iJST EXPLORE International Journal of Science and Technology
CENTRE OF PROFESSIONAL RESEARCH PUBLICATIONS
ISSN 2049-7318

International Journal of Science and Technology Volume 2 No. 6, June, 2013

Investigating the Mechanical Properties of Post Weld Heat Treated *0.33%C* Low Alloy Steel

Momoh I.M., Akinribide O.J., Ayanleke J., Olowonubi J., Olorunfemi G.O., Oshodin T.
Department of Research and Development, Engineering Materials Development Institute, Akure, Nigeria.
Department of Manufacturing, Engineering Materials Development Institute, Akure, Nigeria.

ABSTRACT

The mechanical properties of 0.33%C low alloy steel was investigated in the post weld heat treated (PWHT) condition, the as-received ribbed form steel was firstly machined, cut and welded using submerged arc welding (SAW) technique before subjecting it to conventional heat treatments. Microhardness and tensile tests were utilized to characterize the mechanical properties of the PWHT steel. From the results, it was observed that there was a significant improvement in the tensile (UTS and strain-to-fracture) and microhardness properties of the selected medium carbon steel.

Keywords: *Cloud, security, CABLE, Botcloud, legal*

1. INTRODUCTION

Steel is an effective, cheap and commercially available materials for structural applications, a large tonnage of commercial steels in Nigeria contains very little alloying elements with carbon composition at varied percentage and thus are classified as low carbon, medium carbon and high carbon steel[9,11]. Due to its amenability to heat treatment processing and alloying, this segment of steel find its wide application in both structural and domestic applications[10] These processes are widely utilized to achieve high mechanical (high yield strength, high proportional limit, and high fatigue strength) properties for their respective applications. The desirable properties of medium carbon steel can be achieved by adding suitable alloying elements and secondly by various conventional heat treatment[6]. The mechanical strength of medium carbon steels can also be improved by quenching in appropriate medium. However, the major influencing factors in the choice of the quenching medium are the kind of heat treatment, composition of the steel, the sizes and shapes of the parts[5,7]. These properties can further be enhanced by welding.

The term weldability characterizes the suitability of a material to produce sound and reliable welded joints. It comprises the tendency of the material to produce hard and brittle areas in the heat affected zone (HAZ) or fusion zone. It's susceptibility to form defects like hydrogen induced cold cracks (fig. 1), lamellar tearing, solidification cracks, stress relief cracks or others is greatly influenced by the choice of welding technique(s) selected. Steels of poor weldability may require either restrictions in the welding process or special measures to avoid defects on the material.

Applications of carbon steel includes: Ship's hull, structural castings, Railway rolling stock, Automotive castings, Hot metal ladles, Rolling mill equipment, Rolls and rollers, Machines and tools, Mine and quarry equipment, Oil and petroleum equipment. For instance, the most commonly used material for petroleum pipelines is mild steel, this is because of its strength, ductility, weldability formability and it's amenability to heat treatment for varying mechanical properties[1,2,3,4].

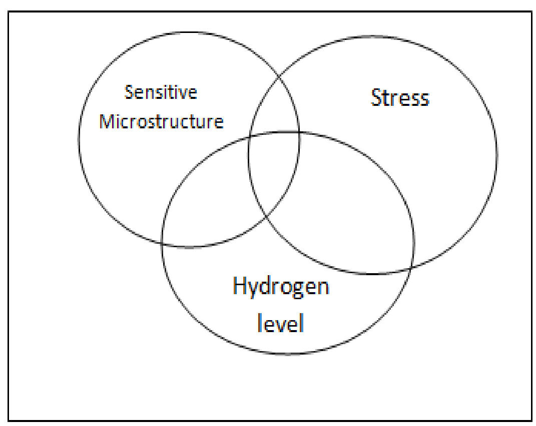

Fig. 1: Criteria for Hydrogen Induced Cracking[8].

2. RESEARCH METHODOLOGY

2.1 Sample Preparation

Table 1 shows the chemical analysis of medium carbon steel containing 0.33% carbon content as carried out at the universal steel (U-Steel) Ltd, Ikeja, Lagos. The specimen, which was received in ribbed form, was firstly machined to a standard tensile test configuration of 5mm and 40mm gauge diameter and length respectively.

