Metamorphic Manufacturing

Fall 2020 Videoconference

October 13-15, 2020

Students: Lauren Drew (Mines Undergraduate)
Gabriella Tuell (Mines Undergraduate)
Faculty: Kester Clarke (Mines)
Industrial Mentors: TBD

Metamorphic Manufacturing

CANFSA
CENTER FOR ADVANCED NON-FERROUS STRUCTURAL ALLOYS

- Student(s): Gabriella Tuell, Lauren Drew (Mines)
- Advisor: Kester Clarke (Mines)

Project Duration
May 2020 - May 2021 (REU & MURF)

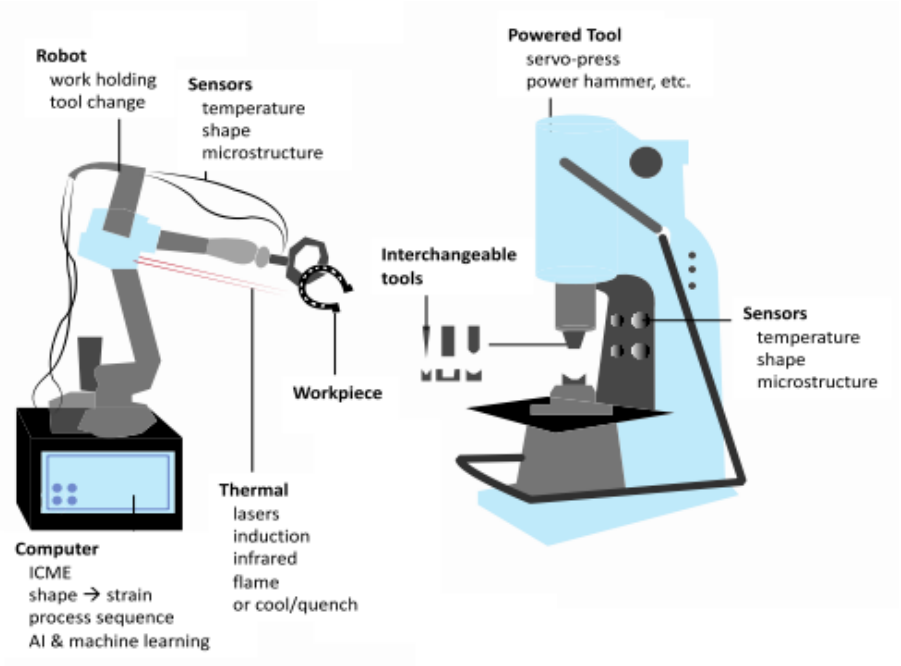
- Problem: Traditional manufacturing techniques are highly inefficient, costly, and time-consuming.
- Objective: Develop robotic controls to automate the blacksmithing process, enhance mechanical properties, and decrease the number of finishing processes required to meet specifications.
- Benefit: Metamorphic Manufacturing could prove to be a low-cost, low-risk alternative to traditional forging and metal printing processes in the creation of specialized parts.

Recent Progress

- Achieved an understanding of traditional blacksmithing techniques.
- Created a list of control variables to fully automate the forging process.
- Designed an axisymmetric rotary shaft to serve as an indication of future process applications.
- Developed a deformation process utilizing a roto-linear actuator and hydraulic press.
- Annealed Aluminum 1/2 in, 1 in, and 2 in bars.

Metrics		
Description	**% Complete**	**Status**
1. Background research, literature review	50%	●
2. Blacksmithing proficiency and identification of control variables	80%	●
3. Rotary shaft and deformation process design	75%	●
4. Programming and hardware interface	5%	●
5. Analysis of mechanical properties and microstructure	0%	●

Industrial Relevance



Daehn, G. Taub, A., *Metamorphic Manufacturing (a.k.a. Robotic Blacksmithing):The Third Wave of Digital Manufacturing*. National Network for Manufacturing Innovation: Lightweight Metals Institute, 2018

Applications:

