Predicting Temperature Distribution and Track Integrity in Oscillatory and Conventional WAAM

Muhammad Ayaan Afzal, Mohammad Arjomandi, Tuhin Mukherjee
Department of Mechanical Engineering, Iowa State University

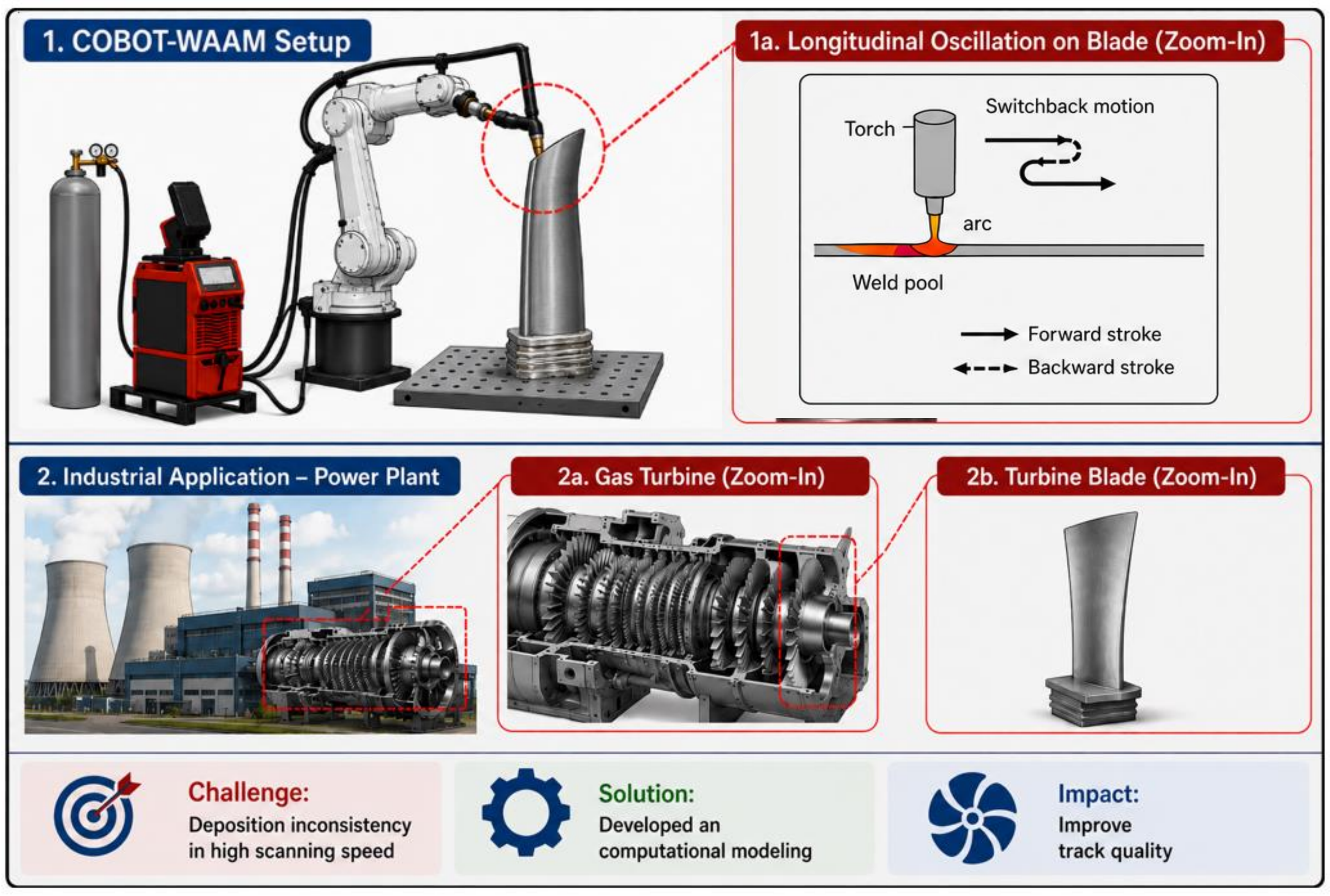

Figure 1: A schematic representation of the methodology used in this work.

Discussion

- Oscillatory motion spreads heat more uniformly, reducing peak temperatures and promoting improved dimensional stability.
- Compared with non-oscillatory deposition, longitudinal oscillation produces a narrower, shallower bead with reduced penetration.

