

Background & Motivation

- Ti-6Al-4V (Grade 5 Titanium) is widely used because of its strength and light weight, making it applicable to fields such as aerospace and medicine. Laser welding is often used in these types of settings because of its concentrated effect and low distortion.
- This project simulated a live experiment using the same parameters (Figure 1). The live experiment used an Argon shielding gas, but the simulation does not include a gas phase. The physical testing also included making welds while applying ultrasonic waves. The simulation focused on the tests without ultrasonics, but the effect can be added in the future.
- The enthalpy-porosity method is a way to model solidification and melting by tracking the liquid fraction of the material, a value representing how much of a computational cell is melted. This method uses the liquid fraction to control fluid flow, allowing regions to move more freely as they reach higher liquid fractions.
- Understanding the weld pool can predict which welds will be strongest and find the causes of defects. Some dynamics, such as temperature, are difficult to capture during live experiments, so the simulation is necessary. Developing this base simulation is needed to advance into further research, including ultrasonic simulation.

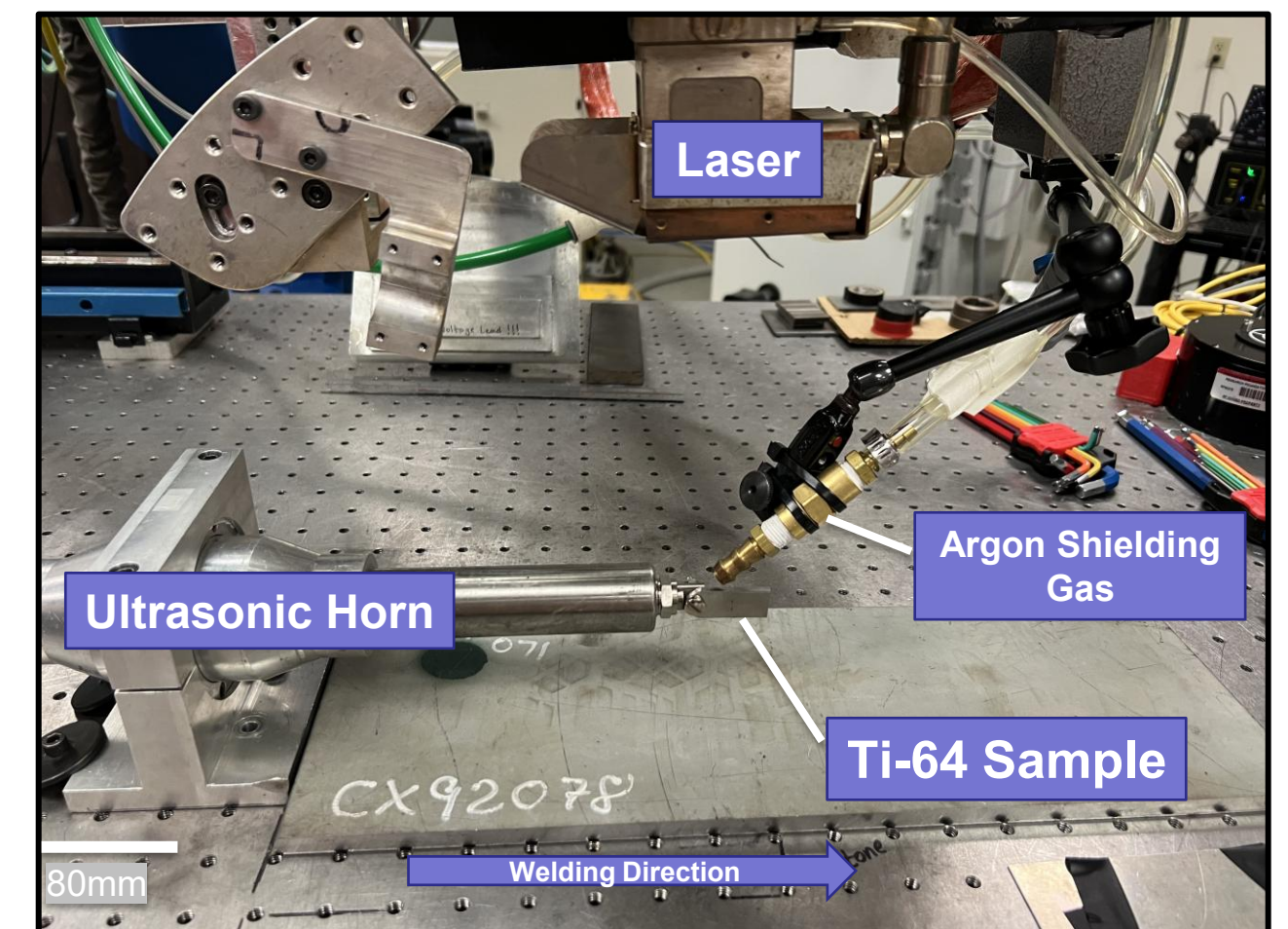


Figure 1: Physical experiment setup

Objective & Approach

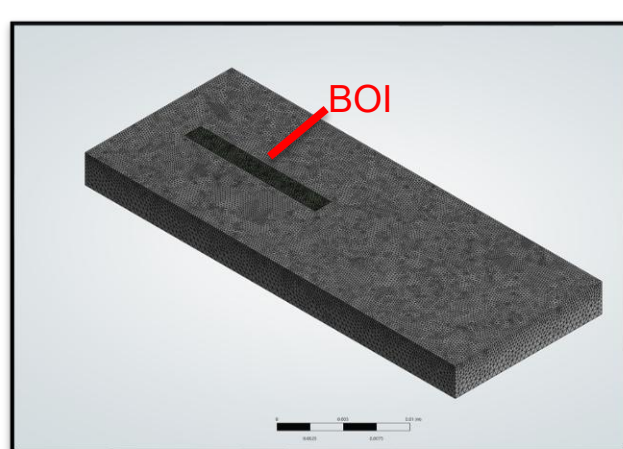
Objective:

- Identify weld pool dynamics from laser welding Ti-64 based on different laser parameters using an enthalpy-porosity simulation.

Approach:

- ANSYS Fluent software was used for this simulation.
- Metal piece designed with an ultra refined mesh top face and body of influence for the weld pool that progressively coarsens to help improve accuracy while maintaining efficiency

Figure 2: Overview of mesh



BOI Size	Top Size	Global Size	Growth Rate
0.1mm	0.2mm	1.2mm	1.1

Table 1: Mesh parameters

