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The Effect of Manganese, Nitrogen and Molybdenum on the Corrosion Resistance of a Low Nickel (<2 wt%) Austenitic Stainless Steel

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Abstract

This dissertation is a study of the effect of manganese, nitrogen and molybdenum on the corrosion behaviour of a low nickel, austenitic stainless steel. The trademarked steel, Hercules^{TM}, has a composition of 10 wt% Mn, 0.05 wt% C, 2 wt% Ni, 0.25 wt% N and 16.5 wt% Cr. Eighteen alloys with a Hercules^{TM} base composition were made with varying manganese, molybdenum and nitrogen contents, to establish the effect of these elements on the corrosion behaviour of the steel, and to determine a composition that would ensure increased corrosion resistance in very corrosive applications. The manganese was varied in three levels (5, 10 and 15 wt%), the molybdenum in three levels (0.5, 1 and 2 wt%) while the nitrogen was varied only in two levels (0.15 and 0.3 wt%).

The dissertation details the manufacturing and electrochemical corrosion testing of these alloys. Preliminary tests were done on 50g buttons, and full-scale tests on 5 kg ingots. The buttons had a composition that was not on target, this was however rectified in the making of the ingots. Potentiodynamic tests were done in a 5 wt% sulphuric acid solution and the corrosion rate (mm/y) was determined directly from the scans.

From the corrosion test results, it was clear that an increase in manganese decreases the corrosion rate, since the 5 wt% Mn alloys had the highest corrosion rate, whereas the 15 wt% Mn alloys, the lowest.

The addition of molybdenum at 5 wt% Mn decreased the corrosion rate such that a trend of decreasing corrosion rate with increasing molybdenum was observed. At 10 and 15 wt% Mn molybdenum again decreased the corrosion rate significantly, but the corrosion rate value remained more or less constant irrespective of the increasing molybdenum content.

At nitrogen levels lower than those of Hercules^{TM} (less than 0.25 wt%) there was no change in corrosion rate as nitrogen was increased to levels closer to 0.25 wt%. For nitrogen levels higher than 0.25 wt%, corrosion rates decreased as nitrogen levels were increased further from 0.25 wt% but only at Mo contents lower than 1.5 wt%.

The Hercules^{TM} composition was developed for its mechanical properties. Microstructural analyses revealed that the 5 wt% Mn alloys were not fully austenitic and since the 15 wt% Mn alloys behave similarly to the 10 wt% Mn alloys, it was concluded that 10 wt% Mn was optimum for Hercules^{TM}. All the alloys tested had a much lower corrosion rate than Hercules^{TM}. Any addition of molybdenum thus improved the corrosion rate of this alloy. An alloy with a Hercules^{TM} base composition, 10 wt% Mn, 0.15 wt% N and a minimum addition of 0.5 wt% Mo would be a more corrosion resistant version of Hercules^{TM}.

Pitting tests were done on the 10 wt% Mn ingots in a 3.56 wt% sodium chloride solution. The results showed that an increase in molybdenum increased the pitting resistance of the ingots.

Immersion tests in a 5 wt% sulphuric acid solution at room temeperature on the 10 wt% Mn ingots confirmed that the ingots corroded by means of general corrosion.