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Experimental Investigation of SS 304L Welded By Plasma Arc Welding and Gas Tungsten Arc Welding for Comparative Study of Mechanical Properties

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Abstract— The present research work aims to study the comparative effect of PAW (Plasma Arc Welding) and GTAW (Gas Tungsten Arc Welding) on SS 304L to check the mechanical properties and quality for a particular weld joint. The process parameters are current, welding speed and flow rate of shielding gas with ER316L electrode for tensile strength, hardness of weld metal, hardness of heat affected zone, and weld penetration to width ratio. Artificial Neural Network has been developed for both Plasma Arc Welding and Gas Tungsten Arc Welding process. Regression analysis has been done to establish mathematical model of process and response parameter.

Key words: GTAW, PAW, SS 304L, Artificial Neural Network, Regression Analysis, Tensile Strength, Hardness, Weld Penetration to Width Ratio

I. INTRODUCTION

Modern welding technology started just before the end of the 19th century with the development of methods for generating high temperature in localized zones. Welding generally requires a heat source to produce a high temperature zone to melt the material, though it is possible to weld two metal pieces without much increase in temperature. There are different methods and standards adopted and there is still a continuous search for new and improved methods of welding. As the demand for welding new materials and larger thickness components increases, gas flame welding which was first known to the welding engineer is no longer satisfactory and improved methods such as Metal Inert Gas welding, Tungsten Inert Gas welding, electron and laser beam welding have been developed.

In order to fulfill demands for quality and efficiency in the field of welding engineering, numerous works in research on the optimization of the welding processes are in progress. The aim of this work is to study a comparison between the traditional welding processes (TIG-Tungsten Inert Gas and PAW-Welding Plasma Arc) and this was performed defining the influence of different process parameters. The aims of this research are increasing the welding speed, increasing the Penetration, decreasing the reject rate and reducing the pre and post welding machining. To evaluate the mechanical properties were used tensile and hardness test and study about Elongation and the Tensile strength. Plasma arc welding has been increasingly considered as an alternative to traditional techniques to join the metals.

An increase in penetration depth and a reduction of possible welding defects is indeed achieved. There are many types of welding process available for welding, but we can choose Plasma Arc Welding and TIG welding because of this equipment is portable, it has non-consumable electrode. There are few studies of the process of Plasma arc welding and Gas Metal Arc Welding (TIG), making it important to study the mechanical property and microstructure of welding processes. Welding is a joining process in which coalescence produced between two metals by using heat, with or without use of pressure and with or without uses of filler metals and form uniform and homogeneous joint. Main two welding processes are TIG-Tungsten Inert Gas and PAW-Welding Plasma Arc.

Gas-tungsten arc welding (GTAW), also known as tungsten inert gas (TIG). Tungsten Inert Gas welding (TIG) is the old name for TIG welding process was developed in the late 1930s when a need to weld magnesium became apparent. The process now known as gas tungsten arc welding GTAW and the new name became popular in the technical books. The Gas Tungsten Arc Welding (GTAW) process is applicable when the highest weld quality is required. It can be used to weld almost all types of metals. The operator has excellent control of heat input, and vision is not limited by fumes or smoke from the process. TIG welding consist of Welding torch, non-consumable electrode, argon and helium as a shielding gas and its main application are Ferrous and various non-ferrous metal. Join various dissimilar metals together. Good for fabrication such as aircraft and race car frames, Used for welding thinner metal parts.

Arc welding process that produced coalescence metals by heating them with a constricted arc between electrode and work piece (transferred arc) or between electrode and water cooled constricting nozzle (non-transferred arc). Plasma: A gas mixture of positive ions, electrons and neutral gas molecules. Main objective of plasma arc welding to increase the energy level of the arc plasma in controlled manner. This is achieved by providing a gas nozzle around a tungsten electrode operating on DCEN. Main components of PAW are DC power supply, High frequency generator and current limiting resistors, Plasma Torch, Shielding gas. Application of PAW are in Aerospace industries, Cryogenics. Foodstuff and chemical industries, Machine and plant construction, Automobiles and railways, Ship construction, Tank equipment and pipe line construction.