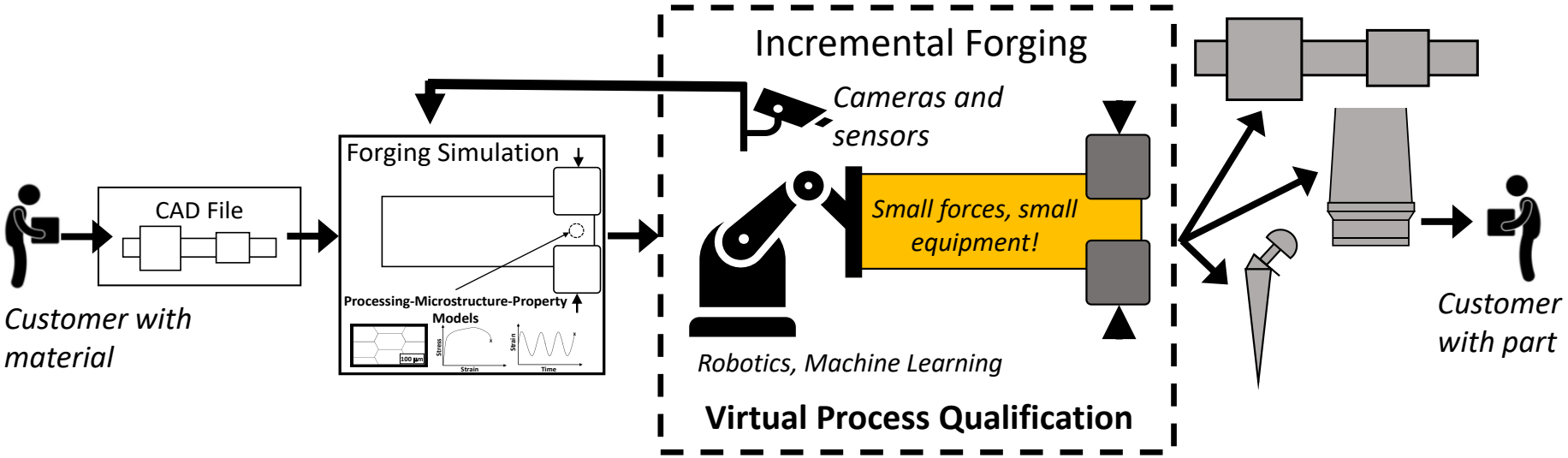
- A wide range of industries that currently utilize close-die forging including
  - Automotive
  - Aerospace
  - Agriculture
  - Defense
  - Oil & Gas

Benefits:

- Customizable component geometries
- Maintain performance while ensuring manufacture of components is economically viable
- Enhanced material properties
- Increased efficiency, decreased waste

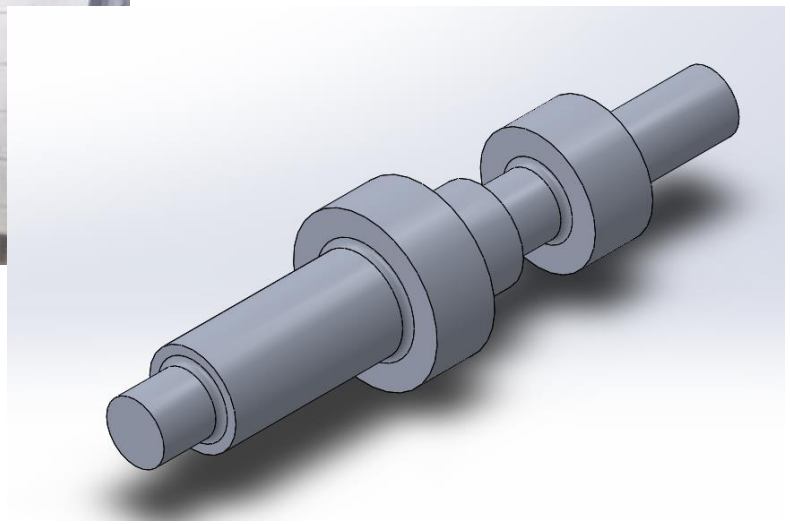
Metamorphic Manufacturing

SolidWorks Model → DEFORM Simulation → Physical Deformation



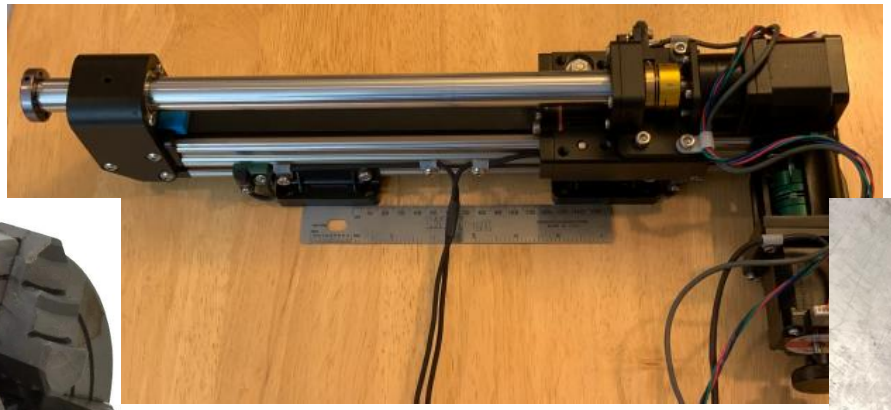
Summary of Research Tasks

- Phase 1: Determination of pathways in conjunction with forging press
  - Development of traditional blacksmithing skills and hydraulic press use for Gabriella Tuell
  - Simulation and modeling of proposed component using CAD tools

