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 denudation[1] (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.

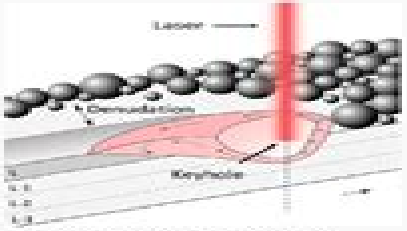

Figure 1 Principle of LBM.

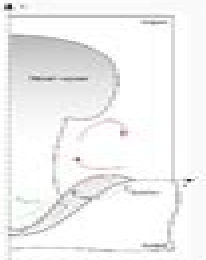

Figure 2 Static laser shot configuration.

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

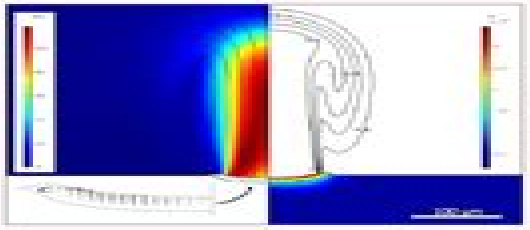

Figure 3 Melt pool shape, gas velocity field and streamlines (left), melt pool temperature field and fraction of metal vapour contours (right) | P = 400 W, D_0 = 150 µm, t = 4e-5 s.

→ 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.

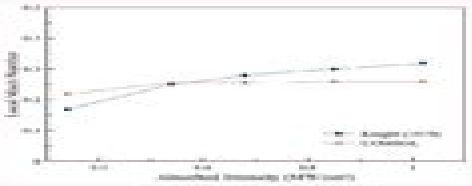

Figure 4 Local Mach number (at the interface) against absorbed laser intensity | D_0 = 150 µm, τ_{pulse} = 0.3 ms.

→ Plume velocity validated with Knight's analytical model[2].

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

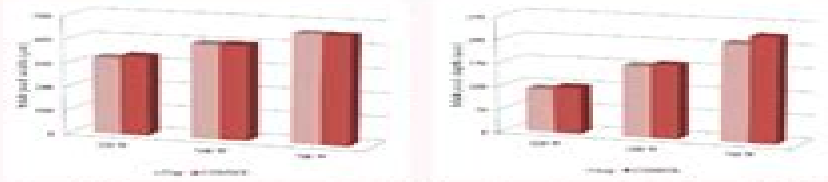

Figure 6 Comparison between simulated and experimental melt pool width (left) and depth (right) | P = 320 W, D_0 = 205 µm (top hat), tpulse = 3 ms.

→ 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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2. Knight, C. J. Theoretical Modeling of Rapid Surface Vaporization with Back Pressure. AIAA J. 17, 519–523 (1979).

Modelling And Experimention In Twophase Flow

Wolfgang Rodi

Modelling And Experimention In Twophase Flow:

Modelling and Experimentation in Two-Phase Flow Volfango Bertola,2014-05-04 This is an up to date review of recent advances in the study of two phase flows with focus on gas liquid flows liquid liquid flows and particle transport in turbulent flows The book is divided into several chapters which after introducing basic concepts lead the reader through a more complex treatment of the subjects The reader will find an extensive review of both the older and the more recent literature with abundance of formulas correlations graphs and tables A comprehensive though non exhaustive list of bibliographic references is provided at the end of each chapter The volume is especially indicated for researchers who would like to carry out experimental theoretical or computational work on two phase flows as well as for professionals who wish to learn more about this topic *Two-phase Flow Modelling and Experimentation 1995* G. P. Celata,Ramesh K. Shah,1995

