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

Processes and engineering in Mechanics and Materials

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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.

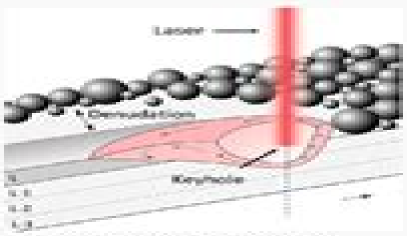

Figure 1 Principle of LBM.

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

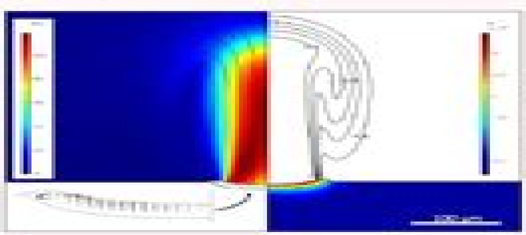

Figure 3 Melt pool shape, gas velocity field and streamlines (left), melt pool temperature field and fraction of metal vapour contours (right) | P = 400 W, D_0 = 150 µm, t = 4e-5 s.

→ 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.

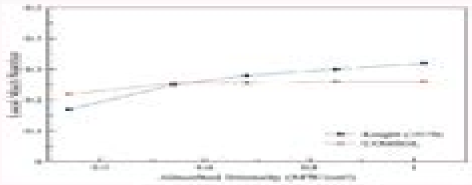

Figure 4 Local Mach number (at the interface) against absorbed laser intensity | D_0 = 150 µm, τ_{pulse} = 0.3 ms.

→ 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.

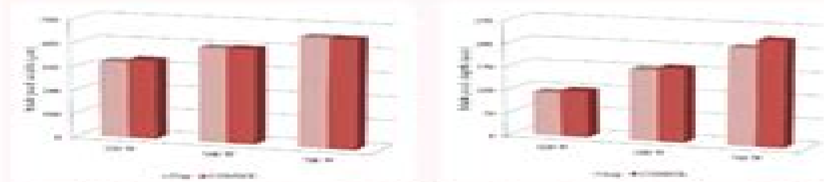

Figure 6 Comparison between simulated and experimental melt pool width (left) and depth (right) | P = 320 W, D_0 = 205 µm (top hat), τpulse = 3 ms.

→ 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

D. Laurence,W. 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 **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 the reliability of CFD analysis depends more and more on the performance of the turbulence models 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 *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 *Multiphase Flow Dynamics 1* Nikolay Ivanov Kolev,2007-06-04 Multi phase flows are part of our natural environment such as tornadoes typhoons air and water pollution and volcanic activities as well as part of industrial technology such as power plants combustion engines propulsion systems or chemical and biological industry The industrial use of multi phase systems requires analytical and numerical strategies for predicting their behavior In its third extended edition this monograph contains theory methods and practical experience for describing complex transient multi phase processes in arbitrary geometrical configurations providing a systematic presentation of the theory and practice of numerical multi phase fluid dynamics In the present first volume the fundamentals of multiphase dynamics are provided This third edition includes various updates extensions and improvements in all book chapters **Experimental and Analytical Modeling of Natural Circulation and Forced Circulation BWRs** Masahiro Furuya,2006 20% of the Nuclear Power Plants are known as Boiling Water Reactors BWRs These BWRs have pumps that cool their reactor In the design of new BWRs ways to cool the core by a natural circulation flow without pumps also called natural circulation BWRs are being considered In these new systems a chimney is installed on top of the core to increase natural circulation flow A possible disadvantage of natural circulation BWRs might be their susceptibility to instabilities which could then lead to both flow and power oscillations The stability features of both natural circulation and forced circulation BWRs have been investigated thoroughly using dedicated experimental setups analytical models and numerical codes We distinguish between pure thermal hydraulic stability where the fission power is assumed to be constant and coupled thermalhydraulic neutronic stability where the two phase mixture in the core influences the fission chain reaction *Handbook of Porous Media* Kambiz Vafai,2015-06-23 Handbook of Porous Media Third Edition offers a comprehensive overview of the latest theories on flow transport and heat exchange processes in porous media It also details sophisticated porous media models which can be used to improve the accuracy of modeling in a variety of practical applications Featuring contributions from leading experts i *Multiphase Flow Handbook, Second Edition* Efstathios Michaelides,Clayton T. 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Sasmito,Arun S. Mujumdar,2019-07-16 Heat and Mass Transfer in Drying of Porous Media offers a comprehensive review of heat and mass transfer phenomena and mechanisms in drying of porous materials It covers pore scale and macro scale models includes various drying technologies and discusses the drying dynamics of fibrous porous material colloidal porous media and size distributed particle system Providing guidelines for mathematical modeling and design as well as optimization of drying of porous material this reference offers useful information for researchers and students as well as engineers in drying technology food processes applied energy mechanical and chemical engineering **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 consultants for chemical industries Presents findings and discussions from the 29th European Symposium of Computer Aided Process Engineering ESCAPE event Applied Mechanics Reviews ,1966 Nuclear Thermal Hydraulic and Two-Phase Flow Jun Wang,Kaiyi Shi,Zhaoming Meng,Shripad T. 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Ilegbusi,2010-11-10 Modeling Multiphase Materials Processes Gas Liquid Systems describes the methodology and application of physical and mathematical modeling to multi phase flow phenomena in materials processing The book focuses on systems involving gas liquid interaction the most prevalent in current metallurgical processes The performance characteristics of these processes are largely dependent on transport phenomena This volume covers the inherent characteristics that complicate the modeling of transport phenomena in such systems including complex multiphase structure intense turbulence opacity of fluid high temperature coupled heat and mass transfer chemical reactions in some cases and poor wettability of the reactor walls Also discussed are solutions based on experimental and numerical modeling of bubbling jet systems recent advances in the modeling of nanoscale multi phase phenomena and multiphase flows in micro scale and nano scale channels and reactors Modeling Multiphase Materials Processes Gas Liquid Systems will prove a valuable reference for researchers and engineers working in mathematical modeling and materials processing **Hydraulic Research in the United States and Canada** ,1972

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