Optimization of process parameter for tensile strength and hardness of S.S 304 by TIG welding

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***Abstract* - Tungsten inert gas welding (TIG) is a high quality welding process commonly used to join plates of higher thickness in load bearing components. This process provide a purer and cleaner high volume weldments. The main purpose of present work is to investigate and correlated the relationship between various parameters and hardness and tensile strength of single square butt joint and predicting weld bead qualities before applying to the actual joining of metal by welding. Changing different welding parameters like effect of Gas flow, voltage and welding current on the tensile strength of the weld joint has been investigated of weld joint. Hardness value of the welded zone has been measured at the cross section to understand the change in mechanical property of the welded zone. In the study which parameter is most effectively effect the weld strength. Weld strength varies under various conditions. By using Taguchi and ANNOVA technique an optimal solution is find out, which provides us an optimal results of the varying condition.**

***Keywords* - TIG Welding, hardness Test, Tensile Test, Stainless Steel-304, Minitab, Taguchi, ANNOVA.**

I. INTRODUCTION

Modern welding technology started just before the end of 19th century with the development of methods for a generating high temperature in localized zone. Welding generally requires a heat source to produce a high temperature zone to melt raw material, though it is possible to weld two metal pieces without much increasing temperature. As the demand for welding new materials and larger thickness components increase, mere gas flame welding, which was first known to the welding engineer, is no longer satisfactory and improved such as metal inert gas welding, tungsten inert gas welding, electron and laser beam welding have been developed [1].Welding is the process of joining two pieces of metal by creating a strong metallurgical bond between them by heating or pressure or both. A welded joint is obtained when two clean surfaces are brought into contact with each other and either pressure or heat, or both are applied to obtain a bond. The tendency of atoms to bond is the fundamental basis of welding. The basic equipment for TIG welding comprises a power source, a welding torch, a supply of an inert shield gas, a supply of filler wire and perhaps a water cooling system. Type 304: The most common austenitic grades, containing approximately 18% chromium and 8%nickel[3]. It is used for chemical processing equipment, for food, dairy, and beverage industries, for heat exchangers, and for the milder chemicals. As the stainless steel is classified in different categories like austenitic, ferritic, martenstic etc., from this we have chosen austenitic stainless steel (304) because of its low cost, easy availability in the market. The problem that has faced the manufacturer is the control of the process input parameters to obtain a good welded joint with the required weld quality. Traditionally, it has been necessary to study the weld input parameters for welded [2]

