Sugino Cavitation Abrasive Surface Finishing for Additively Manufactured Metals

INTRODUCTION

The objective of our project is to determine how the design of additively-manufactured (AM) Ti-6Al-4V tubular parts can be optimized to maximize the effectiveness of Cavitation Abrasive Surface Finishing (CASF) with respect to surface texture and integrity.

What is CASF?

CASF is a surface treatment process that combines high-pressure water jets, cavitation bubbles, and abrasive particles to improve surface finish.

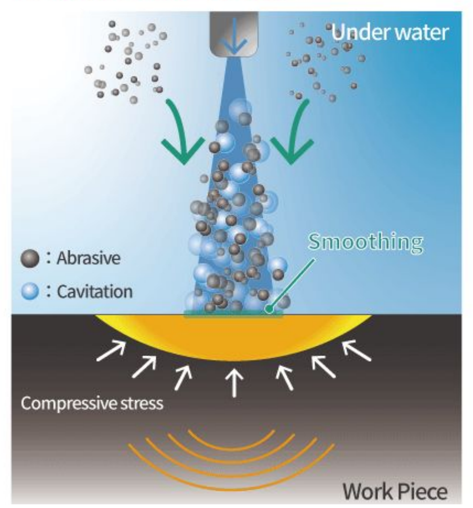

Figure 1. CASF Process

Traditional surface treatment methods utilize hazardous chemicals and struggle to effectively treat complicated internal geometries.

Variability of CASF

Previous studies note that CASF treatment is highly variable for complex geometries.

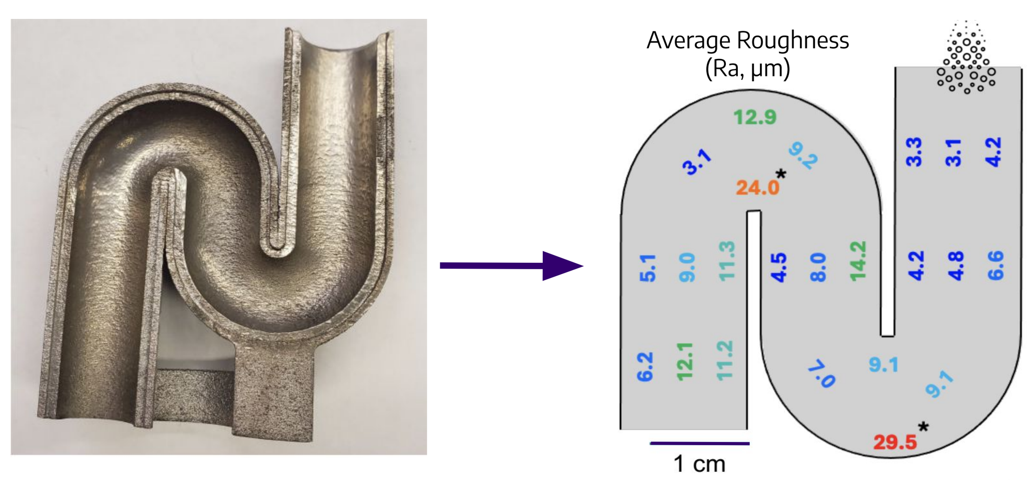

Figure 2. CASF treated S-Bend tube (left) and corresponding roughness (right). *As-Built Ra = 10 - 30 µm (JCATI)

METHODS

Materials

Ti-6Al-4V is a high-performance titanium alloy widely used in aerospace, biomedical, and marine applications due to its excellent strength to weight ratio and biocompatibility.

Metals produced by Laser Powder Bed Fusion (LPBF) have high surface roughness, undesirable for many applications

METHODS

Design

Using the principles of fluid dynamics, our designs aimed to mitigate velocity loss factors associated with CASF flow by controlling internal diameter and angle of curvature. Parts were designed with Solidworks and exported as Standard Triangle Language (STL) files to print.

