Unsteady interfacial coupling of plasma and weldpool models

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ABSTRACT

Since it appears difficult to ensure the constant quality of the weld beads during some repairs on nuclear power plants, Computational Fluid Dynamics is used to simulate some adjacent phenomena within the plasma and the weld pool to improve the knowledge of welding operating process. Then, one of the difficulties is to take into account the effects induced by the variations of surfactant element concentrations and the thermal gradient on the weld pool surface known as the Marangoni effect [2].

The most used approach to simulate the heat transfer in welding processes consists in only modeling the molten metal part with the plasma represented by a "Gaussian distribution" type boundary condition which approximates the heat flux distribution from the plasma to the work piece. However, this approach has a significant drawback implying an incorrect heat transfer. A two-way coupling is needed to overcome this boundary condition by modeling the transfers of the plasma temperature and the electromagnetic forces through the weld pool surface. Also, when describing small-scale dynamical phenomena such as surfactant advection and Marangoni force since, the underlying phenomena cannot be captured with the use of a large-scale parametrized boundary condition.

Therefore, we present in this paper a numerical approach for the unsteady three-dimensional coupling of the thermal plasma and the weld pool models to simulate GTA welding processes. Both models are based on the dilatable Navier-Stokes equations which enable important variations of the density due to high thermal gradients between the electrodes. Then, we use the Maxwell's equations, the energy conservation equation and species transport equations which are numerically solved with *Code_Saturne* [1]. The plasma model is completed by ion and electron enthalpy conservation equations which allow the charge separation effects taking place in anodic and cathodic zones and the Generalized Ohm's law which depends on electron pressure and density [4]. The variables solved are the fluid total density, the velocity, the electric and magnetic potentials, and the ion and electron enthalpies. Then, a non-linear system of equations is solved at each time step to determine the exact plasma composition. It is based on the Dalton's law of partial pressures and quasi-neutrality hypothesis to link the total pressure and the total density to the ion and electron temperatures and densities. The ideal gas equations of state express the ion and electron temperatures according to the enthalpies and the Saha ionisation equation completes the system of equations whose resolution yields the ion and electron temperatures and densities. The Arbitrary Lagrangian-Eulerian (ALE) method [3] is used to take into account the phenomena taking place at the plasma/weld pool interface: the Marangoni effect, the arc pressure, the aerodynamical shear stress and the gravity.

Some results of simulations obtained with the present numerical coupling approach will be presented in comparison to the experimental data on the weld pool dimensions.

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