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Full Length Research Paper

An Investigation to Improve the Mechanical Properties of A36 Steel Weldment

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Abstract

This research work is aimed at improving the mechanical properties of a mild steel weldment. It was done to understand the problem of poor mechanical properties of the weldment from the thermal effect of the welding process. The problem was addressed by heat treatment, destructive test such as tensile test, hardness test and metallographic examination test. Nine (9) Samples of low carbon steel were examined from a weldment, six (6) sample was subjected to annealing and hardening heat treatment while the other three (3) served as the control sample. The mechanical properties such as tensile strength, hardness and microstructures of the weldment are observed. The results are compared with reference to the heat inputs and heat treatments. The result after the test shows that the annealed sample has high tensile strength, yield strength and ductility; the hardening gives a low yield strength and tensile strength with relatively low ductility, while the control gives moderate tensile strength, yield strength and very low ductility. The hardness result shows that hardening has high hardness, followed by the control and then the annealed. From the microstructure result the annealed has more ferrite than pearlite, big grain size which makes it to be soft and very ductile, the hardening has more pearlite than ferrite, small grain size which make it to have low ductility and high hardness, while the control has moderate pearlite and ferrite, the grain size is moderate, it has reduced ductility and hardness. Hence heat treatment affects the strength, ductility and hardness of the A36 low carbon steel.

Keywords: Steel, welding, hardness, tensile.

INTRODUCTION

Welding is that part of engineering processes that deals with joining of material in industries to fabricate and to repair of damage structures such as pipelines, heat exchangers and pressure vessels. The thermal effect of welding process sometimes produces hard and brittle microstructures which adversely affect the mechanical properties in the heat affected zone (Aloraier 2005). In shielded metal arc welding process, the heat for the welding is generated by an arc established between a flux covered consumable electrode and the work piece. The wire conducts the current to the arc and provides filler metal for the joint. The heat of the arc melts the core wire and flux covering at the electrode tip into the metal droplet. Molten metal in the weld pool solidifies into the weld metal while the lighter molten flux floats on the top surface and solidifies as slag. The weld area is projected by a gaseous shield obtained from the combustion of the flux. Additional shield is also provided by the slag (Robert and Messler 2004).

The shield Metal Arc welding process is an operation involving high temperature, which produces several distortions and high level of residual stress. These extreme phenomena tend to reduce the strength of the 22 structure, which makes it to become vulnerable to fracture, buckling, corrosion and other types of failure. During welding high heating and rapid cooling influence the grain size, microstructure and the mechanical properties of the heat affected zone (HAZ).

Heat treatment which is the heating and cooling of metals to achieve desired physical and mechanical properties through the modification of their crystalline structure can be done which may improve the grain size, microstructure and the mechanical properties of the heat affected zone (HAZ) which is the essence of this project work.

In the shield metal arc welding process of mild steel, the thermal effect of the welding process sometimes produces hard and brittle micro structures which adversely affect the mechanical properties in the heat affected zone. This makes the weldment to fail very early when subjected to service condition. Hence this project work is carried out to solve this problem.

In order to complement previous findings, the investigations have been concentrated as to partly overlapping fields of study:

1. An investigation to improve on the mechanical properties of A36 steel weldment, which requires the examining the microstructures of the heat affected zone (HAZ), weld and parent metal as it relates to it mechanical properties.
2. To establish the relationship between heat input and the mechanical properties of the weldment.


Figure 1; Welded A36 Low Carbon steel Plate

EXPERIMENTAL PROCEDURE

In this research work, the following materials were used: A36 Low carbon steel plate (302mm in length, 100 in width by 10mm thickness) [Figure 1], Carbolite Muffle Furnace (Figure 2), bench vice, lathe machine, sea water, power saw, Tensile Testing Machine (Figure 3), Vicker Hardness machine (figure 4), metallurgical Microscope (figure 5), Mounting Press (figure 6) and wire brush.

