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Effect of FCAW & SAW Welding Process on the Tensile, Impact and All Weld Properties of Multipass Butt Welded Joints of High Carbon Steel

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***Abstract*: -- Flux cored arc welding and submerged arc welding are widely known as high quality, high deposition rate processes, commonly used to join the plates of higher thickness in pressure vessel components. These processes provide a pure and cleaner, high volume weldment that has a relatively high material deposition than other traditional welding methods. In this research work high carbon steel plate SA 516 Gr. 70 was used to evaluate the best welding process for heavy thickness and good impact & tensile properties of HAZ and weld metal. Two test coupons were welded with FCAW and SAW welding separately. After welding the coupons were subjected to radiography testing and destructive testing such as tensile and impact test. There was significant difference found between the results and it was concluded that SAW welding is the best method which enhance the tensile and impact properties of butt weld joints of high carbon steel.**

***Keywords* — FCAW, HAZ, Impact Strength,SAW.**

I. INTRODUCTION

Boiler and pressure vessel plate SA-516 grade 70 have been widely used in boilers and pressure vessels, boats, bridges, wind turbine towers, oil and gas pipelines. Boiler and pressure vessel plate are the most important structural materials for construction because of their high strength and toughness and relatively low cost. Welding is the most reliable, efficient and practical metal joining process which is widely used in industries such as nuclear, aerospace, automobile, transportation, and off-shore[1, 2]. Submerged arc welding (SAW) and flux cored arc welding (FCAW) are the welding process which produce high quality, high deposition rate provided a purer and high volume weldment. Use of this technology has huge economic and social implications in the national perspective. It is observed that a refined microstructure of HAZ imparts largely the intended properties of the welded joints [1, 3] . In submerged arc welding (SAW) and flux cored arc welding (FCAW) welding process, the parameters are current, arc voltage, travel speed and nozzle to plate distance. They affect the microstructure and mechanical properties of the welded joints as well as welding process also affects the mechanical properties of the welded joints they all affect the microstructure and mechanical property of the welded joints. Mechanical properties such as tensile strength, toughness and all weld in arc welded mild steel plates were found to be higher in the submerged arc welding(SAW) reduce to the base metal value under all the welding conditions. Impact of initial metal preheat on mechanical properties diminishes with increased temperature in the heat affected zone. Microstructures of preheated specimens differ from the no preheat specimen, showing traces of precipitation of bainite [4]. Studied that increased in heat input the percentage of graphitic phase was slightly decreased whereas the percentage of ferrite sharply increased and finally the ferrite structures were observed. The proportionate value of transverse value were observed The influence of the submerged arc welding (SAW) process parameter on the transverse tensile, toughness and all weld test of high carbon steel of butt welded joints. The Toughness was found higher at high welding speed compared to that at low welding speed for a given welding current [6]. In multilayer welds partial or complete re-crystallization of weld metal occurs depending upon the heat input, bead dimensions and time interval between successive deposition with the exception of final layer the structure is refined with corresponding improvement in ductility and toughness [7,8]. With a view to achieving the above mentioned aim design of experiment based on to evaluate the best welding process to enhance the tensile and impact value of heavy thickness butt welded joints in carbon steel on as well as reduce the cost, time and obtain the welding data for production weld with study of tensile properties and impact properties of weld metal and heat affected zone in multipass, submerged arc welding (SAW) and flux cored arc welding (FCAW) are the welding process. This paper presents the experimental results of the affect of the welding process on the tensile, impact and

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Vol 3, Issue 2, February 2018

all weld metal properties of the boiler and pressure vessel plates.

II. EXPERIMENTATION

The material of plate used for present work is SA 516 Gr. 70 used for making boiler and pressure vessel plate. The chemical composition and mechanical properties of the plate material is shown in table 1 and table no 2.

