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# MODELLING THE VAR PROCESS

***Georgi S. Djambazov[1], Koulis A. Pericleous[2] and Valdis Bojarevics[3]**

[1] University of Greenwich
Park Row, London, SE10 9LS
G.Djambazov@gre.ac.uk
http://staffweb.cms.gre.ac.uk/~dg06

[2] University of Greenwich
Park Row, London, SE10 9LS
K.Pericleous@gre.ac.uk
http://staffweb.cms.gre.ac.uk/~pk01

[3] University of Greenwich
Park Row, London, SE10 9LS
V.Bojarevics@gre.ac.uk

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## ABSTRACT

Vacuum Arc Remelting (VAR) is a refining metallurgical process where a long cylindrical electrode is being melted by the heat of electrical arcs in a vacuum furnace. It is done with special alloys in order to meet the very strict requirements for cleanliness, homogeneity, improved fatigue and fracture toughness of the final product when those cannot be achieved in conventional melting and casting processes.

DC power is applied to strike an arc between the electrode and the base plate of a copper mould contained in a water jacket. The intense heat generated by the electric arc melts the tip of the electrode and a new ingot is progressively formed in the water-cooled mould. A high vacuum is being maintained throughout the remelting process.

The required properties of the final material can only be obtained if the inevitable segregation of the alloy components during solidification is kept to a minimum. This can be achieved if the solidification structure of the newly formed ingot is predominantly directional and dendritic. Such structures are formed when high temperature gradient at the solidification front is maintained during the entire remelting process and the depth of the molten pool at the top of the ingot is kept within optimal limits. (The depth of the pool influences its profile which determines the direction of dendrite growth whose angle relative to the ingot axis needs to be within an optimal range in order to achieve the desired structure.)

A good macroscopic computational model of the VAR process would predict the shape of the molten pool and its evolution under various influences. The model would also supply data for microscopic calculations.

From a macroscopic point of view the VAR process involves

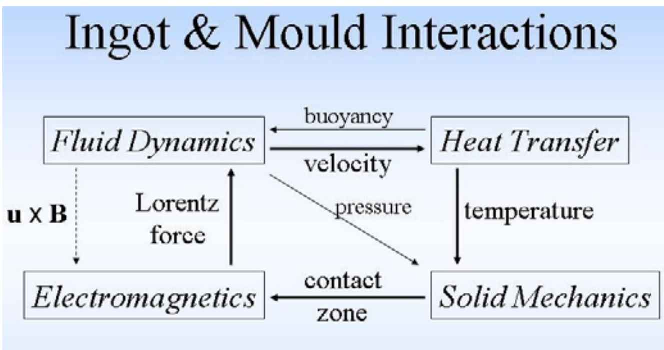


Figure 1. Multi-physics nature of the VAR process

inter-related fluid flow, heat transfer, phase changes, solid deformations and electromagnetics (Fig. 1). The feedback loop indicated by the thick arrows is strong and, ideally, the process should be modelled with a multi-physics approach where all sets of equations are solved on the same mesh.

The 'contact zone' between the ingot and the mould is restricted to only the uppermost part of the ingot where the material is still too hot and plastic for shrinkage to occur. Below, where the solid shell becomes sufficiently thick and strong, the ingot shrinks away from the mould, a gap is formed and electrical contact is lost.

If one needs to use specialised software for CFD and electromagnetics (EM) rather than using a single multi-physics code, it is possible to make the following simplifications.

- Replace '*Solid Mechanics'* with *empirical* critical temperature for gap formation ($T$cr)
- Specify **contact zone** instead of $T$cr , check resulting $T$ at shrinkage gap against $T$cr and iterate, if necessary, updating also the electrical conductivity for the new temperature
- Ignore weaker interaction links like $\mathbf{u}\times\mathbf{B}$ and pressure

Thus EM can be solved prior to and independently of CFD. Comparisons are made for accuracy, speed and set up time between the two approaches for time-averaged simulations under axisymmetric assumptions.

Experimental studies [1] have revealed precession of the 'preferred spot' of the arc which is slow enough to interact with the flow of liquid metal and possibly with surface waves in the molten pool. Then, the decoupling approach may not be sufficiently accurate for time-dependent, 3-dimensional simulations and fully coupled multi-physics will be the preferred option.

In this contribution we are developing a 3D model of the VAR process which takes into account the full coupling between the EM and flow fields, including the effects of electrode melting and arc precession. The results in the form of solid front position, velocity, temperature and magnetic field are presented and compared against the simpler axisymmetric version.

## REFERENCES

[1] D.M. Shevchenko and R.M. Ward, "Liquid Metal Pool Behaviour during the VAR of Inconel 718", *Proc. LMPC 2007*, Nancy, France, pp. 25–30, (2007).