The A36 low carbon steel plate was welded with ISO 9606-1 Welding Procedure Specification (see Table 1, table 2, figure 7 and figure 8) using a combination of E6010 for the root pass and E7018 for the filling and capping of the joint.

Nine (9) samples of welded A36 mild steel were obtained for the purpose of this investigation. Three (3) standard test specimens were machined, each for tensile, hardness and microstructure examination. Three (3) specimens each were heat treated by annealing, hardening and the remaining three (3) samples were not subjected to any heat treatment to serve as control. The specimens were placed in an electric furnace and heated to annealing and hardening temperature specified for A36 mild steel.

Three (3) specimens were heated to a temperature 920°C, one each for tensile, hardness and microstructure examination test. At 920°C the specimen were held for 15 minute in the furnace before switching the furnace off. The specimens were taken out of the furnace after 24hrs when the furnace temperature has already reached the room temperature.


Figure 2: Muffle Furnace

Figure 3; Ram-Pac Tensile Testing Machine

Figure 4: Vicker Hardness Machine

Figure 5; Meji Metallurgical Microscope

Figure 6: Mounting Press

Table 1. ISO 9606-1 Welding Procedure Specification

Process	**Shielded Metal Arc Welding**
Material Specification	Mild Steel (A36)
Plate thickness / Sizes	10mm × 100mm × 200mm
Pipe diameter/ thickness and length	N/A
Joint design	Single butt joint
Filer metal specification/ classification	A5.1, E6010 and E7018
Electrode classification	Cellulose and basic
Number of beads	5 runs
Polarity	DCEP
Position	PA (1G)
Direction of weld	Any
Number of welders	One
Time lapse between passes	5 – 7 minutes
Types and removal of line up	N/A
Initial and internal cleaning method	Wire brushing and grinding
Pre-heat and stress relief	N/A
Shielding gas and flow rate	N/A
Technique (stringer or wave)	Weaving
Qualifying specification	ISO 9606-1
Open corner weld	N/A

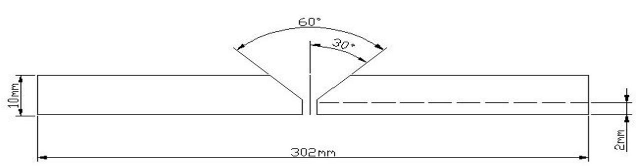

Figure 7: Joint Design for WPS

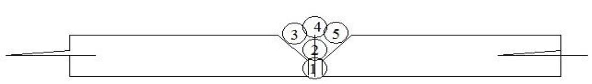

Figure 8: Weld Sequence for WPS

Table 2. Electrode Size and Number of Weld Beads

Bead	Electrode size (mm)	Electrode Type	Voltage (V)	Ampere (A)	Speed of Welding CM/min
1	3.25	E6010	28-32	65-90	12-15
2	2.5	E7018	28-32	90-110	12-15
3	3.25	E7018	28-32	100-130	12-15
4	3.25	E7018	28-32	100-130	12-15
5	3.25	E7018	28-32	100-130	12-15

Figure 9: Mounted and Polished Specimen

Figure 10: Fractured Tensile Specimen

The three (3) specimens were heated to the temperature of 920°C and were allowed to homogenize at that temperature for 10 minute. After 10 minute the specimens was taken out of the furnace and directly quenched in the bath of water.

The Microstructural and Vicker hardness sample was cut from the heat affected zone, fusion zone and the parent metal then were mounted in an epoxy compound and grind with emery papers of 220mn, 320mn, 400mn, 600mn and finally polished with DAC cloth (2200microns) to create a mirror like surface before conducting the test. Furthermore, the heat treated and non-heat treated tensile specimen were subjected to tensile load and the result tabulated.

