International Journal of Science and Technology Volume 1 No. 11, November, 2012

Weldability Assessment of Dual Phase Medium Carbon Low Allow Steel

Momoh I.M.; *Dongo E.I.; Olusunle S.O.O.; Ogundare O.D.
Engineering Materials Development Institute, Akure, Nigeria
*Department of Metallurgy, Kogi State Polytechnic, Lokoja, Nigeria.

ABSTRACT

The weldability of ultra high strength Dual Phase Steel (DPS) was investigated. DPS was developed by adoption of intercritical treatment technique and then welded using a Submerged Arc Welding (SAW) technique, following a conventional standard of pre heat treatment method. Microhardness and tensile tests were used to evaluate the mechanical properties; also the microstructures were also analyzed at different reaction points. It was observed from the results that, medium carbon low alloy steel, when intercritically heat treated and welded, possess significantly higher mechanical properties as compared to the conventional heat treated steel.

Keywords: *Dual Phase Steel, Fusion Zone, Heat Affected Zone, Submerged Arc Welding, Intercritical treatment, Microhardness.*

1. INTRODUCTION

Plain carbon and medium carbon low alloy steels are utilized for a number of applications particularly for structural use where high strength, toughness, reasonable ductility, and corrosion resistance are some of the crucial engineering properties that are required for excellent service performance [5]. The conventional medium carbon steel microstructures (normalized, pearlitic, tempered martensite, bainitic, martensitic) have been observed not to offer the broad property base highlighted above. The processing-structure-properties-performance paradigm in engineering materials has led to the development of advanced high strength steel (AHSS) such as TRIP steel, Dual Phase (DP) steel etc. This kind of steels has unique mechanical properties and performance and thus, has been in use in the automobile and other engineering based industries. The strength and life span of heavy components and structures like turbine, ship hulls and bridges will be enhanced when such materials are used; it is normally essential to join the individual parts of these components by welding during assembly.

Welding, a form of joining process, have been found useful in the manufacturing and assembly industries. However, the most economically viable welding method has been the Submerge Arc Welding (SAW), which is also known as Manual Metal Arc (MMA) welding, flux shielded arc welding [1] or informally as stick welding. Shielded metal arc welding is one of the world's most popular welding processes, because of the versatility of the process and the simplicity of its equipment and operation.

Several researchers have worked on the post welding heat treatment of both conventional heat treated steel [2, 3, 10] and advanced high strength steel [6]. Only few, however, have investigated on the pre-weld heat treatment of some ferrous material [4]. This work seeks to investigate into the weldability of developed DP steel using SAW technique.

2. MATERIALS AND METHOD

2.1 Dual Phase Development

The chemical composition of the medium carbon low alloy steel used in this work as analyzed using spectrometric analyzer at the Universal Steel Company, Lagos, Nigeria is shown in Table 1. The tensile test samples were machined according to ASTM E38 standard. The machined samples were normalized by austenitizing at a temperature of 860^{o}C, held for 60 minutes and allowed to cool slowly in air. This is essentially to annul the mechanical history of the materials and also promote homogeneity in the samples. A set of the normalized samples were set aside and used as control, while two other sets were used for intercritical treatment to produce dual phase steel by isothermally treating them at two different temperatures of 750^{o}C and 790^{o}C. At each temperature, the samples were held for a period of 30 and 60 minutes before quenching it in warm water (42^{o}C) in order to avoid quench crack. The samples were designated as shown in table 2.

Table 1: Spectrometric Analysis of the Medium Carbon Low Alloy Steel used after Sparking.

Elements	Composition
C	0.3300
Si	0.1740
S	0.0499
P	0.0341
Mn	0.8225
Ni	0.0911
Cr	0.0585
Mo	0.0018
V	0.0029
Cu	0.3031
As	0.0060
Sn	0.0230
Co	0.0094
Al	0.0019
Zn	0.0037
Fe	Bal.

