Project 40-L: Evaluation of Processing Path Effects on Microstructure and Properties of Powder-Based Al-TM alloy

Fall Meeting

October 13th – 15th 2020

Student: Stuart Shirley (Mines)

Faculty: Kester Clarke (Mines)

Industrial Mentors: Rob Mayer (Queen City Forge)

Project 40-L: Evaluation of Processing Path Effects on Microstructure and Properties of Powder Al-TM alloy

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CENTER FOR ADVANCED NON-FERROUS STRUCTURAL ALLOYS

- Student: Stuart Shirley (Mines)
- Advisor(s): Kester Clarke (Mines)

Project Duration
Masters: August 2019 to December 2021

- Problem: Al-TM alloys have excellent performance, but can be challenging to process via conventional processing pathways.
- Objective: Evaluate the effect of processing path on the microstructure and mechanical properties of Al-TM alloy.
- Benefit: Improved understanding of processing path effects on microstructure and properties Al-TM powders.

Recent Progress
- Literature review
- Hardness testing of thermal stability testing
- Microstructural evaluation
- Powder compaction pre-processing for additive friction stir deposition

Metrics

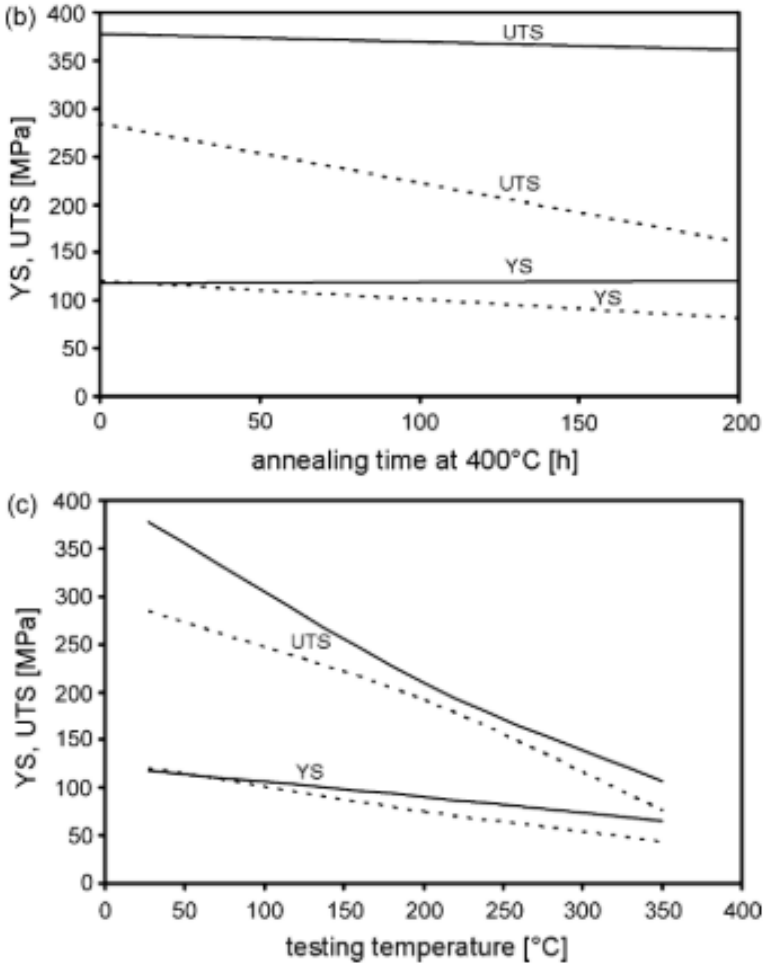
Description	% Complete	Status
1. Literature review	65	●
2. Microstructure Characterization of Forged Al-TM	20	●
3. Microstructure Characterization of Additive Friction Stir Deposition (AFSD)	0	●
4. Microstructure Characterization of ShAPE Al-TM alloy	10	●
5. Thermal Stability Testing	65	●

Outline

- Alloy background
- Experimental material
- Processing pathways
- Recent work

Al-TM background

- Produced as a powder via melting and gas atomization
- Aluminum alloyed with Fe, Cr and Ti
  - Other alloys are Al-Fe-Cr-X
  - X; Ti, Nb, Ta, V [2]
- High temperature thermal stability
- Ductility
  - 15% elongation via ShAPE processing [3]
  - 4-9% elongation via extrusion [4]

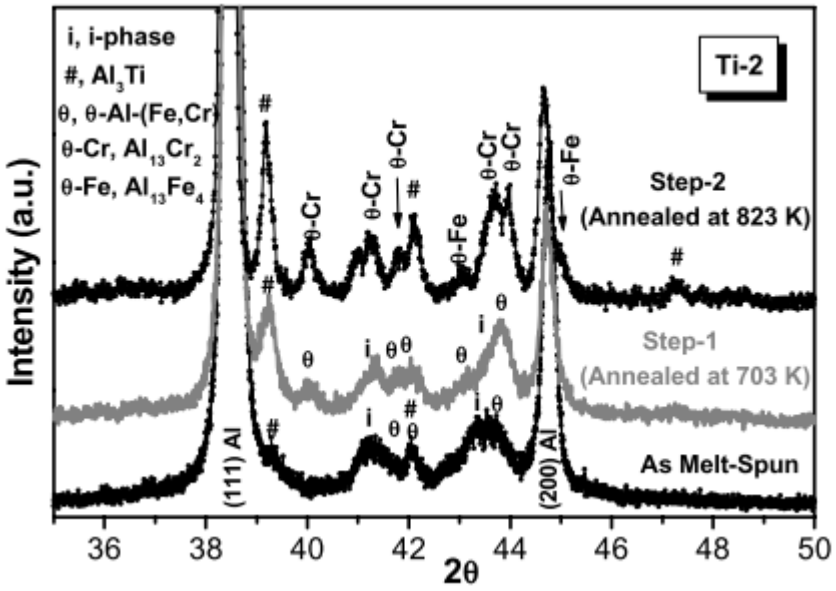


Solid line: PM extrusion consolidated Al-Cr-Fe-Ti
Dashed line: Al–12Si–1Ni–1Cu–1Mg casting alloy
Sourced: Adapted from [1]