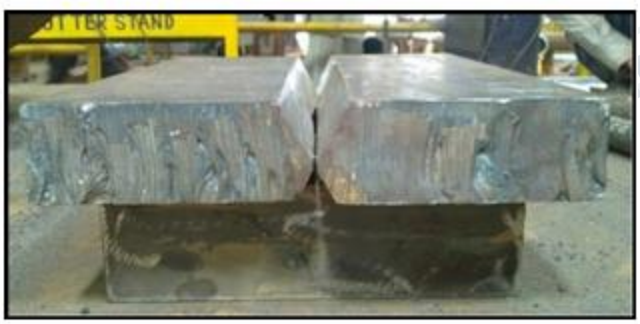
Table 1Chemical Compositions for Base Metal

Material	Chemical Composition by weight				
Carbon Steel	C	Mn.	P	S	Si
	0.30	0.79-1.30	0.035	0.035	0.13-0.45

Table 2 Mechanical Properties for Base Metal

Material	Yield Strength (MPa)	Ultimate tensile Strength (MPa)	Elongation (%)
Carbon Steel	38 [260]	70-90 [485-620]	17

Total four plates of size 500 x 150 x 63 mm were used for two test pieces with double vee groove joint on each test pieces, prepared with the help of shaper machine as shown in figure no-1.



Before the welding start, preheat the both test coupons with heating burner up to 100ºc and measured by thermal chalk to reduce the temperature difference as result to avoid cracks and distortion in butt welded joints and then the first test piece was welded by root run was done by using SMAW using the electrode E-7018-1. Then the subsequent filling of weld metal is done by using automatic submerged arc welding (SAW) machine by using EH-14 saw wire with 4mm dia. and granular saw flux having grade F7A4 is used for welding. The chemical composition and mechanical properties of the SAW wire and saw flux is shown in table 3 and table no 4.

Table 3 Chemical Compositions for solid SAW wire

AWS Class	Chemical Composition by weight				
EH-14	C	Mn	Si	S	P
	0.10-0.20	1.70-2.20	0.10	0.030	0.030

Table 4 Mechanical Properties for solid SAW wire & Flux

AWS Class	Tensile Strength (psi)	Min.Yield Strength (psi)	Elongation (%)	Min. Average Energy Level
EH-14+ F7A4	70000-95000	58000	22	20 ft-lbf

The interpass temperature considered for experimental work is 150° C as per ASME section IX 5.17. After completion of one side of welding the SMAW deposited metal is gouged and removed from the joint and then subsequently filled by SAW welding. Second specimen is made by using multipass FCAW welding using ADOR Champ multi 400 with filler wire E71T-1. During making of this specimen the interpass temperature is again considered 150 °C as per ASME section IX 5.17. the chemical composition and mechanical properties of the filler wire and saw flux is shown in table 3 and table no 4 The second side of the plate is welded and vee groove is filled completely. The duration of welding was noted down for each passes. After welding both test coupon was subject to stress relieving process up to 620ºc to remove the internal stress and fine the grains of weld metal and heat affected zones. After stress reliving both test coupons were tested with radiography to check the internal defect of weldment and there was no defect was found. The specimens for tensile strength are impact machined by using lathe machine and facing machine. Tensile and impact tests coupons were prepared also to evaluate the tensile and toughness properties of the joint made by flux arc welding (FCAW) and submerged arc welding (SAW)welding. Second specimen is made by using multipass FCAW welding using Ador Champ multi 400 with filler wire E71T-1. The chemical composition & mechanical properties of the FCAW wire is given in table 5 & 6 respectively.

Table 5 Chemical Compositions for FCAW Electrode

AWS Class	Chemical Composition by weight				
E-71T-1	C	Mn	Si	S	P
	0.12	1.75	0.90	0.03	0.03

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 3, Issue 2, February 2018

Table 6 Mechanical Properties for FCAW Electrode

AWS Class	Tensile Strength (ksi)	Min. Yield Strength (ksi)	Min. Elongation (%)	Min. Impact Energy
E71T-1	70- 95	58	22	20 ft-lbf at 0°C

During making of this specimen the interpass temperature is again considered 150 °C AS PER ASME SECTION IX 5.17. The second side of the plate is welded and vee groove is filled completely. The specimen for tensile strength is machined by using lathe machine for conducting tensile test. Specimens of impact tests are also prepared to evaluate the toughness properties of the joint made by both flux cored arc welding (FCAW) and submerged arc welding (SAW).

