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Heat Transfer Mode and Effect of Fluid Flow on the Morphology of the Weld Pool

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Abstract. In this work, the heat transfer by conduction and convection mode, effect of the fluid flow on the morphology of the weld pool and the welding properties are investigated during Tungsten Inert Gas (TIG) process. In the first part, a computation code under Fortran was elaborated to solve the equations resulting from the finite difference discretization of the heat equation, taking into account the liquid-solid phase change with the associated boundary conditions. In order to calculate the velocity field during welding, the Navier-Stokes equations in the melt zone were simplified and solved considering their stream-vorticity formulation. A mathematical model was developed to study the effect of the melted liquid movement on the weld pool. The evolution of the fraction volume of the liquid and the thermal fields promoted the determination of the molten zone (MZ) and the Heat Affected Zone (HAT) dimensions, which seems to be in good agreement with literature.

Introduction

TIG welding is an electrical arc process for assembling. During welding, several physical phenomena occur, such as heat transfer by conduction and convection, fluid flow of molten metal; these phenomena have great importance on the morphology and size of the weld, as well as on the microstructure of the welded sheet. Indeed, during TIG welding, the weld pool is the seat of a strong thermal gradient, which, creates weldability problems due to the appearance of risk zones, noted by MZ for the melted zone and by HAZ for the heat affected zone. These weldability problems correspond to cracking to solidification, cold cracking, residual stresses and distortion [1, 2]. There are three modes of heat transfer by convection, natural convection, forced convection and mixed convection. The mode of thermal transfer by natural convection is widely studied in recent years in renewable energies. Siham et al. [3] conducted a numerical study of the convective flow of water between two inclined coaxial cylinders. Mixed convection transfer mode is very important in many technologies such as the electronics industry to avoid damaging electronic components. Recently, Hanane et al. [4] numerically studied the problem of mixed convection in an horizontal channel with an open trapezoidal enclosure arranged with a heat source of different lengths. The heat transfer and fluid flow simulation in the weld pool has been the subject of many research works. In order to evaluate the effect of fluid flow on the weld penetration, Kou et al. [5] developed a 2D model and numerical simulation of welding with stationary arc. Fan et al. [6] have presented a numerical model to describe the melt zone partially or totally penetrated using TIG welding process. They reported that the physical area represented by the system should be transformed into a rectangular area (calculation area) before a standard finite difference method could be applied to solve the equations system. W. Zhang et al [7, 8] studied the heat transfer and the fluid flow in three-dimensional model of the fillet weld in order to examine the temperature profiles, the speed fields, the shape and the melt size during GMA. On the other side, a complete models of heat