THE ANALYSIS OF CHANGING MICROSTRUCTURE AND MECHANICAL PROPERTIES BY CHANGING IN HEAT INPUT DURING MULTIPASS WELDING (SMAW) OF AISI 304

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Abstract: AISI 304 SS grade is one of the most widely used fabrication material in the chemical, petrochemical, and aerospace industry. Welding of these plates especially having large thicknesses poses a great challenge to the fabrication industry as many problems are encountered during welding.In view of the challenges encountered during welding of thick plates of AISI 304 SS grade it was decided to undertake the present work where the effect of multipass welding on various mechanical properties of 20mm thick plates have been studied. The main objective of this work is to investigate how different levels of welding arc energy affect the microstructure of the weld metal and the HAZ under different welding conditions and consequently, how mechanical properties viz. ductility,transverse tensile strength and impact toughness of the weld joints were affected.

Key words: AISI 304 SS,, Transverse tensile testing, Impact testing (Charpy V-notch testing), Bend testing, Weld zone,Microstructure, HAZ, Microhardness,

I. INTRODUCTION

Welding can be defined as the joining of two components by a coalescence of surfaces in contact with each other. This coalescence can achieved by melting of two part together fusion welding or by bringing two parts together under pressure with the help of heat, to form a metallic bond across the interface. Welding joins different materials or alloys with the help of a number of processes, in which heat is supplied either electrically or by means of a gas torch. In order to join two or more pieces together by one of the welding processes and the most of the essential requirement is heat. Based on the method of heat generation and its application the welding processes can be grouped into six main classes. The main classes of the welding are arc

1.Welding processes, 2. Resistance welding processes, 3.Solid-state welding processes, 4.Radiant energy welding processes, 5.thermit welding processes 6.oxy-fuelgas welding processes. Among all of these welding processes the arc welding processes are generally used to weld the metals

II. PROBLEM FORMULATION

From the past reports that many works are available where research attempts have been made on section thickness up to 12mm plates using various welding processes but only few works are reported for large section thicknesses. The main reason for this is that large sections often pose major challenges in terms of achieving sound quality and consistent mechanical properties.

Since microstructure changes in the joint are found to affect the microstructure properties. Some papers are available on the study of effect of heat input or the microstructure properties. Changing heat input viz. varying no. of weld passes is known to affect the microstructure properties in favorable manner

Experimental Details

The present work was carried out to experimentally study the effect of multipass welding of 20mm thick stainless steel joints. Two welding heat input combinations, i.e. low and high heat input were selected from the operating envelope of SMAW process. Four plates each of size 250x100x20 mm which would form a double V-groove joint between them were used to make two finished weld pads of size 250x200x20 mm, i.e. one at low heat input and the other at high heat input welding. The 1/3 double V-groove design was used so that welding could be accomplished ensuring full penetration.

Specification of the base material The base material used in this study was AISI 304 stainless steel (rolled condition). The chemical composition of base metal is summarised in Table 1.1.

Table 1.1: Chemical composition of AISI 304 stainless steel, % weight

Elements	C	Si	Mn	P	S	Cu	Cr
%wt.	0.074	0.473	1.59	0.0344	0.0206	0.525	18.62
Elements	**Ni**	**Mo**	**Ti**	**Al**	**Sn**	**Nb**	**Fe**

%Wt.	8.20	0.209	0.0061	0.00335	0.0192	0.0167	69.9

Welding Consumables used The coated electrodes of 2.5mm and 3.15mm diameter of grade 308L were used for the work. The chemical composition (wt. %) of filler material is summarised in Table 1.2.

Table 1.2: Chemical composition of 308L electrode, wt. %

Elements	**C**	**Si**	**Mn**	**P**	**S**	**Cr**	**Ni**	**Fe**
%wt.	0.03	0.43	1.65	0.021	0.02	19.70	9.30	Balance

III. NON-DESTRUCTIVE TESTING

In the present study the X-ray radiography was used to inspect the internal flaws or discontinuities, present in the weld metal before subjecting the welded joints to mechanical testing. The radiography testing was conducted under the following conditions, shown in table 1.3.