III .METHODLOGY

The experiments carried out in following steps:

A. Preparation of base plate
B. Select the limit of the process parameters
C. Welding the plates using FCAW and SAW.
D. Preparing the specimens for tensile and impact test.
E. Conducting the tensile and impact test on the specimen made from welded plate.
F. Comparing the test results of specimens of FCAW and SAW.
G. Optimum welding process and parameter.

Welding Parameters

The selected process parameters were arc voltage (V), welding current(I), welding speed (S), and nozzle to plate distance (NTPD).Welding was started as per the selection of welding parameters depending on the diameter of the wire and the maximum and minimum range was selected upon by inspecting the bead for smooth appearance without any visible defects and heat input tolerate by root pass. The upper limit and lower limit of the current, voltage and nozzle to plate distance with their units and notations are given in table 7 & 8 respectively.

Table 7 welding process parameter for FCAW

Parameter	Units	Lower limits	Higher limits
Welding Current	Amp	170	250
Arc Voltage	Volts	20	27
Nozzle to plate distance	mm	15	20

The sequence of test procedure, welding sequence and welded test piece are shown in figure no-2, welding sequence is most important in the case of multipass welding to control the distortion.

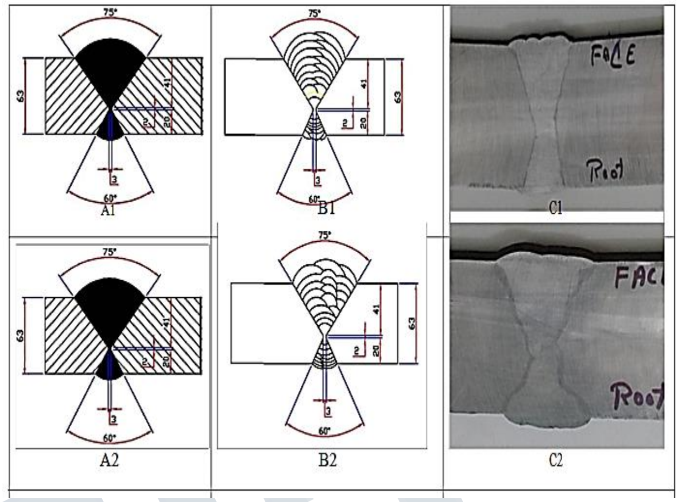


Fig. 2. Different groove designs shown schematically (all dimensions in mm).; (A1) Double V butt joint for flux cored arc welding process (B1) Welding sequence for Flux cored arc welding (C1) Cross sectional view of butt welded joint of flux cored arc welding(FCAW) (A2) Double V butt joint for submerged arc welding process(SAW) (B2) Welding sequence for submerged arc welding process (C1) Cross sectional view of butt welded joint of submerged arc welding process(SAW)

Table 8 Welding process parameter for SAW

Parameter	Units	Lower limits	Higher limits
Welding Current	Amp	590	610
Arc Voltage	Volts	31	35
Nozzle to plate distance	mm	20	25

IV. RESULTS AND DISCUSSION

A. Macrostructure

Macro test or macro examination is performed on the cross section, an independent test to evaluate subsurface conditions or as a subsequent step of another test to reveal the effects on the subsurface. Generally macro test. Several semi-finished and samples of finished products are subjected to macro test to reveal internal discontinuities such as impurities, inclusions in rolled products or grain flow in forgings after exposure to appropriate preparation and exposure to chemicals or heat. Macro test is also performed on the test specimens as shown is figure figure-2-C1 and C2

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Vol 3, Issue 2, February 2018

respectively. The most common test is weld cross section examination to reveal internal discontinuities, weld profile, weld passes and sequence, extent of penetration and the quality of weld. It has been observed from the macro test that the penetration of the submerged arc welding (SAW) test coupon was observed wide and as compare to flux cored arc welding (FCAW) test coupon on other hand the penetration of flux cored arc welding (FCAW) test coupon appears narrow different zones of the heat affected zone are encountered as shown in Fig.2-C1and C2, which indicates that the patterns in which the welding heat dissipates from the joints, largely following the conductive mode of heat transfer through the HAZ, lead to micro- structural changes in the HAZ. It is observed that adjacent to the fusion boundary lies the course grained heat affected zone, also called under bead zone, which undergoes austenitic transformation range of high temperature thus promoting the grain growth or recrystallization in this region. A similar observation is reported Another important region of the heat affected zone as found in these weldment is the region that possesses minimum microhardness, and this zone has been named as sub-critical heat affected zone (SCHAZ) .