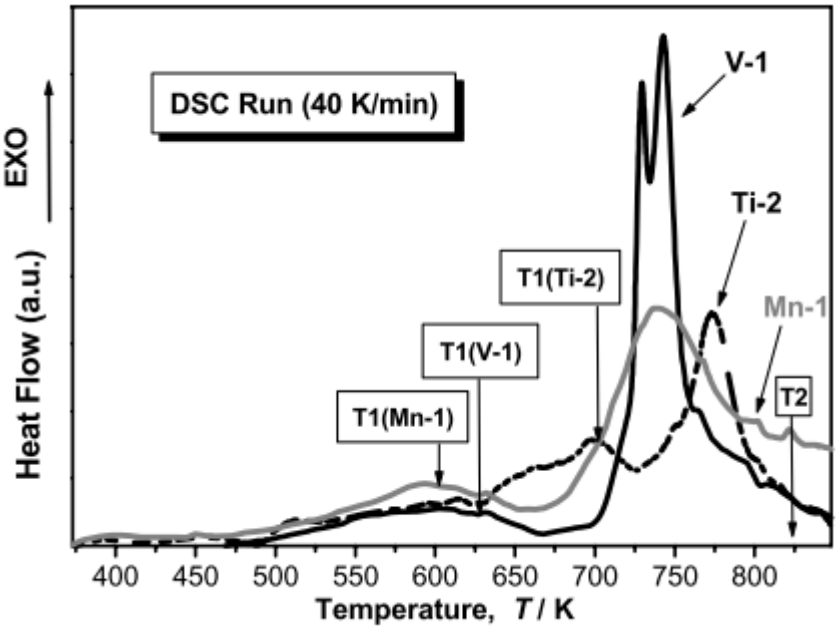
Al-TM continued

Strengthening Precipitates

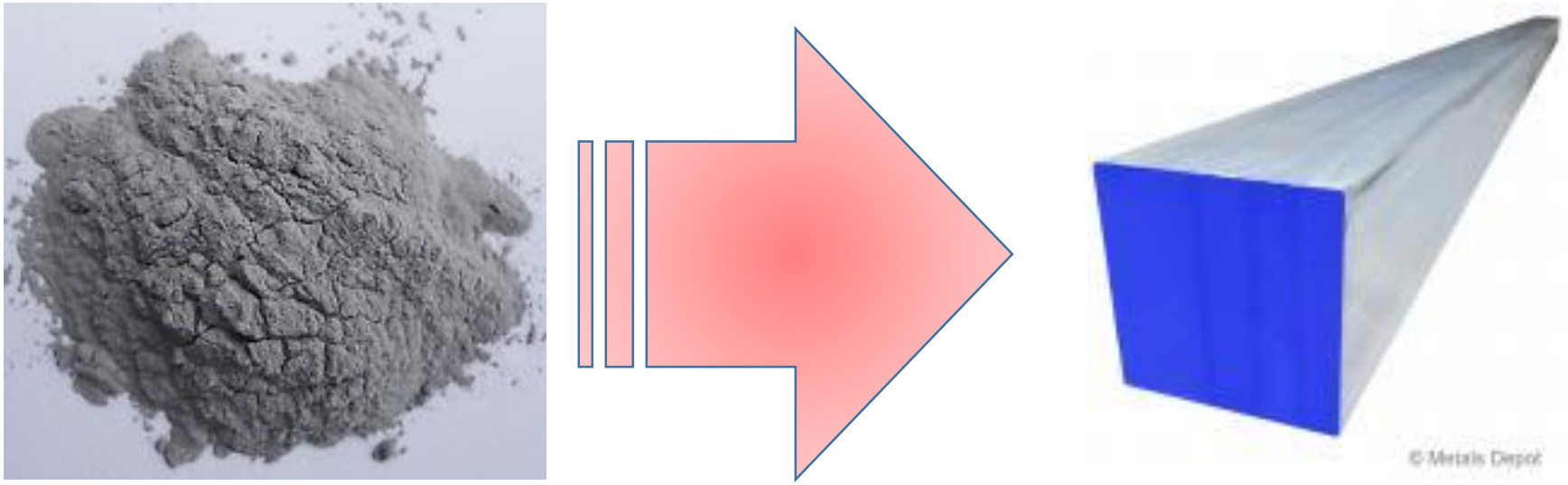
- Quasi-crystalline particles 50-80 nm [5]
- Coarsening at ~427°C and transformation at ~500°C [5,6]



Adapted from [5]



Motivation



Adapted from [7,8]

Experimental Material

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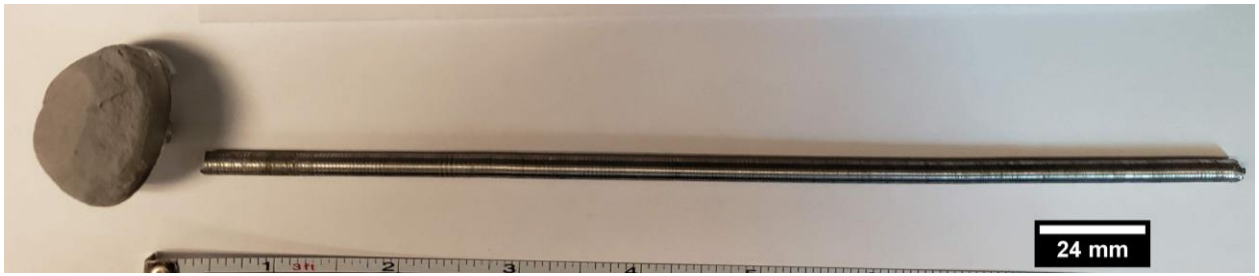
Received Material

- Extruded
  - Al- TM
  - Material from two extrusion ratios. 17.4:1 and 25:1
- Forgings
  - Al-TM
  - Produced from extrusions of 6.25:1

Experimental Material

- Shear Assisted Processing and Extrusion (ShAPE)
  - Two powder sizes
  - Same processing conditions



Anticipated Material

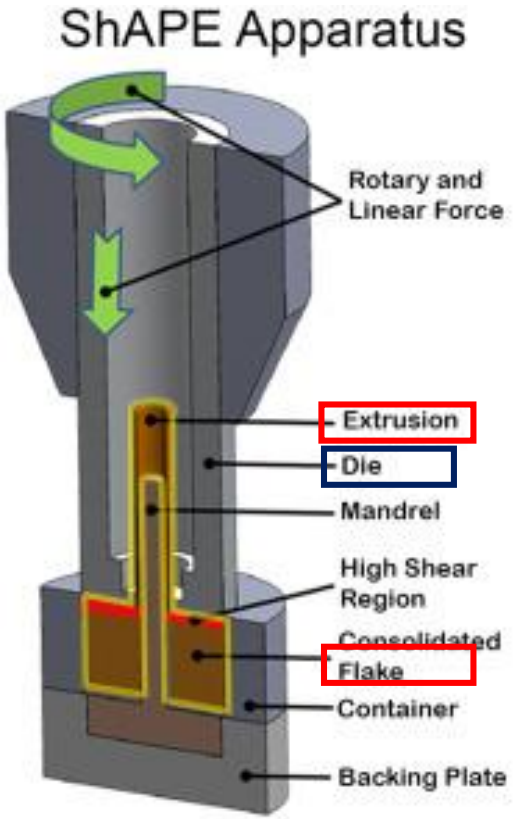
- Additive Friction Stir Deposition (AFSD)
  - Supplied by Virginia Tech and University of Alabama
  - UA will use green compacts
  - VT will use a powder in tube

Processing Pathways

- Shear Assisted Processing and Extrusion (ShAPE)

- Additive Friction Stir Deposition (AFSD)