Table 1: Chemical analysis of locally sourced medium carbon low alloy steel (Composition in wt %)

Elements	Composition
C	0.3300
Si	0.1740
S	0.0499
P	0.0341
Mn	0.8225
Ni	0.0911
Cr	0.0585
Mo	0.00180
V	0.0029
Cu	0.3031
W	0.0003
As	0.0060
Sn	0.0230
Co	0.0094
Al	0.0019
Ca	0.0002
Zn	0.0037
Fe	Bal.

2.2 Welding Procedure

The machined samples were cut with the aid of hacksaw and a bench vice to a V-shape configuration at the centre of each of the samples and subsequently filled with electrode by adopting the Submerged Arc Welding (SAW) technique. The schematic setup of a typical SAW is as shown in Figure 2.

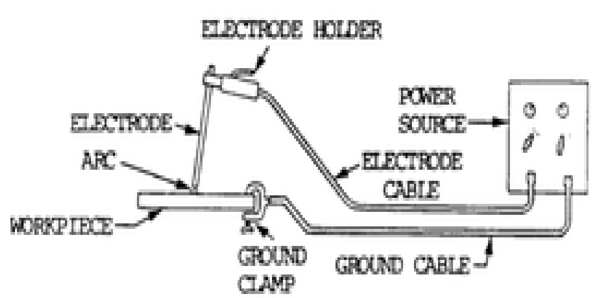

Fig. 2: schematic view of a typical SAW setup[12].

2.3 Heat Treatment

A minimum of two samples were selected per treatment. Some of the conventional heat treatments procedure chosen include: annealing, normalizing, quenching (in automobile engine oil and water) and tempering after water quenching. Two other sample were also set aside to serve as control for the assessment of the heat treated ones.

Annealing

The samples, after machining, were heated to 950ºC – a temperature in the region of 30 – 50ºC above the A_1 line of the Fe – Fe_3C phase diagram. At 950ºC the samples was held for 1 hour to ensure thorough homogeneity, then the furnace was switched-off so that the furnace and samples temperature gradually decrease to room temperature. The specimen was taken out of the furnace after 48 hours of gradual loss of heat when the furnace temperature would have attain the nominal room temperature

Normalizing

Another set of machined samples, after heating at 950ºC – a temperature in the region of 30 – 50ºC above the A_1 line of the Fe – Fe_3C phase diagram, was also soaked at that temperature for 1 hour, then allowed to cool in air at a controlled rate.

Quenching

The selected samples were heated to 950ºC – a temperature in the region of 30 – 50ºC above the A_1 line of the Fe – Fe_3C phase diagram. At 950ºC the samples were held for 1 hour to ensure uniform homogeneity. In order to enhance the hardness, the red hot steel is directly and rapidly cooled. Pair of two samples was cooled in automobile engine oil while another pair of two was cooled in water that is at an elevated temperature – 40ºC. This is to avoid quench crack that could ensue if it were cooled at room temperature or below.

Tempering

After quenching the samples from red hot condition to a temperature above room temperature (as explained above), the samples were subsequently re-heated in the muffle furnace to 250ºC, held for 30 minutes and then air-cooled in order to toughened it and improve on the ductility as compared to the quenched specimens.

2.4 Mechanical Testing

Hardness Measurements

The hardness of the untreated and post-treated welded samples was evaluated using a Vickers Hardness (LECO AT700 Microhardness Tester). Prior to testing, the steel specimens were mounted using phenolic powder, grinded and polished to obtain a smooth surface finish. A direct load of 490.3mN (50.03kg) was thereafter applied on the specimen for a dwell time of 10 seconds and the hardness readings evaluated following standard procedures. Multiple hardness tests were performed on each sample and the average of the best values taken as a measure of the hardness of the specimen.

Tensile Testing

Room temperature uniaxial tension tests were performed on round tensile samples machined from the steel sample with dimensions of 5mm gauge diameter and 40mm length. P2000 *electronic tensiometer* was used to conduct the test following standard test procedures in accordance with the ASTM E8M – 91 standards (1992). The samples were tested at a nominal strain rate of 10^{-3}/s until failure. Multi tests were performed for each test condition to ensure reliability of the data generated. The tensile properties evaluated from the engineering stress-strain curves developed from the tension test are – the ultimate tensile strength (σ_u), the yield strength (σ_y), and the strain to fracture (ε_f).

