JOURNAL OF IRON AND STEEL RESEARCH, INTERNATIONAL. 2011, 18(9): 41-46

A New Resource-Saving, High Chromium and Manganese Super Duplex Stainless Steels 29Cr-12Mn-2Ni-1Mo-xN

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Abstract: A new family of resource-saving, high chromium and manganese super duplex stainless steels (DSSs), with a composition in mass percent, % of Cr 0.29, Mn 0.12, Ni 2.0, Mo 1.0, and N 0.51—0.68, has been developed by examining the effect of N on the microstructure, mechanical properties and corrosion properties. The results show that these alloys have a balanced ferrite-austenite relation. The austenite volume fraction decreases with the solution treatment temperature, but it increases with an increase in N content. The increases in nitrogen enhance the ultimate tensile strength (UTS) and reduce the ductility of the material slightly. The pitting corrosion potential increases first and then decreases with an increase in nitrogen content when the amount of N arrives to 0.68%. The yield stress and ultimate tensile strength of solution-treated samples were more than 680 and 900 MPa, the elongation of experimental alloys are higher than 30%, respectively, what is more, the pitting potentials were beyond 1 100 mV.
Key words: duplex stainless steel; microstructure; mechanical property; pitting potential

Duplex stainless steels (DSSs) formed by austenite (30% to 70%) show an attractive combination of corrosion resistance and mechanical properties[1]. Over the past decade, nitrogen as an alloying element to stabilize austenite phase and further replace nickel has become a growing tendency. H Vannevik et al[2] found it was possible to obtain typical dual phase structure and high critical pitting temperature within the alloys by investigating the high chromium and nitrogen DSSs containing Fe-29Cr-7Ni-2Mo-xN (x=0.31%—0.44%). A nickel-free DSS having high performance on mechanical and corrosion properties was developed through the combination effect of N and Mn[3]. However, there is no report of the nitrogen effects on new Fe-29Cr-12Mn-2.0Ni-1.0Mo-xN (x=0.51%—0.68%) super duplex stainless steels (SDSS). The present work was concerned with the influence of nitrogen on the microstructure, mechanical properties and pitting corrosion properties of a high chromium, manganese and low-nickel SDSS.

1 Experimental

The experimental alloys designated as N1, N2, N3 and N4 were melted in a 50 kW vacuum furnace. The ingots chemical compositions after spectroscopic analysis are shown in Table 1. The ingots were hot forged into bars of 40 mm in diameter. The specimens for microstructures were machined from the as-forged bars with dimension of 10 mm×10 mm ×3 mm, and then solution-treated in a temperature range from 850 to 1 100 ℃ for 30 min followed by water-quenching. To symbolize the microstructures, experimental specimens were electrochemically etched in 10% of KOH solution, which made the austenite phase bright and the ferrite phase dark. The volume fraction of austenite was measured by optical microscope with quantitative metallographic analysis system. The average of ten measurements on each sample was taken as the volume fraction of austenite. X-ray diffraction (XRD) analyses were conducted in a DL-MAX-2550 diffractometer with CuKα radiation (λ=

Foundation Item: Item Sponsored by Innovation Fund of Education Commission of Shanghai Municipality of China (09yz20)
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Table 1 Chemical composition of experimental stainless steels (mass percent, %)

Alloy	Cr	Mn	Ni	Mo	N	C	S	Fe
N1	29.24	11.93	1.98	0.82	0.51	0.036	0.0061	Balance
N2	29.03	11.75	2.10	0.96	0.55	0.034	0.0063	Balance
N3	28.76	11.58	2.02	1.18	0.58	0.036	0.0060	Balance
N4	28.71	12.02	1.78	1.06	0.68	0.035	0.0054	Balance
SAF2507	24.90	1.01	6.90	3.84	0.27	0.030	0.0080	Balance

0.15406 nm) and the scan rate was 8(°)/min.