Table 2: Sample Designation

Treatments	Designation
Normalized	C
750°C/30mins	A1
750°C/60mins	A2
790°C/30mins	B1
790°C/60mins	B2

2.2 Welding Procedure

The developed DPS is cut with the aid of hacksaw and a bench vice to a V-shape configuration which will be filled with electrode. The samples were subsequently joined using a SAW method before subjecting them to tensile test, microhardness and microstructural analysis. The schematic setup of a typical SAW is as shown in Figure 1.

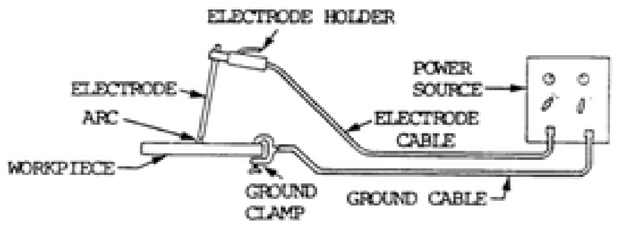

Fig. 1: Diagram for welding setup [11].

2.3 Properties Characterization

Microhardness, tensile and microstructural tests were used to assess the weldability of the developed DP from medium carbon low alloy steel. A uniaxial tensile test was calculated, the samples were pulled to failure in a P2000 electronic tensiometer at 20mm/min strain rate. A Leco LM700 microhardness tester was also used to analyze the hardness property of the samples. Prior to this operation, the samples were subjected to metallography processes to enhance a mirror-like surface before viewing, capturing and analyzing the hardness values.

3. RESULTS AND DISCUSSION

Figure 2 shows the variation of the hardness values of the samples treated at different intercritical temperatures and holding time. After a load of 490.3MN was applied over a period of 10 seconds, a significant increase in the hardness values of the fusion zone (FZ) and that of the heat affected zones (HAZ) was observed especially on samples A2 and B1 in comparison to the control sample C (normalized). The increase in the hardness values of the FZ is as a result of the absence of flux/filler in the electrode that diffuses out to the partially melted zone (PMZ) due to the high welding temperature involved and thus only the welding rod is used to fill the V-shape cavity created in the developed DPS. The resultant effect is also observed at the HAZ where no melting occurs and only phase transformation took place. The welding heat is sufficient for the DPS to re-form austenite that cool and transform to a hard phase (martensite) depending on the temperature gradient thereby accounting for the noticed increased in the hardness values of the welded DPS with sample A2 (treated at 750°C/60min) having the highest hardness value of the FZ to be 243.4HV and the HAZ to be 222.7HV. This is in comparison to the developed DPS observed to have a hardness value of 209.3HV at the FZ and 183.6HV at the HAZ.