Manufacturing

Parts were printed at UW using the EOS M290 for LPBF

Figure 3. Preliminary CAD (left) and EOS M290 printer (right)

Characterization

Contact and Optical Profilometry
- Roughness (Optical)
- Stress Concentration Factor (Contact)

Scanning Electron Microscopy (SEM)
- Surface Morphology (Micrographs)

X-ray Diffraction (XRD)
- Surface Residual Stress

RESULTS

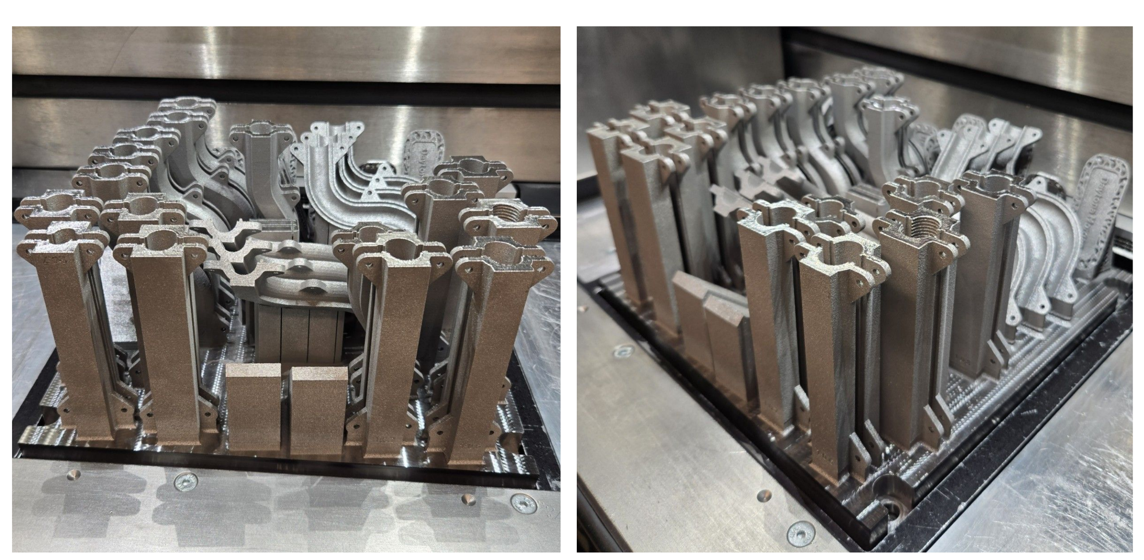

Figure 4. Printed Ti-6Al-4V parts for design iteration 1

RESULTS

Significant Results

- The roughness and residual stress at the *entrance* of the parts was *statistically different* than at the *exit* following CASF treatment.