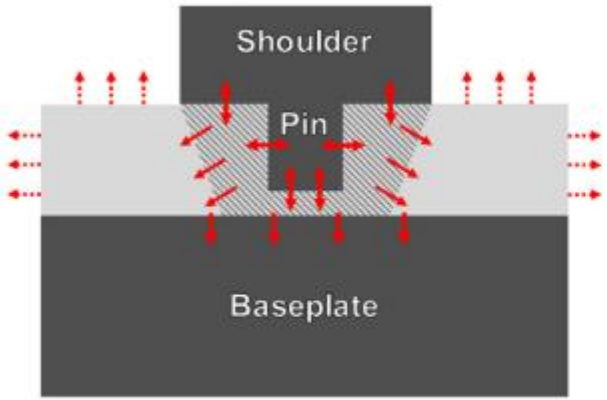
ShAPE



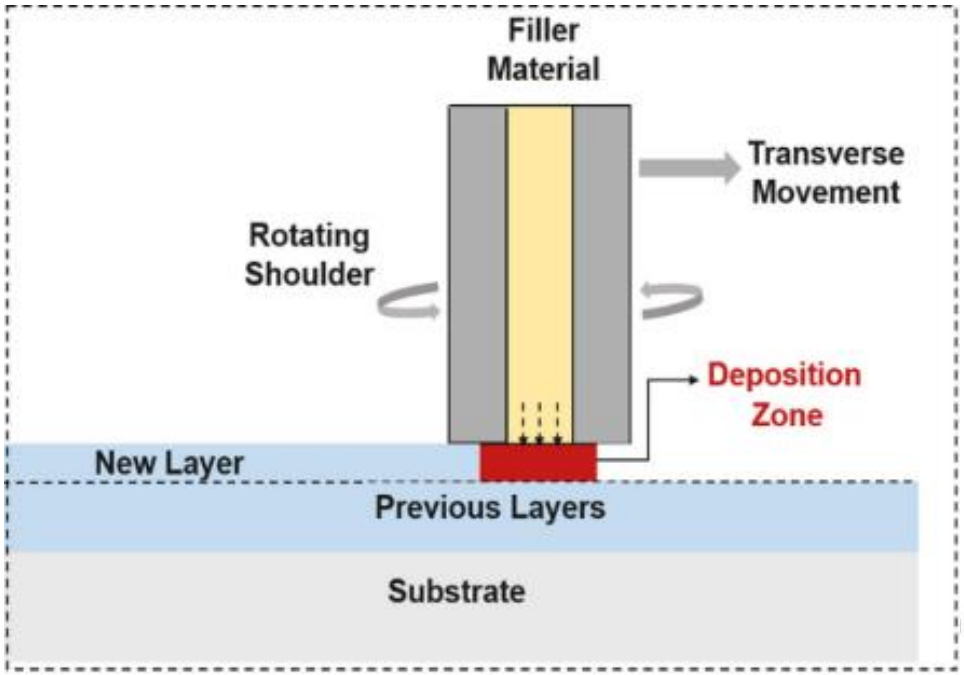
Source [8]

- Shear assisted processing and extrusion (ShAPE)
- Friction stir extrusion
- Friction stir back extrusion is a related process [10]
- Aluminum, Copper, Magnesium [9-11]

Additive Friction Stir Deposition (AFSD)



Friction Stir Welding

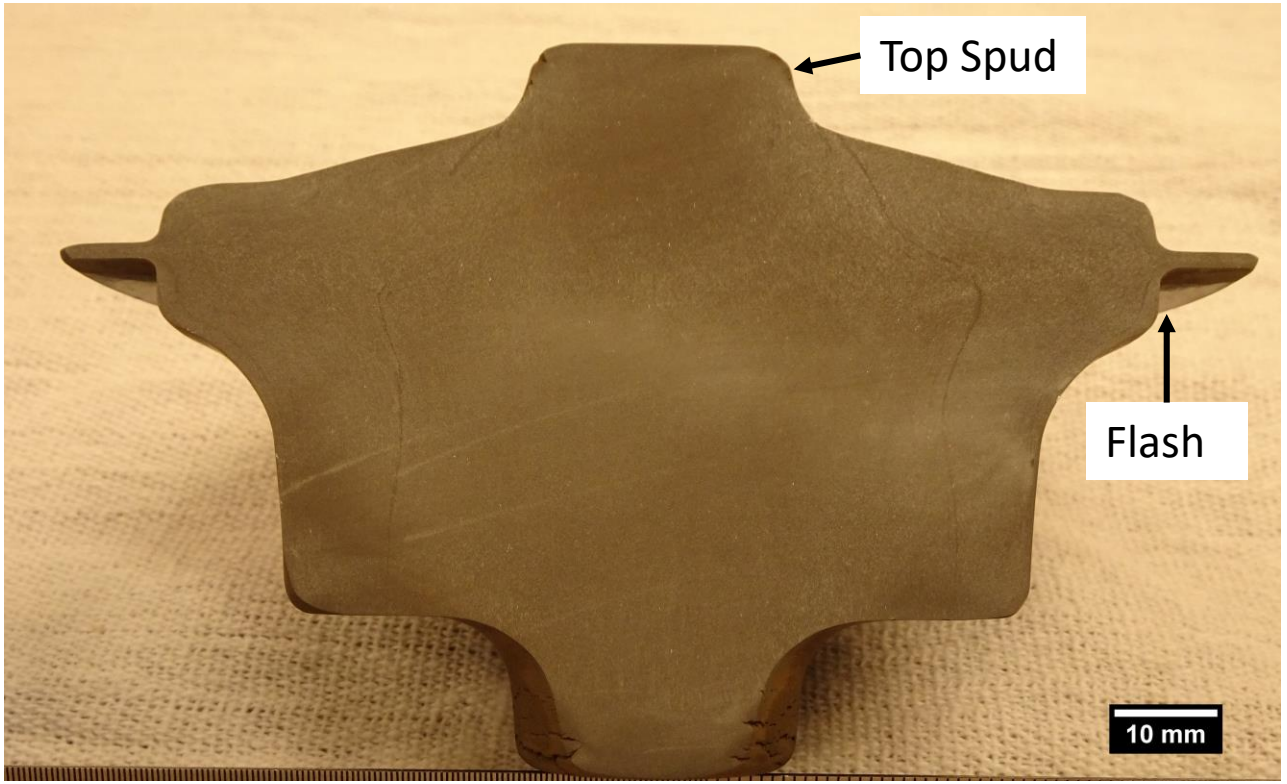


Additive Friction Stir Deposition

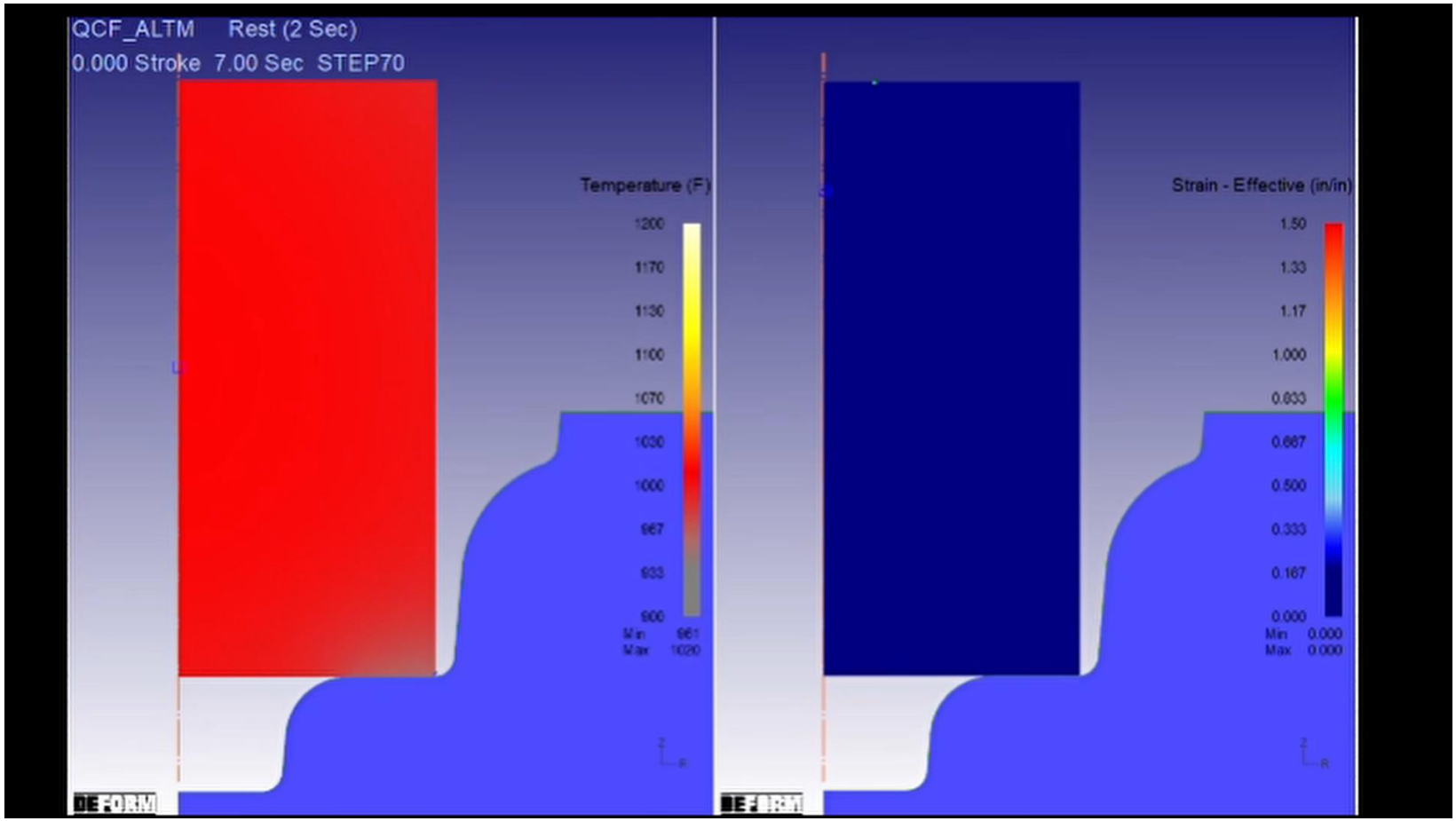
Adapted from [12]

