doi:10.22364/mmp2017.3

VIII International Scientific Colloquium
Modelling for Materials Processing
Riga, September 21 - 22, 2017

Numerical Aspects of Multiphysical Modelling in ANSYS

S. Spitans, H. Franz, E. Baake

Abstract

Practical and numerical challenges that have been encountered during implementation of multiphysical models by means of coupling between ANSYS and FLUENT, as well as solutions that led to physically valid results, are explained on examples of electromagnetic levitation, electrode induction melting for inert gas atomization and vacuum arc remelting.

1. Conventional electromagnetic (EM) levitation

The levitation melting was invented in the 1920's, whereas the first experiments appeared only thirty years later as the first high-frequency generators became available [1]. Nowadays, EM levitation of a small molten metal droplet (1 to 10 mm in diameter) is a well-established experimental technique for measurements of thermophysical properties.

Since EM field adjusts to a transient shape of the levitating droplet, numerical modelling of EM levitation of molten metal requires coupling between EM field and dynamic free surface shape.

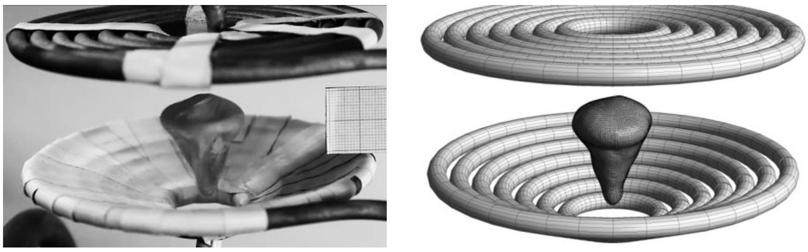

Fig. 1. Levitation of molten aluminium (m = 20 g) in experiment and 3D simulation

A numerical model for the liquid metal free surface flow in an alternate EM field has been developed by means of external coupling between the Lorentz force recalculation in ANSYS, Volume of Fluid (VOF) simulation of a transient two-phase flow in FLUENT and free surface shape reconstruction in CFD-Post [2].

Practical challenges that have been encountered during implementation of the model as well as solutions that led to obtaining physically valid results will be discussed (Fig. 1).

2. Electrode induction melting for inert gas atomization (EIGA)

One of the methods for powder production for additive manufacturing is EIGA [3]. The process can be conducted ceramic-free and is therefore especially suited for reactive and refractory metals/alloys (e.g. Ti-Al6-V4, TiAl). The prealloyed cylindrical electrode is immersed into a conical induction coil and the generated AC magnetic field melts the electrode tip. The liquid metal flows down along the surface of the heated cone and falls into a gas nozzle, where it is

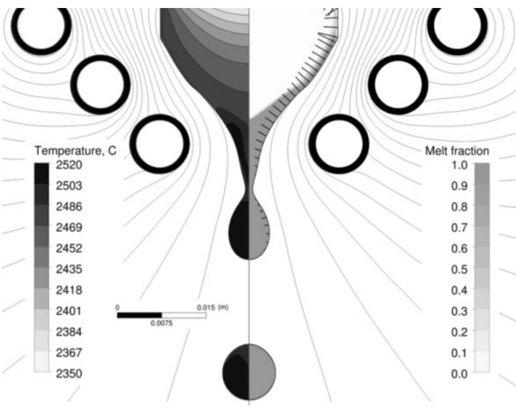

Fig. 2. 2D simulation of Nb electrode induction melting

atomized using inert gas. Size of the molten metal droplets and superheat temperature directly influences the size of produced particles.

Numerical model of the electrode melting and dripping involves coupling between EM field and dynamics of the free surface shape as well. Additionally, heat transfer that involves phase change and heat radiation from the transient free surface has to be calculated.

Correct choice of the turbulence model, value of the mushy zone constant for numerical description of solidification/melting and implementation of the simple radiation boundary condition from the free surface inside the calculation domain allowed to obtain accurate process description (Fig. 2) and will be presented in this work.

3. Ingot growth during Vacuum Arc Remelting (VAR) process

VAR is a continuous remelting of a consumable electrode into a homogeneous and clean ingot by means of an electric arc under vacuum [4]. VAR is used for production of Ni, Ti, Zr and iron-based alloys for aerospace, power, defence, medical and nuclear industries.

During the VAR process a DC voltage is applied to strike the arc between the electrode and some start material at the bottom of a copper crucible. Intense heat generated by the arc heats the bottom surface of the electrode and start material, eventually melting both. Molten metal drips off from the electrode tip and a solid ingot forms in the water-cooled crucible (Fig. 3). Later the ingot cools down and shrinks away from the cooled crucible wall, thus affecting the current flow and heat transfer through the side surface of the ingot.

The growing ingot has a molten metal pool. The flow in the pool is driven in meridional plane by the counter-acting thermal buoyancy and the Lorentz force (arc current interaction with its own magnetic field). The arc can be confined with the aid of an axial DC magnetic field created by external coil. In this case, external magnetic field additionally stirs the melt in azimuthal direction.

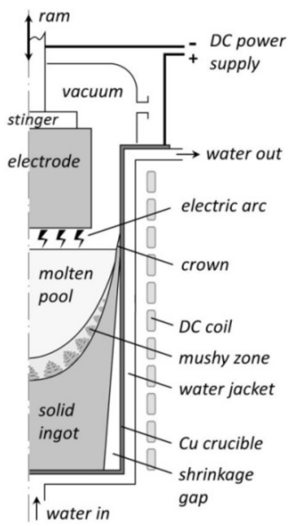

Fig. 3. The VAR process

Numerical modelling of the ingot growth during the VAR process requires coupling between EM, fluid flow and thermal problems. Additionally, dynamic mesh layering has to be applied to account for the ingot growth. Model implementation and solved numerical difficulties that led to an accurate simulation of the ingot growth will be discussed.

Three different flow regimes and their transitions will be observed in the molten metal pool and obtained characteristic process values will be correlated with analytically derived measure for the dominant flow type.

References

[1] Okress, E. et al.: *Electromagnetic Levitation of Solid and Molten Metals.* J. Appl. Phys., 23, 1952, 545-552.

[2] Spitans, S. et al.: *Numerical modelling of free surface dynamics of melt in an alternate electromagnetic field. Part II: conventional electromagnetic levitation.* Metall. Mater. Trans. B, 47/1, 2015, 522-536.

[3] Bojarevics, V. et al.: *Numerical model of EIGA*. COMPEL, 30/5, 2011,1455-1466.

[4] Spitans, S., et al.: *Numerical simulation of the ingot growth during the Vacuum Arc Remelting process.* Proc. of the XVIII Int. UIE-Congress on Electrotechnologies for Material Processing, 2017, 39-47.

Authors

Dr.-Phys. Spitans, Sergejs
Franz, Henrik
ALD Vacuum Technologies GmbH
Otto-von-Guericke-Platz 1, 63457 Hanau, Germany
E-mail: sergejs.spitans@ald-vt.de

Dr.-Ing. Baake, Egbert
Institute of Electrotechnology
Leibniz University of Hannover
Wilhelm-Busch-Str. 4, 30167 Hannover, Germany
E-mail: baake@etp.uni-hannover.de