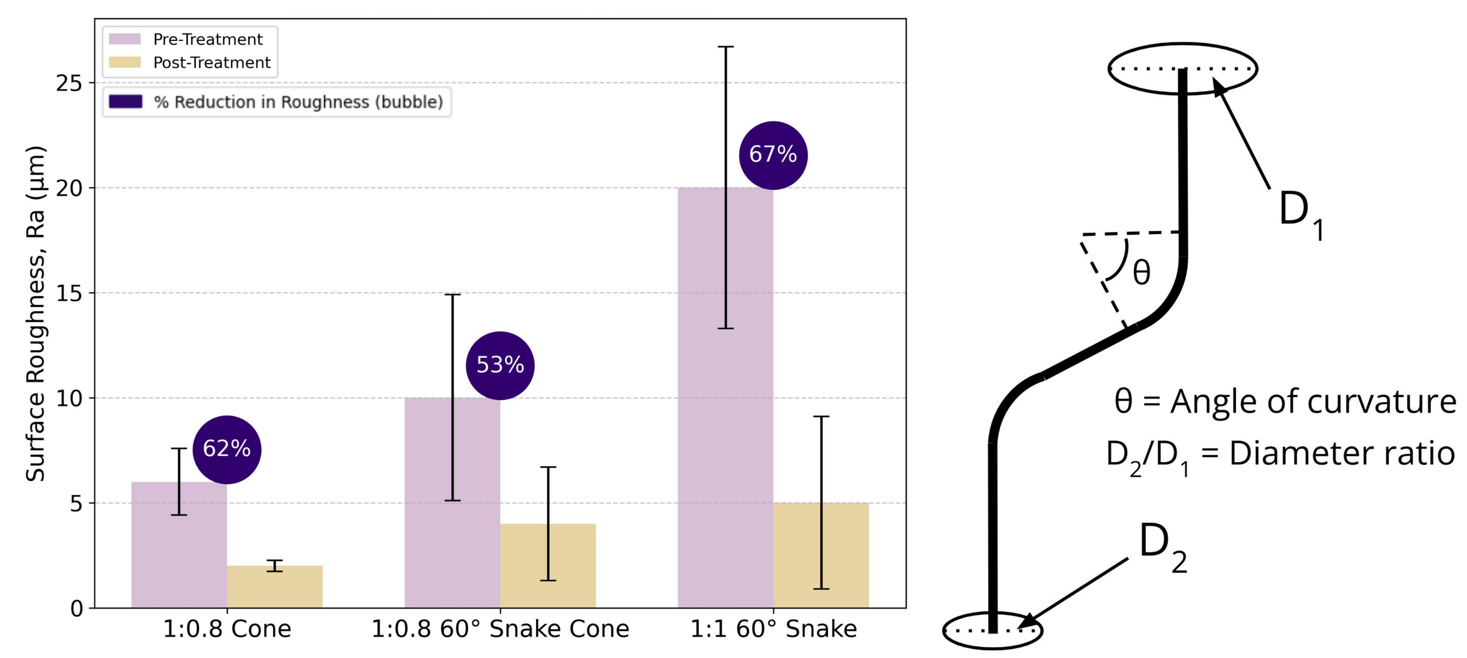

Figure 5. Part variations with largest percent reduction in average roughness (left) and schematic of part design (right)

