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Microstructure and corrosion behaviour of gas tungsten arc welds of maraging steel

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Abstract

Superior properties of maraging steels make them suitable for the fabrication of components used for military applications like missile covering, rocket motor casing and ship hulls. Welding is the main process for fabrication of these components, while the maraging steels can be fusion welded using gas tungsten arc welding (GTAW) process. All these fabricated components require longer storage life and a major problem in welds is susceptible to stress corrosion cracking (SCC). The present study is aimed at studying the SCC behaviour of MDN 250 (18% Ni) steel and its welds with respect to microstructural changes. In the present study, 5.2 mm thick sheets made of MDN 250 steel in the solution annealed condition was welded using GTAW process. Post-weld heat treatments of direct ageing (480 °C for 3 h), solutionizing (815 °C for 1 h) followed by ageing and homogenizing (1150 °C for 1 h) followed by ageing were carried out. A mixture of martensite and austenite was observed in the microstructure of the fusion zone of solutionized and direct aged welds and only martensite in as-welded condition. Homogenization and ageing treatment have eliminated reverted austenite and elemental segregation. Homogenized welds also exhibited a marginal improvement in the corrosion resistance compared to those in the as-welded, solutionized and aged condition. Constant load SCC test data clearly revealed that the failure time of homogenized weld is much longer compared to other post weld treatments, and the homogenization treatment is recommended to improve the SCC life of GTA welds of MDN 250 Maraging steel.

Keywords: 18% Ni maraging steel; Gas tungsten arc welding; Post weld heat treatment; Solutionising; Ageing treatment; Pitting corrosion; Stress corrosion cracking (SCC)

1. Introduction

The high yield strength and excellent fracture toughness of maraging steel make it suitable for defence applications such as missile, rocket motor casing and ship hull. Age hardening is the main strengthening mechanism which develops yield strength of 2400 MPa, of low carbon martensite with nickel, cobalt and molybdenum precipitates [1]. The components for the defence applications are fabricated using various welding processes [2–4]. One of the primary requirements of fabricated components is long storage life. The corrosion is one of the major problems during storage. It is now well established that the high strength steels suffer from poor stress corrosion cracking (SCC) resistance and their SCC resistance decreases with increase in strength [5]. Previous investigations revealed that the threshold yield strength value for SCC in high strength steels is about 1400 MPa [6]. Hence it can be concluded that ultra high strength maraging steels also suffer from SCC problem. Although SCC behaviour of maraging steel in wrought condition has been studied in some detail, work available on the SCC behaviour of maraging steel welds is relatively scarce. Hence, any attempt made to understand SCC behaviour of maraging steel welds used for making defence

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components is important. The mechanisms proposed for SCC of maraging steel are anodic path dissolution and hydrogen embrittlement [7]. Cracking was found to occur in a plane and inclined to precracking [8]. Crack growth velocity was found to be much faster in water than in oil [9]. Jha et al. [10] studied SCC of maraging steel and found that an intergranular mode of cracking occurs. Study made on 250 grade maraging steel at elevated temperature in steam has shown that it offers better protection compared to manganese phosphate treatment [11]. SCC susceptibility of steel was caused by acid dip step in the pretreatment of phosphating process [12]. Brook et al. studied the role of oxygen in SCC of maraging steel and found that cracking occurred along prior austenite grain boundaries [13]. Mellor et al. found the mechanism of hydrogen embrittlement in SCC failure of maraging steel components [14]. SCC behaviour of wrought maraging steel was studied in detail, but the investigations on welds are very limited. Kenyon et al. revealed that the maraging steel welds have poor SCC resistance compared to base metal [15]. One of the problems in fusion welding of maraging steel is the segregation of alloying elements in the interdendritic arm spacing. This may cause the formation of reverting austenite in the fusion zone of the welds. Both the segregation and reverted austenite affect the toughness and SCC resistance of maraging steel welds. Studies on the influences of reverting austenite and segregation on corrosion behaviour of maraging steel welds have not been available in the existing literature. Understanding of the corrosion behaviour of these welds is important in exploring a remedy to overcome the problem of cracking during storage of welded components made of maraging steel. The present study is aimed at studying the pitting and stress corrosion behaviours of MDN 250 (18% Ni) steel and its welds.

2. Experimental

MDN 250 (18% Ni) steel of 5.2 mm thick sheet was used in the present study. The preparation details of the weld joint are shown in Fig. 1. Welding was carried out using gas tungsten arc welding process. Table 1 gives the welding variables. Table 2 gives the chemical composition of the base metal and filler wire. The steps of post weld heat treatment are (i) ageing at 480 °C/3 h, followed by air cooling; (ii) Solutionizing at 815 °C/1 h/air cooling + ageing at 480 °C/3 h/air cooling; and (iii) Homogenizing at 1150 °C/1 h/air cooling + ageing at 480 °C/3 h/air cooling in the study of corrosion behaviour. Optical microscopy was used to study the microstructural changes of MDN 250 (18% Ni) steel during welding. Stress Tech 3000 X-ray system using CrKα radiation was used to measure the retained austenite content and its fraction in welds and base metal.

GILL AC basic electrochemical testing was used for general corrosion test. Standard flat cells with an exposure area of 1 cm^2 was used for experiments in aerated 3.5% NaCl solution with a scan rate of 0.166 mVs^{-1}. Corrosion potential (Ecorr) values and corrosion rates were recorded.

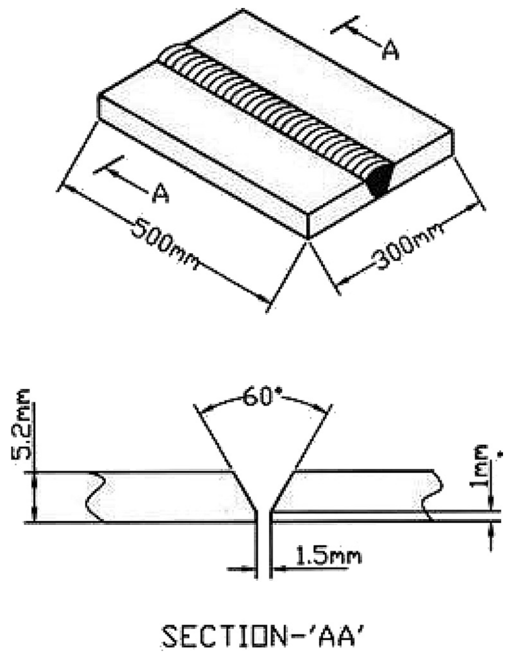

Fig. 1. Weld joint preparation details.

A Constant load type SCC test rig was used for SCC testing of both base metal and welds. Standard tensile and SCC specimens (Fig. 2) were machined out from the 5.2 mm rolled plate of the maraging steel and its welds as per ASTM E8 standards. 3.5% NaCl solution was used for alternate cycles of immersion of specimen. A Constant load of 50 percent yield strength value of specimen for a given condition was applied. The Yield strength values are determined from tensile test data given in Table 3. The time taken for failure of the specimen at a constant load was used to compare the different conditions of steel. The longer the time to failure is, higher will be the SCC resistance.

3. Results and discussion

3.1. Microstructure

The Optical micrograph of the base metal is shown in Fig. 3, which clearly indicates the martensite with grain size

Table 1
Gas tungsten arc welding variables.

Parameters	Values
Welding current/A	130
Welding speed/($mm \cdot min^{-1}$)	60
Electrode polarity	DCSP
Arc voltage/V	18–20
Filler wire diameter/mm	1.6
Electrode	2% thoriated tungsten
No. of passes	2
Shielding gas	Argon, flow rate 35CFH
preheat	None