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MECHANICAL AND METALLURGICAL CHARACTERIZATION OF TIG WELDED HIGH TEMPERATURE MATERIALS

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ABSTRACT

Tungsten Inert Gas (TIG) welding is a commonly used welding technique due to its versatility and ease that can be maintained in almost all type of working conditions. Stainless Steel possessing high strength and toughness is usually known to offer major challenges during its welding. The current study presents some fundamental observations on the effect of TIG welding process on the mechanical and metallurgical properties such as hardness, microstructure and tensile strength of the high temperature material Stainless steel 310. The TIG welding is selected in this investigation due to its wide range of applications over the high temperature materials. The welding was done on specimens with different process parameters like welding current, shielding gas. The mechanical properties like tensile, Vickers hardness test have been carried out for the weld samples. Microstructure studies have been carried out for Base Metal (BM), Heat Affected Zone (HAZ) and Weld Zone (WZ). From these test results, the welding properties were compared and the optimal parametric point was found.

Keywords:TIG welding, Stainless Steel, Welding Current, Weld Zone

INTRODUCTION

Several situations arise in industrial practice which calls for joining of materials. Welding is a joining process producing coalescence of materials by heating them to the welding temperature with or without the application of pressure or by the application of pressure alone, and with or without the use of filler metal[1]. The interfaces of the two parts to be joined are brought to a temperature above the melting point of them and allowed to solidify so that a permanent joining takes place. Compared with other welding methods, TIG welding technology is the main welding method adopted for stainless steels because of its advantages of utility and economy[2]. In TIG welding wherein coalescence is produced by heating the job with an electric arc struck between a tungsten electrode and the job with shielding gas (argon or helium) used to avoid contamination of the molten pool[3]. Several studies reportedthe effect of TIG welding process parameters on mechanical and metallurgical properties of stainless steels. However there is no information available in the open literature on prediction of optimum welding process parameters to attain maximum mechanical properties in stainless steel joints. Hence, in this investigation an attempt was made to find out the optimal parameter in which good mechanical and metallurgical properties will obtained.

EXPERIMENTAL WORK

In order to achieve the desired aim, the present investigation was planned in the following sequence:

Selection of welding method

Selection of material

Fabrication of weld joints

Evaluating the mechanical and metallurgical properties

Selection of Welding Method

The selection of weld process methods for joining stainless steel plates for various applications are attempted by several researchers to standardize the welding procedures and characterization. Tungsten Inert Gas (TIG) welding is one of the main processes used for joining of the stainless steel plates. The choice of TIG welding is due to its strengths like imparting good mechanical properties, ease of access and cost effectiveness[4]. Also TIG welding method was selected due to its wide range of applications in aerospace, automobile and nuclear reactor fields.TIG welds are highly resistant to corrosion and cracking over long time periods, and it is the welding procedure of choice for critical welding operations like sealing spent nuclear fuel canisters[5]. It affords greater control over the weld area than other welding processes, can produce high-quality welds.The machine selected for this work is 30IS TIG 200Amos, whose specifications are:

Maximum Current: 200A

Gas: Argon

Maximum Gas Flow Rate: 50 l/min

The TIG welding machine is shown in Figure 2.1.

Figure 2.1: TIG Welding Machine

Selection of Material

Austenitic is the most widely used type of stainless steel. It has a nickel content of at least of 7%, which makes the steel structure fully austenitic and gives it ductility, a largescale of service temperature, non-magnetic properties and good weld ability. The austenitic stainless steels, because of their high chromium and nickel content, are the most corrosion resistant of the stainless group providing fine mechanical properties[3].

The high temperature material selected for this proposed work is Stainless Steel 310. This material is widely used in high temperature applications because of their high melting point and high corrosion resistant even at high temperatures. SS 310 is austenitic steel extensively used in heavy gauge component and nuclear vessel components. The austenitic structure also gives these grades excellent toughness, even down to cryogenic temperatures [2]. The dimensions of the steel plates are 150mm x 75mm x 6mm.The chemical composition and mechanical properties of the base materials are shown following Table 2.1 and Table 2.2.