II. LITERATURE REVIEW

Ajit Khatter et al[3] Investigate properties of the welded joints are affected by a large number of welding parameters. Properties include Tensile strength, Impact force, Hardness etc. Weld strength varies under various conditions. By using Taguchi and ANNOVA technique an optimal solution is find out, which provides us an optimal results of the varying condition. **A. Kumar et al[4]** Optimization of pulsed TIG welding process parameters on mechanical properties of AA 5456 Aluminum alloy weldments. They were used Taguchi method to optimize the pulsed TIG welding process parameters of AA 5456 Aluminum alloy welds for increasing the mechanical properties. They developed Regression models. Analysis of variance was employed to check the adequacy of the developed models. **Wang Rui et al[5]** carried out **e**xperimental Investigation on Out-of-Plane Distortion of Aluminum Alloy 5A12 in TIG Welding. They found that increase of welding heat input will cause downward distortion for plate thickness of 2.5 mm. They concluded from experiment that the plate thickness of 2.5 mm, with increasing of the welding heat input, the residual distortion of the plate changes from arch to buckling. **Shekhar Rajendra Gulwade et al [6]** Investigate the influence of welding parameters like welding current, welding voltage and gas flow rate on hardness of austenitic stainless steel on 304 grade material during welding. A plan of experiments based on Taguchi technique has been used to acquire the data, To find out percentage contribution of each input parameter for obtaining optimal conditions, we were used analysis of variance (ANOVA) method. **S.P.Gadewar et al [7]** investigated the effect of process parameters of TIG welding like weld current, gas flow rate, work piece thickness on the bead geometry of SS304. It was found that the process parameters considered affected the mechanical properties with great extent. **Dongjie Li et al[8]** investigated on a double-shielded TIG to improve weld penetration and has been compared with the traditional TIG welding method. The results show that the changes in the welding parameters directly impact the oxygen concentration in the weld pool and the temperature distribution on the pool surface. **He Lin et al[9]** conducted experiment on Mechanical Properties for TIG Welding Joint of High Boron Fe-Ti-B Alloy. Tensile tests were carried out on TIG welded joints after the post weld heat-treatment. The result shows that the welds have slightly higher yield strength (YS), and lower ultimate tensile strength compared to those of the base metal. **Ramesh Kumar Buddu et al[10]** investigation on Mechanical properties and microstructural of TIG welded 40 mm and 60 mm thick SS 316L samples for fusion reactor vacuum vessel applications. The mechanical properties like tensile, bend tests, Vickers hardness and impact fracture tests have been carried out for the weld samples. Tensile property test results indicate sound weld joints with efficiencies over 100%. Hardening was observed in the weld zone in non-uniform manner. **F. Souza Neto et al[11]** conducted experiment to investigated mechanical behavior of AISI 4130 Steel through TIG and Laser welding process. They measured tensile strength of the joint, heat affected zone and fusion zone by this two technology and compared with them. They showed that the Laser welding process is faster, easily automated and produces area phase transformation area (Fusion Zone and Thermally Affected Zone) about ten times smaller than TIG welding process.

III. TAGUCHI'S DESIGN AND EXPERIMENT

Optimization of process parameters is the key step in the Taguchi method for achieving high quality without increasing cost. This is because optimization of process parameters can improve quality characteristics and the optimal process parameters obtained from the Taguchi method are insensitive to the variation of environmental conditions and other noise factor. To solve this task, the Taguchi method uses a special design of orthogonal arrays to study the entire process parameter space with a small number of experiments only[6].

1.WORK MATERIAL

The work material used for present work is austenitic stainless steel 304 the dimensions of the work piece length 150 mm, width 20mm, thickness 3 mm. Argon is used as a shielding gas. The specimen welded by TIG welding as per the standard of ASTM A240.

Table 1:Composion of stainless steel-304

Element	C	Cr	Ni	P	Mn	Si
composition	0.08	20	10.5	0.45	2	0.75

Table 2 Mechanical properties of s.s-304

Material	UTS(MPa)	Y.S(MPa)	%Elongation	Density(gm/cm^3)
SS304	515	205	40	8.03

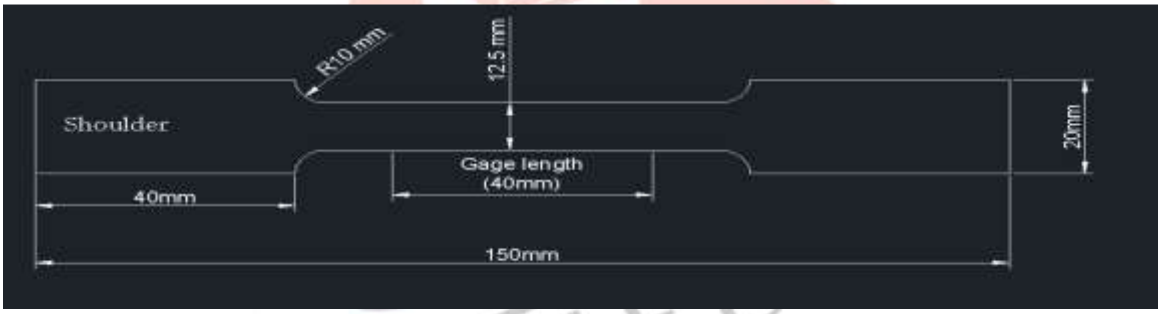

Fig.1 Test specimen size

	Unit	Level 1	Level 2	Level 3
Gas flow rate	Lit/min	15	20	25
Current	A	70	100	130
Voltage	Volt	20	25	30