Recent work

- Forging macro etching
- Polishing process
- Thermal stability testing

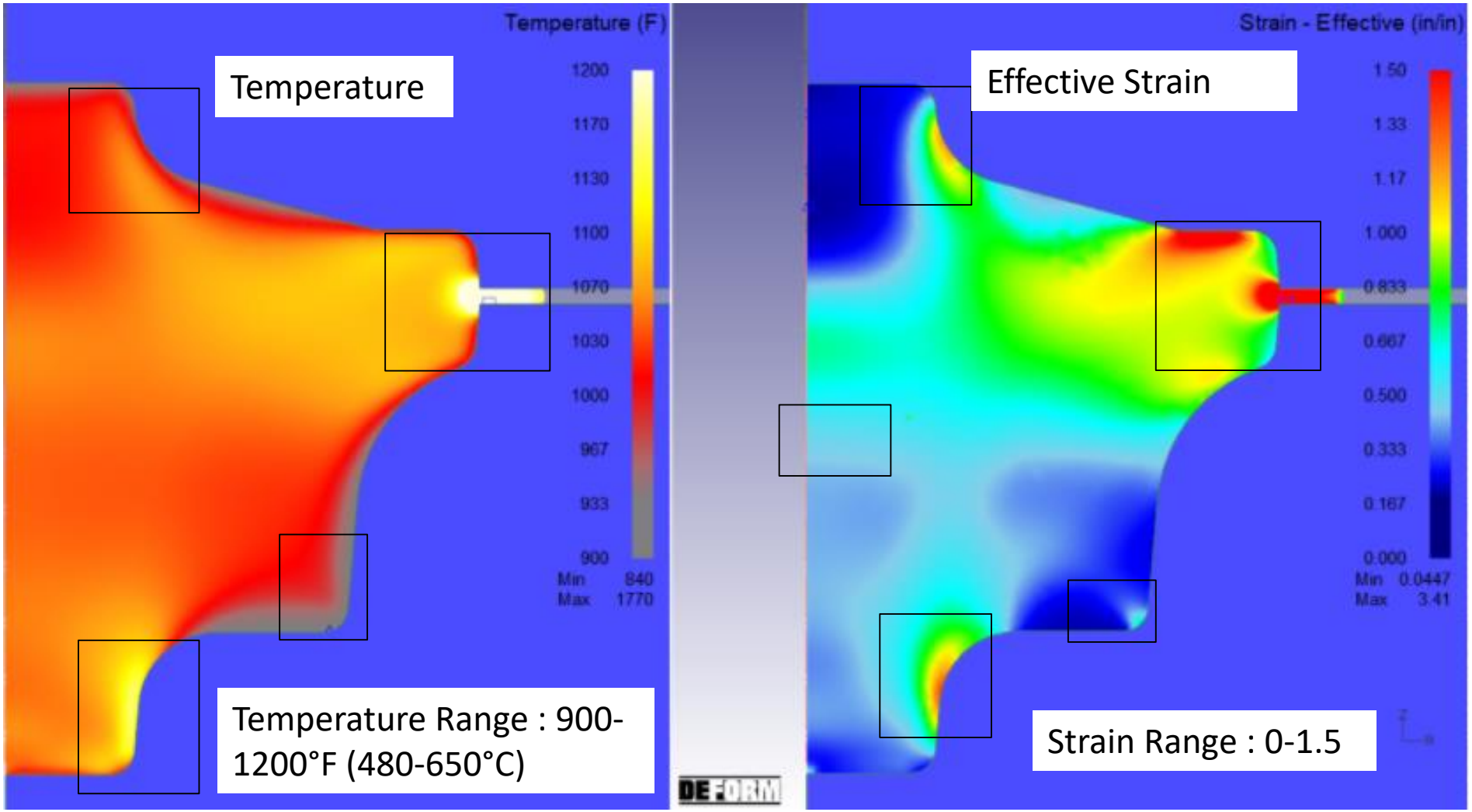


Deform Simulation



Simulation of Al-TM forging provided by Tkach Metal Forming Consulting

