Numerical investigation of bubble transfer in additive manufacturing technology by a multiphase particle method

*Guangtao Duan and Mikio Sakai
The Univ. of Tokyo

Abstract

The bubble transfer from the powder bed to the melt pool in additive manufacturing is investigated by coupling the moving particle semi-implicit (MPS) method and the discrete element method (DEM). It is found that bubble radius and laser beam shapes could significantly affect the bubble entrapment behaviors in the melt pool.

Keywords: MPS method, Multiphase flow, Bubbles; DEM; Additive manufacturing

1. Introduction

Additive manufacturing (AM) is a new technology with rapid progress, and its applications in nuclear engineering are increasing fast. The parts by fabricated AM face the high-porosity problem, which may be due to the porosity in the powder feedstock. This study investigates the transfer of the bubbles from the granules into the melt pool.

2. Numerical methods

An improved moving particle semi-implicit (MPS) method [1] is employed to simulate the melt-pool dynamics. The surface tension, Marangoni effect, recoil pressure due to fast vaporization, granule melting, and laser heat source, are implemented in the simulations. The consistent MPS schemes are used to discretize the governing equation.

The bubble dynamic is simulated by the discrete element method (DEM). The drag, buoyance, lift, thermocapillary force [2], and the added-mass effect are considered for the bubble motion. The influence of the melt flow on bubble dynamics is only considered in this study. Initially, frozen bubbles were seeded inside the granules and the substrate. When the nearby solid was fully melted, the bubble was activated and began to move.

3. Simulations and discussion

The influence of bubble radii (i.e., 1, 2, 5, 10 μm) on entrapment was investigated. Most activated bubbles were discharged at the main depression region due to the large thermocapillary force [2]. It is found that the trapped ratio of bubbles increased significantly as the bubble size decreased, due to the increasing drag force.

The influence of round, horizontal-oval, and transverse-oval laser-beam shapes on the bubble entrapment was discussed. It is found that the horizontal-oval laser beam generated the lowest trapped ratio of bubbles. This happened because the bubbles had longer pathway to be discharged when the horizontal oval laser beam was used.

4. Conclusions

The bubble behaviors inside the melt pool in additive manufacturing were investigated by coupling the MPS and DEM methods. It is found that (1) the bubble entrapment happened more frequently as the bubble size decreased; (2) the horizontal oval laser beam produced lower trapped ratio of bubbles compared the round laser beam.

5. Acknowledgement

This research was supported by the MEXT Quantum Leap Flagship Program (MEXT Q-LEAP) under Grant No. JPMXS0118067246.

References

[1] Duan G, & Sakai M., An enhanced semi-implicit particle method for simulating the flow of droplets with free surfaces, Comput. Methods Appl. Mech. Eng. 389 (2022) 114338.

[2] Hojjatzadeh S.M.H. et al., Pore elimination mechanisms during 3D printing of metals, Nat. Commun. 10 (2019) 1–8.