RESULTS AND DISCUSSION

The results of tensile test for the three different sets of A36 low carbon steel is shown in Table 3. There was a huge increase in the yield stress and ultimate tensile strength of the annealed specimen. The hardened specimen exhibited low degree of elongation and a lower yield strength when compared to the control sample.

Table 3. Tensile Test Result

Specimen	UTS (PSI)	Yield stress (PSI)	% Elongation	% Reduction in area
Annealed	97729.03	74602.31	9.33	70.15
Hardening	72598.71	55418.86	3.4	72.04
Control	83767.74	63944.84	6.8	58.5

The Vicker hardness result (Table 4) for the annealed specimen showed an acceptable values ranging from 168 to 201.6 HBV 10 while the hardened specimen obviously exhibits high hardness values as reported. From the result the average hardness of the control specimen is 253.65HBV 10, hardening specimen is 289.83 HBV 10 and the annealed is 170 HBV 10. The hardening has the higher hardness than that of the control and the annealed because it grain size is small and there was fast cooling rate which result to finer structure. Finer structure imparts higher hardness.

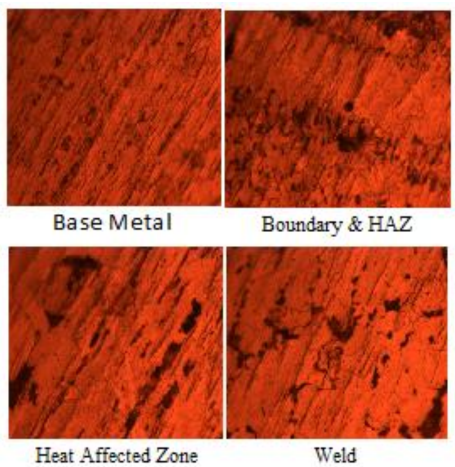

Figure 11. Microstructure of the annealed Sample

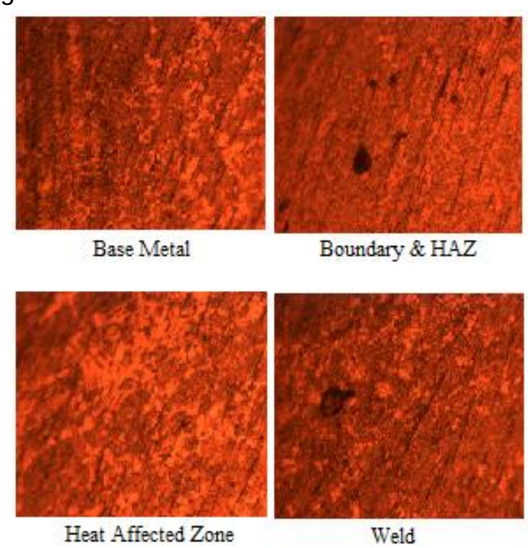

Figure 12: Microstructure of the Hardened Sample

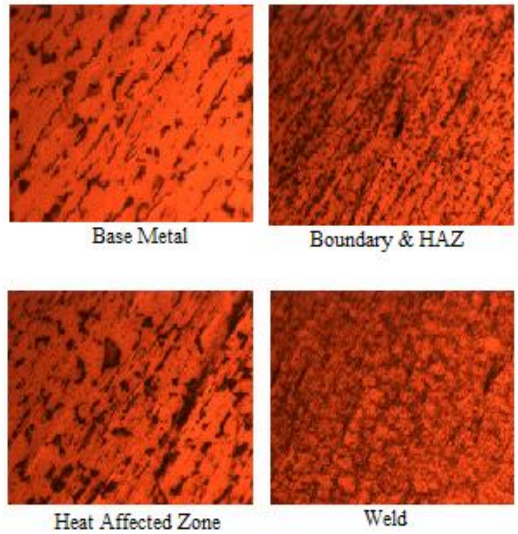

Figure 13: Microstructure of the Control Sample

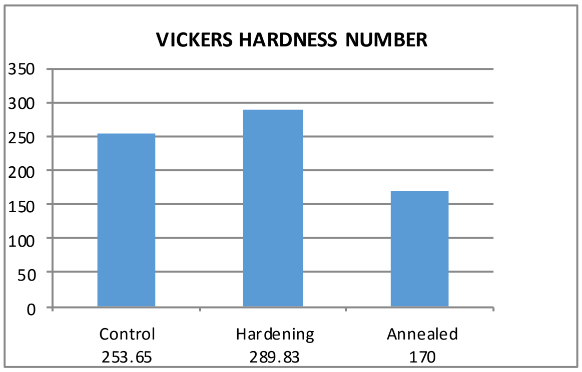

Figure 14. Vicker Hardness Values

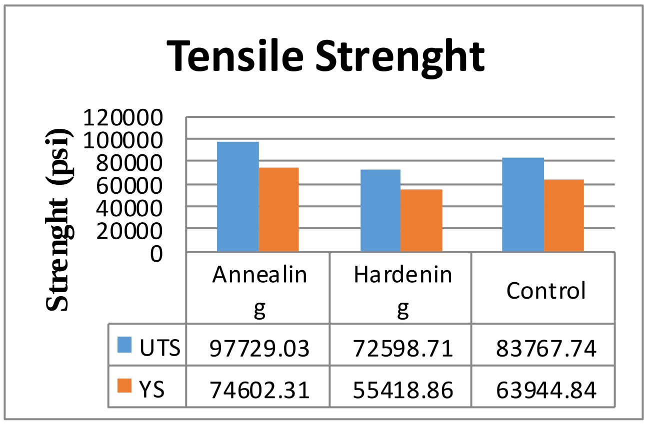