Forgings



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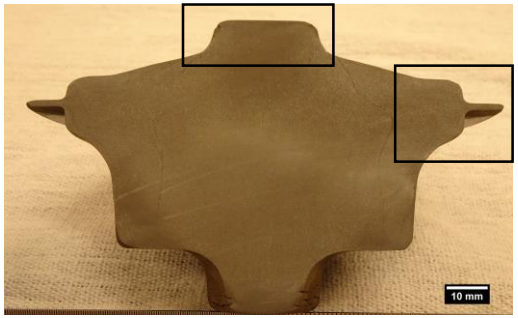
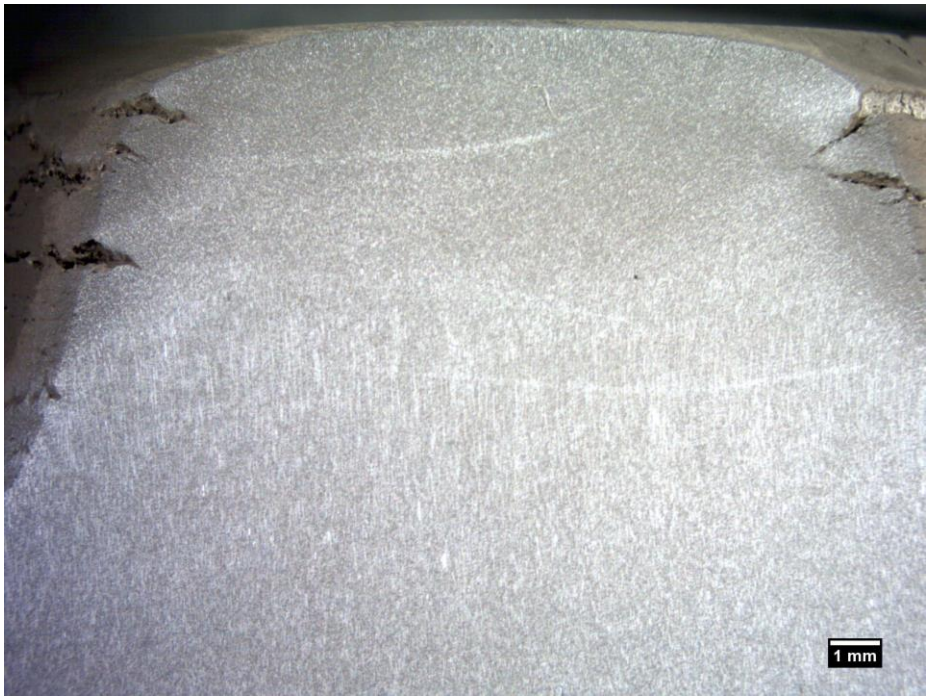
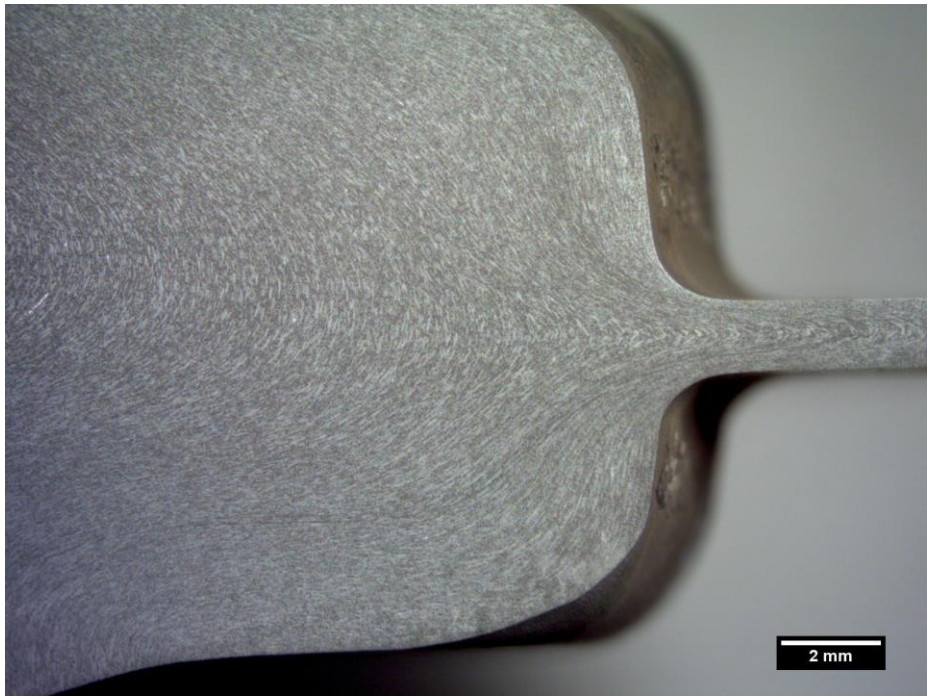
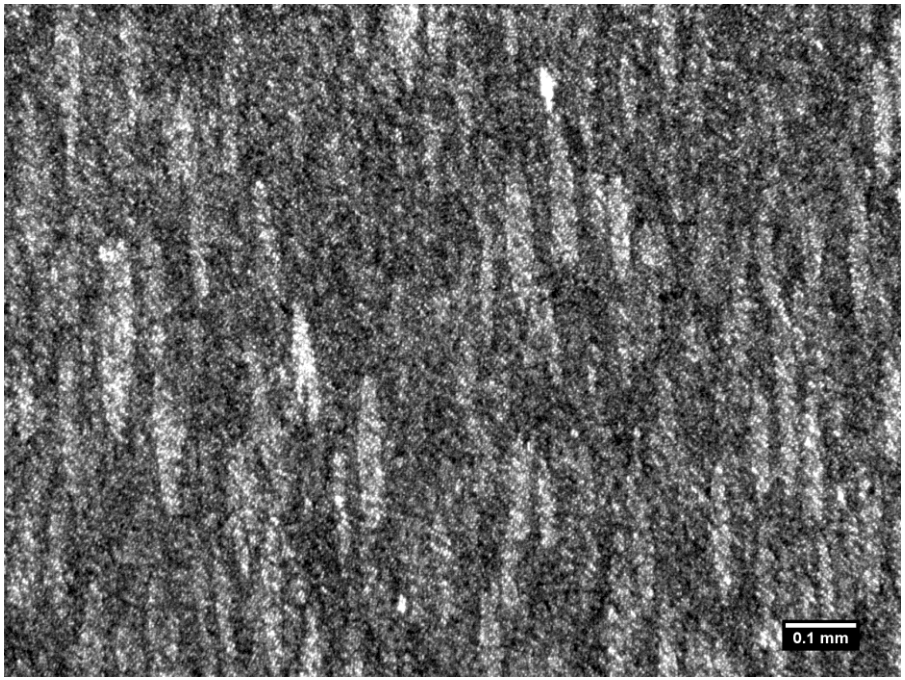