- Solidification/Melting model enabled to interact with temperature dependent material properties
- User defined function (UDF) in C code accounted for evaporation based on Hertz-Knudsen equation but simplified to avoid need for a gas phase
- Temperature-dependent UDF to model Marangoni convection
- UDF applied a 3D Gaussian heat source

Laser Radius	Laser Power	Laser Speed	Sample Dimensions	Laser Track	Timestep Size
300 μ m	1200W; 800W	100mm/s; 50 mm/s	39.37mm x 15.6 mm x 3 mm	10mm	0.0002s

Table 2: Laser and Experimental Parameters

Conclusions

- The enthalpy-porosity model successfully predicted overall weld pool temperature distribution and depth with quick computation time. Because the recorded maximum velocities between samples of different power but the same speed are very close, further development of the Marangoni UDF is needed to confidently accept this data to describe fluid flow.
- Increasing power and decreasing laser speed created a deeper and wider weld pool because of the increased energy input per unit of material. Furthermore, laser power drove weld pool depth more than laser speed did (within the tested parameters).

Future Work

- Test with different time steps, mesh sizes, laser powers, and speeds.
- Current model cannot capture surface deformation (which affects Marangoni convection), include shielding gas, or gauge the keyhole dynamics because it does not allow for the gas phase. Adding a VOF model, for example, to the current setup would allow for measuring of these dynamics because it incorporates the gas phase and tracks its interaction with the metal boundary.
- Incorporate ultrasonic effect into the simulation

Results & Discussion

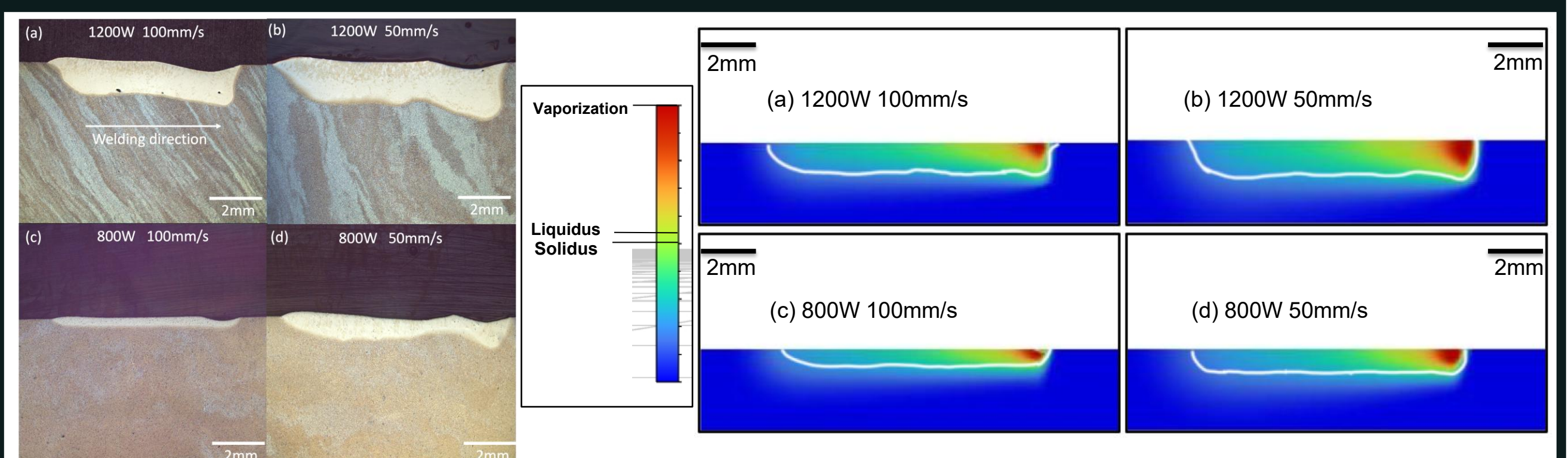


Figure 3: Longitudinal image comparison of actual (left) and simulated (right) welds. On simulation images, white line traces approximate weld pool using liquid fraction contour, mapped onto temperature contour from final timestep with vaporization threshold as maximum.

