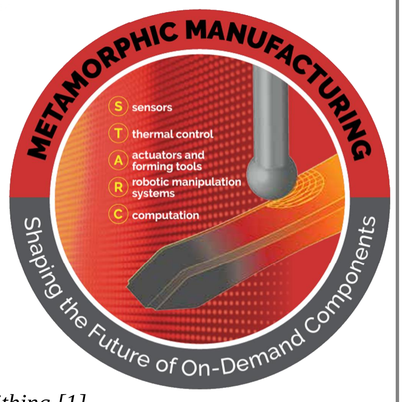
Development and Initial Testing of Robotic Blacksmithing Apparatus

Pedro Doukas, Dr. Brad Kinsey
John Olson Advanced Manufacturing Center, University of New Hampshire

INTRODUCTION

Metamorphic manufacturing, also known as Robotic Blacksmithing, allows for the creation of specialized parts with customizable material properties. Viewed as the third wave in digital manufacturing, robotic blacksmithing aims to enhance material limits from CNC milling and 3D printing [1]. Point-of-need, autonomous manufacturing platforms, such as robotic blacksmithing, enable safe ways to manufacturing complex parts. Combining robotic blacksmithing with another process, such as 3D printing, allows for a flexible hybrid manufacturing process [2] .

This study is part of a larger NSF-funded research project to establish a sustainability framework for In-space Manufacturing [2].

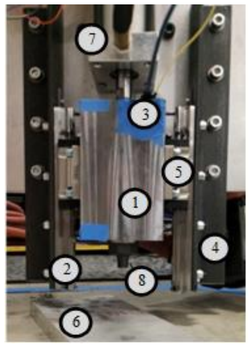


5 elements of Robotic Blacksmithing [1]

METHODS

- Tested and improved end effector
- Quantified system and impact data
- Incorporated accelerometer and video analysis to calculate force and velocity
- Utilized KUKA robotic arm to impact workpiece
- Analyzed impacts for surface roughness and hardness

(1) 4041 alloy steel block
(2) Guide rails (x2)
(3) Accelerometer
(4) 90-degree steel angle
(5) Ball bearing carriage
(6) Workpiece
(7) Pneumatic cylinder
(8) Indenter flat tip

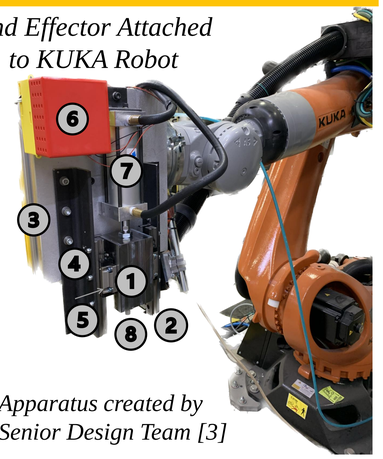


SYSTEM

1) 4041 Alloy Steel Block
2) Guide Rails (x2)
3) Aluminum Plate
4) Low Carbon Steel 90 Degree Angle
5) Ball bearing Carriage
6) Arduino Housing
7) 100mm Stroke 63.5mm Bore Air Cylinder
8) Indenter 12.7mm Flat

Workpiece:
AA6061; 25.4 mm (1 in.) thickness

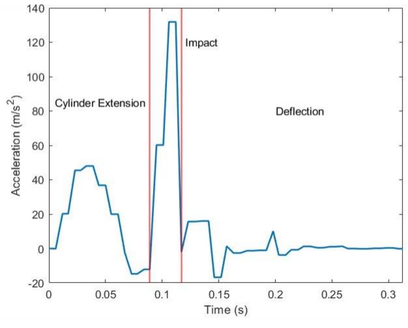
End Effector Attached to KUKA Robot



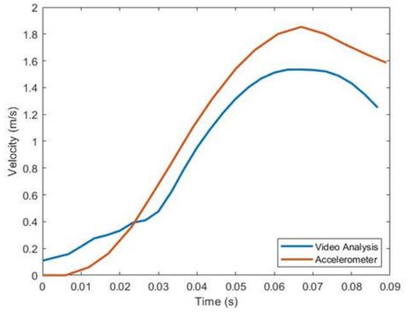
Apparatus created by Senior Design Team [3]

EXPIRIMENTAL RESULTS

- Calculated Impact pressure of 938 MPa, force of 119 kN
- Velocity of extension peak ~1.8 m/s
- Max indent distance: 0.127mm
- Surface Roughness reduction of 33%
- Hardness increase of over 20%

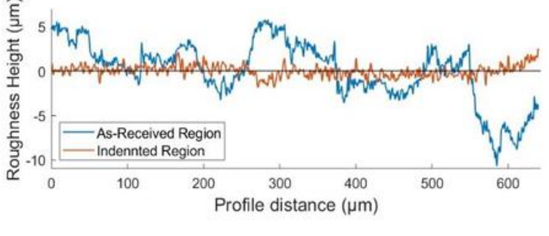


Acceleration of Indenter



Velocity of Indenter

Indentation left on AA6061 from a single impact

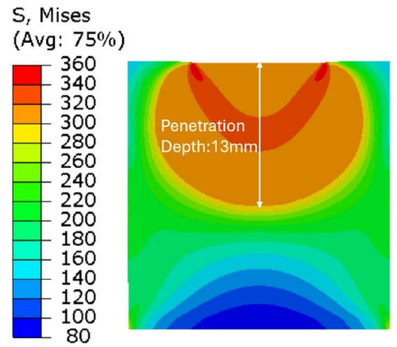


Surface profile roughness of workpiece

THEORETICAL RESULTS

- Peak stress of 350 MPa
- Anticipated depth of deformation is ~13 mm
- Reaction force of 91 kN

Simulated in Abaqus 2023 as an axisymmetric finite element analysis



CONCLUSIONS AND FUTURE WORK

- Robotic blacksmithing is a viable method of precision cold forging enabling localized manipulation of material properties
- Successful demonstration of cold forging process enables future work with different materials
- Sequence of impacts will be combined creating an area of deformation replicating a more realistic process
- Testing on a lunar regolith and aluminum powder mixture to replicate material available in space
- For military purposes, can be part of a point-of-need manufacturing platform to fabricated needed components.

ACKNOWLEDGEMENTS | LINKEDIN

- Dr. Brad Kinsey (Research Advisor)
- Sha Ouyang (PhD Student)
- Laura Catalano (Senior Design Team)
- Noah MacAdam (Technical Service Center)
- Nathan Daigle (Manufacturing Engineer)
- With support from the CEPS Makerspace

REFERENCES

1. Glenn Daehn, et al. *Metamorphic Manufacturing: Shaping the Future of On-Demand Components*. The Minerals, Metals & Materials Society, 2019, https://www.tms.org/portal/portal/Publications/Studies/MetamorphicManufacturing/Download_MM_Study _Report.aspx.
2. *FMRG: Eco: GOALI: CAS: Understanding the Sustainability Framework for Convergent In-Space Manufacturing*. NSF Proposal Grant number 2328383
3. Catalano, et al. *Robotic Blacksmithing Apparatus: End of Semester 2 Report.*