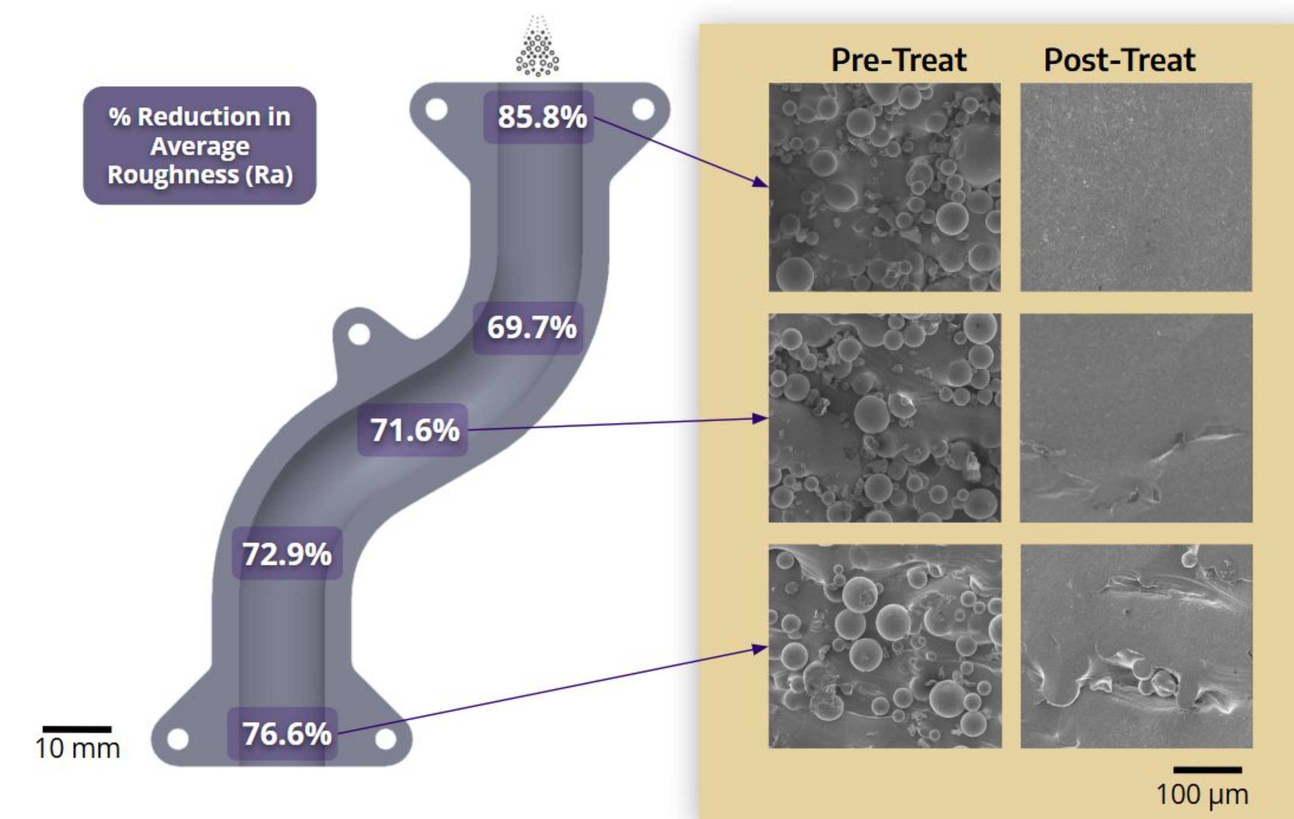

Figure 6. SEM micrographs for a 1:1 60° snake tube pre- and post-CASF treatment

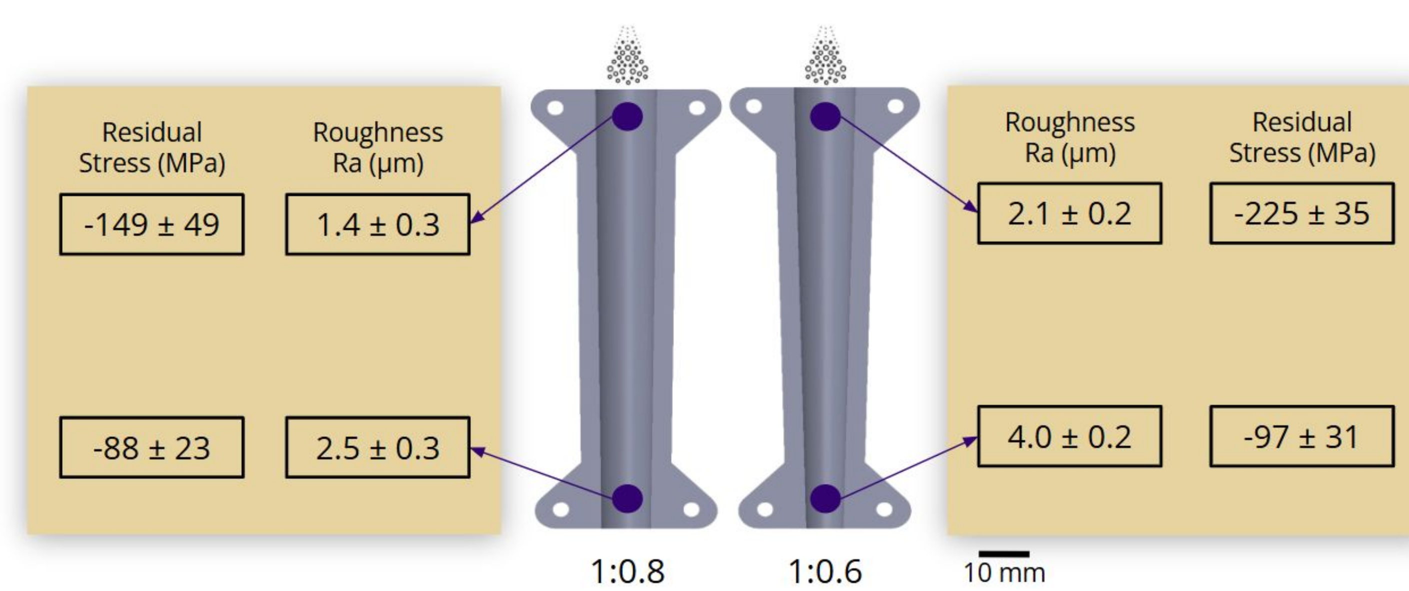

Figure 7. Resulting residual stress and roughness for two CASF treated cones

CONCLUSIONS

Statistical Significance

- Part geometry had no significant impact on the post-treated roughness (Ra) of parts.
- Significant reduction in compressive residual stress over the length of the tubing.
- Approximations of jet velocity reduction based on fluid dynamics did not correlate well with observed changes in surface roughness. This is likely due to the complex interactions within CASF such as cavitation bubble dynamics, abrasive behavior, and part geometry.