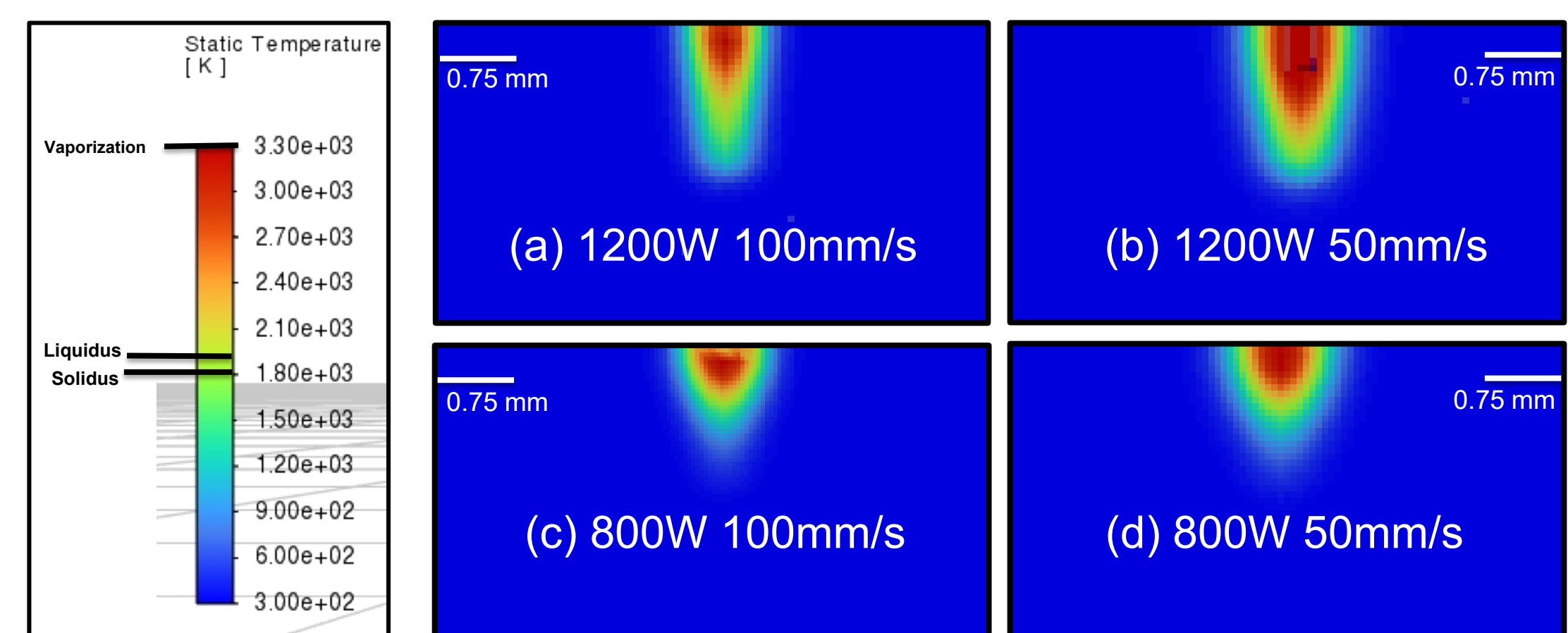


Figure 4: Transversal images from simulation using temperature contour with vaporization threshold as maximum. These were taken from the deepest part of the weld pool at the last timestep, though transversals were practically identical throughout each calculation.

Laser Power (W)	Laser Speed (mm/s)	Depth Actual (mm)	Depth Simulated (mm)	Max. Liquid Velocity (mm/s)
1200	100	1.07	1.02	35.76
1200	50	1.58	1.50	22.43
800	100	0.41	0.54	35.30
800	50	0.71	0.78	21.33

Table 3: Depth comparison from live and simulated experiments, and maximum velocity report from the simulation.

- Simulated depths overall match actual depths. Undercalculation for the 800W could be corrected by refining the depth of laser penetration in the heat source UDF. 1200W simulated depths are slightly shallower than the live results perhaps for the same UDF reason or because of a lack of recoil vapor pressure from not having the gas phase, which is exasperated at the higher power.
- The very close velocities at different powers suggest that the current Marangoni UDF is not behaving as reality. This could be in part because the model cannot track surface deformation, affecting the boundary that drives the flow.