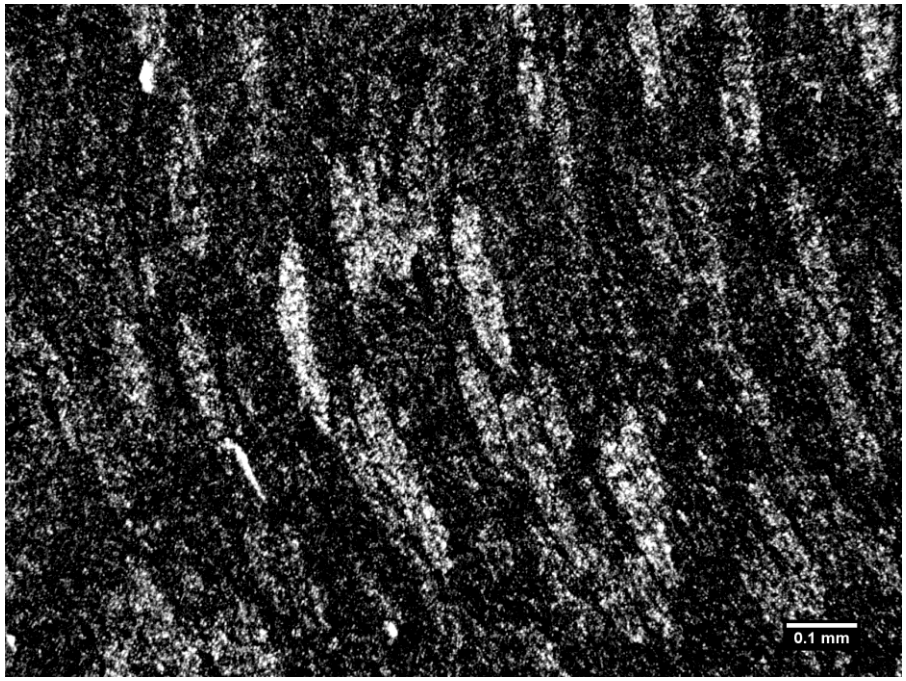




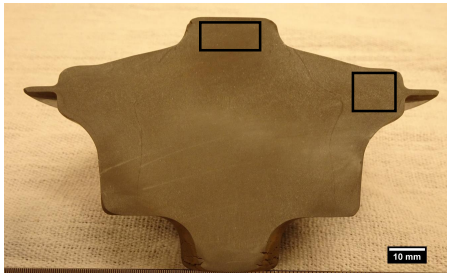
Forging Microstructures



Top Spud

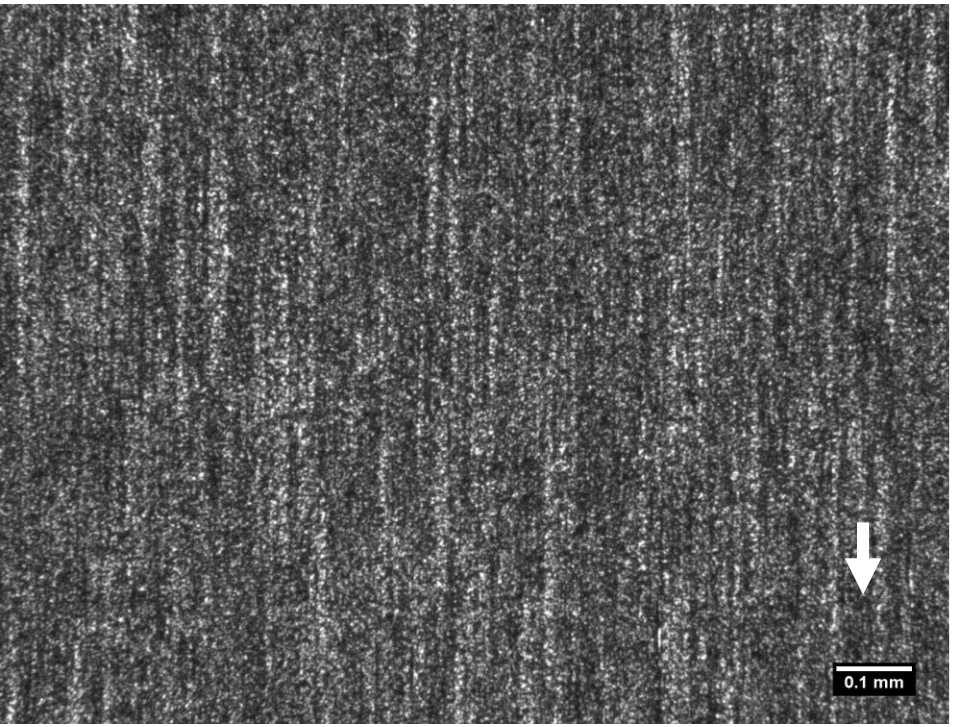


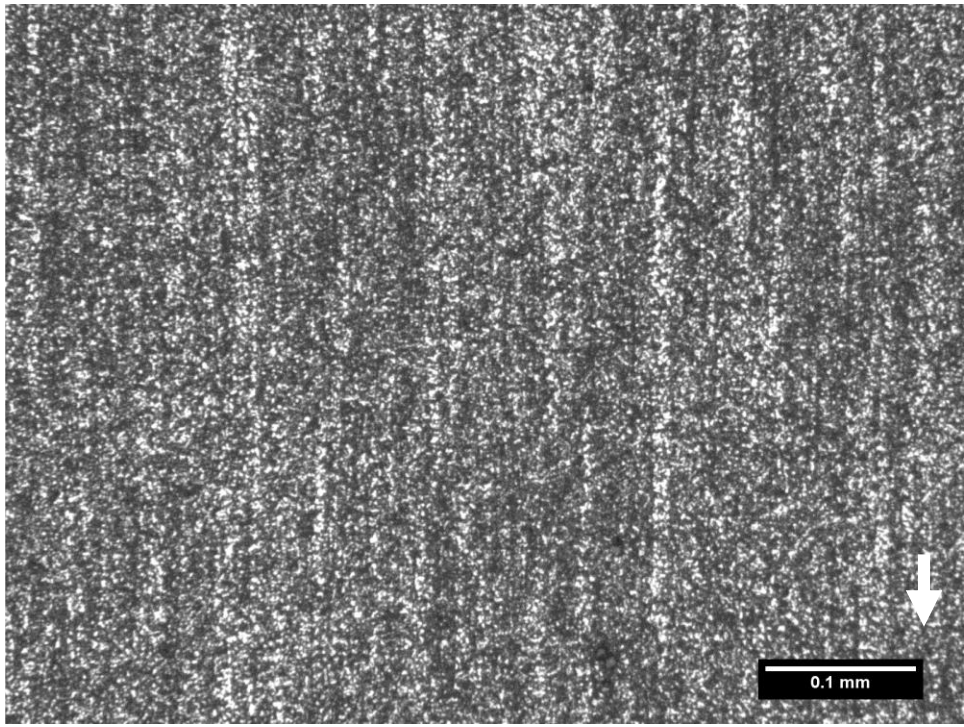
Flash



550°C billet temperature
Extrusion starting stock with extrusion ratio of 6.25:1
Kellers etchant

