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QUENCHING AND HEAT TREATMENT OF WELDED DUPLEX STAINLESS STEEL TO AVIOD INTERGRANULAR CORROSION

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ABSTRACT

Stainless steel has been known for its high performance in manufacturing industries, oil and gas industries for minimum susceptibility to defect such as corrosion. Welding is a relevant joining process with heat application capable of altering the microstructure of corrosion resistance alloy CRA. Intergranular corrosion or weld decay is a welding defect in stainless steel due to sensitization known as the formation of chromium carbide on heat affected zone. Analysis of quenched sample in water , normalized sample after welding and heat treatment sample after welding were studied using SEM, hardness test and energy dispersive spectroscopy. The result obtained from SEM showed that there was more carbide precipitation on welded sample without quenching and heat treatment. EDS suggested that less composition of chromium at heat affected region of quench and heat treated sample.

Keywords: Heat affected zone, sensitization and weld decay.

1. INTRODUCTION

Duplex stainless steel DSS is kind of steel with nearly equal ratio of ferrite and austenite [1,2]. This dual nature of DSS has given it a wide application is pipeline, sea water, well design and generally system that requires high corrosion and wear resistance. Engineering asset exist with stochastic time definition of defect or failure which might arise due to certain operating factor such as temperature, pressure, environmental effect such liquid content carried by material or seismic which can induce defect on stainless steel. Operating limits has been has provided in NACE MR0175 for corrosion resistance alloys CRA operating in CO_2 and H_2S environment because of their to susceptibility to sulfide stress corrosion cracking, hydrogen induced cracking and other localized defect. [3,4]. Welding is applied in manufacturing industries as joining process and also used in repair of existing defect in stainless steel such pipeline, valves etc. Instability in microstructure of duplex stainless within the sensitization temperature has triggered much awareness to users and researchers to quest effort in minimizing detrimental effect of weld decay or intergranular corrosion [3-6] .Weld decay which is a result of chromium depletion from the phase of ferrite and austenite forming chromium carbide at the grain boundary and other intermetallic phase within austenite and ferrite which propagates localized corrosion [7] These work is to analyze the effect of quenching and heat treating of DSS after welding to determine to minimize weld decay and other intermetallic phase precipitation which initiates sites for material degradation and sudden failure.

a) Precipitation of intermetallic phase in stainless steel and effect of electromagnetic field during welding

It can be envisage that there is a possible precipitation of metallic phase in duplex stainless steel during welding process. This metallic phase such as sigma phase and chai phase has been studied and found to exacerbate the corrosion and mechanical properties of stainless steel. Precipitation of sigma solid solution is a eutectic reaction where ferrite transforms to sigma and secondary austenite [6-10]. Previous works has showed that the use of gas metallic arc welding in joining process on 2205 DSS will induce the coarseness and increase in volume fraction of ferrite phase. A work has showed that welding of DSS under external electromagnetic field will reduce the vulnerability of interegranular corrosion at HAZ on stainless steel [5,11-12]. The quality of weld obtained in DSS is dependent on several welding parameters such as voltage, current, travel time; others are the fillers metal, shielding gas, rate of cooling or nucleation of molten metal. . Chromium is responsible for excellent resistance of corrosion in stainless steel , hence good composition control should be adopted to reduce the is depletion. Diffusion is faster in ferrite than austenite phase which give the root cause of sigma precipitation , chromium carbide, chromium nitride just along ferrite –ferrite boundary and ferrite – austenite boundary [13]. The use of nitrogen with a mixture of inert (argon) gases during weld DSS welding will stabilize austenite phase because nitrogen is an austenite former while inert gas will prevent the oxidation of molten metal's [12-15]. HAZ in DSS is predominately characterized with $Cr_{23}C_6$ sigma and chai phase which attributes to decrease in mechanical property and increase in susceptibility to localized corrosion in HAZ. This work is to reaffirm the effect of quenching and post heat treatment on HAZ the minimize weld decay and further jeopardizing weld engineering asset integrity.