Results

- The model accurately captured the molten pool shape, velocity vectors, and temperature gradients.
- Oscillatory motion produced more uniform heat distribution and molten pool geometry, improving bead consistency and reducing height variation.
- The predicted molten pool dimensions showed good agreement with experimental measurements, confirming the reliability of the computational model.

Conclusions

- The model predicts temperature distribution and its influence on track integrity under oscillatory and non-oscillatory deposition.
- Oscillatory deposition improves thermal distribution and promotes more uniform track geometry, reducing the risk of localized defects.
- The validated framework can support process parameter optimization across different WAAM deposition strategies.

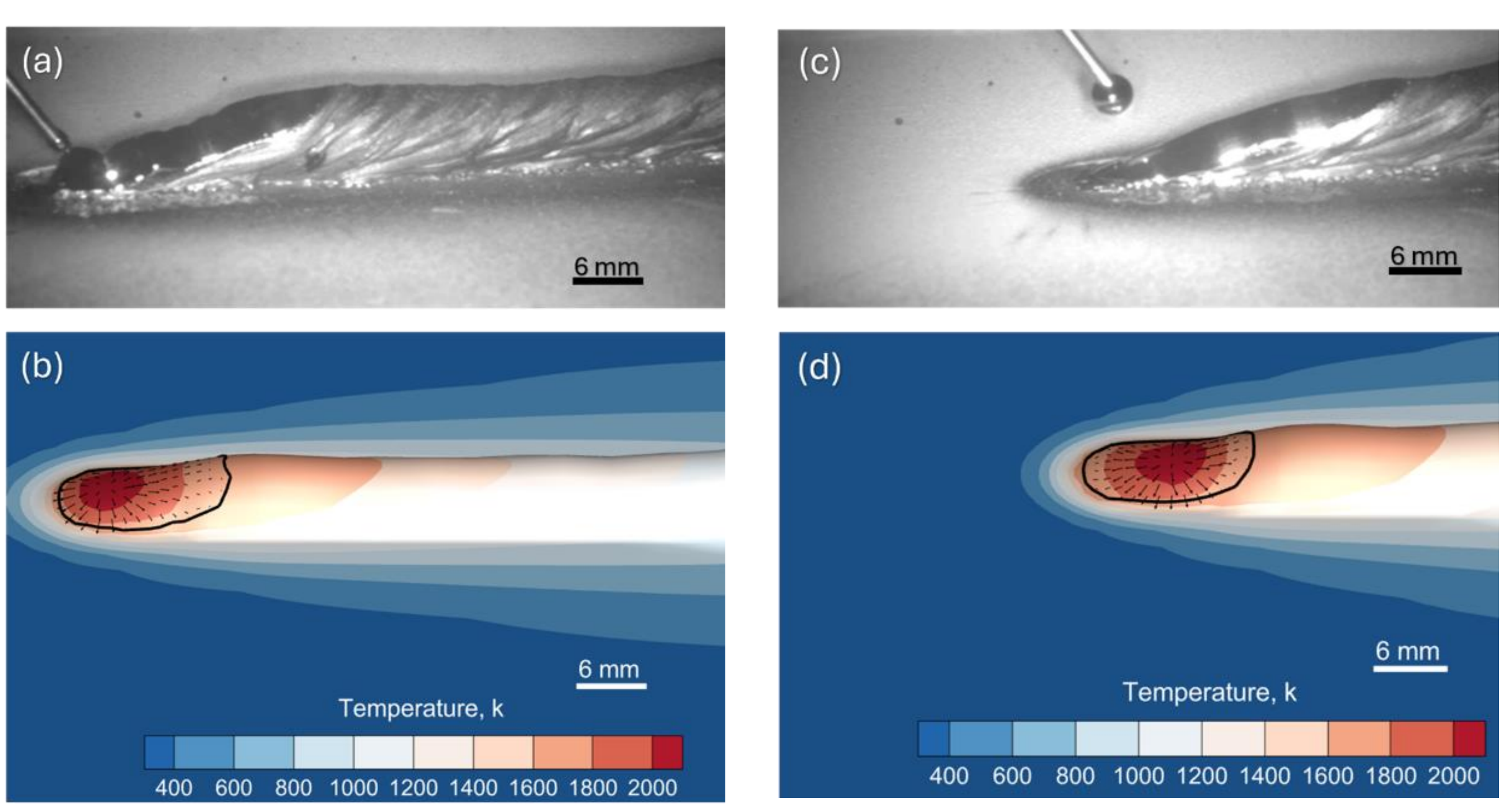

Figure 3: Different time steps for temperature distribution in oscillatory movement for tracking deposition consistency in wire arc additive manufacturing.