Table 2.1: Chemical Composition of Base Material (% by wt.)

C	***Cr***	***Ni***	***Si***	***S***	***Mn***	***P***	***Fe***
0.138	25.78	19.17	0.79	0.021	1.62	0.033	52.448

Table 2.2: Mechanical Properties of Base Material

Hardness(HV)	***Tensile Strength (N/mm^2)***	***Yield Strength(N/mm^2)***	***Elongation %***	***Melting Point ^oC***
236	512.2	410.7	38	1370

Fabrication of Weld Joints

Tungsten Inert Gas (TIG) welding process parameters used forthe fabrication of stainless steel plates were shown in Table 2.3.

Table 2.3: Process Parameters for Welding

Sr.No.	***Current (A)***	***Gas***	***Gas flow rate(1/min.)***
1	140		
2	160	Argon	10
3	180		

Before the welding process, the prepared samples are cleaned properly with suitable chemicals, polished carefully and properly aligned. No filler material was used during fabrication of weld joints. Square butt joint configuration was used to fabricate the joints. The final welded plate dimensions are 150mm x 150mm x 6mm. The fabricated weld plates are shown in Figure 2.2.

Figure 2.2: Fabricated Weld Samples

Evaluating the Mechanical and Metallurgical Properties

The weld samples were subjected to the mechanical properties characterization such as tensile and hardness test and microstructural analysis for Base Metal (BM), Heat Affected Zone (HAZ) and Weld Zone (WZ).

Tensile Test

The basic test for determination of material behaviour is the tensile test. When determining the strength of a welded joint, standardized flat specimens are used. The most important characteristic values which are determined by this test are yield stress, tensile strength, and elongation. The smooth un-notched tensile specimens were prepared to evaluate the tensile strength. The fabricated joints were machined to the required dimension, according to the ASTM E8 standard[6] for sheet type material with 50 mm gauge length and 12.5 mm gauge width, using

EDM wire cut machine. The test was carried out in electro-mechanical controlled Universal Testing Machine TUE-CN 400. Figure 2.3 shows the tensile test specimens.

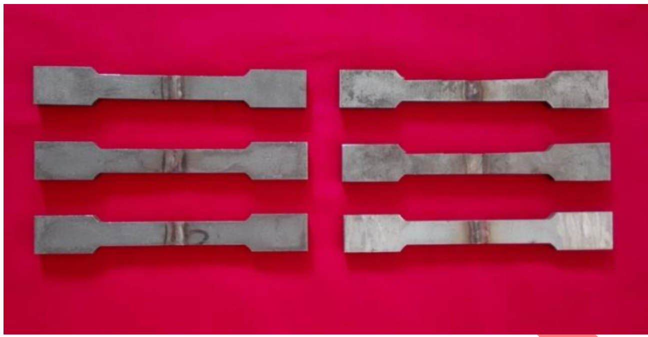


Figure 2.3: Tensile Test Specimens

Hardness Test

Another typical characteristic of material behaviour is the hardness of the work-piece. The hardness was measured at HAZ and mid-thickness regionof the welded joint. The hardness values were measured at various places and the average was taken. The hardness test was carried out using Vickers Hardness Testing Machine which is shown in Figure 2.4.

Figure 2.4: Vickers Hardness Testing Machine

Microstructure

The microstructure images reveal information about the sample including external morphology, chemical composition and orientation of grains. The specimens were cleaned, polished and etched before taking microstructure images. The emery sheets of various grades were used to polish the specimens and nitric acid was used to etch the specimen. The images were taken with magnification of 200x at BM, HAZ, interface region and WZ [6]. The optical microscope is used to take microstructure images.