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

Engineering Turbulence Modelling and Experiments 5 W. Rodi,N. Fueyo,2002-08-21 Turbulence is one of the key issues in tackling engineering flow problems As powerful computers and accurate numerical methods are now available for solving the flow equations and since engineering applications nearly always involve turbulence effects the reliability of CFD analysis depends increasingly on the performance of the turbulence models This series of symposia provides a forum for presenting and discussing new developments in the area of turbulence modelling and measurements with particular emphasis on engineering related problems The papers in this set of proceedings were presented at the 5th International Symposium on Engineering Turbulence Modelling and Measurements in September 2002 They look at a variety of areas including Turbulence modelling Direct and large eddy simulations Applications of turbulence models Experimental studies Transition Turbulence control Aerodynamic flow Aero acoustics Turbomachinery flows Heat transfer Combustion systems Two phase flows These papers are preceded by a section containing 6 invited papers covering various aspects of turbulence modelling and simulation as well as their practical application combustion modelling and particle image velocimetry Engineering Turbulence Modelling and Experiments - 4 D. Laurence,W. Rodi,1999-04-14 These proceedings contain the papers presented at the 4th International Symposium on Engineering Turbulence Modelling and Measurements held at Ajaccio Corsica France from 24 26 May 1999 It follows three previous conferences on the topic of engineering turbulence modelling and measurements The purpose of this series of symposia is to provide a forum for presenting and discussing new developments in the area of turbulence modelling and measurements with particular emphasis on engineering related problems Turbulence is still one of the key issues in tackling engineering flow problems As powerful computers and accurate numerical methods are now available for solving the flow equations and since engineering applications nearly always involve turbulence effects

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the fission chain reaction *Thermal Hydraulics for Space Power, Propulsion, and Thermal Management System Design* William J. Krotiuk,1990 **Engineering Turbulence Modelling and Experiments 6** Wolfgang Rodi,2005-05-05 Proceedings of the world renowned ERCOFTAC International Symposium on Engineering Turbulence Modelling and Measurements The proceedings include papers dealing with the following areas of turbulence Eddy viscosity and second order RANS models Direct and large eddy simulations and deductions for conventional modelling Measurement and visualization techniques experimental studies Turbulence control Transition and effects of curvature rotation and buoyancy on turbulence Aero acoustics Heat and mass transfer and chemically reacting flows Compressible flows shock phenomena Two phase flows Applications in aerospace engineering turbomachinery and reciprocating engines industrial aerodynamics and wind engineering and selected chemical engineering problems Turbulence remains one of the key issues in tackling engineering flow problems These problems are solved more and more by CFD analysis the reliability of which depends strongly on the performance of the turbulence models employed Successful simulation of turbulence requires the understanding of the complex physical phenomena involved and suitable models for describing the turbulent momentum heat and mass transfer For the understanding of turbulence phenomena experiments are indispensable but they are equally important for providing data for the development and testing of turbulence models and hence for CFD software validation As in other fields of Science in the rapidly developing discipline of turbulence swift progress can be achieved only by keeping up to date with recent advances all over the world and by exchanging ideas with colleagues active in related fields **Energy Research Abstracts** ,1992-11 **Physics of Fluids in Microgravity** Rodolfo Monti,2002-01-10 In a microgravity experiment the conditions prevalent in fluid phases can be substantially different from those on the ground and can be exploited to improve different processes Fluid physics research in microgravity is important for the advancement of all microgravity scients life material and engineering Space flight provides a unique laboratory that allows scientists to improve their understanding of the behaviour of fluids in low gravity allowing the investigation of phenomena and processes normally masked by the effects of gravity and thus difficult to study on Earth Physics of Fluids in Microgravity provides a clear view of recent research and progress in the different fields of fluid research in space The topics presented include bubles and drops dynamics Maragoni flows diffustion and thermodiffusion solidfication a nd crystal growth The results obtained so far are in some cases to be confirmed by extensive research activities on the International Space station where basic and applied microgravity experimentation will take place in the years to come **29th European Symposium on Computer Aided Chemical Engineering** Anton A. Kiss,Edwin Zondervan,Richard Lakerveld,Leyla Özkan,2019-06-28 The 29th European Symposium on Computer Aided Process Engineering contains the papers presented at the 29th European Symposium of Computer Aided Process Engineering ESCAPE event held in Eindhoven The Netherlands from June 16 19 2019 It is a valuable resource for chemical engineers chemical process engineers researchers in industry and academia students and

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