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Effects of post weld heat treatment on friction welded duplex stainless steel joints

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ABSTRACT

In the present work, the effects of post weld heat treatment (PWHT) on friction welded UNS S31803 duplex stainless steel samples at three different temperatures namely 1080 °C, 1150 °C and 1200 °C followed by water quenching were studied. Microstructural evaluations such as volume fraction of austenite/ferrite, grain size measurements, SEM-EDS, TEM and microhardness aspects were carried out. The volume fraction of ferrite to austenite ratio was balanced at 1080 °C. Ni element is more effective in controlling the dual phase balance. Finer grains were obtained at 1080 °C due to recrystallization effect. Microhardness was affected by reduction of ferrite percentage. Dual phase presence and absence of precipitates were conformed through XRD and TEM which follow Kurdjumov–Sachs relationship. Under the following: heating pressure: 40 heating time: 4 upsetting pressure: 80 upsetting time: 2 (Experiment no. 5) on PWHT at 1080 °C, the balance of dual phase ratio, finer grains and increased microhardness were obtained.

1. Introduction

Duplex stainless steel (DSS) has the unique combination of ferrite (α)/austenite (γ) proportion in the vicinity of 1:1. It gives high strength by ferrite and good toughness by austenite. The ferrite–austenite phase balance will be disturbed during welding, especially in conventional fusion and high energy welding. It is because of high rates of heating, solidification and cooling involved in most weld thermal cycles. They drive excessive ferritization and lower the austenite content, causing a vivid worsening of mechanical properties and corrosion resistance of duplex stainless steel welds. Friction welding, a solid state joining process, presents more rewards than the conventional arc welding like low heat input and short cycle time which make friction weld especially suitable to large quantity claims. Friction welding of duplex stainless steels have wide range of applications like manufacture of propeller shafts, high Strength Pump Shafts, fasteners and for the manufacture of eye bolts in marine and shipbuilding industries, reinforcing bars welding for concrete structures where corrosion of steel is difficult to avoid, primary closure for waste canister in Waste/pollution treatments etc., friction welded duplex stainless steel results in better resistant properties for sulphuric and nitric acid environments, thus making it suitable for valve extension rods, sucker rods, oil pump gears, shafts welding in oil and gas industries. It is found that the chemical elements play a major role in influencing the austenite content [1]. PWHT is recommended after welding of duplex stainless steel [2]. It has been revealed that 15 min of PWHT at 1050 °C effectively raises the percentage of austenite phase and toughness of the DSS weld joints [3]. It is found that after heat treatment, weld reaches the balanced α/γ proportion, that is, chromium and molybdenum get enhanced in ferrite whereas nickel and nitrogen get enriched in austenite [4]. PWHT of DSS is almost followed by water quenching to avoid sigma and chromium nitrides during cooling. All these literature reveal that PWHT plays a vital role in phase balance cum microstructures of welds. In this study, the main objectives planned are: to analyze the effects of friction welding on DSS, to study the influence of three different PWHT temperatures, to establish the thermal effects on DSS by phase balance and to study microstructural characterization. Finally, optimum PWHT temperature to restore the ferrite/austenite phase balance lost during welding was determined.

2. Material and methods

DSS (chemical composition in wt% C:0.02, Co:0.09, N:0.14, Si:0.29, Mn:1.60, P:0.02, S:0.01, Cr:21.65, Mo:2.56, Ni:4.84, Cu: 0.43, Nb:0.003, Ti:0.002, V:0.06 Fe: balance) rod of 16 mm diameter with 100 mm in length was friction welded with a constant