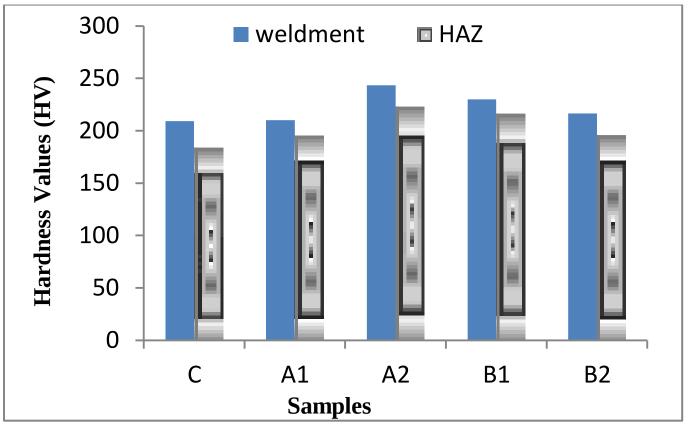

Fig. 2: Microhardness values of welded DP steel

Figure 3 shows the plot of engineering stress versus strain when subjected to a uniaxial tensile test in electronic tensile testing machine at room temperature in accordance with ASTM E8M – 91 standards (1992). Observation shows that the developed dual phase structures exhibited continuous yielding typical of traditional dual phase steel compositions despite the large volume fractions of martensite. The continuous yielding phenomenon could be due to phase straining (plastic deformation) induced in the ferrite matrix, as a result of accommodating the volume expansions associated with the austenite to martensite transformation on quenching from the intercritical phase region [7,5]. Thus when the dual phase (ferrite and martensite) structure is subjected to tensile loading, plastic deformation commences immediately (plastic deformation of the ferrite continues), resulting in the continuous yielding behavior observed in the structures [8]. The increase in tensile and yield strength is in harmony with the observations of Kumar et al [9] which is also observed in the welded samples by the same reasons. The engineering strength of the welded samples was observed to be significantly improved with a maximum UTS value of 643 N/mm^2 (sample B1 treated at 790°C/30mins) while maintaining its strain-to-fracture in comparison with the control sample having UTS value of 559 N/mm^2.

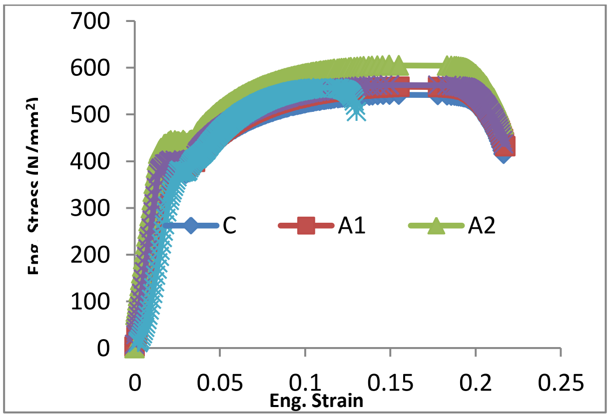

Fig. 3: Variation of engineering stress to strain of a welded DPS

After etching, the photomicrographs of the developed DPS, FZ and HAZ are shown in plates 1 – 4 as captured using Daheng software – driven metallurgical microscope. The micrograph of the control sample is respectively observed to consist essentially of a homogenized ferrite (gray phase) and martensite (dark – formerly austenite). The phase volume fractions of each of the phases in the DPS before welding was determined by using Linear Intracept Technique (LIT) involving the drawing of a line of a known length and measuring the length of the preferred grain that fall along the line and was found to possess 58.81% and 61.95% for 750^{o}C/30 minutes and 750^{o}C/60 minutes treatments respectively; 54.60% and 58.41% for 790^{o}C/30 minutes and 790^{o}C/30 minutes treatments respectively. The phase homogenization and the high volume of martensite present has enhanced the hardness and tensile properties of the developed DPS. The microstructures are, however, refined at the weld fusion zone after welding thereby resulting in a corresponding improvement in the hardness property. The poor weld geometry has been discovered to have adverse effect on the UTS and percentage elongation.