B. Mechanical properties

I. Tensile properties

Transverse tensile testing was carried out on all the joints to evaluate for properties such as yield strength, ultimate strength, percentage elongation, percentage reduction in area and joint efficiency, and the results of the same are presented in figure-3 along with the comparison study of both welding joints welded with flux cored arc welding(FCAW)and submerged arc welding(SAW) process Total two test coupon was tested having one test piece of each process .During transverse tensile testing fracture took place in the base metal region indicating that the strength of the welded joint is more than the base metal. It is observed from figure-3 that the tensile strength of submerged arc welded sample has highest when compared to flux cored arc welding sample. The increases in tensile strength is due to high temperature of welding and good dilution and after heat treatment there is no internal stress are remaining in the material, so molecule cohesion increases, refine structure of the material and it increases the tensile strength of the material. This stresses are relieved leading to enhance the tensile strength of material.

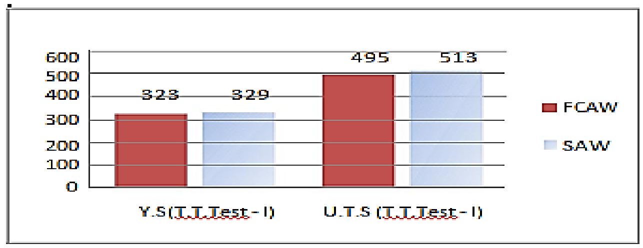

Figure 3Transverse tensile butt weld tests results

II. Toughness

Charpy impact testing was conducted -40ºc temperature total thirty test sample was taken fifteen form each test pieces these sample were taken from different location from Weld metal ,heated affected zone and base metal the teat was performed on toughness testing machine of the specimens prepared with V-notch locations in the main weld pass as well as the root pass of each joint and the comparison results obtained are shown in figure 4 and 5 respectively Toughness of the carbon steel was checked and increased after the PWHT- Post Weld Heat Treatment.The impact strength has been improved by the heat treatment the residual stress is decreased, the impact value of the welded joint is depends on the heat input given during the welding if the heat input increase the impact value decrease .heat input is depends upon the current, voltage and speed of welding the grain structure also refined after post weld heat treatment.

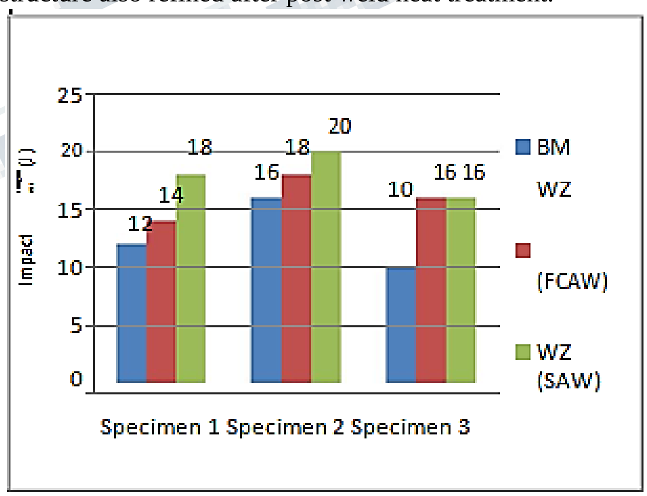

Figure 4 Charpy Impact test results of weld Zone

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 2, February 2018

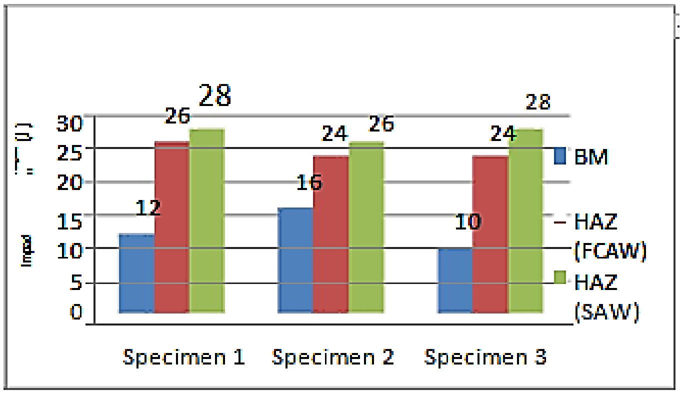

Figure 5 Charpy Impact test results of Heat affected Zone

It has been observed from graph, that the Impact value of SAW is more as compare to FCAW welding in case of HAZ-Heat affected zone, WZ-Weld zone respectively as shown in figure4 and figure 5

