Parametric Optimisation of TIG Welding by using Design Of Experiments for SS304 and SS304L

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***Abstract*—SS304 is the most widely and most versatile, which is available in a different range of products, forms and etc. It has good welding and forming characteristics. On the other hand SS304L also has the same properties as of the Grade 304 but the only difference is in its Chemical Composition. It is corrosion resistance while the Grade 304 is not. This paper investigates the effects of input process parameters like voltage and gas pressure. For joining SS304 and SS304L TIG welding played an important role. The TIG Welding is commonly used in various applications such as automotive and aircraft industries. In this paper, design of experiment is used with 3 levels of voltage, Gas Pressure, and constant Current as the input Parameters and also the output parameters are hardness and depth of penetration. These parameters are measured with the help of Hardness testing machine for which we get Brinell hardness and with the help of Ball indenter we calculated Depth of Penetration. As depth of penetration increases the stress carrying capacity also increases. In this paper the welding was done on TIG welding machine and attempts were made to predict the process parameters fir getting maximum hardness and a good depth of Penetration. After the experimentation validation is done by NDT Testing.**

***Keywords*—Hardness testing , NDT Testing , TIG Welding.**

I. INTRODUCTION

Welding is a process in which we join similar or different materials with the help of heat and applying pressure. While Welding the plates that we have to join are melted at the interface and are solidified to form a permanent joint. For strong bonds sometimes a filler material is added. Stainless Steel (SS) has a family of alloys (301, 302, 304, 316 and 347) etc. SS304 is low carbon content alloy which has less carbide precipitation and is used in high temperature applications. One such example of high temperature is of aircraft industry. Whereas SS304L has a corrosive resistive properties which is used in chemical, food, dairy, cryogenic and pharmaceutical company and etc. Ramakrishnan [1] studied the effect of process parameters on bead geometry. The experiment was conducted to join AA6063 by TIG Welding. The processed joint exhibited better metallurgical and mechanical characteristics. Change in heat value creates so many metallurgical defects. These effects were validated by NDT Testing. Chellappan.M [2] studied the effect of different parameters on Supermatensitic stainless steel using TOPSIS. In his investigation he found that with these parameters the grain size was influenced and also the microstructure of weld had mixture of bright phase of delta ferrite with the increase in heat. Fan Ding and Huang Yong [3] studied the effect of activating flux and flux coating method on weld penetration. In their study they found that A-TIG welding with AF305 flux increases the weld penetration by 3 times as of conventional welding .weld penetration by 3 times as of conventional welding . Joby Joseph and S.Muthukumaran [4] made an attempt to optimize parameters for sintered hot forged AISI 4135 steel by using TIG Welding and the experiments were done by using Tagauchi L9 array. In their experimental work they used Response surface methodology (RSM) and to optimize process parameters they used Genetic Algorithm and Simulated Annealing. In their study they found that using low voltage, low current and medium welding speed maximum tensile strength was obtained. G Magudeeswaran [5] in their study the ATIG welding of UNS S32205 duplex stainless steel (DSS) was carried out by performing orthogonal array and with the help of Anova and Pooled Anova techniques the weld parameters were optimized for the aspect ratio of DSS joints. In their study they found that the aspect ratio was influenced and the desirable joint was obtained by optimizing the input parameters and also they found that there was no evidence of solidification cracking macroscopically for the DSS joints and also the electrode gap was the predominant factor that affects the aspect ratio.

II. TIG WELDING

Tungsten inert gas welding is a process in which an arc uses non consumable tungsten electrodes .Weld area is protected by argon .It is commonly known as TIG Welding which was first used during 2^{nd} world war. It has widespread applications for welding varieties of metals like mild steel and high tensile steel and other alloys.TIG Welding provides higher quality of welds and therefore commonly used for joining stainless steels and other metals.

III. Mechanism Of TIG Welding

It uses non consumable electrodes to produce good quality of welds. The weld has a protective environment which is provided by a shielding gas which is commonly used is Argon or Helium or mixture of both the gases and a filler material is used. A tungsten electrode is fitted to the hand piece and the power is supplied to the hand piece from the rectifier. As the power source is turned on the electric arc is generated between the work piece and the electrode by using a constant current and welding power supply . The heat produced by this arc has a temperature on an around up to 20000^{0}C which can be used for joining two materials. The base metal can be joined with or without filler material .