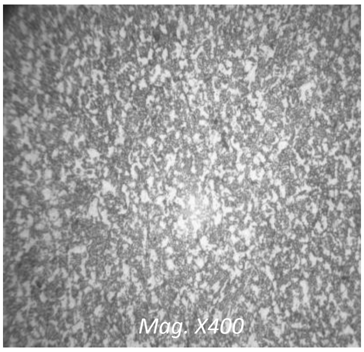

Plate 1(a): 750^{o}C/30mins

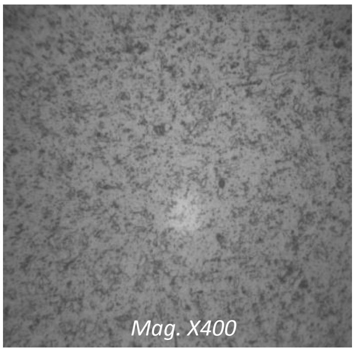

Plate 1(b): 750^{o}C/30mins FZ

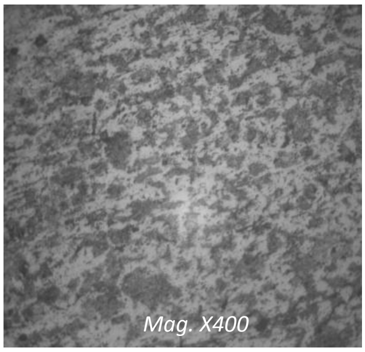

Plate 1(c): 750^{o}C/30mins HAZ

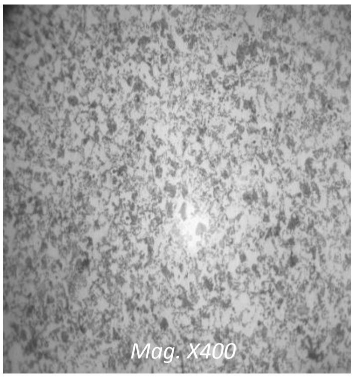

Plate 2(a): 750^{o}C/60mins

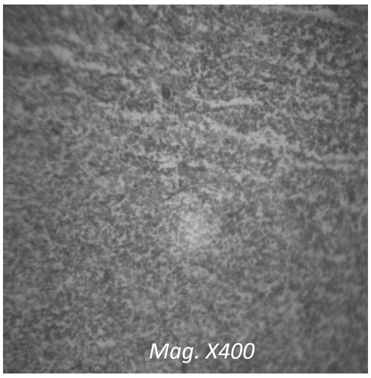

Plate 2(b): 750^{o}C/60mins FZ

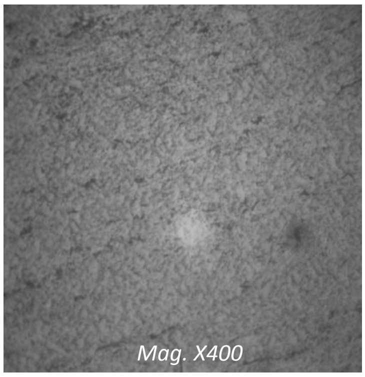

Plate 2(c): 750^{o}C/60mins HAZ

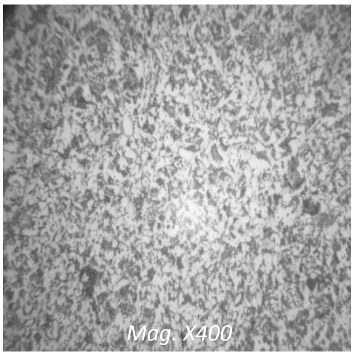

Plate 3(a): 790^{o}C/30mins

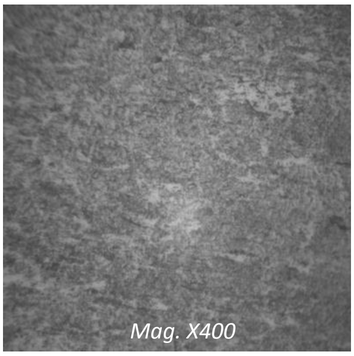

Plate 3(b): 790^{o}C/30mins FZ

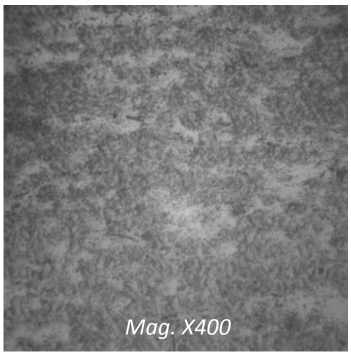

Plate 3(c): 790^{o}C/30mins HAZ

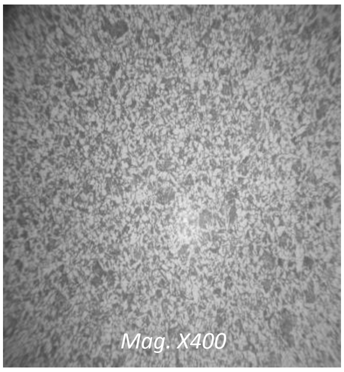

Plate 4(a): 790°C/60mins

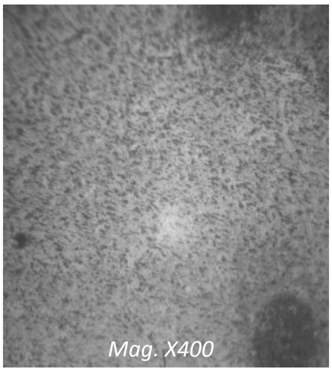

Plate 4(a): 790°C/60mins FZ

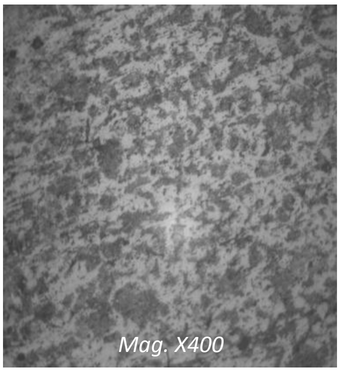

Plate 4(b): 790°C/60mins HAZ

4. CONCLUSION

In this work, the weldability assessment of dual phase steel was investigated by adopting the pre heat treatment method. Microhardness and tensile assessment were used to evaluate the mechanical properties and the micrographs at different reaction points. From the results, it was observed that:

1. A uniquely distinguished dual phase structure was produced from medium carbon low alloy steel by the adoption of intercritical treatment.
2. A significant hardness values was recorded both on the FZ and HAZ as compared to the control sample.
3. The ultimate tensile strength (UTS) was observed to be higher than the control sample while maintaining its ductility.
4. Finer grains were produced after welding thus enhancing the mechanical properties of the developed dual phase steel.

REFERENCES

[1] **Houldcroft P.T. (1973):** "Chapter 3: Flux-Shielded Arc Welding". *Welding Processes*. Cambridge University Press. p. 23.