FUTURE WORK

Iterative Design

- Additional parts were printed based on similar fluid dynamics principles.

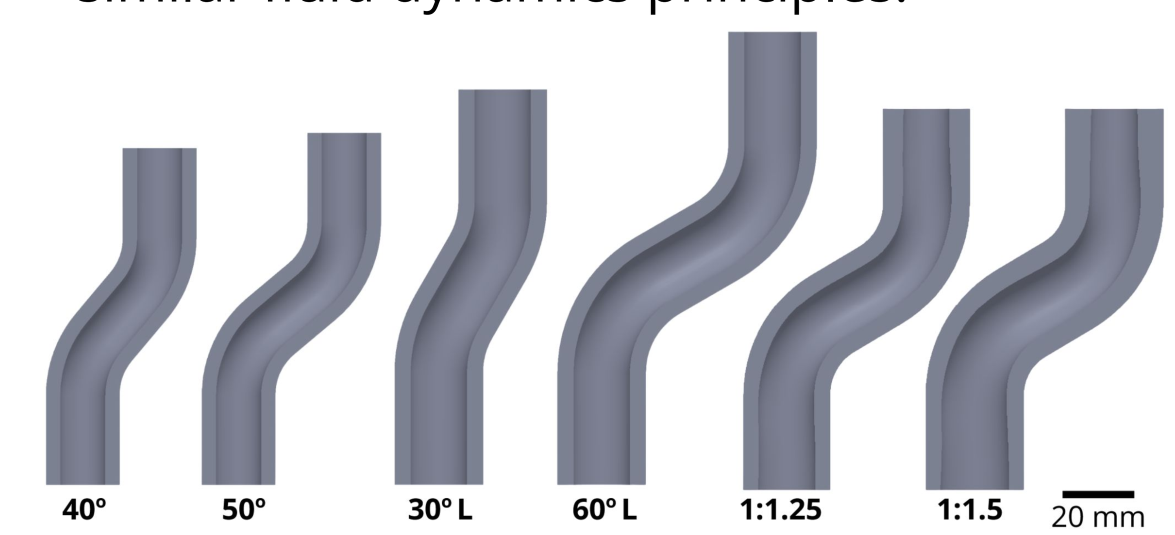

Figure 8. Design iterations 2 models from Solidworks

Roughness as a Function of Length

- Further investigation may be performed by analyzing the roughness as a function of length of the part.
- Future work includes development of part length guidelines.

Acknowledgements

UNIVERSITY of WASHINGTON
MATERIALS SCIENCE & ENGINEERING

UNIVERSITY of WASHINGTON
MECHANICAL ENGINEERING

LAMP

Molecular Analysis Facility