RESULTS AND DISCUSSIONS

Tensile Test Results

The tensile test results were observed and it shows that the tensile strength of welded regions is lesser than that of base metal with maximum efficiency of 77.2% at 160A and minimum efficiency of 64.7% at 140A. Also, the tensile strength increases upto a point and then started to decrease. Table 3.1 shows the tensile test results and Figure 3.1 shows the tensile test specimens after test.

Table 3.1: Tensile test results for welded specimens

Sr.No.	*Current (A)*	*Yield Strength (N/mm^2)*	*Ultimate Strength(N/mm^2)*	*Elongation %*	*Efficiency %*
1	140	281.4	331.4	1.3	64.7
2	160	333.9	395.4	2.7	77.2
3	180	318.4	360.8	2.6	70.4

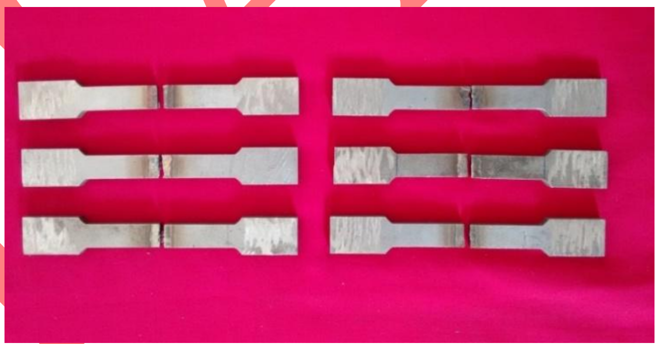


Figure 3.1: Tensile Test Specimens after Test

The Figure 3.2 shows the comparison of tensile test results between base metal and fabricated joints with different welding currents.

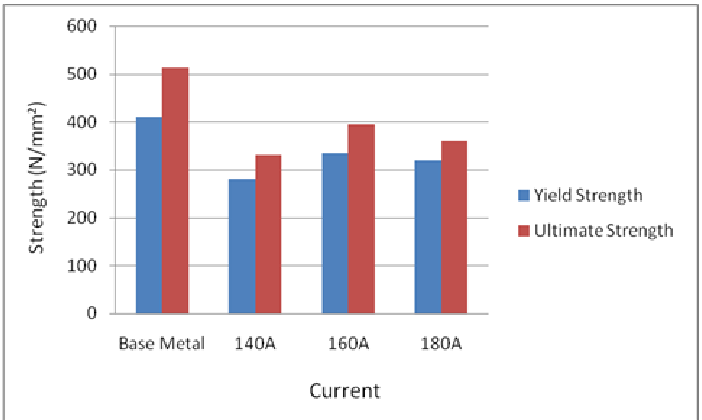


Figure 3.2: Tensile Test Result

Hardness Test Results

The hardness test results were observed in base metal, HAZ and WZ. It shows that the hardness value of weld region is higher than that of base material with maximum hardness of272HV at 160A and minimum hardness of 257HV at 140A in WZ. The hardness value increases from 140A to160A and decreases at 180A. The Vickers hardness results are shown in Table 3.2 and Figure 3.3.

Table 3.2: Vickers Hardness Values (HV) of Welded Specimens

Sr.No.	***Current (A)***	***Base Metal***	***HAZ***	***Weld Zone***
1	140	235	244	257
2	160	238	256	272
3	180	236	248	263