As Received Extrusion

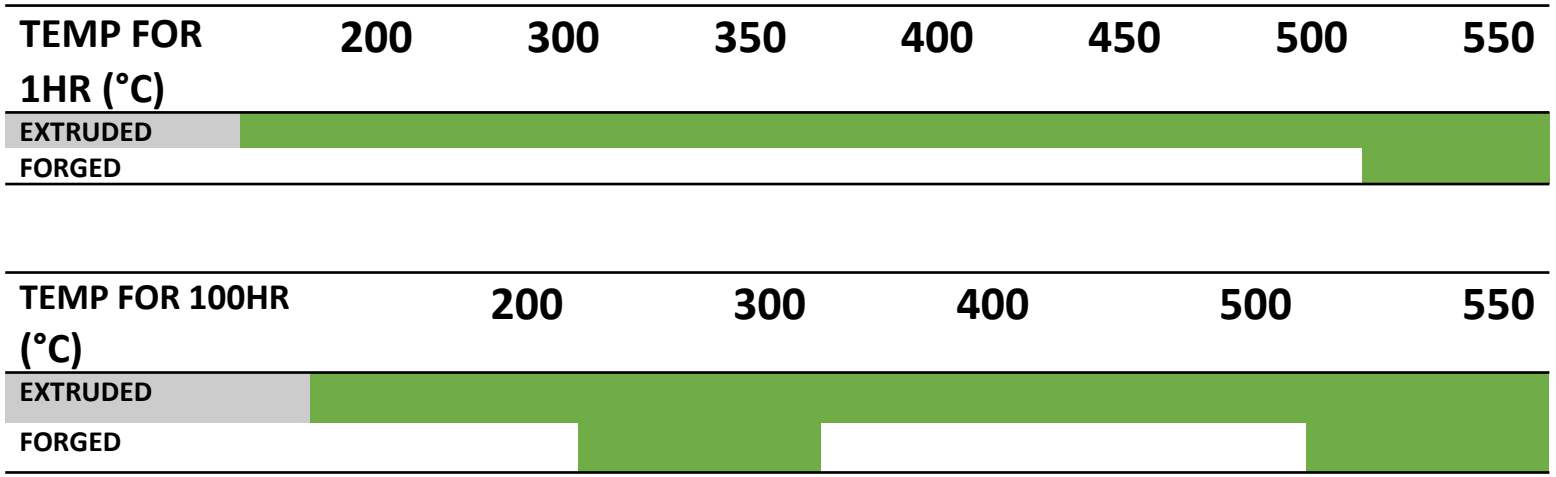




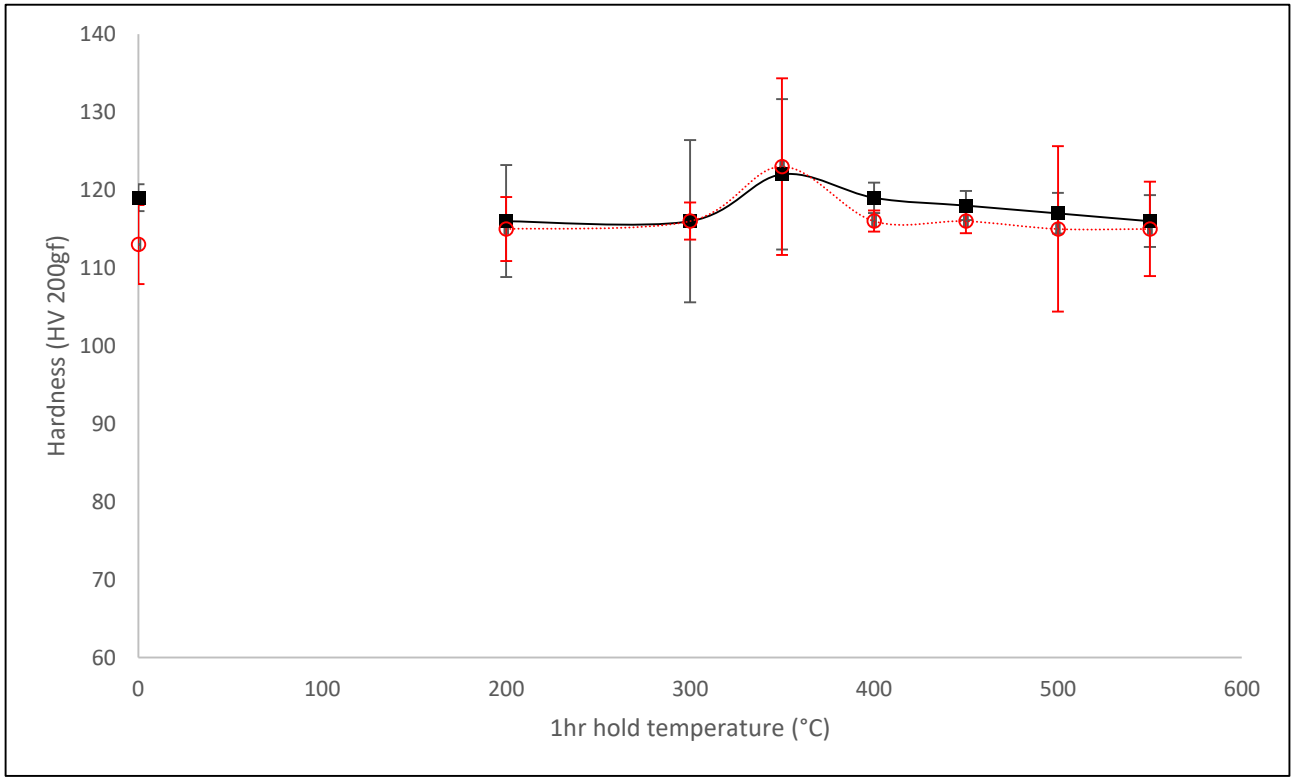
17.4:1 extrusion as received
Kellers etchant
Extrusion direction indicated by arrow

Thermal Stability

- 1 hour thermal stability test to determine temperatures of interest
- 100 hour long time treatment
  - ~~Considering a high temperature short time simulation to reduce heat treat times~~

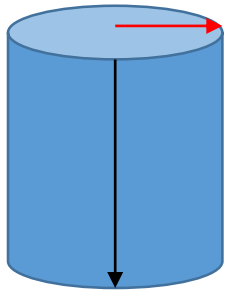


Thermal Stability 1hr Results

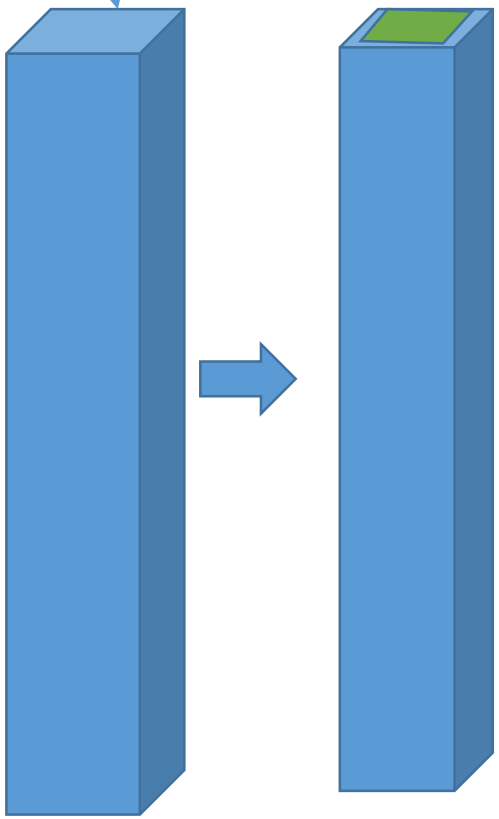


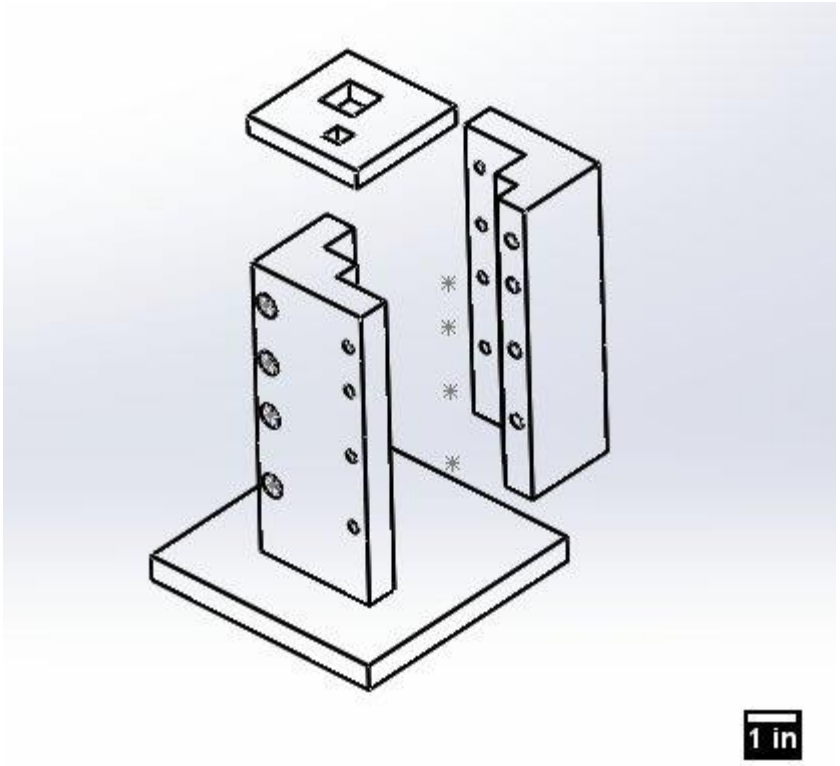
- Vickers hardness 200gf
- Average of 20 indents with a 2.5d spacing or greater
- Error bars are one standard deviation