Table 1.3Reference Standard ASTM-446

Material	Weld joint
Thickness	20mm
Film type	ISO Class-C5
Technique	SWSI
Density of the film	2.0-2.2
Penetrameter	10 ISO 16

Non-Destructive Testing

To understand any type of defects or discontinuities such as cracks, inclusions and porosity the radiography of the low and high heat input welded plates have been carried out which is shown in Fig. 1.1 and 5.2.In radiography there are mainly three levels i.e. level 1, 2 and 3 which represents the quantity of defects in the material. In the present study the defects were found at level 1, i.e. the slag inclusion and porosity shows the minor effect on the welded plates.

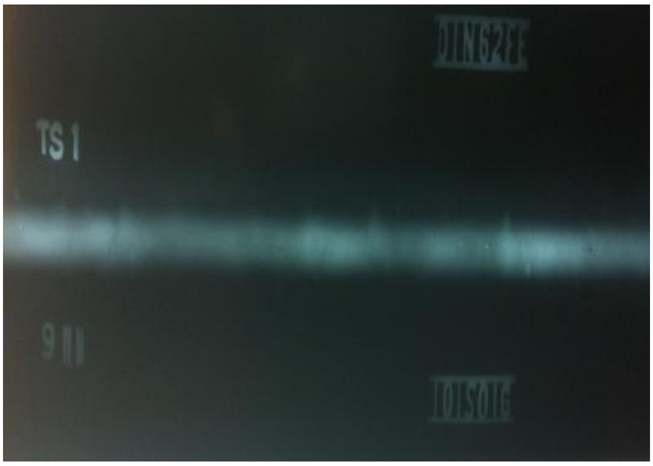

Figure 1.1 X-ray radiography of low heat input welded plates

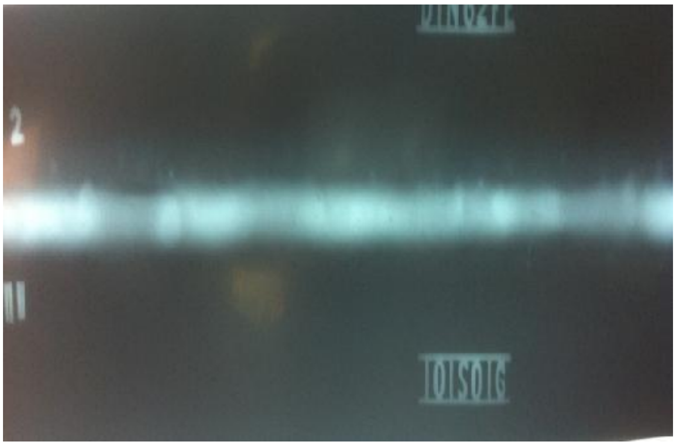

Figure 1.2 X-ray radiography of high heat input welded plates

The Table 2.1 shows the result of non-destructive testing on the welded joints of the 304 stainless steel plates. Any types of internal flaws or discontinuities such as cracks, shrinkage, hot tear, insert and molting have not been observed in the weldment. Only slag inclusion and porosity is there in the weld pads which is at level 1, i.e. at very minor level as discussed earlier.

Table 5.1: X-ray Radiography results

Type of defects	**Slag inclusion**	**Porosity**	**Internal shrinkage**	**Crack**	**Hot tear**	**Insert**	**Molting**
Results obtained from plate 1	Level-1	Nil	Nil	Nil	Nil	Nil	Nil
Results obtained from plate 2	Nil	Level-1	Nil	Nil	Nil	Nil	Nil

IV. MECHANICAL TESTING RESULTS

Tensile, impact and bend testing results of the welded specimens are discussed and analysed in the forgoing paragraphs.

5.2.1 Tensile testing results The transverse tensile strength of the joints. made using different heat input conditions has been evaluated. In each condition three specimens were tested and the strength of the specimens corresponding to low (17 pass) and high (15 pass) heat input joints and their corresponding percentage elongations, percentage reduction in area and yield stress thus obtained are mentioned in the Table 5.2

Table 5.2: Results from transverse tensile test

Specimen Name	Heat Input	Ultimate break load(KN)	Max. displacement (mm)	Ultimate stress KN/mm^2	% elongation	Yield stress(KN/mm^2)	Location of fracture
L-T1 (17 pass -low heat)	Low	296.680	53.100	1.057	48.00	0.520	Base metal
L-T2 (17 pass -low heat)	Low	290.240	48.400	0.904	41.00	0.500	Base metal
L-T3 (17 pass -low heat)	Low	287.620	42.220	0.882	38.00	0.496	Base metal
H-T1 (15 pass - high heat)	High	220.440	42.500	0.675	34.600	0.432	Weld metal
H-T2 (15 pass - high heat)	High	217.260	51.300	0.673	30.200	0.425	Weld metal
H-T3(15 pass high heat)	High	223.260	51.300	0.673	28.400	0.425	Weld metal

