Modeling of Transport Phenomena in Gas Tungsten Arc Welding of Ni to 304 Stainless Steel

A. Bahrami[1], D. K. Aidun[1]

[1]MAE Department, Clarkson University, NY, USA

Abstract

This study investigates transport phenomena in the weld pool of gas tungsten arc welding (GTAW) of Nickel to 304 stainless steel. A finite element 3D simulation of fluid flow and heat and mass transfer of spot welding without consumable is accomplished which leads to prediction of fusion zone shape, weld penetration and dilution of alloying elements. The model includes magneto-hydrodynamics (MHD), the effects of surface tension and buoyancy, and dilution of alloying elements along with moving interface of solid-liquid. Different thermophysical properties of alloys subjected to the weld also makes the problem more complicated.

COMSOL Multiphysics® is used to simulate welding process of dissimilar alloys. The physics interfaces of Electric Currents (ec) and Magnetic Fields (mf) are used to solve for the Lorentz force which is one of the major driving forces of the fluid. A Gaussian distribution of current density at the top surface of the weld is applied as a boundary condition to simulate the effect of the arc.

Laminar Flow (spf) is used to simulate flow field. The moving interface of liquid-solid (for melting and solidification) is modeled using Kozeny Carman theory. Besides, Lorentz force and Buoyancy are applied as Volume forces to the fluid domain. Marangoni effect also plays an important role in fluid circulation in the fusion zone. This effect is applied to the surface as a weak contribution. In order to save computational resources, fluid flow was solved only for part of the metals that has probability of melting.

Heat Transfer in Fluids (ht) is applied to the whole model but for solid parts Heat Transfer in Solid node is added. A Gaussian distribution of heat flux is applied to the flow to simulate the arc. Convective-Radiative heat flux is applied to all boundaries. Due to symmetry with respect to the cross sectional plane, laminar flow and heat transfer are solved for half of the model geometry.

Due to lower melting temperature of 304 and higher thermal diffusivity of Ni, an asymmetric weld pool is created which is larger in 304 side. According to the literature, mixing of molten metals in the fusion zone happens in a few milliseconds. The melt is assumed to be composed of a uniform mixture of Ni and 304. The thermophysical properties of the melt are volume average of the base metals.

Figure 1 shows the distribution of Lorentz force in the model. Ni is placed on the left and 304 is on the right. Due to higher electric conductivity of Ni, Lorentz force is higher at Ni side.

Figure 2 represents the profile of the fusion zone. It is seen that weld penetration is deeper in the 304 side.

Figure 3 shows the velocity field in the fusion zone. It is seen that velocity at the surface is higher than the velocity inside the weld. Marangoni effect at the surface of the weld plays the most important role in fluid circulation in the weld.

Figure 4 depicts the temperature distribution in the weld.

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Figures used in the abstract

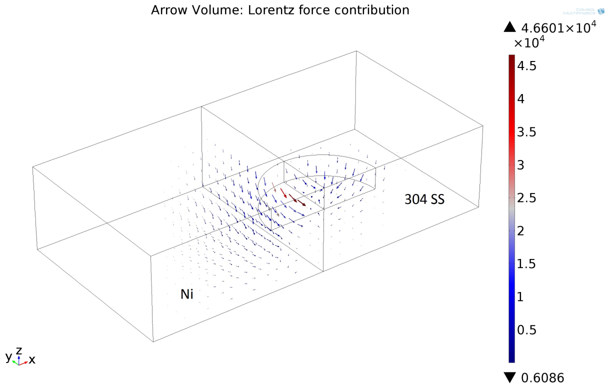

Figure 1: Lorentz force distribution

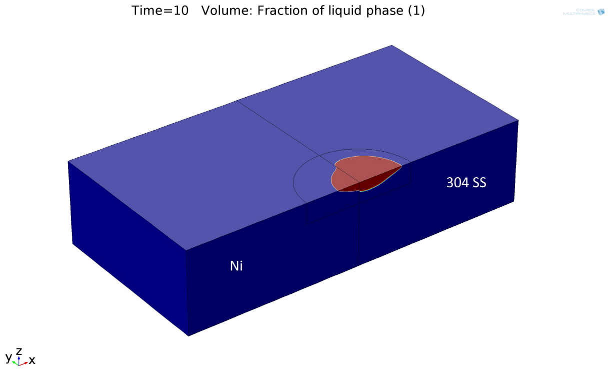

Figure 2: Fusion zone profile

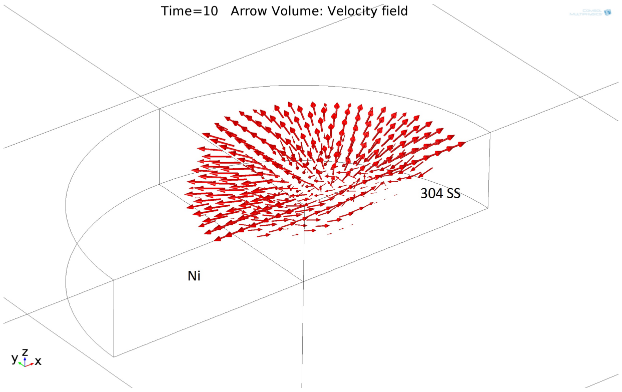

Figure 3: Flow field

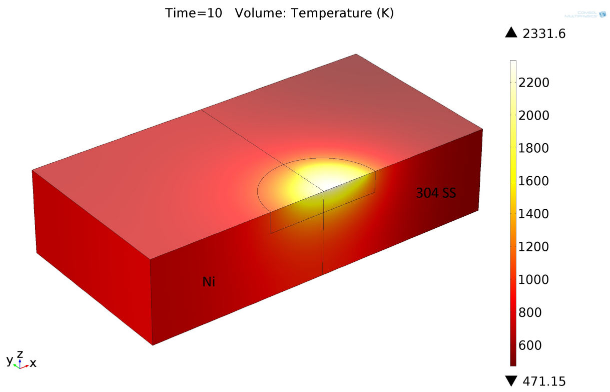

Figure 4: Temperature distribution