Radius
Extrusion Direction



Pre-processing for AFSD

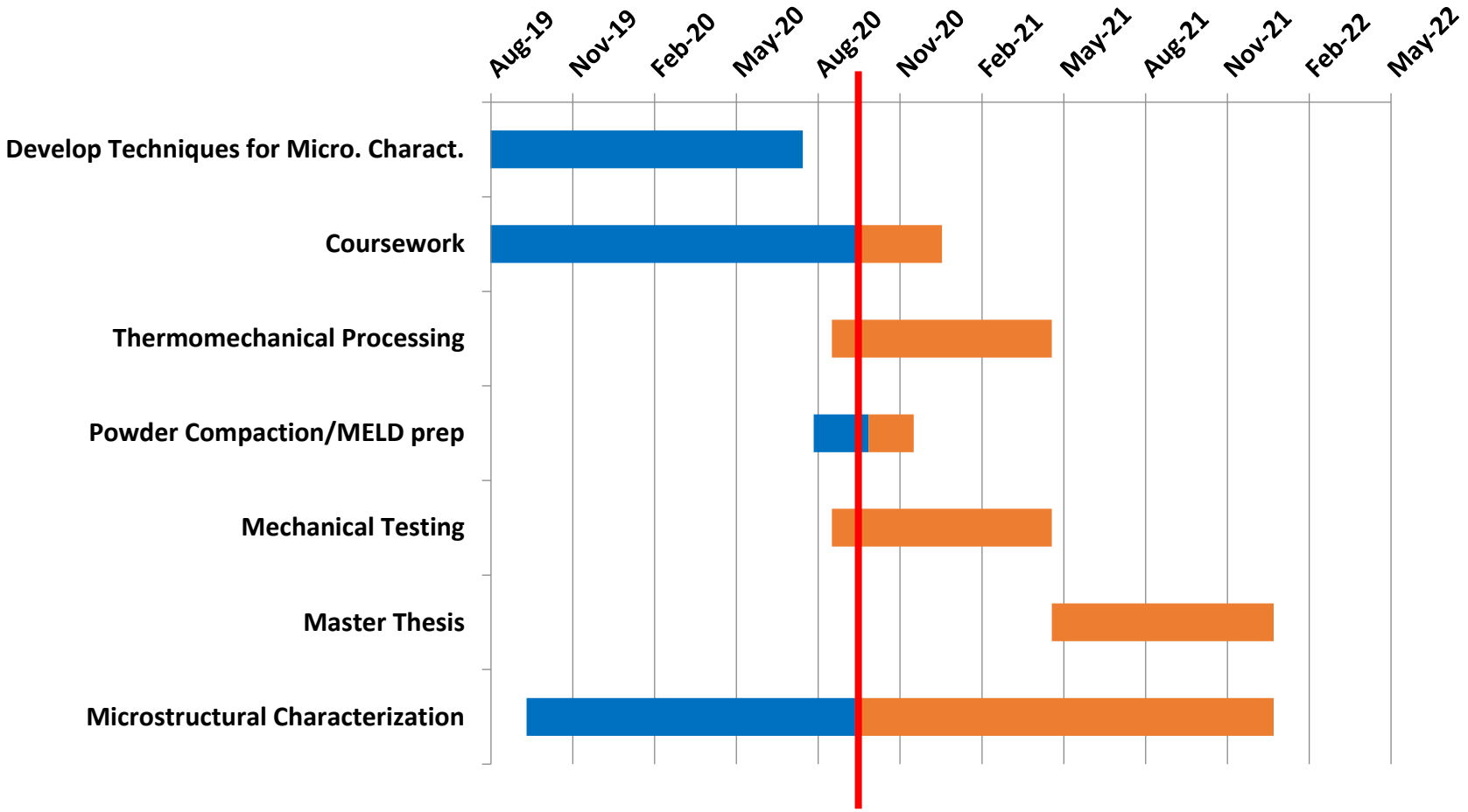




Summary of Recent Work

- Forging macro etch
- Forging and extrusion LOM microstructure evaluations
- Thermal stability tests
  - Hardness testing
- Pre-processing for AFSD

Progress



Challenges & Opportunities

- Pre-processing for AFSD
- Thermal Stability Hardness testing 100 Hr specimens
  - Intermediate time test
- Thermomechanical Testing
  - Gleeble compression testing

Acknowledgements

- Kymera International provided Al-TM extrusions and powder for this research project. Special thanks to Tom Pelletiers and Wayne Daye for technical information and project support.
- AFSD billets are to be produced by research groups at Virginia Tech under Dr. hang Yu and University of Alabama under Dr. Paul Allison.
- Friction extrusion (ShAPE) material was provided for this project by Scott Whalen, Pacific Northwest National Laboratories.
- Forgings and project support provided by Rob Mayer, Queen City Forge.
- Deform™ simulations provided by Suzanne Tkach, Tkach Metal Forming Consultants. Jim Miller & Scientific Forming Technologies for the use of Deform™.

Questions?

Thank you!

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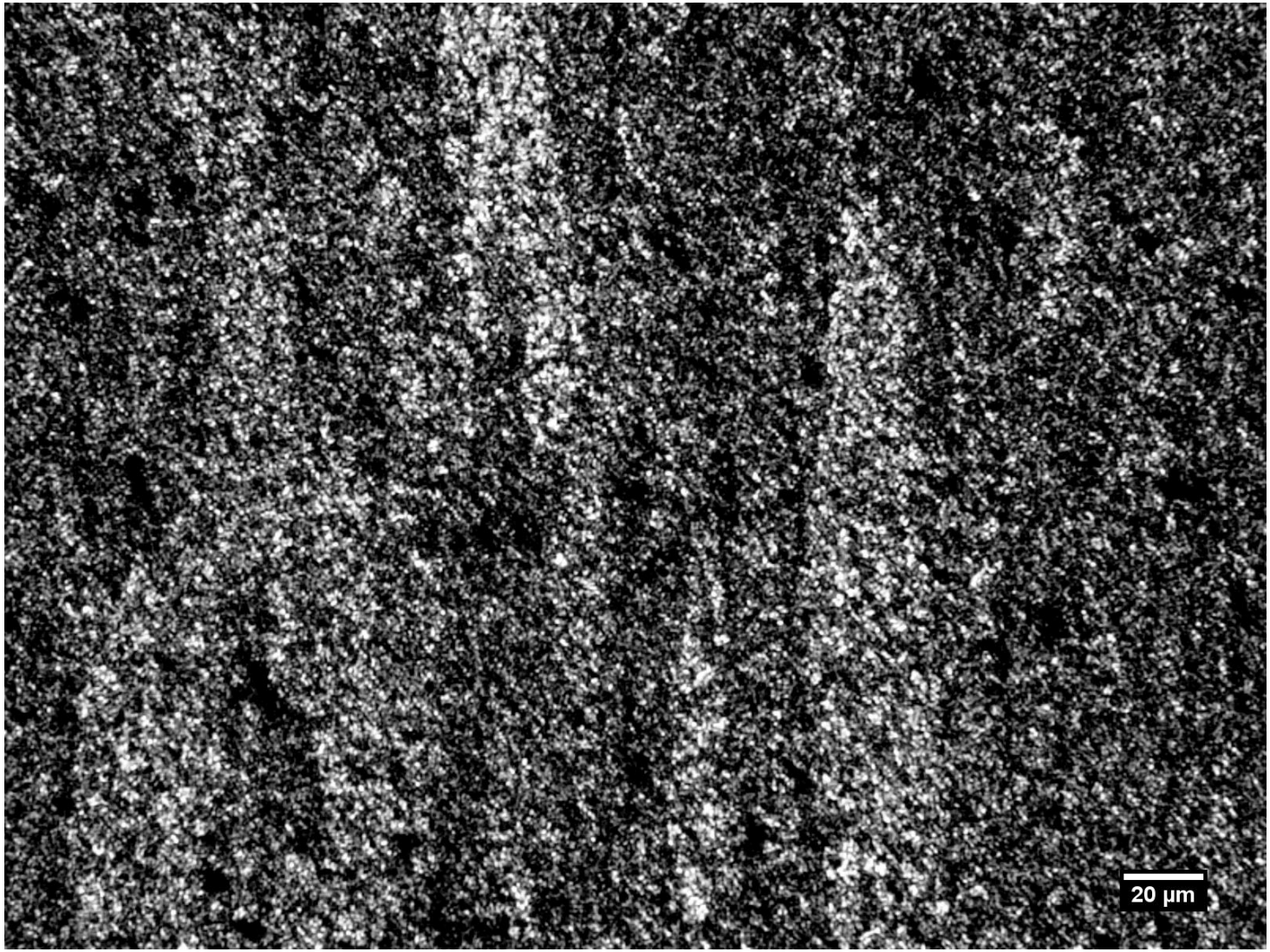

Forging Top Spud
Keller's Etch