[2] **Nattaphon T. Weerasak H., Gobboon L. (2011):** Effect of Postweld Heat Treatment on Microstructures and Hardness of TIG Weldment between P22 and P91 Steels with Inconel 625 Filler Metal. Journal of Metals, Materials and Minerals, Vol.21 No.1 pp.93-99.

[3] **da Trindade V.B., Filho, A.S. Guimarães, J. da C. Payão Filho and R. P. da R. Paranhos (2004):** Normalizing Heat Treatment Effect on Low Alloy Steel Weld Metals. J. of the Braz. Soc. of Mech. Sci. & Eng., Vol. XXVI, No. 1 Pp. 62 – 66.

[4] **Pradeshi R., Tewari S.P., Jyoti P. (2008):** A Review on Metallurgy of Welding of Cast Iron and Effect of Preheat. Pp 1 – 6.

[5] **Alaneme K.K.; Kamma C.M. (2010):** Phase transformation studies of a low alloy steel in the (α + γ) phase region. Mat. Res. vol.13 no.1.

[6] **Kenneth H. (2002):** Weld Metal Properties for Extra High Strength Steels. Doctoral Thesis. Division of Welding. The Royal Institute of Technology. Pp. 7 – 36.

[7] **Park .K, Lee .C.S, and Shin .D.H (2005):** Strain Hardenability of Ultra fine Grained low Carbon Steels Processed by ECAP, Rev. Adv. Mater. Sci (10) Pp 133 – 137.

[8] **Salehi A.R, Serajzadeh .S and Tarehi A.K, (2006):** A Study on the Microstructural Changes in Hot Rolling of Dual-Phase Steels. Materials Science. Vol.41, Pp 1917-1925.

[9] **Kumar A., Singh S.B., Ray K.K. (2008):** Influence of bainite/Martensite – content on the tensile properties of low carbon dual phase steels, Materials Science and Engineering A - 474 Pp 270 – 282.

[10] **Adedayo A.V., Ibitoye S.A. and Oluwole O.O. (2011):** Tempering Heat Treatment Effects on Steel Welds. *Journal of Minerals & Materials Characterization & Engineering*, Vol. 10, No.8, pp.755-764.

[11] http://en.wikipedia.org, 07.08.2012, 21:23GMT.