Figure 15. Tensile Strength Chart

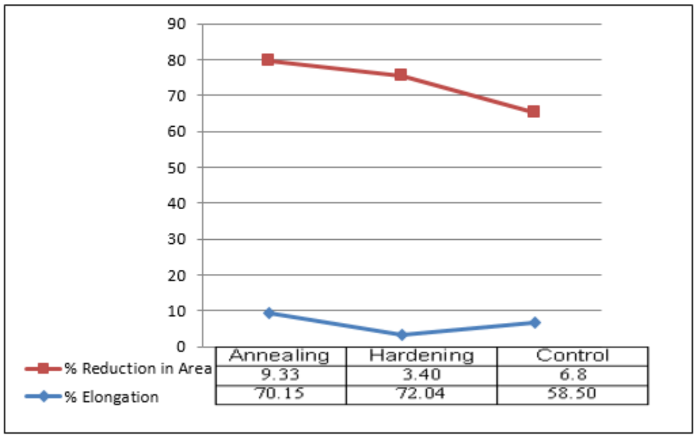

Figure 16. Percentage Elongation Variation

From the microstructural result, the annealed sample shows that the ferrite (white) is more than the pearlite (black). Since the ferrite is more than pearlite because there is enough time for the molecular structure to move which indicate that the grain size is big since there is proper diffusion and slow cooling process and carbon percentage is low. As a result of the big grain size the ductility is more while it hardness is low because of carbon diffusion rate.

From the microstructure of the hardened sample, it shows that the pearlite (black) is more than the ferrite (white). There is no enough time for the molecule to move and the grain size is small since there is insufficient time for the carbon to be redistributed and there is no proper diffusion due to fast cooling rate.

The changes in the microstructure of the specimen give birth to two phases and the carbon is trapped in the FCC crystal lattice. When the iron attempts to undergo its allotropic change to the BCC unit cell structure, the excess carbon interferes, elongating the BCC cells forming instead the unique BCT (tetragonal) structure Martensite.

The structure of the control sample (figure 12), the ferrite and pearlite are moderately combine together; there is moderate time for the molecules to move. The grain size is bigger than the hardening but not as the annealed. It is more ductile than the hardening specimen.