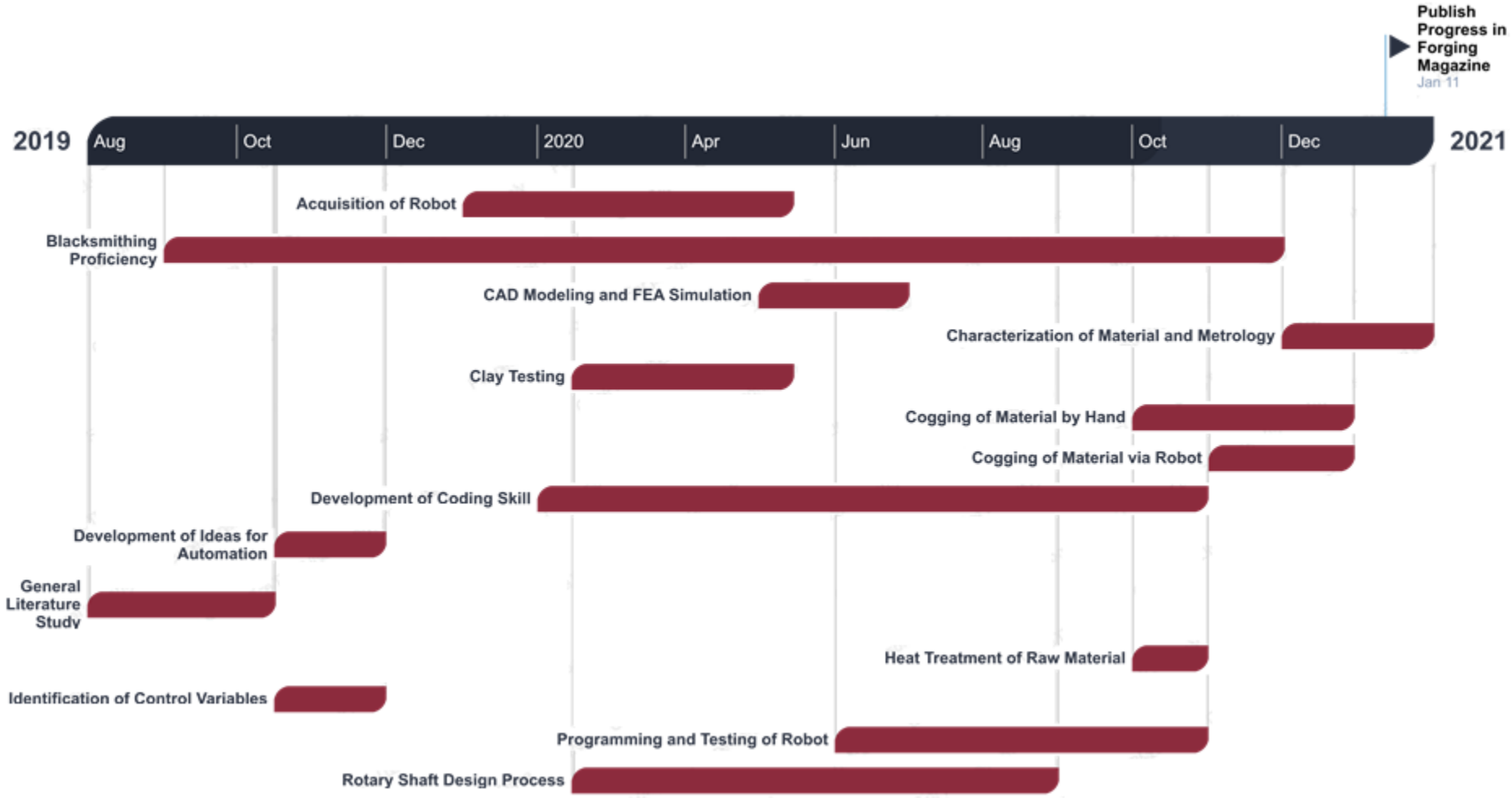


Summary of Research Tasks

- Phase 2: Operation of robotic components
  - Use of IMAC controls to operate linear actuator
  - Programming hardware interface (DEFORM and IMAC controls)
  - Annealing 1 in., 1.5 in., and 2 in. bars [3]
  - Chuck attachment for linear actuator
  - Room temperature aluminum deformation with the linear actuator and hydraulic press



Progress



Challenges & Opportunities

- Immediate Challenges
  - Designing attachment component for linear actuator to hold material
  - Limited deformation of annealed aluminum at room temperature

- Future Concerns
  - Sensing and feedback of complex pathways (metrology, control variables)
  - Underdeveloped standards and specifications
  - Predicted performance validation for component geometries

Thank you!

Gabriella Tuell
gtuell@mines.edu

Lauren Drew
drew@mines.edu

References

[1] Metamorphic Manufacturing: Shaping the Future of On-Demand Components, vol. 1. Pittsburgh, PA: The Minerals, Metals and Materials Society, 2019.

[2] Daehn, G. Taub, A., Metamorphic Manufacturing (a.k.a. Robotic Blacksmithing): The Third Wave of Digital Manufacturing. National Network for Manufacturing Innovation: Lightweight Metals Institute, 2018

[3] "Heat Treating of Aluminum Alloys," *ASM Handbook, Volume 4: Heat Treating*, vol. 4, pp. 841–879, 1991.