III. All Weld Metal tensile test

The purpose of such testing is to test welding filler metal mechanical properties for their suitability for the job concerned and the quality of deposited metal in welded joint. In the case of SAW to check the mechanical property of weld metal with combination of saw wire and saw flux .Total two test coupon was tested having one test piece of each process. This sample was taken from the pure weld metal to check the ultimate tensile strength (UTM), yield strength, percentage elongation, and percentage reduction in area of weld metal only and was performed on universal tensile testing machine. The comparison study of the both test sample is give in the figure no -6 and figure no-7 respectively.

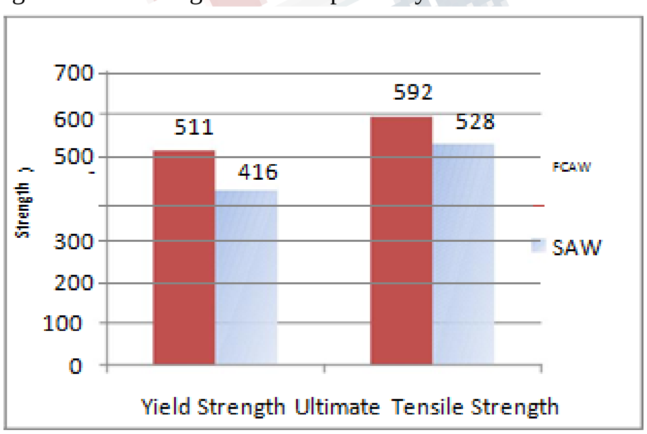

Figure no 6 All Weld Metal test results

It is observed from graph, that the yield strength and ultimate tensile strength of flux cored arc welding found more as submerged arc welding as result flux cored weldment show more ultimate strength as compare to submerged arc welding process.

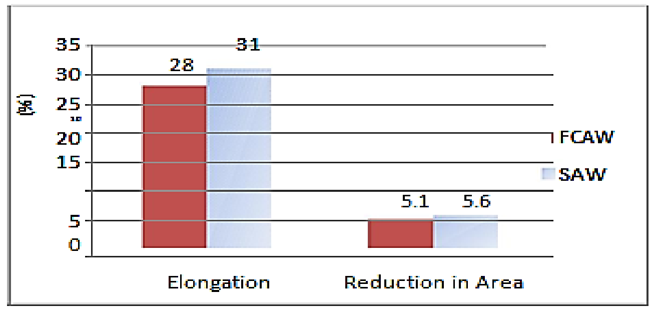

Figure no 7 All Weld Metal test results (Ductility)

It is observed from graph, that the percentage elongation and reduction in area found more in submerged arc welding as compare to flux cored arc welding as result saw welding shows more ductility in weld metal.

V .CONCLUSION

The following conclusions have been drawn based upon the findings of the present work:

(1) Relatively study of macrostructure of flux cored are welding and submerged arc welding, SAW welded joint show deep penetration into the base metal

(2) It is observed from the transverse tensile test that the tensile strength of submerged arc welded sample has highest as compared to flux cored arc welding sample as result the joint is more efficient as compare to flux cored arc welding

(3) In the case of multipass welding the charpy impact value observed more in the case of submerged arc welding as compare to flux cored arc welding

(4) Corresponding to different welding process, submerged arc welding joints show, highest overall Charpy impact toughness (including weld zone heat affected zone)

(5) It is observed from the study of all weld metal, that the percentage elongation and reduction in area found more in submerged arc welding as compare to flux cored arc welding as result saw welding shows more ductility in weld

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International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 2, February 2018

metal as significantly more efficient welded joint formed by submerged arc welding.

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