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2. METHODOLOGY

a) Material used

Material used in this work is 2205 grade of duplex stainless steel which was procured in form a sheet of 10mm thickness and dimension of 150mm X 80mm. It was further cut into 50mm X 40mm using shear cutting machine. The composition of the material composition used is in Table-1. Four samples were prepared for better comparison.

Table-1. Material composition.

Element Name	Weight Concentration S.1, (%)
Iron	53.7
Chromium	14.1
Manganese	1.5
Nickel	7
Silicon	0.4
Niobium	1
Tungsten	19.2
Molybdenum	0.5
Copper	1.4
Nitrogen	0.9
Titanium	0.2
Carbon	0.2

b) Welding process

The samples were joined using Gas tungsten arc welding in which International molybdenum association standard was adopted. A voltage of 12 was applied with a current of 110A. The filler wire diameter of 2mm. The welding process was carried out using argon as shield gas to prevent oxidation of molten metal. A travel speed during welding was 80mm/min to obtain effective penetration and fusion between base metal and filler metal.

c) Quenching and heat treatment

Three sample where made from welding as sample 1, 2, 3 and 4. Sample 1 not welded, sample 2 welded and cool in air, Sample 3 was immediately quenched in water after welding and sample 4 was normalized and heat treated using gas acetylene with a temperature of 800^{o} C for 10 minutes. Infra-red thermometer used to monitor the temperature of the process.

After each welding process, possible oxide layer was removed by striking one on the welded joint with the aid of a hammer.

d) Sample preparation for characterization

Each sample was properly sectioned with the use of abrasive cutter to prevent microstructural alteration. Suitable section size was obtained and mounted in an epoxy for proper handling subsequently grinding and polishing with the use of 1.5um diamond paste.

e) Elemental evaluation

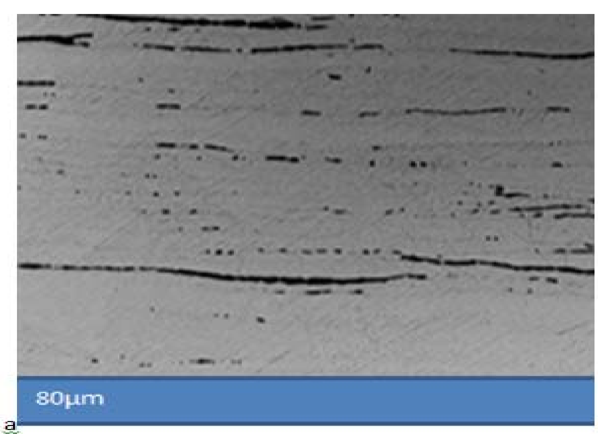
This was done to compare elemental composition at HAZ of the sample using scanning electron microscope SEM and energy dispersive spectroscope EDS.

f) Hardness Test

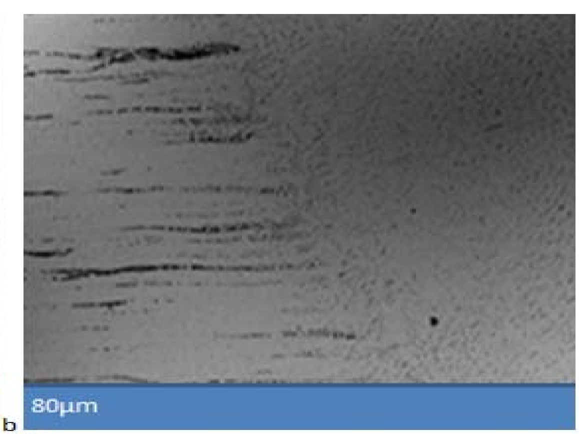
Hardness test was performed on the sample using Rockwell C and adopting NACE MR075 standard with load of 100kg for 10s seconds was applied. An average hardness value was obtained from 7 point of indentation on each sample where three points are on the welded joint and four points on HAZ.

