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Heat treatment temperature influence on ASTM A890 GR 6A super duplex stainless steel microstructure

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Abstract

Duplex and super duplex stainless steels are ferrous alloys with up to 26% chromium, 8% nickel, 5% molybdenum and 0.3% nitrogen, which are largely used in applications in media containing ions from the halogen family, mainly the chloride ion (Cl^-). The emergence of this material aimed at substituting Copper–Nickel alloys (Cupro-Nickel) that despite presenting good corrosion resistance, has mechanical properties quite inferior to steel properties.

The metallurgy of duplex and super duplex stainless steel is complex due to high sensitiveness to sigma phase precipitation that becomes apparent, due to the temperatures they are exposed on cooling from solidification as well as from heat treatment processes.

The objective of this study was to verify the influence of heat treating temperatures on the microstructure and hardness of ASTM A890/A890M Gr 6A super duplex stainless steel type. Microstructure control is of extreme importance for castings, as the chemical composition and cooling during solidification inevitably provide conditions for precipitation of sigma phase. Higher hardness in these materials is directly associated to high sigma phase concentration in the microstructure, precipitated in the ferrite/austenite interface.

While heat treatment temperature during solution treatment increases, the sigma phase content in the microstructure decreases and consequently, the material hardness diminishes. When the sigma phase was completely dissolved by the heat treatment, the material hardness was influenced only due to ferrite and austenite contents in the microstructure.

Keywords: Sigma phase; Microstructure; Super duplex; Hardness

1. Introduction

Stainless steels have been continually improved by the optimization of their heat treatments, alloy-

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Table 1
Mechanical properties of some copper based alloys compared to duplex stainless steels [1]

Alloy	Y.S. (MPa)	T.S. (MPa)	El.(%)
G-CuSn 10	130 min.	270 min.	18.0 min.
G-CuSn5 ZnPb	90 min.	220 min.	11.0 min.
G-CuSn 12	140 min.	260 min.	12.0 min.
G-CuSn 12 Ni 2	160 min.	280 min.	12.0 min.
G-CuSn 10 Zn	130 min.	260 min.	15.0 min.
DSS	450 min.	650 min.	25 min.

ing techniques and steel making practice, thus aiming to adequate mechanical properties and corrosion resistance. The duplex stainless steels appeared with the objective of substituting copper alloys, which are used for marine applications (Table 1). The properties of duplex and super duplex stainless steels are related to a unification of what is best of these two phases, where austenite contributes with the tenacity and ferrite, which is harder, improves the mechanical and welding characteristics [2]. These steels present an advantage to austenitic stainless steels: they possess higher stress corrosion and intergranular corrosion resistances, and superior mechanical properties. The mechanical properties depend on the ferrite content in the microstructure. The normal ferrite content is between 60% and 40% by volume. Larger contents of δ ferrite increase mechanical resistance; however, they promote sigma phase precipitation during cooling from solidification process.

A super duplex stainless steel contains nominally (in weight) 25% Cr; 7% Ni; 3.5% Mo; 0.25% N. The incubation time for σ phase precipitation is around 5 min between 850 and 900 °C. The material ductility and toughness are strongly reduced due to σ phase formation. The effect of this phenomena increases with the increase of the volumetric fraction of σ phase. The formation mechanism of this phase is given by controlled nucleation and subsequent growth. A large array of undesirable phases such as: complex chromium and molybdenum carbides, nitrides and inter-metallic phases can appear in these alloys and strongly affect their properties if an appropriate manufacturing process is not selected. The σ phase is the most important as it drastically affects the material tenacity and corrosion resistance.

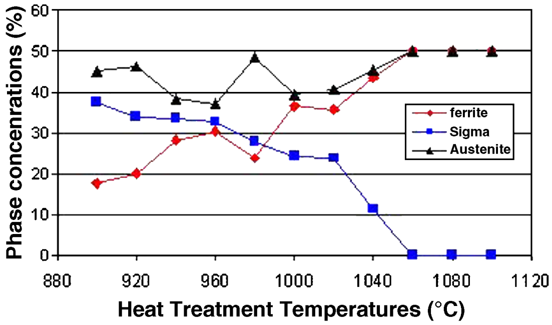

Fig. 1. Phase proportions versus heat treatment temperatures.

2. Experimental procedure

Cylindrical specimens 25 mm diameter and 260 mm length were formed by casting the steel into phenolic–uretanic resin bonded sand molds. The gate and feeding system designed in Autocad 2000 was simulated in Solstar software. Melting was carried out in a vacuum induction furnace at a 60-Hz frequency and maximum power of 400 kW.

The chemical composition was obtained by means of optical emission spectrometry in a BAIRD DV2 spectrometer. Based on the chemical composition, the Cr equivalent and Ni equivalent values were calculated according to expressions below [3].

$$Cr_{eq} = Cr(\%) + [(1.5)(\%)Si] + [(1.4)(\%)Mo] + (\%)Nb - 4.99 \quad (1)$$

Table 2
Concentration of chemical elements (weight percent), obtained by optic emission spectrometry

C (%)	Cr (%)	Mo (%)	Ni (%)	Si (%)	Mn (%)	Cu (%)	W (%)	N (%)	P (%)
0.016	25.69	3.80	7.18	0.74	0.52	0.716	0.736	0.22	0.027
Nb (%)	Ti (%)	Al (%)	V (%)	Zr (%)	Co (%)	Sn (%)	Pb (%)	S (%)	Fe (%)
0.014	0.005	0.016	0.049	0.065	0.055	0.0069	0.0018	0.008	Rest.