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3D Transient Numerical Modelling of Vacuum Arc Remelting Process and its implication on 2D Axisymmetric Model

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Computational modeling of the Vacuum Arc Remelting (VAR) Process has been developed to provide a deeper physical and metallurgical understanding and assist in the reliable and efficient manufacture of defect-free ingots. While 3D VAR models with transient (time varying) arc behavior have been developed, 2D axisymmetric models with steady-state arc boundary conditions remain the primary tool in industrial applications due to their computational efficiency and the accepted representation of fundamental physical phenomena. In this study, a multi-physics computational model was established in ANSYS Fluent to simulate the VAR process for Inconel 718 in 3D with a transient arc. The model accounts for critical aspects, including magnetohydrodynamics, heat transfer, fluid dynamics, as well as melting and solidification, facilitated through highly customizable user-defined functions. Using widely accepted assumptions from existing literature, the 3D transient model was validated against experimentally measured melt pool geometry. Further, numerical experiments were conducted with a verified 2D axisymmetric VAR model to explore its efficacy and accuracy under identical boundary conditions as the 3D transient model, varying only the profiles of the current density distribution. The melt pool morphology, flow pattern, and solidification environments from the 2D mode, including the commonly adopted Gaussian distribution for arc behavior, were compared with those obtained from the 3D transient model. In order to bridge the gap between 2D and 3D representations, the feasibility of using novel temporally averaged arc distributions in 2D to reproduce the effects of the actual arc behavior in a 3D context is explored.

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