

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.

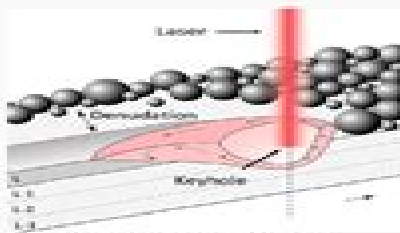


Figure 1 Principle of LBM.

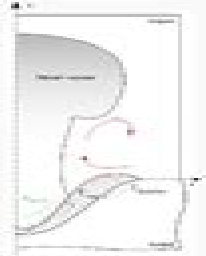


Figure 2 Static laser shot configuration.

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

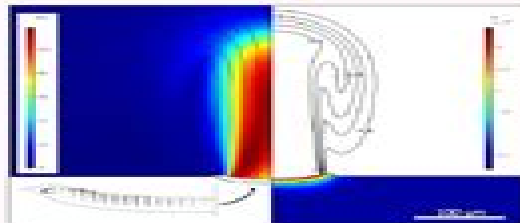


Figure 3 Melt pool shape, gas velocity field and streamlines (left), melt pool temperature field and fraction of metal vapour contours (right) | $P = 400$ W, $D_0 = 150$ μ m, $t = 4 \times 10^{-5}$ s.

- 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.

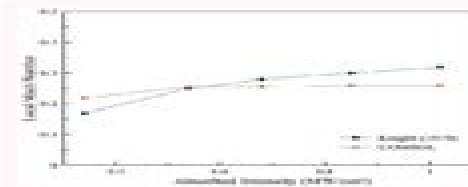


Figure 4 Local Mach number (at the interface) against absorbed laser intensity | $D_0 = 150$ μ m, $\tau_{pulse} = 0.3$ ms.

→ Plume velocity validated with Knight's analytical model².

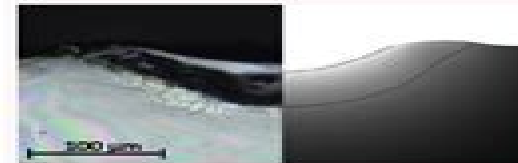


Figure 5 Comparison of melted zone given by experiment and numerical model | $P = 320$ W, $D_0 = 205$ μ m (top hat), $\tau_{pulse} = 3$ ms.

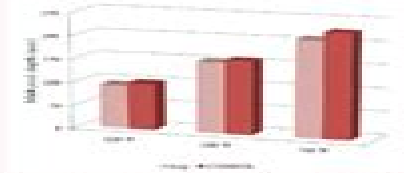
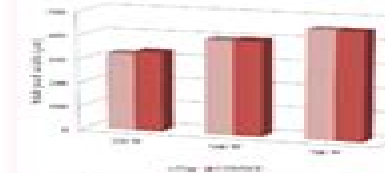


Figure 6 Comparison between simulated and experimental melt pool width (left) and depth (right) | $P = 320$ W, $D_0 = 205$ μ m (top hat), $\tau_{pulse} = 3$ ms.

→ 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

D. Laurence, W. Rodi



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Two-phase Flow Modelling and Experimentation, 1995 G. P. Celata, 1995 Third International Symposium on Two Phase Flow Modelling and Experimentation ,2005 Two-phase flow modelling and experimentation 1999 G. P. Celata, P. Di Marco, R. K. Shah, 1999 Third International Symposium on Two Phase Flow Modelling and Experimentation ,2004

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William J. Krotiuk,1990 **Engineering Turbulence Modelling and Experiments 6** Wolfgang Rodi,2005-05-05
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Table of Contents Modelling And Experimentation In Twophase Flow

1. Understanding the eBook Modelling And Experimentation In Twophase Flow
 - The Rise of Digital Reading Modelling And Experimentation In Twophase Flow
 - Advantages of eBooks Over Traditional Books
2. Identifying Modelling And Experimentation In Twophase Flow
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Modelling And Experimentation In Twophase Flow
 - User-Friendly Interface
4. Exploring eBook Recommendations from Modelling And Experimentation In Twophase Flow

- Personalized Recommendations
- Modelling And Experimentation In Twophase Flow User Reviews and Ratings
- Modelling And Experimentation In Twophase Flow and Bestseller Lists
- 5. Accessing Modelling And Experimentation In Twophase Flow Free and Paid eBooks
 - Modelling And Experimentation In Twophase Flow Public Domain eBooks
 - Modelling And Experimentation In Twophase Flow eBook Subscription Services
 - Modelling And Experimentation In Twophase Flow Budget-Friendly Options
- 6. Navigating Modelling And Experimentation In Twophase Flow eBook Formats
 - ePub, PDF, MOBI, and More
 - Modelling And Experimentation In Twophase Flow Compatibility with Devices
 - Modelling And Experimentation In Twophase Flow Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Modelling And Experimentation In Twophase Flow
 - Highlighting and Note-Taking Modelling And Experimentation In Twophase Flow
 - Interactive Elements Modelling And Experimentation In Twophase Flow
- 8. Staying Engaged with Modelling And Experimentation In Twophase Flow
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Modelling And Experimentation In Twophase Flow
- 9. Balancing eBooks and Physical Books Modelling And Experimentation In Twophase Flow
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Modelling And Experimentation In Twophase Flow
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Modelling And Experimentation In Twophase Flow
 - Setting Reading Goals Modelling And Experimentation In Twophase Flow
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Modelling And Experimentation In Twophase Flow

- Fact-Checking eBook Content of Modelling And Experimentation In Twophase Flow
- Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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