

Influence of Manganese on the Properties of a Vanadium-bearing Ferritic Stainless Steel

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For the purpose of further increasing toughness, the influence of manganese contents up to 4% was investigated in a 4% vanadium-bearing experimental ferritic stainless steel. The tensile and formability properties were also studied. The corrosion properties were measured using electrochemical techniques in 1 N H₂SO₄ and 3.5% NaCl solutions.

No marked effect was found on the tensile and formability properties. In contrast, manganese has a strong detrimental effect on the general and localized corrosion properties of this 4% vanadium alloy. The passivation characteristics in normal sulphuric acid are much poorer. However, spontaneous passivation occurs in this environment where the manganese content is 0.1%. Similarly, the propensity to pitting corrosion is greatly improved at low manganese levels, with pitting potentials superior to both type 304 and 316L stainless steels.

KEY WORDS: stainless steels; ferritic; vanadium; manganese; mechanical properties; corrosion properties.

1. Introduction

In the past, manganese has been used in carbon–manganese steels¹⁾ to achieve grain refining of the ferrite and reduce the grain-boundary carbide thickness, *i.e.*, to improve toughness. In low silicon-steels (0.01 to 0.07% Si), manganese has also been reported to have a significant effect on the impact properties, with a 40°C drop in the impact transition temperature.²⁾

In ferritic stainless steels, however, the use of manganese as an alloying addition has been kept to a minimum. In fact, manganese, (like vanadium), is not commonly added to ferritic stainless steels. Manganese is not regarded as a useful alloy addition as such, and American Iron and Steel Institute (AISI) grades specify a maximum limit of 1% manganese. In the 300 series of stainless steels, manganese additions are allowed up to 2% maximum, as a useful and more economical austenitizer than nickel. In 1979, Japanese workers³⁾ developed an 18% Cr ferritic stainless steel with manganese additions of up to 2%, having improved toughness of sheets and plates in the welded condition. Little effect, however, was observed on the formability of the cold-rolled and annealed sheet product.

Recent work⁴⁾ has shown the potential of vanadium in improving the impact roughness and localized corrosion performance of an 18% Cr ferritic stainless steel. The combined effects of vanadium and manganese on the properties of this material are worthy of investigation.

In this paper, the effects of manganese additions (up

to 4%) are investigated on the toughness and formability properties of a vanadium-bearing (4% V) 18% Cr ferritic stainless steel in sheet and plate form. Reference to the modified Schaeffler diagram⁵⁾ shows that up to 4% manganese can be accommodated in 18% Cr ferritic stainless steels without forming austenite. The general and pitting corrosion properties were also examined. In addition, the opportunity was taken to assess the influence of nickel on the 4% V alloy. It is well known in the literature that nickel improves resistance to cleavage fracture in ferrite by increasing the surface energy term (τ) in the Cottrell–Petch equation:

$$(\sigma_0 d^{1/2} + k_y)k_y = \beta\mu\tau,$$

where β is a constant related to stress state, τ is the effective surface energy of the crack, μ is the shear modulus, d is the grain diameter, σ_0 and k_y the friction stress and Petch slope respectively.⁶⁾

2. Experimental Procedure

Experimental ingots of about 10 kg, and with the chemical composition given in **Table 1**, were cast in a vacuum induction furnace. The (C+N) levels, which markedly influence the toughness of the alloy, were maintained as much as possible within the 200–300 ppm range, which is typical of electric-arc and argon–oxygen decarburization (AOD) practice. The carbon levels, which determine the extent of intergranular corrosion, are within a 50 ppm experimental error.

The ingots were surface-dressed and homogenized at