Acknowledgments

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Problem Statement and Objective

- WAAM enables rapid deposition of large metallic components, but controlling track geometry and thermal history remains a key challenge.
- A physics-based computational approach can reduce reliance on costly trial-and-error experiments by revealing how process conditions influence thermal behavior and track formation.
- This work aims to improve a computational framework for predicting temperature distribution and track integrity by simulating heat transfer, fluid flow, and deposit evolution under varying WAAM conditions.

Methods

- Temperature-dependent properties of stainless steel, including thermal conductivity, specific heat, and latent heat, were incorporated into the model.
- Heat transfer, fluid flow, and molten pool evolution were simulated under oscillatory and non-oscillatory conditions.
- Molten pool dimensions (length, width, and depth) were validated against experimental measurements.
- 3D confocal microscopy was used to evaluate track height consistency for both deposition strategies.

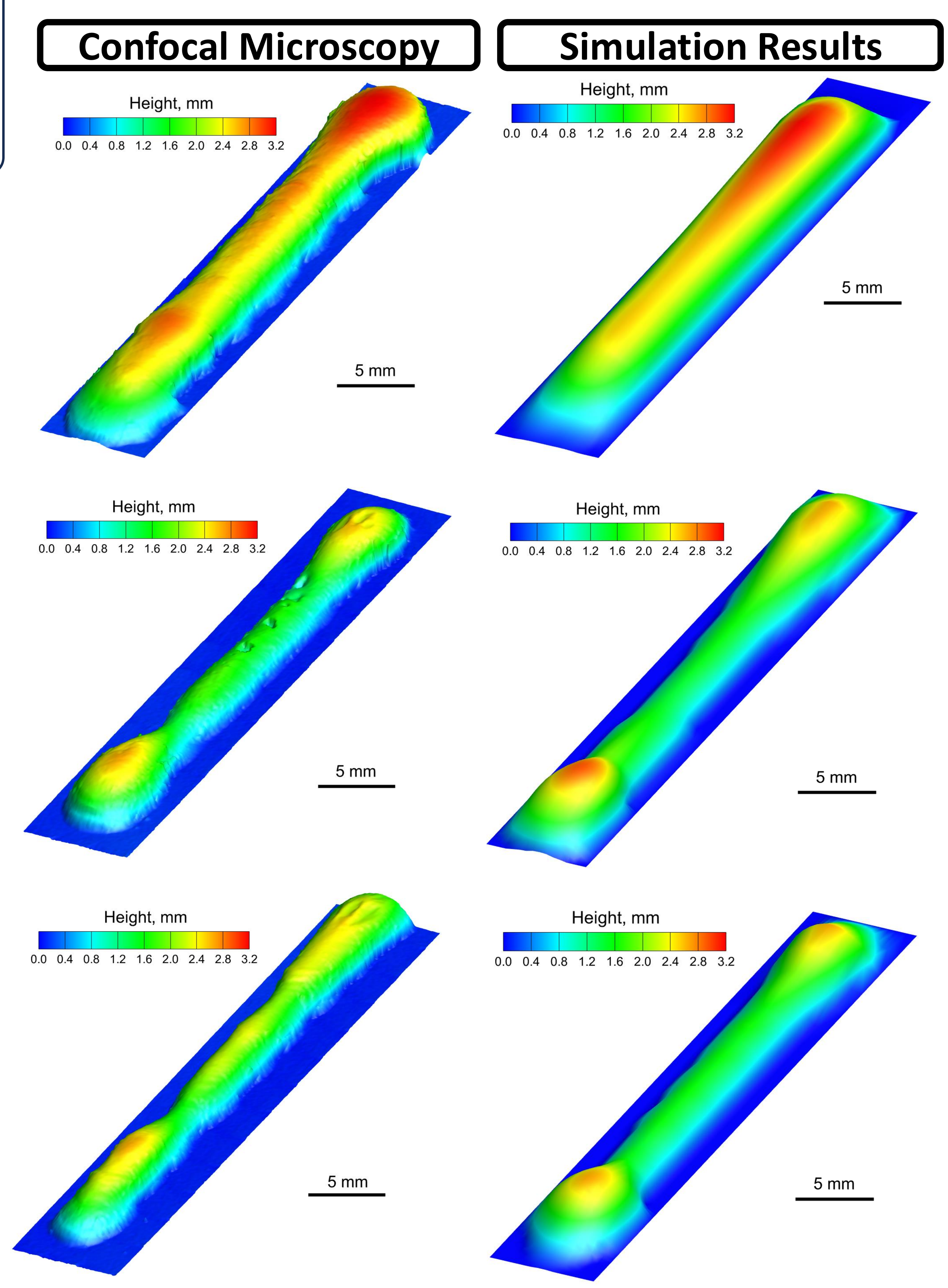

Figure 2: Comparison between confocal microscopy and simulation

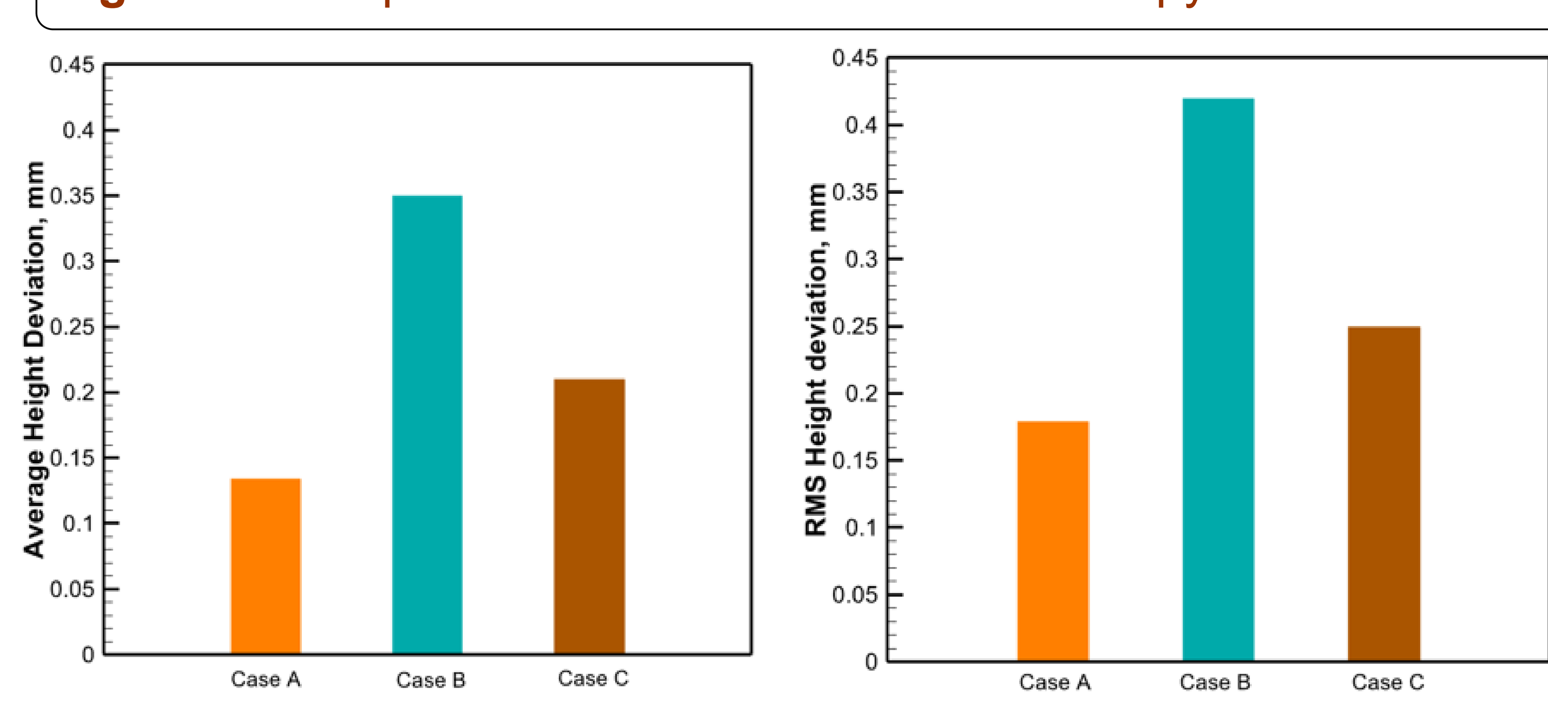

Figure 4: Average height and RMS deviation for three cases