CONCLUSION

The results so far shows that the annealed specimen fracture at the heat affected zone (HAZ). The fracture load was high and the yield strength and the ultimate tensile strength are high compare to the control. The percentage elongation is high which show it is more ductile when compared to the control and the hardening. For the hardened specimen the fracture also occur at the heat affected zone (HAZ). The fracture load is the lowest and the yield strength, and the ultimate tensile strength, percentage elongation is low when compare to the annealed and the control specimen. For the control specimen the fractured also occurred at the heat affected zone. It has moderate fracture load, the yield strength, ultimate tensile strength, percentage elongation is also moderate when compare to the annealed and the hardening. From the result it shows that the annealed is more ductile than the control and the hardening specimen.

It can be concluded that heat treatment has effect on the mechanical properties such as the hardness, ductility, yield strength and the tensile strength of the mild steel weldment. The annealed has the highest value of ultimate tensile strength, yield strength, ductility and lowest hardness value; the control has the moderate value of ultimate tensile strength, yield strength, ductility and hardness value while the hardening specimen has the lowest value of ultimate tensile strength, yield strength, ductility and the highest hardness value.

REFERENCES

Adedayo, A., Ibitoye, S.A. and Oyetoyan O.A. (2010), 'Annealing Heat Treatment Effects on Steel Welds' .Journal of Minerals and Materials Characterization and Engineering,

Aloraler, A. (2005). Optimization Flux Core Arc Welding with Bead Tempering for Repair of Critical Structures without Post Weld Heat Treatment, in Mechanical Engineering Monash University: Melbourne, Australia, pages 21-25

ASM Metals HandBook (1993), "Welding, Brazing, and Soldering". ASM International, Vol.6

C. Adnan (2009). Effect of cooling rate on hardness and microstructure of AISI 1020, AISI 1040 and AISI 1060 steels. International Journal of Physics Sciences, vol. 4(9), 14 – 518

D.A. Fadare, T.G. Fadara, O.Y. Akanbi (2011). Effect of heat treatment on mechanical properties and microstructure of NST 37-2 Steel, Journal of Minerals & Materials Characterization & Engineering, 10(3), 299- 308

F. M. F. Al-Quran and H. I. Al-Itawi (2010). Effects of the heat treatment on corrosion resistance and micro hardness of alloy steel, European Journal of Scientific Research, Vol. 39, No. 2

P.O. Atanda, O.E. Olorunniwo, O.D. Alabi, O.O. Oluwole (2012).Effect of Iso-Thermal Treatment on the Corrosion Behaviour of Low Carbon Steel (Nigerian C2R grade) in a Buffered Solution containing Chloride and Carbonate Ions, International Journal of Materials and Chemistry, 2(2): 65-71

Quar'n F.A., "Effect of heat treatment on the microstructure and hardness of chromium-nickel steel", Contemporary engineering services, vol.2, no.8, 2009, pp 366-359.

Robert, S. and Messier, W. (2004), Welding as a Joining Process in Joining of Materials and Structures, Butter- worth Heinemann: pages 285-290

Ravinder, P. S. et al (2012), Parametric Effect on Mechanical Properties in SAW Process: International Journal of Engineering Science and Technology, vol III, page 3

Tadashi, K., Nobutaka, Y. and Makoto, O. (1995), "Methods for Predicting Maximum Hardness of Heat Affected Zone and Selecting Necessary Preheat Temperature for Steel Welding".

Trindade Filho, V.B., Guimaraes, A.S., J. da C. Payao Filho, R.P. da R. Paranhos (2004), "Normalizing heat treatment effects on low alloy steel weld metals". Journal of Brazilian Society of Mechanical Sciences and Engineering, Vol. 26, No. 1

Xue, Q., Benson, D., Meyers, M., Nesterenko, V. and Olevsky, E. (2003). "Constitutive Response of Welded HSLA 100 Steel". Journal of Materials Science and Engineering, A354: 166-179.