II. EXPERIMENTATION

Welding specimen has been prepared to fabricate GTAW welded joints. Austenitic stainless steel SS304L specimen in the dimension 150mm x 100mm x 6mm was considered for welding of 60 degree V joints. Welding process has been carried out in GTAW machine. ER316L filler wire used for welding and two passes in the welding.

Welding specimen has been prepared to fabricate PAW welded joints. Austenitic stainless steel SS304L specimen in the dimension 150mm x 100mm x 6mm was considered for welding of 60 degree V joints. Welding process has been carried out in PAW machine. ER316L filler wire used for welding and two passes in the welding.

A. *Workpiece Specification*

The workpiece used for research work is AISI 304L steel with a dimension of 150mm x 100mm x 6mm. Chemical composition of workpiece material are given in table.

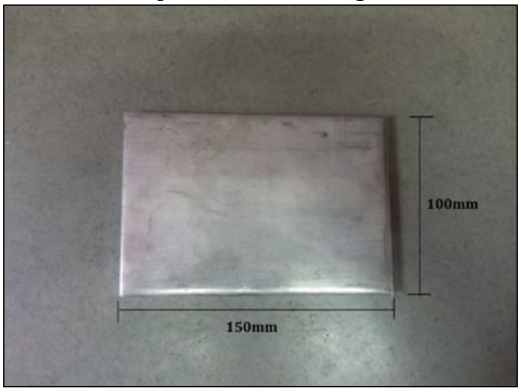

Fig. : Top view of workpiece

Fig. : Side view of workpiece

Sr. No.	Element	Percentage
1.	Carbon	0.019 %
2.	Manganese	1.56 %
3.	Phosphorus	0.031 %
4.	Sulphur	0.001 %
5.	Silicon	0.47 %
6.	Chromium	18.220 %
7.	Nickel	8.210 %
8.	Molybdenum	0.021 %

Table: Chemical composition of workpiece

B. *Factors and levels*

Factors	Notation	Levels		
		-1	0	1
Welding current (Amps)	I	130	145	160
Welding speed (mm/min)	S	90	100	110
Gas flow rate (LPM)	FR	12	14	16

Table: Factors and level of GTAW

Factors	Notation	Levels		
		-1	0	1
Welding current (Amps)	I	130	145	160
Welding speed (mm/min)	S	180	200	220
Gas flow rate (LPM)	FR	15	18	21

Table: Factors and level of PAW

III. RESULTS AND DISCUSSION

Sr. No.	Current (A)	Welding Speed (mm/min)	Shielding Gas Flow Rate (LPM)	Ultimate Tensile Strength (N/mm^2)	Hardness in HV 10			Weld P/W Ratio
					WELD	HAZ	BASE	
1	130	90	12	585.621	194.518	187.484	185.748	1.17
2	130	90	14	597.841	194.513	185.579	184.129	1.22
3	130	90	16	598.762	194.806	185.602	183.474	1.22
4	130	100	12	580.719	193.513	187.469	184.597	1.25
5	130	100	14	585.163	194.544	188.072	184.233	1.21
6	130	100	16	585.405	195.228	186.759	182.910	1.26
7	130	110	12	575.403	193.548	189.220	184.329	1.28
8	130	110	14	578.191	194.053	189.076	183.591	1.28
9	130	110	16	578.731	194.073	187.773	182.273	1.27
10	145	90	12	600.749	194.339	185.449	184.695	1.21
11	145	90	14	593.815	194.553	186.232	184.420	1.20
12	145	90	16	601.903	195.494	185.591	183.433	1.23
13	145	100	12	597.110	193.852	187.907	184.780	1.25
14	145	100	14	594.524	194.981	187.123	183.722	1.26
15	145	100	16	591.335	195.250	187.153	183.070	1.24