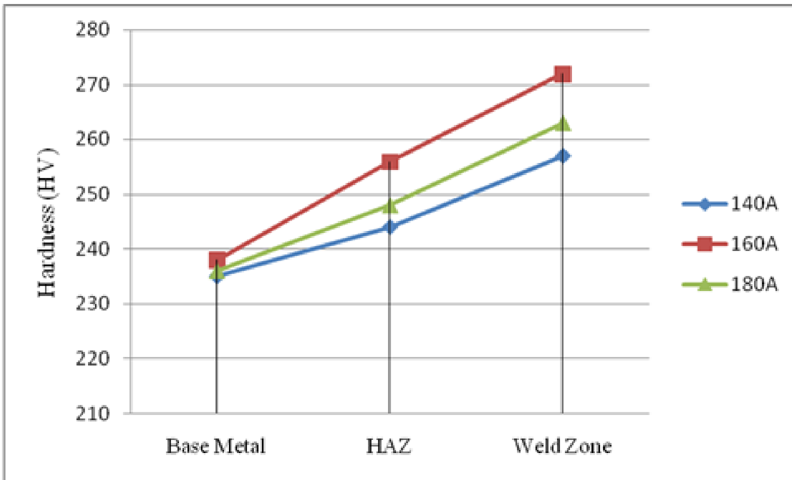


Figure 3.3: Hardness Test Result

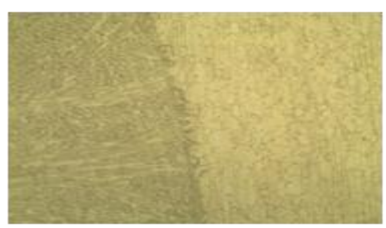
Microstructure

The microstructure images shows the finer grains in the weld region were achieved at the current of 160 A. Heat transfer experienced by the weldment during welding can alter the microstructure and thus the property of the weldment [7]. At 180A, grain growth was observed due to high heat input. The microstructure images taken at different process parameters are shown in Figure 3.4, Figure 3.5 and Figure 3.6

Base Metal

HAZ

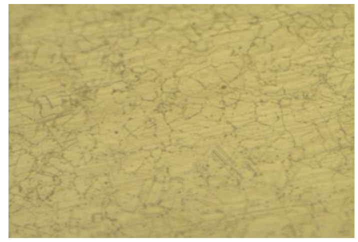
Weld Zone



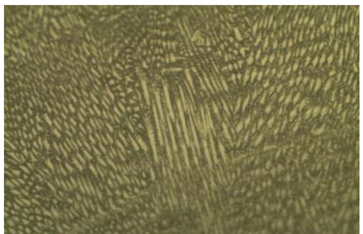
Interface Region

Figure 3.4: Microstructure images of specimens welded at 140A

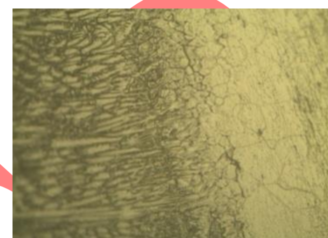
Base Metal



HAZ

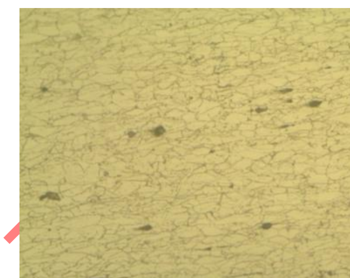


Weld Zone



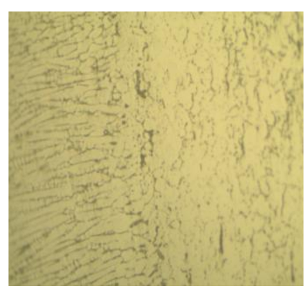
Interface Region

Figure 3.5: Microstructure images of specimens welded at 160A



HAZ

WZ



Interface Region

Figure 3.6: Microstructure images of specimens welded at 180A

CONCLUSION

The effect of TIG welding process on stainless steel 310 with different process parameter has been analyzed. From this investigation, the following conclusions are derived.

- The ultimate tensile strength at optimum condition of the joints fabricated with 160A showed relatively higher strength of 395.4 N/mm^2.
- The highest hardness value was recorded at 160A current of 204HV.This is due to sufficient heat input in this condition and finer grains present in the weld region.
- The hardness values for welded region increases upto an optimal point and after that the hardness values started to decrease.
- The grain size will be finer at optimal conditions and higher heat inputs will leads to grain growth which results in reduction of hardness and tensile properties.
- Reduction in grain boundaries increases possibility and amount of dislocation movement as line defects in structure. It will cause a reduction in strength and hardness of welded metal.

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