3. RESULTS AND DISCUSSION

3.1 Microhardness

Figure 3 shows the hardness property of post weld heat treated (PWHT) medium carbon low alloy steel after subjecting it to welding using SAW technique. A load of 490.3mN was applied on the grinded and polished surface of the samples for a period of 10 seconds. The machine, which is automated, evaluated the diamond-like impression on the surface of the sample and subsequently displays the hardness value digitally. From the results, the weld fusion region in most of the PWHT samples were observed to have exhibited higher hardness values with the samples quenched in water exhibiting a highest value of about 303HV. The welded portion of the normalized and annealed samples were observed to be slightly lower than the base and HAZ region respectively, this could be due to the irregularities during the welding operation leading to Hydrogen Induced Cracking – HIC[8] which thus result into slag formation in the weld pool. A general significant improvement in the hardness of the heat affected zone (HAZ) portion of the samples, this as a result of the metallurgical reactions taking place in this region and the relatively increased cooling rate thus resulting in the formation of hard and brittle martensite / bainite phase. The general significant increment at the base of all the PWHT medium carbon steel corresponds to the metallurgy of conventionally heat treated steel. Summarily, the base and HAZ of the quenched (in oil) sample exhibited the highest hardness values of about 411 and 422HV.

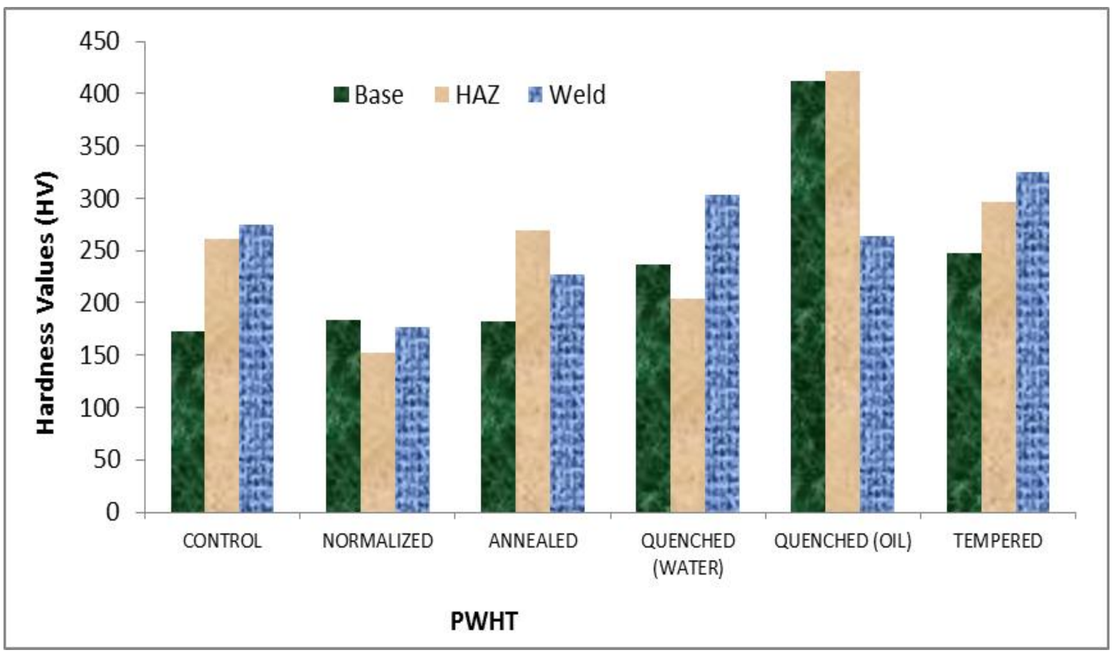

Fig. 3: Hardness property of Post Welded Heat Treated (PWHT) medium carbon low alloy steel

3.2 Tensile Result

Figure 4 show the engineering stress – strain plots for the PWHT structures produced by subjecting the welded samples to normalizing, annealing, quenching (oil and water) and tempering (from water quenching) treatments. For the purpose of comparing stress – strain behaviour, the stress-strain profiles of a control sample (i.e non-treated) structure is superimposed in the graphs. The conventional PWHT structure exhibited as expected – discontinuous yielding (i.e presence of definite yield point). Thus when the structure is subjected to tensile loading, plastic deformation commences immediately (plastic deformation of the ferrite continues) at a point other than the weld point, resulting in the discontinuous yielding behaviour observed in the structures. A significantly increased UTS is observed in all the heat treated samples after welding, with the quenched – in automobile engine oil – samples having the highest value of about 828MPa as indicated in figure 5 when compared to the control sample that have about 335MPa; the annealed sample is observed to possess a percentage elongation of 6.95% thereby indicating the endurance limit of the material when subjected to SAW.

