World Academy of Science, Engineering and Technology
International Journal of Aerospace and Mechanical Engineering
Vol:9, No:12, 2015

LES Simulation of a Thermal Plasma Jet with Modeled Anode Arc Attachment Effects

Authors : N. Agon, T. Kavka, J. Vierendeels, M. Hrabovský, G. Van Oost

Abstract : A plasma jet model was developed with a rigorous method for calculating the thermophysical properties of the gas mixture without mixing rules. A simplified model approach to account for the anode effects was incorporated in this model to allow the valorization of the simulations with experimental results. The radial heat transfer was under-predicted by the model because of the limitations of the radiation model, but the calculated evolution of centerline temperature, velocity and gas composition downstream of the torch exit corresponded well with the measured values. The CFD modeling of thermal plasmas is either focused on development of the plasma arc or the flow of the plasma jet outside of the plasma torch. In the former case, the Maxwell equations are coupled with the Navier-Stokes equations to account for electromagnetic effects which control the movements of the anode arc attachment. In plasma jet simulations, however, the computational domain starts from the exit nozzle of the plasma torch and the influence of the arc attachment fluctuations on the plasma jet flow field is not included in the calculations. In that case, the thermal plasma flow is described by temperature, velocity and concentration profiles at the torch exit nozzle and no electromagnetic effects are taken into account. This simplified approach is widely used in literature and generally acceptable for plasma torches with a circular anode inside the torch chamber. The unique DC hybrid water/gas-stabilized plasma torch developed at the Institute of Plasma Physics of the Czech Academy of Sciences on the other hand, consists of a rotating anode disk, located outside of the torch chamber. Neglecting the effects of the anode arc attachment downstream of the torch exit nozzle leads to erroneous predictions of the flow field. With the simplified approach introduced in this model, the Joule heating between the exit nozzle and the anode attachment position of the plasma arc is modeled by a volume heat source and the jet deflection caused by the anode processes by a momentum source at the anode surface. Furthermore, radiation effects are included by the net emission coefficient (NEC) method and diffusion is modeled with the combined diffusion coefficient method. The time-averaged simulation results are compared with numerous experimental measurements. The radial temperature profiles were obtained by spectroscopic measurements at different axial positions downstream of the exit nozzle. The velocity profiles were evaluated from the time-dependent evolution of flow structures, recorded by photodiode arrays. The shape of the plasma jet was compared with charge-coupled device (CCD) camera pictures. In the cooler regions, the temperature was measured by enthalpy probe downstream of the exit nozzle and by thermocouples in radial direction around the torch nozzle. The model results correspond well with the experimental measurements. The decrease in centerline temperature and velocity is predicted within an acceptable range and the shape of the jet closely resembles the jet structure in the recorded images. The temperatures at the edge of the jet are underestimated due to the absence of radial radiative heat transfer in the model.

Keywords : anode arc attachment, CFD modeling, experimental comparison, thermal plasma jet
Conference Title : ICFMT 2015 : International Conference on Fluid Mechanics and Thermodynamics
Conference Location : Sydney, Australia
Conference Dates : December 10-11, 2015