Table.3 Range of process parameters

2.Tig welding machine

It is precision engineered range of inverter based TIG machines, which are in compliance with set industrial benchmarks. Fabricated from superior quality raw materials, these machines are used to weld mild steel, stainless steel, copper & titanium. Our Inverter TIG Welding Machines are known amidst clients for accurate dimension and capability to deliver optimum performance for long time.

Fig.2 Tig welding machine

3.Testing machine

In this experimental work, it has been investigated on tensile strength and hardness by varying various process parameters like voltage, current and gas flow rate. There are following performance characteristics investigated.

1.Tensile test
2. Hardness test

Fig.3 UTM machine

Fig.4 Vicker hardness test machine

4.L27 TAGUCHI ORTHOGONAL ARRAY

The number of parameters and the number of levels, the proper orthogonal array can be selected. Using the array selector table and the name of the appropriate array can be found by looking at the column and row corresponding to the number of parameters and number of levels. In the present study, three 3-level process parameters i.e. welding current, welding voltage and gas flow rate are considered. The values of the welding process parameters are listed in Table 3.

Sr. No.	Gas flow rate [lit./min]	Current [A]	Voltage [Volt]	Tensile strength[MPa]	Hardness [HV]
1	15	70	20	585	180
2	15	70	25	581	178
3	15	70	30	578	174
4	15	100	20	589	186
5	15	100	25	594	183
6	15	100	30	589	180
7	15	130	20	622	194
8	15	130	25	609	190
9	15	130	30	596	189
10	20	70	20	593	193
11	20	70	25	587	190
12	20	70	30	582	189
13	20	100	20	612	196
14	20	100	25	607	195

15	20	100	30	601	192
16	20	130	20	631	199
17	20	130	25	613	198
18	20	130	30	607	196
19	25	40	20	601	203
20	25	40	25	599	201
21	25	40	30	592	194
22	25	50	20	617	210
23	25	50	25	611	208
24	25	50	30	603	204
25	25	60	20	637	218
26	25	60	25	622	211
27	25	60	30	619	207

Table.4 L27 Orthogonal array experiment result

IV. EXPERIMENT RESULT

1.ANALYSIS OF VARIANCE

Analysis of variance (ANOVA) is a statistical model which can be used for find out effect of independent parameter on single dependent parameter and also it can be use full to find out the significant machining parameters and the percentage contribution of each parameter. MINITAB16 statistical software used to analyze the ANOVA analysis for Tensile strength and Hardness.

Table 5.Analysis of Variance for Tensile strength

Welding parameter	Degree of freedom	Sum of squares	Mean squares	F	P(%)
Gas flow rate	2	1395.85	687.93	32.68	22.07
Current	2	3699.19	1849.59	86.59	58.49
Voltage	2	801.19	400.59	18.75	12.67
Error	20	427.19	21.36		6.75
Total	26	6323.41			100

The percentage contribution of welding current is 58.49%, Gas flow rate 22.07% and voltage 12.67% and the Error is 6.75 %. It can be found that the Current is the most significant welding parameters for affecting the Tensile strength.

