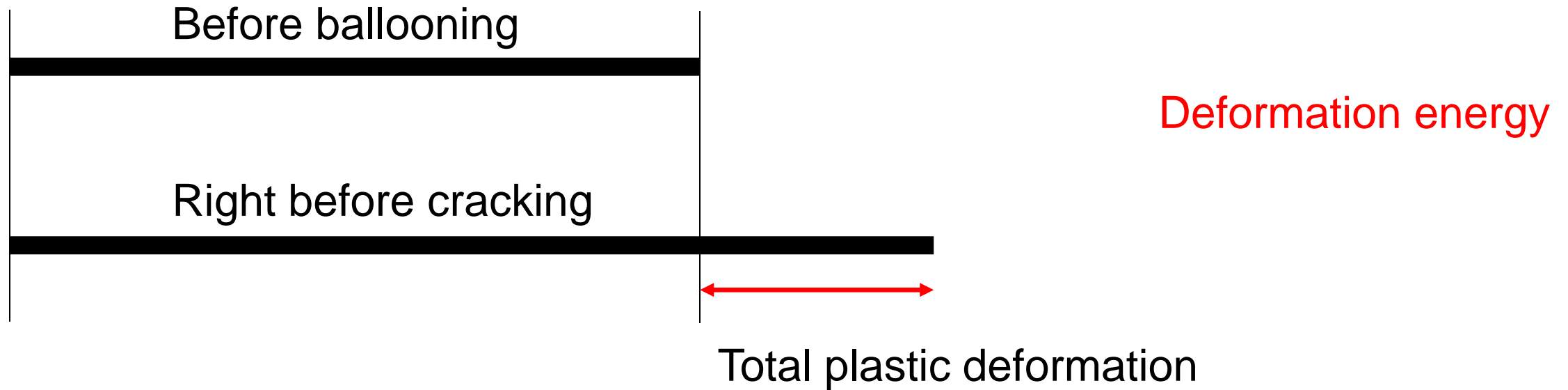Elastic ballooning
(Fully saturated elastic)

Local plastic ballooning
with initiation of cracks

Task 2 Results and Progress

Plastic extension

Elastic release

Speed of the release wave

Elastic release

Saturated elastic

Plastic deformation point

Task 2 Results and Progress

Before ballooning

Right before cracking

Deformation energy

Total plastic deformation

In an ideal case, the total plastic deformation can be distributed evenly along the entire sample, but the nature only allows several points to handle the entire deformation because this is much easier than the even distribution.

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Publications, Presentations, Awards, & Recognitions

PRESENTATIONS

1. Extreme Tension Wave Profile in Aluminium, Seokbin (Bin) Lim PhD, Christopher Rood, Angel Chavira, Matthew Hirsch, Don Ryu. APS March Meeting 2021, online conference

2. Seokbin (Bin) Lim PhD, Christopher Rood, Angel Chavira, Don Ryu, Characteristics of Extreme Tension Wave and Necking in Al6061, SEM Annual conference 2021, online conference

3. Seokbin (Bin) Lim PhD, Explosively Driven Fracture & Fragmentation Patterning in Cylinder – Extreme Tension Physics: Preliminary Study, NSMMS & CRASTE 2022, abstract submitted and accepted

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Future Work

- Study of the energy consumption per each crack/plastic deformation

- Study of wave propagation speed depending on the tension load amplitude

- Study of data compatibility between uniaxial strain vs. stress

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