3. RESULT

Duplex stainless steel has existence of ferrite and austenite. SEM is used in identification of microstructural phases. Ferrite is said to be darker than austenite Figure-2 below shows the microstructure of the all the samples



a



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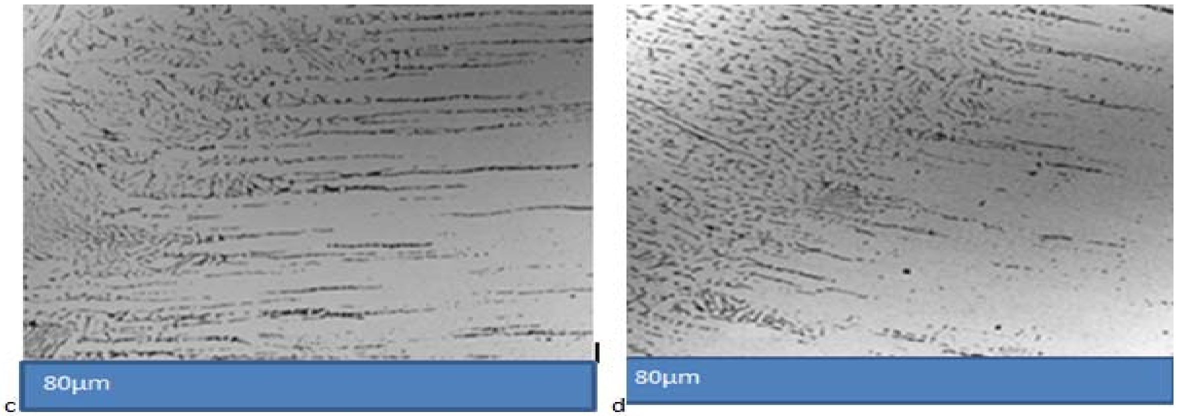

Figure-1. (a) Microstructure of sample not welded (b) microstructure of welded sample (c) microstructure of water quench welded sample (d) microstructure of heat treated sample.

a) Energy dispersive spectroscopy

The EDS result in Figure-3 revealed that there is a differential composition in element of all the samples indicating that different practices after treatment can affect the characterization of heat affected zone.