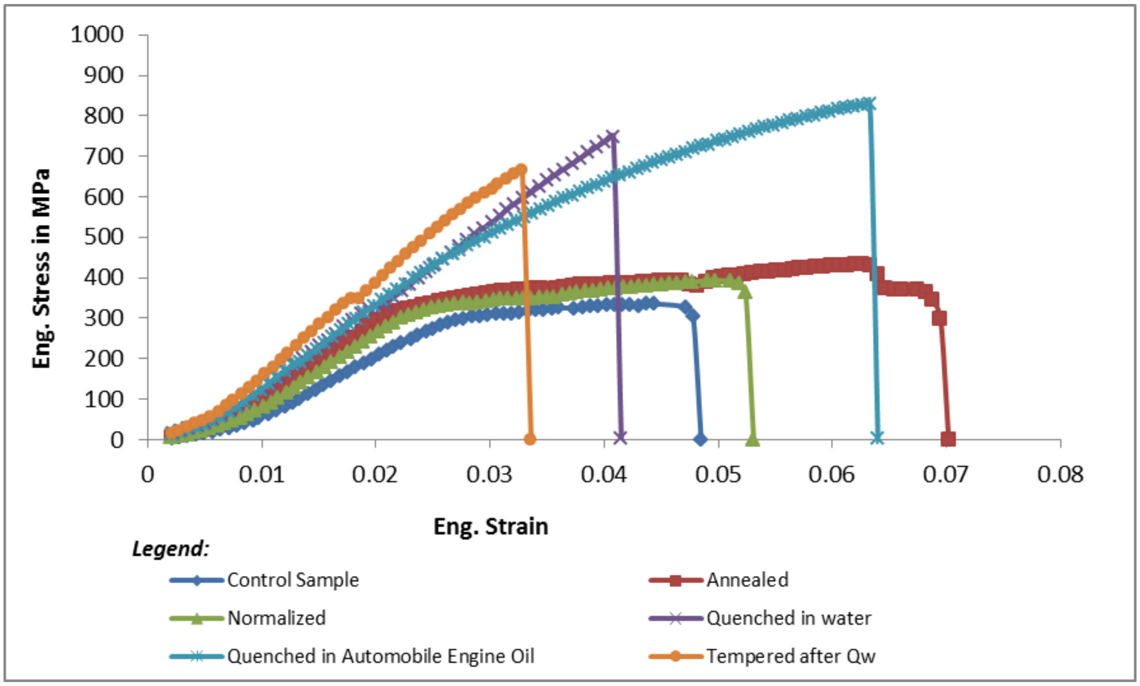

Fig. 4: Plot of Engineering Stress versus Engineering Strain using e-tensiometer

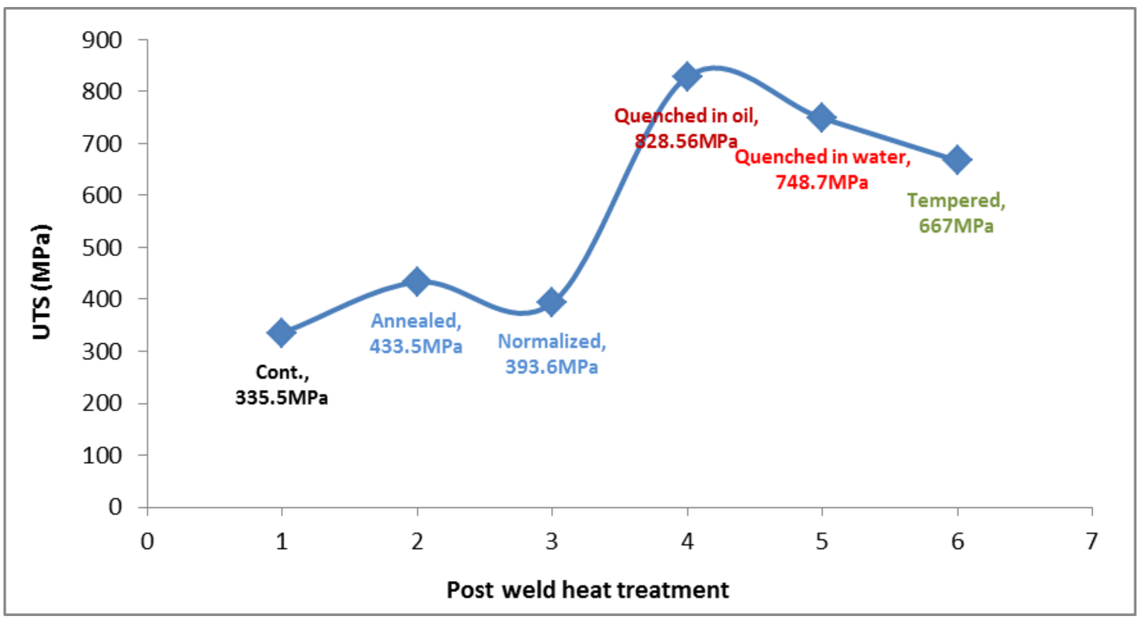

Fig. 5: plot of ultimate tensile strength (UTS) of different PWHT samples

4. CONCLUSION

The mechanical property of PWHT 0.33%C medium carbon low alloy steel was investigated. The as-received steel was firstly machined, cut and welded using SAW technique before subjecting it to conventional heat treatment (i.e Annealing, Normalizing, Quenching (water & oil) and Tempering). Microhardness and tensile test analysis was used to evaluate the mechanical properties. The result indicates a significant improvement in the hardness and tensile properties of the selected steel when subjected to heat treatment after welding following a universally accepted method. Automobile engine oil, if economically viable, is best and thus recommended for such treatment as it exhibited the best combine mechanical properties.

REFERENCES

[1] Abdul Hameed A. (2005), "Evaluation of Quality of Steels Produced Locally" B. Eng. Thesis, Department of Mechanical Engineering, University of Ilorin, Ilorin, Nigeria

[2] Bolton, W. (1994), "Engineering Materials Technology", 2nd Ed, B. H Newness Ltd., Oxford, London, England

[3] Davies, D. J. and Oelmann, L. A. (1983), "The Structure, Properties and Heat Treatment of Metals", First Ed., Pitman Publishing New Zealand Ltd, Wellington, England