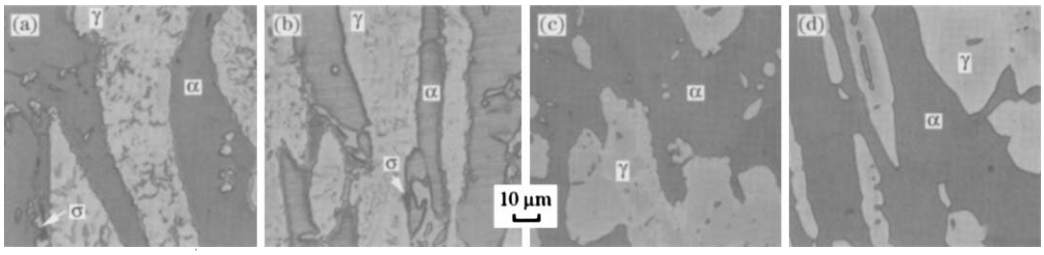
The specimens for the tensile test and the anodic polarization test were solution-treated at 1050 ℃ for 30 min and then water-quenched. The tensile specimens were prepared in a gage length of 30 mm and diameter of 5 mm according to the National Standard of China, GB/T228-2002. The anodic polarization tests were conducted in 1 mol/L NaCl solution using an EG&G Princeton Applied Research Potentiostat/Galvanostat Model 273 A. Pitting corrosion samples were progressively wet ground down to 800 grit sand paper and then well rinsed in water, and edges of the exposed sample were masked with an epoxy resin. Then, the samples with an area of 1 cm^2 were tested in the NaCl solution held at 25 ℃. Before the scan was initiated, the samples were allowed to remain in the pitting solution for 10 min so as to reach their free corrosion potential. A scan rate of 0.7 mV/s was used, and a saturated calomel electrode (SCE) was used as a reference. The value of potential exceeding 10^{-4} A/cm^2 after a sudden increase in electric current was called the pitting corrosion potential. The corrosion behavior was evaluated by the absolute value of the pitting potential.

2 Results and Discussion

2.1 Effect of N on microstructure of solution-treated samples

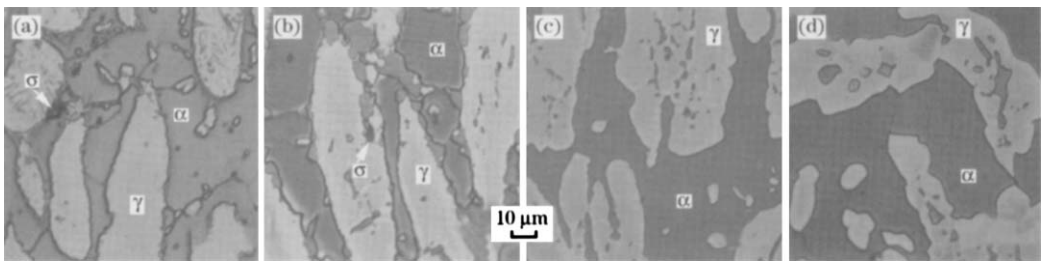
The typical dual microstructure of experimental alloys solution-treated at different temperatures is shown in Fig. 1 to Fig. 4. The bright austenite islands are embedded in the dark ferrite matrix. There are some sigma phases preferentially precipitated in the interfaces between ferrite and austenite of different nitrogen-content alloys when solution-treated temperature is below 1000 ℃. Nevertheless, sigma phase disappeared when the temperature is up to 1000 ℃. The above metallographic results are further confirmed by XRD which is shown in Fig. 5 and Fig. 6. To sum up, the precipitation of sigma phase is primarily influenced by the solid solution treatment temperature.

Fig. 7 shows the relation of nitrogen to the austenite volume fraction of the SDSS with solution treatment



(a) 900 ℃; (b) 950 ℃; (c) 1000 ℃; (d) 1050 ℃.

Fig. 1 Optical micrographs of N1 alloy treated with solution for 30 min at different temperatures



(a) 900 ℃; (b) 950 ℃; (c) 1000 ℃; (d) 1050 ℃.

Fig. 2 Optical micrographs of N2 alloy treated with solution for 30 min at different temperatures