V. ANALYSIS OF MECHANICAL TESTING RESULTS

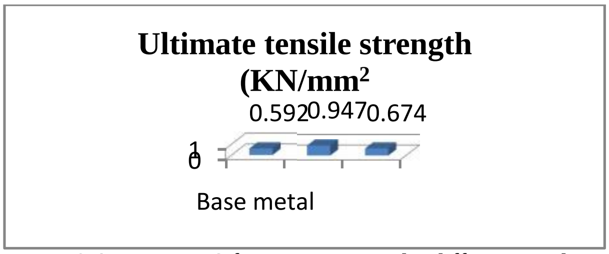

Figure 5.8 Average UTS for specimens under different conditions

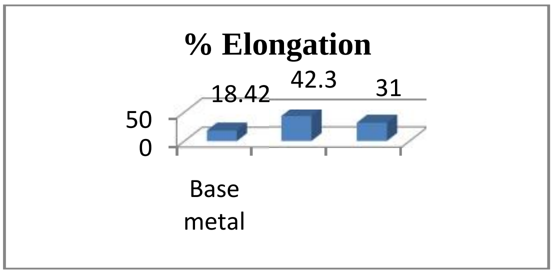

Figure 5.9 Average % elongation for specimens under different conditions

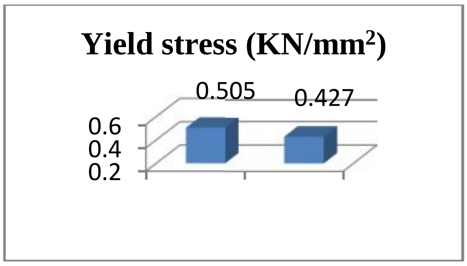

Figure 5.10 Average yield stress for specimens under different conditions

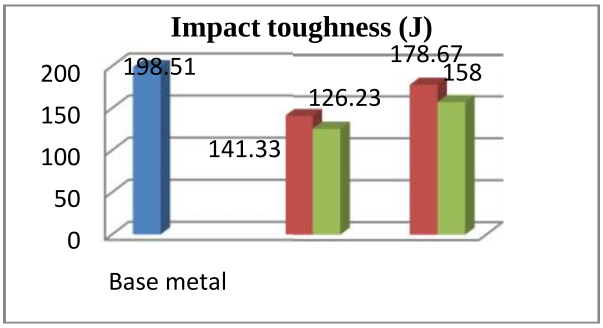

Figure 5.12 Average impact (CVN) value for specimens under different conditions

5.3.1 Analysis of the tensile testing results

Tensile testing results obtained from this study show that the average UTS value is 0.592KN/mm^2 for base metal, 0.947KN/mm^2 for the low heat input combination and 0.427 KN/mm^2 for high heat input combination. It was observed that for the weld joints using low heat condition (Fig. 5.8) the UTS value is increased. Ductility, as shown in (Fig.5.9), which was measured in the form of percentage elongation, was also increased for low heat input combination. Similar results were found for yield strength and percentage reduction in area for low heat input welded plates. The yield strength (Fig. 5.10) shows the average yield strength of 0.505 KN/mm^2 for low heat combination and 0.427 KN/mm^2 for high heat. Similarly as shown in (Fig.5.11), the percentage reduction in area for low heat input (53.48) is much greater than that of high heat input (24.54) combination.

The microstructural changes of the weld metal in terms of dendrite size and cell spacing indicate that relatively high tensile strength and ductility is possessed by the joints at low heat input, which can be attributed to smaller dendrite sizes and lesser inter-dendritic spacing in the fusion/weld zone. Relatively lower tensile strength and ductility is possessed by the joints with long dendrite sizes and large inter-dendritic spacing in the fusion zone of the joint welded using high heat input. Further it is found that all the joints with low heat fractured in the base metal during tensile testing as shown in Fig. 5.3 which indicates that weld metal in all the joints possessed higher tensile strength than the base metal whereas all the joints with high heat fractured in the weld zone during tensile testing as shown in Fig. 5.3 which indicates that base metal possessed higher tensile strength than the weld metal.

