THE BEHAVIOUR OF NITROGEN DURING THE AUTOGENOUS ARC WELDING OF STAINLESS STEEL

by

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ABSTRACT

Nitrogen-alloyed austenitic stainless steels are becoming increasingly popular, mainly due to their excellent combination of strength and toughness. Nitrogen desorption to the atmosphere during the autogenous welding of these steels is often a major problem, resulting in porosity and nitrogen losses from the weld. In order to counteract this problem, the addition of nitrogen to the shielding gas has been proposed.

This study deals with the absorption and desorption of nitrogen during the autogenous arc welding of a number of experimental stainless steels. These steels are similar in composition to type 310 stainless steel, but with varying levels of nitrogen and sulphur. The project investigated the influence of the base metal nitrogen content, the nitrogen partial pressure in the shielding gas and the weld surface active element concentration on the nitrogen content of autogenous welds.

The results confirm that Sievert's law is not obeyed during welding. The weld nitrogen content increases with an increase in the shielding gas nitrogen content at low nitrogen partial pressures, but at higher partial pressures a dynamic equilibrium is created where the amount of nitrogen absorbed by the weld metal is balanced by the amount of nitrogen evolved from the weld pool. In alloys with low sulphur contents, this steady-state nitrogen content is not influenced to any significant extent by the base metal nitrogen content, but in high sulphur alloys, an increase in the initial nitrogen concentration results in higher weld nitrogen contents over the entire range of nitrogen partial pressures evaluated.

A kinetic model can be used to describe nitrogen absorption and desorption during welding. The nitrogen desorption rate constant decreases with an increase in the sulphur concentration. This is consistent with a site blockage model, where surface active elements occupy a fraction of the available surface sites. The absorption rate constant is, however, not a strong function of the surface active element concentration.

Alloys with higher base metal nitrogen contents require increased levels of supersaturation prior to the onset of nitrogen evolution as bubbles. These increased levels of supersaturation for the higher-nitrogen alloys is probably related to the higher rate of nitrogen removal as N_2 at the onset of bubble formation. Given that nitrogen bubble formation and detachment require nucleation and growth, it is assumed that a higher nitrogen removal rate would require a higher degree of supersaturation.

Nitrogen losses from nitrogen-alloyed stainless steels can be expected during welding in pure argon shielding gas. Small amounts of nitrogen can be added to the shielding gas to counteract this effect, but this should be done with care to avoid bubble formation. Supersaturation before bubble formation does, however, extend the range of shielding gas compositions which can be used. Due to the lower desorption rates associated with higher surface active element concentrations, these elements have a beneficial influence during the welding of high nitrogen stainless steels. Although higher sulphur contents may not be viable in practice, small amounts of oxygen added to the shielding gas during welding will have a similar effect.

Keywords: welding, stainless steel, nitrogen, absorption, desorption, surface active elements, sulphur, kinetic model, bubbles, supersaturation

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