16	145	110	12	587.607	194.852	188.306	183.836	1.28
17	145	110	14	581.268	194.748	189.163	183.598	1.29
18	145	110	16	585.362	195.714	189.014	182.857	1.30
19	160	90	12	604.484	194.733	185.384	184.626	1.22
20	160	90	14	605.418	195.788	185.302	183.918	1.23
21	160	90	16	608.790	195.842	185.646	183.424	1.21
22	160	100	12	589.247	195.196	186.353	183.967	1.22
23	160	100	14	601.646	195.635	187.799	184.023	1.26
24	160	100	16	600.791	196.223	188.112	183.514	1.27
25	160	110	12	597.412	194.877	189.343	184.318	1.29
26	160	110	14	593.825	195.808	188.164	183.063	1.26
27	160	110	16	595.936	196.193	189.174	182.901	1.30

Table: Experiment result of GTAW process

Sr. No.	Current (A)	Welding Speed (mm/min)	Shielding Gas Flow Rate (LPM)	Ultimate Tensile Strength (N/mm²)	Hardness in HV 10			Weld P/W Ratio
					WELD	HAZ	BASE	
1	130	180	15	607.543	199.916	178.746	182.549	0.76
2	130	180	18	620.679	199.220	179.235	181.825	0.79
3	130	180	21	621.669	199.460	180.265	181.478	0.82
4	130	200	15	602.273	199.613	179.127	182.060	0.77
5	130	200	18	607.050	199.327	179.677	181.745	0.81
6	130	200	21	607.311	199.542	180.432	181.291	0.82
7	130	220	15	596.558	199.335	179.178	182.012	0.80
8	130	220	18	599.555	199.277	179.598	181.603	0.82
9	130	220	21	600.135	196.830	180.464	180.868	0.80
10	145	180	15	623.806	194.695	178.304	181.531	0.64
11	145	180	18	616.351	197.467	179.846	181.859	0.76
12	145	180	21	625.046	194.653	179.495	180.992	0.77
13	145	200	15	619.893	196.516	178.519	181.658	0.66
14	145	200	18	617.113	197.262	179.155	181.173	0.69
15	145	200	21	613.685	195.158	180.109	181.098	0.74
16	145	220	15	609.677	194.050	178.934	181.218	0.71
17	145	220	18	602.864	193.048	179.793	181.264	0.77
18	145	220	21	607.264	195.778	180.582	181.057	0.79
19	160	180	15	627.821	190.006	178.006	181.203	0.60
20	160	180	18	628.824	192.335	178.607	180.885	0.63
21	160	180	21	632.449	192.537	179.183	180.662	0.64
22	160	200	15	611.441	187.424	178.199	180.930	0.60
23	160	200	18	624.769	188.115	178.966	181.042	0.65
24	160	200	21	623.850	188.159	179.558	180.817	0.69

25	160	220	15	620.218	187.385	178.424	181.149	0.63
26	160	220	18	616.362	188.355	179.272	180.564	0.68
27	160	220	21	618.631	189.266	180.190	180.721	0.74

Table: Experiment result of PAW process

IV. Conclusion

From above discussed conclusion have been made as mention below.

- Higher Tensile strength and Hardness has been obtained by PAW compare to GTAW process.
- Significant effect of current and welding speed for Tensile strength for GTAW process.
- Significant effect of current and shielding gas flow rate for hardness of weld metal for GTAW process.
- Significant effect of welding speed for hardness of heat affected zone for GTAW process.
- Significant effect of welding speed and shielding gas flow rate for weld penetration to width ratio for GTAW process, but welding speed is most significant.
- Significant effect of current and welding speed for Tensile strength for PAW process.
- Significant effect of current and welding speed for hardness of weld metal for PAW process, but current is most significant.
- Significant effect of current, welding speed and shielding gas flow rate for hardness of heat affected zone for PAW process.
- Significant effect of current, welding speed and shielding gas flow rate for weld penetration to width ratio of for PAW process.
- Artificial Neural Network has higher efficiency/accuracy than the regression model for both of the welding processes.
- Tensile strength of PAW process is higher than the GTAW process.
- Hardness of weld metal is similar for the both process.
- Hardness of the heat affected zone of GTAW process is higher than the PAW process.
- Weld penetration to width ratio of GTAW process is higher than PAW process.

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