Materials Science and Engineering A 396 (2005) 302–310

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Effect of different Mn contents on tensile and corrosion behavior of CD4MCU cast duplex stainless steels

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Received 12 October 2004; received in revised form 18 January 2005; accepted 18 January 2005

Abstract

Despite the significant use in the industry, the effect of Mn on the tensile and corrosion behavior of cast duplex stainless steels has not been well established. In the present study, the tensile and corrosion behavior of CD4MCU cast duplex stainless steels with different Mn contents of 0, 0.8 and 2%, respectively, was therefore examined. The polarization and the in situ slow strain rate tests were conducted in 3.5% NaCl + 5% H_2SO_4 aqueous solution to quantify the resistances to pitting corrosion and stress corrosion cracking with different Mn contents. The addition of Mn, which stabilized ferrite in the present study, affected the microstructure of the present alloy, and eventually the tensile and corrosion behaviors in a complex manner. Tensile properties of CD4MCU cast duplex stainless steel, for example, was found to be determined by the volume fraction of hard ferritic phase and the shape of austenitic phase. The addition of 0.8% Mn was detrimental to both pitting corrosion and stress corrosion cracking properties of CD4MCU cast duplex stainless steel due to the significant increase in contact area between the less-noble ferritic and the noble austenitic phases. With the addition of 2% Mn, the resistance to pitting corrosion and stress corrosion cracking in 3.5% NaCl + 5% H_2SO_4 aqueous solution is recovered. The resistance to stress corrosion cracking of the specimen with 2% Mn was still greatly inferior to that of the 0% Mn counterpart. The relationship between the microstructural evolution and the tensile and corrosion behavior of CD4MCU cast duplex stainless steels with different Mn contents was discussed based on the micrographic and fractographic observations.

Keywords: Mn; Tensile behavior; Corrosion behavior; CD4MCU cast duplex stainless steels

1. Introduction

The industrial use of duplex stainless steel is rapidly increasing due to the combined advantages of better mechanical and corrosion properties [1–5]. Since the development of first-generation duplex stainless steels in 1930s, considerable research efforts have been conducted to improve both mechanical and corrosion properties, particularly by controlling alloying elements, such as N, Cr, W and Mo [3,6–16]. Charles, for example, reported that the addition of Cr and/or Mo improved the resistance to pitting corrosion and stress corrosion cracking of duplex stainless steels [4]. He further proposed that the addition of such elements needs to be done with caution since they can promote detrimental sigma phases at elevated temperatures. Despite the extensive research works on the mechanical and corrosion behavior of duplex stainless steels, most of the researches have been conducted on the wrought products, and only a limited number of studies are available on the cast products of duplex stainless steels. Previously, the authors examined the tensile and corrosion behavior of CD4MCU cast duplex stainless steels with different N, Cr and Mo contents, and reported that the mechanical and corrosion properties were strongly influenced by the changes in the shape and the volume fraction of austenitic phase with different amount of N, Cr and/or Mo contents [4,5,7]. Mn is often added to duplex stainless steel to increase the solubility of N to maximize the beneficial effect

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doi:10.1016/j.msea.2005.01.046

of N [17,18]. According to the work of Gunn [19] and Kemp et al. [20] however, the effect of Mn on the microstructural evolution, as well as the mechanical and corrosion properties, of duplex stainless steels has not been well established.

The objective of present study was therefore to examine the effect of Mn on the tensile and corrosion behavior of CD4MCU cast duplex stainless steels. The in situ slow strain rate tests were conducted in air and 3.5% NaCl + 5% H_2SO_4 aqueous solution to quantify the resistance to stress corrosion cracking with different Mn contents. The changes in the volume fraction and the shape of austenitic phase with different Mn contents were correlated with the tensile and corrosion behavior of CD4MCU cast duplex stainless steel, based on the optical and the SEM micrographic and fractographic observations.