[4] Smith, W.F. and Hashemi, J. (2006), "Foundations of Material Science and Engineering", Fourth Edition, McGraw-Hill, New York.

[5] Rassizadehghani, J.; Raygan, Sh.; and Askari, M. (2006). Comparison of the quenching capacities of hot salt and oil baths. Metal Sci. Heat Treat. 48(5-6): 193-8.

[6] Motagi B.S and Ramesh B. (2012): Effect of Heat Treatment on Microstructure and Mechanical Properties of Medium Carbon Steel. International Journal of Engineering Research and Development. Vol. 2, Issue 1, Pp. 07-13.

[7] Jamiu K.O., Tajudeen K.A., Abdullarim B.R. (2012): Evaluation of Mechanical Properties of Medium Carbon Steel Quenched in Water and Oil. AU J.T. 15(4): Pp. 218-224.

[8] Scott R.F. (1998): Key Concepts in Welding Engineering. Welding Innovation Vol. XV, No. 2. Pp. 1-2.

[9] Momoh I.M., Olateju O.O., Oloruntoba D.T. (2012): Investigation on the Corrosion Performance of Nickel Electrodeposited Tempered Steel Substrate. Journal of Science and Technology. Vol. 1, No.8. Pp 400 – 404.

[10] Momoh I.M. (2012): Microstructures, Mechanical Properties and Corrosion Sensitivity of Dual Phase Medium Carbon Low Alloy Steel. M.Eng Thesis. Federal University of Technology, Akure, Nigeria. Pp 1 – 87.

[11] Khanna O.P. (2009): Materials Science and Metallurgy. Dahnpat Rai Publication (P) Ltd, New Delhi, India.

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