Numerical modeling of a thermal plasma flow in electric arc welding using OpenFOAM

Dr. Isabelle Choquet, isabelle.choquet@hv.se	University West SE-461 86, Trollhättan, Sweden
Dr. Håkan Nilsson, hani@chalmers.se	Chalmers University of Technology SE-412 96, Gothenburg, Sweden

Abstract

This study resumes the modeling of a thermal argon plasma flow done in [1] using OpenFOAM 1.4.1. The simulation model has now been implemented in OpenFOAM 1.6.x and further tested.

A thermal plasma is a partially ionized gas with electron energies less than a few hundred of electron volts. It can be made forming an electric arc discharge between electrodes on which a voltage in the range of 10 to 100V is applied. Arc discharges are often coupled with a gas flow to form plasma jets with temperatures above the melting point of many metals and ceramics; they are thus commonly used for material processing. An important application field is in metallurgy to cut, melt or weld.

An electric arc is modeled dividing it into a thermal plasma column in local thermal equilibrium (LTE) or in partial-LTE, surrounded by thin electrode layers (or sheath) in non-LTE. In electric arc welding the plasma column is few millimeters long and the electrode layers (not considered here) are a least two orders of magnitude thinner.

The plasma column was modeled using magnetohydrodynamic and implemented in OpenFOAM 1.6.x. starting from the solver buoyantRhoSimpleFoam. The fluid is thermally expansible and mechanically incompressible. The thermophysical properties (derived using kinetic theory) were implemented in the form of data tables for a temperature range from 200 to 30 000K. The driving force entering the momentum equation is the Lorentz force resulting from the induced magnetic field and the electric current density. The driving heat source entering the enthalpy equation is the Joule heating due to the electric field the electric current density. The electric field can be defined as the gradient of an electric potential. The electric potential is governed by a Laplace equation (because of local electro-neutrality) with a temperature dependent electric conductivity. The magnetic field can be defined as the rotational of a magnetic potential (3-dimensional model). The magnetic potential is governed by a Poisson equation (using the Coulomb gauge condition). The electric current density is given by Ohm´s law.

The obtained solver has been tested against available numerical solution [2] and experimental measurements [3].

Key words: Thermal Plasma, Electric Potential, Magnetic Potential, electric Arc Welding

References

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