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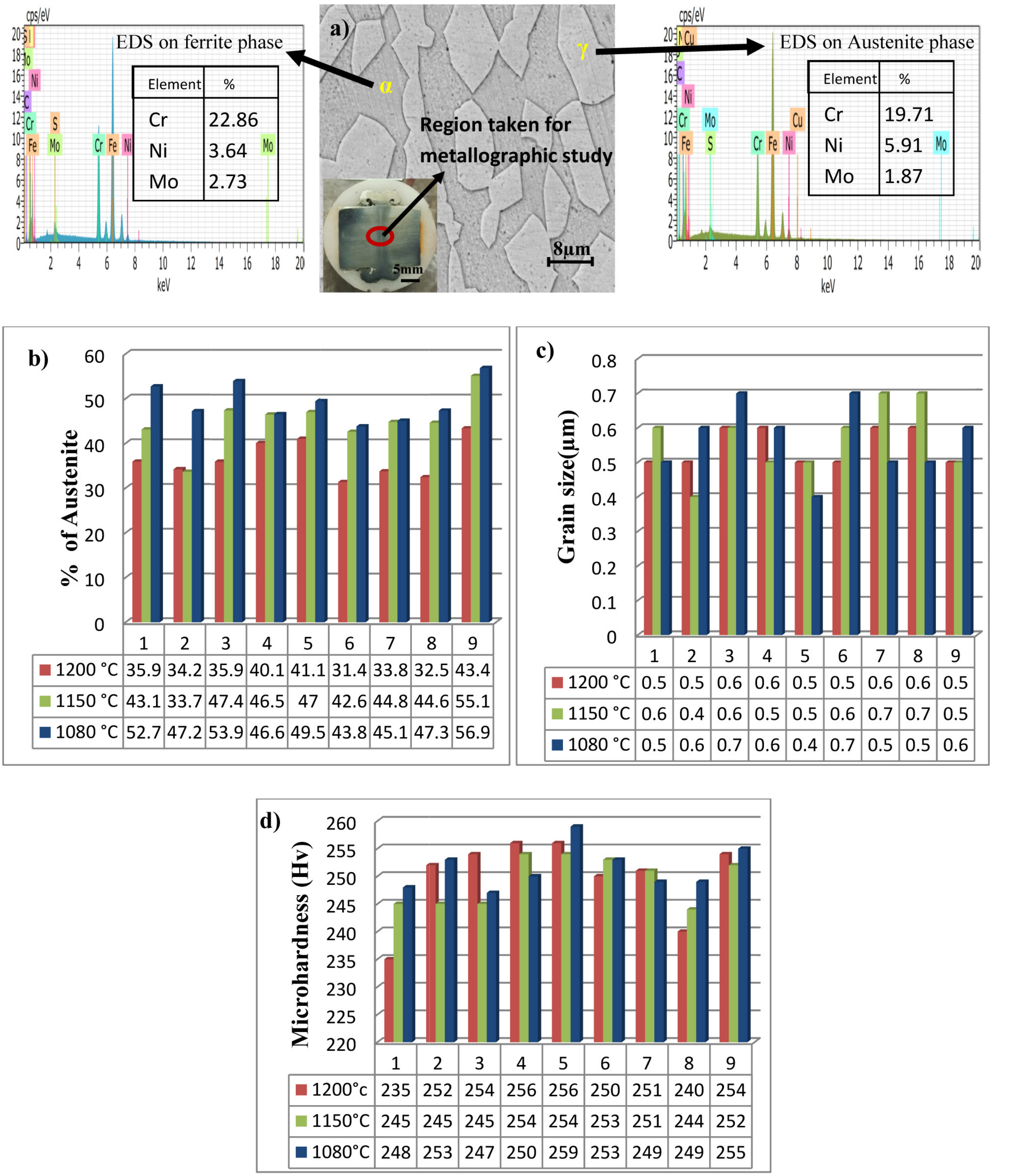

Fig. 1. (a) EDS spectra of PWHT specimen with respect to phases (inner image showing macrostructure of cross section of the weld). Effect of PWHT at various temperatures with respect to (b) % of austenite (c) grain size (d) microhardness.

spindle speed of 1500 rpm and its related parameters are listed in Table 1. Ahead of welding, abrasive cutter machine was used to get specific dimensions of the rod samples. These were then polished through emery papers having grit size in the range of 180–600 μm, and acetone was sprayed on each faying surface for clean-up and removing of oxide scales. Thus the sample rod for friction welding was prepared. Base material contains α/γ balanced percentage of 51.43/48.57. PWHT was performed at three different precipitation free temperatures: 1080 °C, 1150 °C and 1200 °C in a preheated muffle furnace without protecting gas and with aging time of 15 min. This was followed by quenching in water. Metallurgical analysis was done along the direction, which is perpendicular to cross section of the rod and for better understanding it is shown in inner image of Fig. 1(a). i.e., perpendicular to the