

Two-Phase Flow Modelling of Metal Vaporisation under Static Laser Shot using a Double Domain ALE Method

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INTRODUCTION: Layer Beam Melting (LBM) is an Additive Manufacturing process based on the interaction between a laser beam and a metallic powder bed. Understanding the associated physical phenomena is necessary to control the process in an industrial context. Particularly, metal vaporisation induces collateral effects as denudation¹ (Figure 1) which might be detrimental to the process. The present work proposes a multi-physical two-phase flow model of metal vaporisation under static laser irradiation.

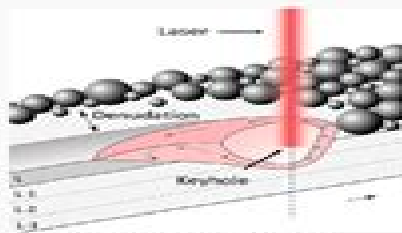


Figure 1 Principle of LBM.

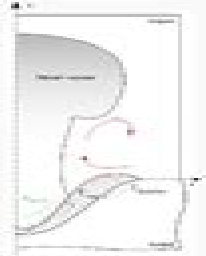


Figure 2 Static laser shot configuration.

COMPUTATIONAL METHODS: Using a double domain ALE approach allows coupling two fluid flows with different natures. A compressible high Mach number flow in the gas side – coupled with heat transfer and chemical species transport – and an incompressible low Mach number flow in the metal phase – coupled with heat transfer. The interface is handle with an ALE algorithm (Figure 2).

RESULTS

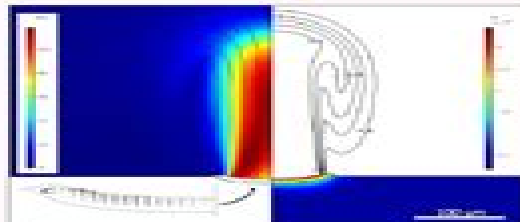


Figure 3 Melt pool shape, gas velocity field and streamlines (left), melt pool temperature field and fraction of metal vapour contours (right) | $P = 400$ W, $D_0 = 150$ μ m, $t = 4e-5$ s.

- Metal vapour ejected at a relatively high velocity (> 100 m/s).
- Recirculation flow on the side of the plume, source of denudation.
- The contours of metal vapour fraction highlights a characteristic mushroom shape due to Rayleigh-Taylor instability.

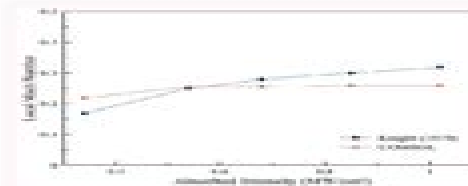


Figure 4 Local Mach number (at the interface) against absorbed laser intensity | $D_0 = 150$ μ m, $\tau_{pulse} = 0.3$ ms.

→ Plume velocity validated with Knight's analytical model².

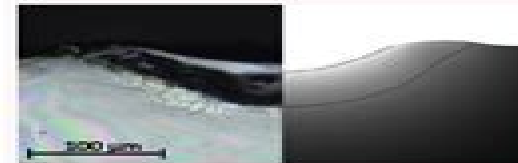


Figure 5 Comparison of melted zone given by experiment and numerical model | $P = 320$ W, $D_0 = 205$ μ m (top hat), $\tau_{pulse} = 3$ ms.

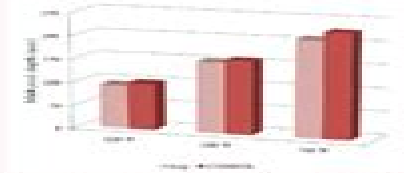
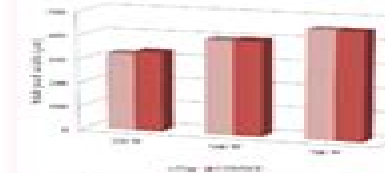


Figure 6 Comparison between simulated and experimental melt pool width (left) and depth (right) | $P = 320$ W, $D_0 = 205$ μ m (top hat), $\tau_{pulse} = 3$ ms.

- Validation of the melt pool shape predicted by the model.
- Agreement between the numerically predicted melt pool dimensions and the experimental results.

CONCLUSIONS: Numerical simulation coupled with experimental study is a key toward understanding the complex physical phenomena which characterise LBM. COMSOL Multiphysics® provides simulation tools which have proven to be efficient to compute and analyse physical features related to metal vaporisation under laser irradiation. This first analysis is promising, the next step is to transpose the present model to powder bed conditions, first in 2D axisymmetric and then in real 3D configuration.

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Modelling And Experimentation In Twophase Flow

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