Tensile Testing of Swaged Aluminum Powder Compacts for Input to the Design of Structural Reactive Materials

Ethan Heo[1], Jesse Grant[1,2], Tim Weihs[1,2]

[1]Johns Hopkins University | Whiting School of Engineering | Baltimore, MD
[2]Johns Hopkins University | Hopkins Extreme Material Institute | Baltimore, MD

Introduction

Reactive materials are a class of materials which react and generate large amounts of heat via chemical energy at a rapid rate.
Usually, reactive materials are in the forms of powders or structured thin films, without any relevant structural properties.
One way of resolving this limitation is via powder compacts, which are consolidated bulk reactive powders.

Objectives

The primary objectives of this project were to

- Identify quasi-static tensile mechanical properties of swaged Aluminum under different processing conditions such as:
  - Strain Rate
  - Particle Size
  - Degree of Cold Work
- Continue repeatability studies

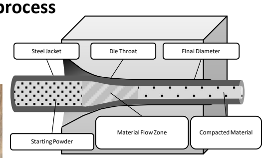
Materials and Methods

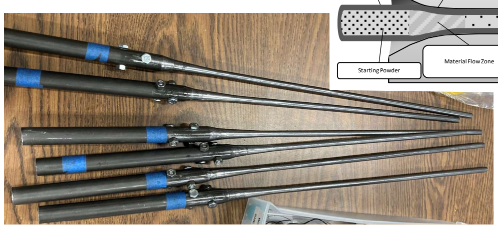
Samples were fabricated via swaging, a rotary forging process which uniformly radially compacts the material together

Initial input materials were powdered aluminum at differing average particle size, ranging from medians 3.5 µm, 20 µm, and 108 µm.

Valimet Al nominal size	Degree of Swaging 81	66	50
H2	H2810X	H2660X	H2500X
H15	H15810X	N/A	N/A
H95	H95810X	N/A	N/A

Figure 1 – Diagram & Image of swaging process
Right: Swaging Process
Bottom: Swaged samples





Results

Figure 2 – Crosshead Measured Tensile curves of Al samples
Tensile Curves of Swaged Aluminum samples, left to right increasing particle size, 81% degree of swaging

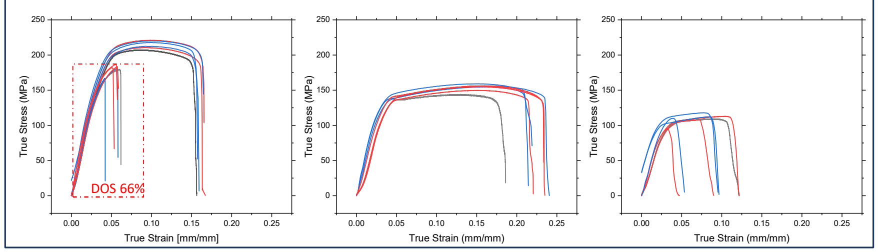


Figure 3 – Digital Image Correlation (DIC) Capture and analysis

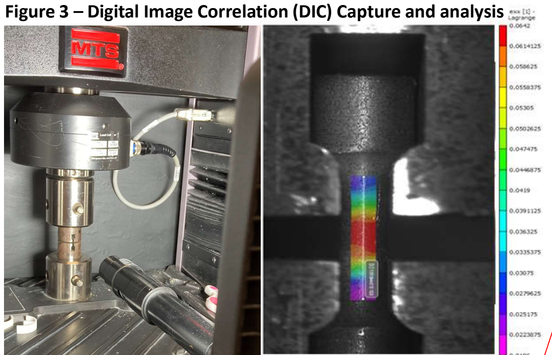


Figure 5 – H15 Al powder in SEM

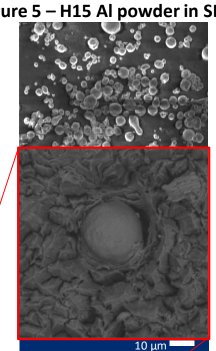
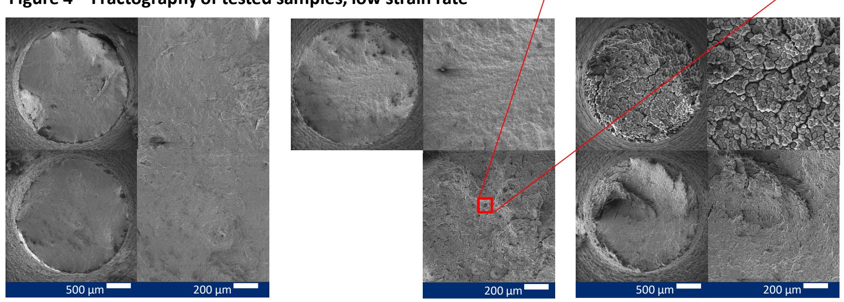
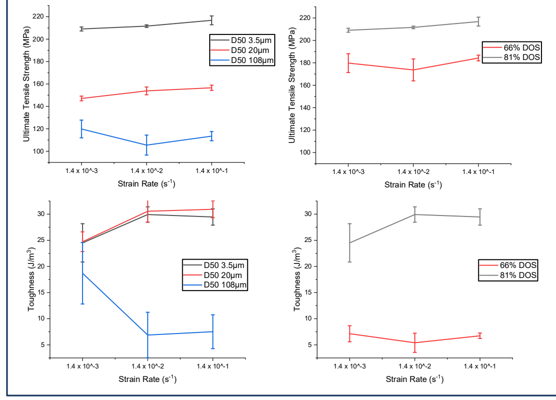


Figure 4 – Fractography of tested samples, low strain rate



Discussion

Figure 6 – Mechanical Properties of Al samples
Top: Ultimate tensile strength
Bottom: Toughness (Integrated area under the curve



Conclusion & Future Work

Mechanical Properties seem to be enhanced with ductile compacted samples, with opposite trends for the brittle

SEM Characterization seems to support possible mechanisms

Future work would benefit from further characterization efforts to understand the grain structure, and expanded to complex reactive materials for fragmentation studies

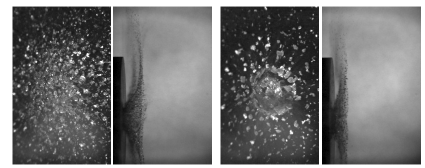


Figure 7 – Dynamic Impact Tests in HyFIRE
Left: H95 66% Right: H2 80% Velocity: 2.08 km/s

Acknowledgements

Additional thanks to Michael Flickinger, Sreenivas Raguraman, John Fite and all the other members of the Weihs Group as well as the members of HEMI. Special thanks to K.T. Ramesh and Gary Simpson for images of impact experiments in HyFIRE.

The project or effort depicted was or is sponsored by the Department of the Defense, Defense Threat Reduction Agency under award HDTRA1-20-2-0001. The content of the information does not necessarily reflect the position or the policy of the federal government, and no official endorsement should be inferred.