

Fundamentals of the Chemical Behavior of Select Welding Fluxes

Changes in weld metal Mn levels as a function of electrochemical reactions in the flux are investigated

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ABSTRACT. This investigation evaluates the relative effects of thermochemical and electrochemical reactions on the transport of elements, particularly manganese, from the flux to the weld metal in submerged arc welding. The experimental fluxes used were silica-calcium oxide-based, containing 20 wt-% MnO, 15 wt-% CaF₂, and SiO₂ to CaO ratios that varied from 5.50 to 1.16. The slags formed show good detachability, and the welds produced have good bead morphology. The dilution effect was eliminated by drawing the welding wire from the same materials as the base plate. The welding parameters were held constant during weld production and two polarities were used. The arc was found to be stable, but was more so for electrode-positive (reverse) polarity welds.

The results of chemical analyses of fluxes, slags and welds are consistent with the following three mechanisms working in parallel that all affect the compositions (and the apparent compositions) of weld metal: 1) the pyrochemical reactions between the slag and the metal; 2) electrochemical reactions at the anodes and cathodes (oxidation and reduction, respectively); and 3) occlusion of slag or solid products of reactions in the weld pool.

Introduction

One of the primary concerns in the welding of metals is to produce welds with physical and mechanical properties similar to or better than those of the materials joined. This concern for the quality of the weld has become more pressing in view of the design and development of

new alloys. These new materials are produced, usually, with the consideration of meeting the most stringent mechanical and chemical requirements, and with little or no attention to the weldability of the alloy.

Many of the new advanced alloys have their designed physical properties only within a confined compositional and microstructural range. This limitation imposes a need for tight control of the weld chemistry and consequently of the weld microstructure. It is therefore important to understand and, to some extent, control the different mechanisms operating in arc welding, which affect the composition of the weld metal.

Systematic studies have been made on submerged arc welding fluxes, focusing on the reactions of these fluxes with the molten metal during welding (Refs. 1-12). Some of this information may be helpful to deduce an elaborate conceptual structure for predicting chemical variations in the weld metal, for explaining the introduction of impurities from the flux, or for establishing the application of a particular welding flux for a given type of weld. Studies of pyrometallurgical reactions between flux and weld metal, in general, are deficient in that fundamental concepts of the thermodynamic properties of slags and metals are not linked with kinetic and electrochemical considerations to deduce

a comprehensive analysis of weld chemistry.

It is widely accepted that the chemical composition of the welding flux affects the final weld metal chemistry (Refs. 12, 13); however, the mechanisms responsible for this elemental transfer (flux to weld metal and vice versa) have not been clearly described. Attempts have been made to develop a purely thermodynamic model (Refs. 9, 12, 14) on the assumption that equilibrium is achieved (or at least approached) between the weld pool and the slag, despite the short time that the weld pool remains liquid. Chai, *et al.* (Ref. 9), observed that elemental transfer between the slag and the weld pool could be explained thermodynamically for the case of Mn and Cr, but their model has discrepancies when it is applied to the transference of Si.

Lately, it has been proposed and experimentally supported that, in addition to thermochemistry, electrochemical effects influence weld metal compositions (Refs. 15-19) of submerged arc welds. In this investigation, we examine the role of electrochemistry in the manganese transport from the flux to the weld metal by selecting a SiO₂-CaO-CaF₂-MnO flux containing 20 wt-% MnO, 15 wt-% CaF₂, and SiO₂ to CaO ratios that varied from 5.50 to 1.16. The changes in the levels of manganese in the weld metal and of manganese oxide in the slag are interpreted based on thermodynamic and electrochemical mechanisms.

Experimental Work

Materials

The SiO₂-CaO-CaF₂-MnO flux system was selected for this investigation with CaF₂ and MnO fixed at 15 and 20 wt-%, respectively; the SiO₂ varied from 35 to 15 wt-% and CaO made up the remainder, as shown in Table 1. These fluxes were processed in the laboratory using reagent grade powders, accurately weighed,

KEY WORDS

Chemical Behavior
Welding Fluxes
Thermochemical Reaction
Electrochemical Reaction
Element Transport
Manganese
SAW
Slag
Welds
Weld Metal

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