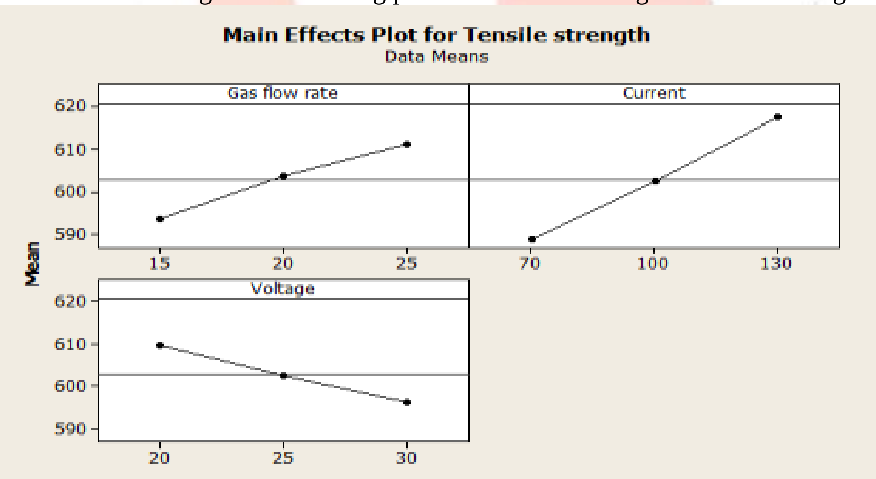

Fig.5 Effect of control factor on Tensile strength

From the fig.5,it has been conclude that the optimum combination of each process parameter for higher Tensile strength is meeting at high Gas flow rate, high welding current and low Voltage.

Table 6 Analysis of Variance for Hardness

Welding parameter	Degree of freedom	Sum of squares	Mean squares	F	P(%)
Gas flow rate	2	2270.52	1135.26	275.15	73.92
Current	2	555.85	277.93	67.36	18.09
Voltage	2	162.30	81.15	19.67	5.28
Error	20	82.52	4.13		2.68
Total	26	3071.19			100

From ANOVA result it is observed that the Gas flow rate, welding current and Voltage of welding influencing parameter for Hardness. The percentage contribution of welding current is 18.09%, Gas flow rate 73.92% and voltage 5.25% and the Error is 2.68 %. It can be found that the Gas flow rate is the most significant welding parameters for affecting the Hardness.

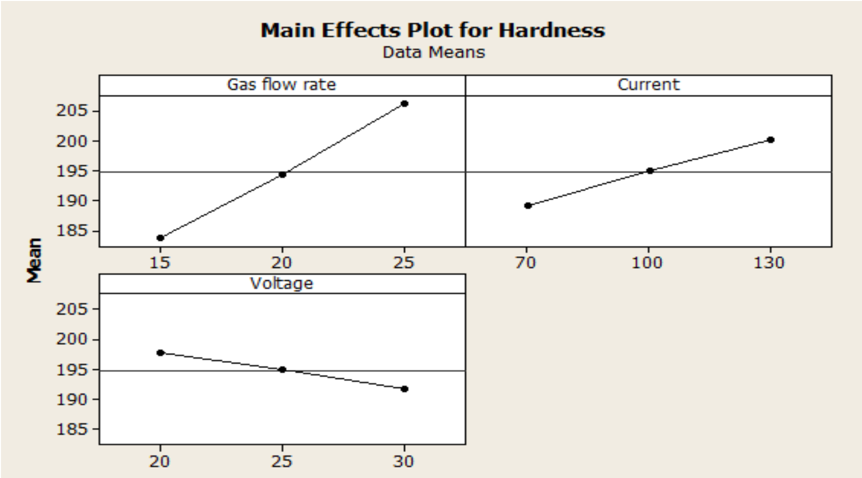

Fig.6 Effect of control factor on Hardness

From the fig.6 it has been conclude that the optimum combination of each process parameter for high hardness value is meeting at high Gas flow rate, high welding current and low Voltage.

V. CONCLUSION

Optimum parameter setting for Tensile strength is obtained at current of 130 amps, 20 volt, and 25-litre/min-gas flow and for Hardness optimum parameter is obtained at current of 130 amps, 20 volt, and 25-litre/min-gas flow.

From the ANOVA it is conclude that the welding current is most significant parameter for Tensile strength which contributes 58.49% and Gas flow rate is most significant parameter for Hardness which contributes 73.92%.

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