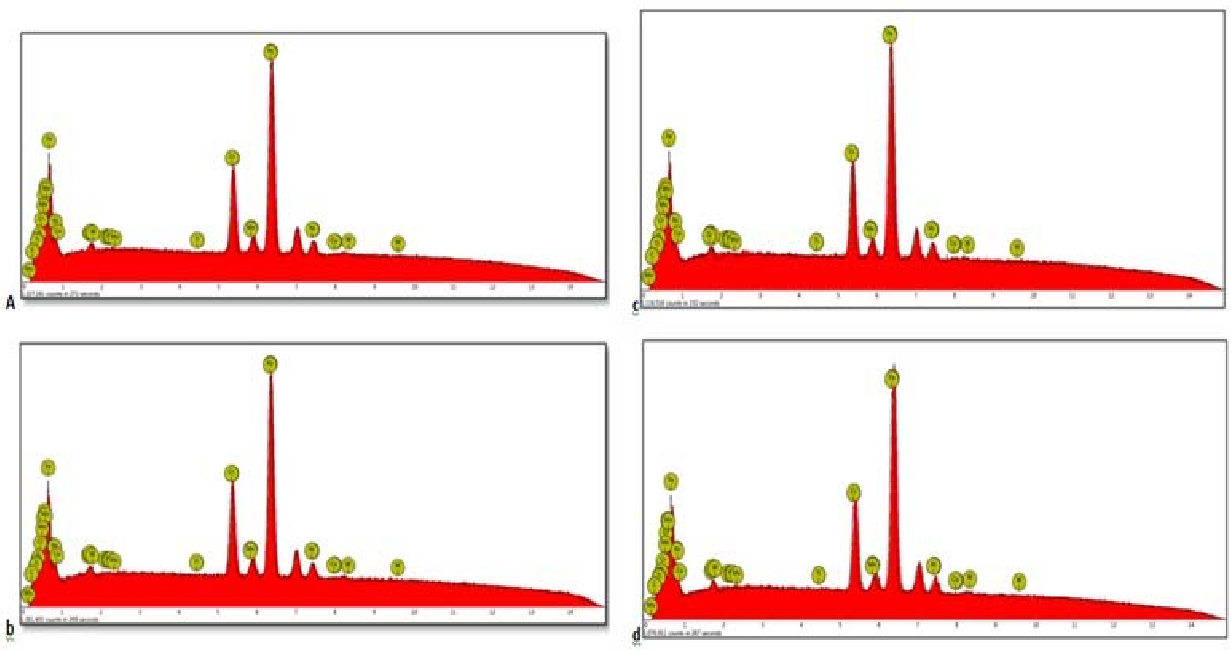

Figure-2. (a) EDS of sample not welded (b) EDS of welded sample (c) EDS of water quench welded sample (d) EDS of heat treated sample.

b) Hardness test result

Hardness was performed to on sample B, C and D compare their mechanical properties. From Table-1 below it will be seen that quenching and reheat treatment of the welded samples are harder than sample A. the hardest region or point was on the welded region followed by HAZ. Figure-3 below showed uneven distribution of mechanical property (hardness)

Table-2. Hardness test result on seven points.

Points	Sample 2 (HRB)	Sample3. (HRB)	Sample 4 (HRB)
1	82.9	88.3	89.3
2	84.6	88.6	91.6
3	86.6	89.5	91.2
4	87.5	92.5	98.4
5	86.1	87.0	92.3
6	86.1	86.4	90.5
7	83.8	85.7	88.8

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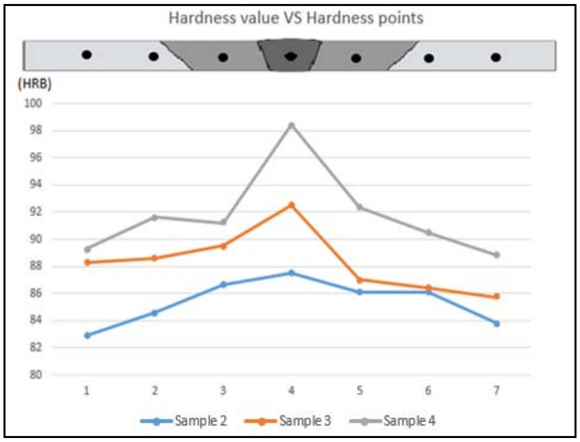

Figure-3. Hardness test on each point.

4. DISSCUSION

From the SEM obtained, it showed that for sample 3 and 4 which is quench and reheat treated sampled respectively, showed a fewer intermetallic precipitation compared with sample 2 which was just welded and normalized. Quenched samples were constrained with time to avoid nucleation forming chromium carbide along ferrite- ferrite and ferrite – austenite grain boundary. SEM result of sample 4 which was heat treated at a temperature between 700-800 ºC had is microstructure with a minimal intermallic phase and chromium carbide precipitation. It can be envisaged that tempering process is responsible for chromium redistribution and long ferrite and austenenite phase.

EDS result also reconfirmed the outcome of SEM result which showed the weight percent of chromium in sample and 3 and 4 where lower. As stated above, chromium is relatively lower in quench and heat treated samples.

From table 1, hardness was more on the welded region than HAZ and heat unaffected zone. Formation of iron nitrides and some other composite on the surface and substrate on welded region is attributed for hardness as nitrogen as an austenite former which was used in welding inadvertently contributed to morphological changes.

5. CONCLUSIONS

Duplex stainless has near to equal ration of ferrite and austenite. Welding of duplex stainless can affect can affect a morphological changes in microstructure and subsequent change in mechanical properties. High temperature agitates for accelerated and rapid compositional change which propagates the precipitation of chromium carbide along HAZ. This work has been able to reaffirm that quenching and tempering process can minimize susceptibility of intergranular corrosion and other localized corrosion within HAZ. SEM and EDS result assisted in characterization which clearly showed morphological changes and unequal elemental composition among the samples.

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