5.3.2 Analysis of impact toughness results

Table 5.3 shows the results of impact toughness tested for the base metal, weld metal zone (WM) and heat affected zone (HAZ) of low(17 pass) and high(15 pass) heat input welded joints. It is found that impact value increase with increase in welding current. As shown in (Fig.5.12), it was found that the average impact value of base material is 198.51J, for low heat input it is 141.33J in weld zone and 126.23J in HAZ. Similarly it shows the impact value of 178.67J in weld zone and 158J in HAZ of high current welded specimens. It was also observed that the weld joints made by using high current showed higher impact energy absorption capacity than those welded using low welding current.

5.3.3 Analysis of bend test results

It was observed that low heat input welded samples have the higher ductility as compared to high heat input welded specimens. Similar results during tensile test has been found by performing the bend test, i.e. bending of the low current welded specimen shows more strength as compare to that of high current welded specimens. All the three high heat input welded specimens were found crack in their weld zone whereas there is no crack found in the low heat input welded specimens. Fig. 5.7 shows the fractured features of low and high heat input welded samples after the test.

5.4 Microhardness testing

The results of microhardness testing as carried out on different welded specimens are presented and discussed as below:-

5.4.1 Micro hardness of butt welded joints

The microhardness was checked for base metal, weld zone and heat affected zone of low and high heat input welded specimens. At every place readings were taken. All the readings are shown in Table 5.4. Average micro hardness of **base metal is 256 VHN.**

Table 5.4 Micro hardness (VHN) results

Specimen name	Base metal	Weld zone	Heat affected zone
Low heat input	253-259	310-316	360-365
High heat input	253-259	306-312	309-318

Analysis of the microhardness results

Figure 5.13(a) and (b) represents the variation of micro hardness values obtained from the different sources such as base metal and as-welded condition. The hardness values of as-welded specimens were much greater than base metal. High hardness values were observed in the HAZ region of the both low and high heat input weldments.

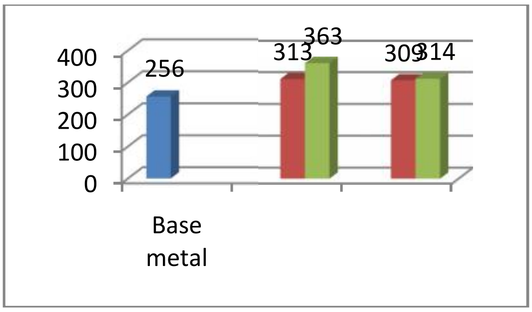

Figure 5.13 (a) Comparison of microhardness of base metal and as welded plates

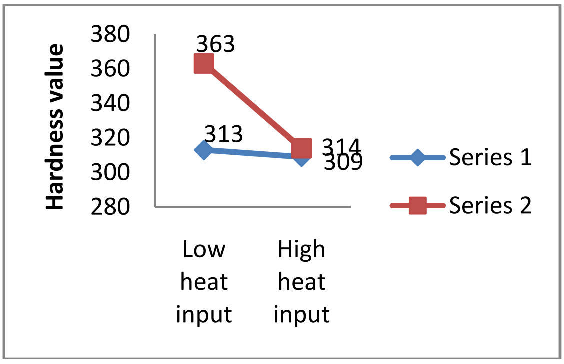

Figure 5.13 (b) Line graph comparison of microhardness of as welded plates

VI. CONCLUSIONS & FUTURE SCOPE

From the above observation it can be easily concluded that at the low heat input welded joints the microhardness has become higher as compared to micro hardness values at high heat input welded joints. The main reason is that the cooling rate of low heat input welded specimen is relatively higher than at the high heat input specimen and the micro hardness is directly related to the cooling rate at that point. Higher the cooling rate will produce higher microhardness. Subodh have reported similar trends while studying the effect of heat input on the mechanical properties of TIG welded 304 SS joints that the micro hardness follows an increasing trend in the order of weld metal, HAZ, unaffected base metal and fusion boundary for all the joints made at different heat inputs. Based upon the present study it is concluded that for the multipass welding of AISI 304SS using SMAW process the low heat input should be preferred because of the reason that it gives good tensile strength and ductility to the joints.

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