2. Experimental procedures

In the present study, CD4MCU cast duplex stainless steels with different Mn contents of 0, 0.8 and 2%, respectively, were used. Table 1 represents the measured chemical compositions of the alloys used in the present study. The alloys were designated as CD4MCUMn0, CD4MCUMn1 and CD4MCUMn2, respectively, depending on the Mn contents. Each alloy specimen was melted at 1620 °C using an induction furnace and subsequently sand cast into an Y-block mold. They were subsequently solution heat treated at 1050 °C for 2 h and water-quenched. The microstructures of the alloy with different Mn contents were documented by using an optical microscope after electro-etching using a solution mixture of 100 ml H_2O and 10 g CrO_3 at an applied potential of 3–6 V. The tensile specimens were prepared from the central portion of each Y-block cast with a gauge length of 20 mm and a diameter of 4 mm. Tensile tests were carried out at a nominal strain rate of $1 \times 10^{-3}\,s^{-1}$ on an R&B (Daejun, Korea) model S2 universal testing system. For the study of general corrosion behavior, polarization tests were conducted in 3.5% NaCl + 5% H_2SO_4 aqueous solution using a PAR (Oak Ridge, TN) model Versastat II potentiostat at a scan rate of $1\,mV\,s^{-1}$. The in situ slow strain rate (SSR) tests were conducted at a nominal strain rate of $1 \times 10^{-6}\,s^{-1}$ in air and 3.5% NaCl + 5% H_2SO_4 aqueous solution at an anodically applied potential of 1100 mV versus Ag/AgCl on an R&B (Daejun, Korea) model V2 constant extension rate tester (CERT). The micrographic and the fractographic analyses were conducted on the tested specimens by using scanning optical microscope (SEM).

Table 1
Chemical compositions of CD4MCU cast duplex stainless steels in wt.%

Specimen	C	Si	Mn	P	S	Ni	Cr	Mo	Cu	N	Fe
CD4MCUMn0	0.04	0.86	0.0	0.027	0.006	5.32	25.19	1.84	2.8	0.13	Balance
CD4MCUMn1	0.03	0.75	0.8	0.029	0.004	5.36	25.37	1.99	2.8	0.13	Balance
CD4MCUMn2	0.04	0.86	2.0	0.027	0.006	5.32	25.19	1.84	2.8	0.13	Balance

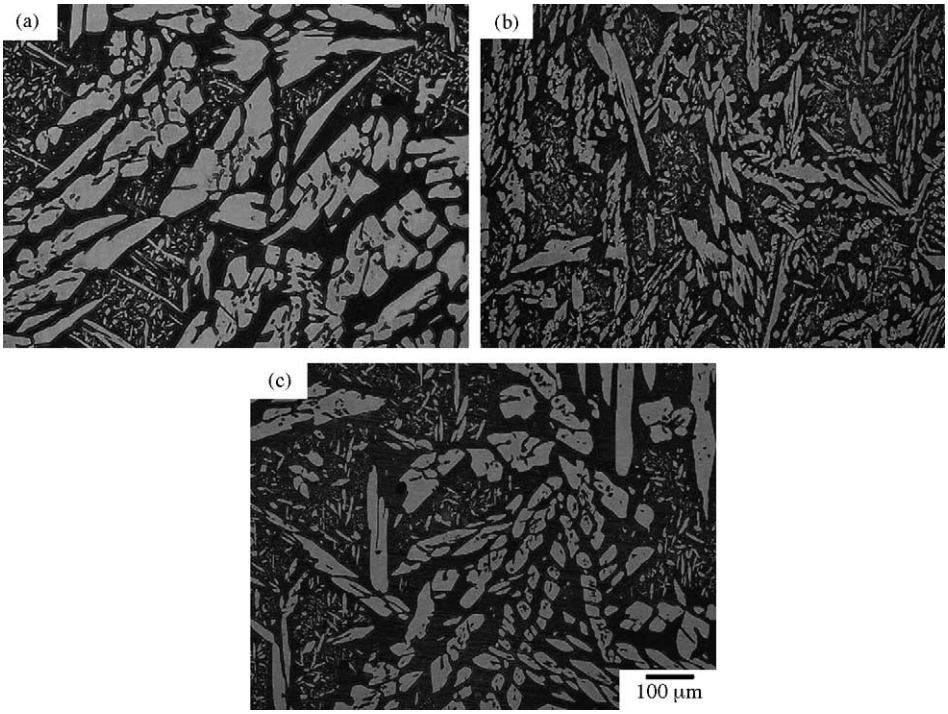

Fig. 1. Typical optical micrographs of CD4MCU cast duplex stainless steels with different Mn contents of (a) 0%, (b) 0.8% and (c) 2%, respectively.