IV. Experimental Details aND Measurement

Commercial stainless steel plates of grade 304 & 304L were selected as the work piece for the current experimental work .Steel plates of 8cm x 4cm were first grinded to smoothen the edge and the surface were polished with the help of emery paper and joined by TIG Welding . Steel plates were fixed with the help of clamp and the welding was done. The filler material used for this process was of grade 304L .After TIF Welding the hardness test were done in the laboratory . After successful experimentation work of hardness testing depth of penetration was measured. After experimental work the best weld was found by using a multi attribute decision making tool which was calculated by using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).

TABLE I. Chemical Composition For SS304 And SS304L

Materials	Elements	C	Mn	P	S	Si	Cr	Ni	Al
SS304	Percentage (% by wt)	0.080	2	0.045	0.030	0.750	19	9.5	0.100
	Elements	**Co**	**Al**	**Ti**	**Mn**	**Si**	Cr	Ni	Al
SS304 L	Percentage (% by wt)	0.030	2	0.045	0.030	0.750	19	9.5	0.100

V. Topsis

Step-1 Calculate Normalised Matrix

$$\overline{X}_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n} X_{ij}^{2}}}$$

Step-2 Calculate weighted Normalized Matrix

Step-3 Calculate the ideal best and ideal worst value

Step-4 Calculate the Euclidean distance from the ideal best

$$S_i^{+} = \left[\sum_{j=1}^{m} \left(V_{ij} - V_j^{+} \right)^2 \right]^{0.5}$$

Step-5 Calculate the Euclidean distance from the ideal worst

$$S_i^{-} = \left[\sum_{j=1}^{m} \left(V_{ij} - V_j^{-} \right)^2 \right]^{0.5}$$

Step-6 Calculate Performance Score

$$P_i = \frac{S_i^{-}}{S_i^{+} + S_i^{-}}$$

TABLE II. Experimentation and Responses

	Voltage (Volts)	Gas Pressure (Kg)	Depth of penetration (microns)	BHN
1	120	10	0.075	72
2	130	11	0.09	62
3	140	12	0.09	62
4	120	11	0.085	62
5	130	12	0.075	71
6	140	10	0.08	65
7	120	12	0.095	49
8	130	10	0.085	67
9	140	11	1	63

TABLE III. Control Factors and levels

Symbol	Parameters	Level 1	Level 2	Level 3
A	Voltage (Volts)	120	130	140
B	Gas Pressure (Kg)	10	11	12

VI. CALCULATIONS

TABLE IV. NORMALIZED MATRIX

	Non Beneficiary	Non Beneficiary	Beneficiary	Beneficiary
Weightage	0.165	0.165	0.33	0.33
	Voltage	Gas Pressure	Hardness	DOP
S1	120	10	72	0.075
S2	130	11	62	0.09
S3	140	12	62	0.09
S4	120	11	62	0.085
S5	130	12	71	0.075
S6	140	10	65	0.08
S7	120	12	49	0.095
S8	130	10	67	0.085
S9	140	11	63	1

TABLE V. IDEAL BEST AND IDEAL WORST VALUE

	Voltage	**Gas Pressure**	**Hardness**	**DOP**
S1	0.307087	0.3022	0.3751	0.073
S2	0.332678	0.33242	0.323	0.088
S3	0.358268	0.36264	0.323	0.088
S4	0.307087	0.33242	0.323	0.083
S5	0.332678	0.36264	0.3699	0.073
S6	0.358268	0.3022	0.3386	0.078
S7	0.307087	0.36264	0.2553	0.092
S8	0.332678	0.3022	0.3491	0.083
S9	0.358268	0.33242	0.3282	0.973

TABLE VI. EUCLIDEAN DISTANCE FROM IDEAL BEST AND IDEAL WORST AND CALCULATION OF PERFORMANCE SCORE

	Voltage	**Gas Pressure**	**Hardness**	**DOP**	**Si+**	**Si-**	**Pi**	**Rank**
S1	0.050669	0.04986	0.1238	0.024	0.297	0.04	0.12	**1**
S2	0.054892	0.05485	0.1066	0.029	0.293	0.024	0.075	**8**
S3	0.059114	0.05984	0.1066	0.029	0.293	0.025	0.079	**6**
S4	0.050669	0.05485	0.1066	0.027	0.294	0.025	0.077	**7**
S5	0.054892	0.05984	0.1221	0.024	0.297	0.039	0.117	**2**
S6	0.059114	0.04986	0.1184	0.026	0.296	0.034	0.104	**3**
S7	0.050669	0.05984	0.0842	0.03	0.293	0.015	0.047	**9**
S8	0.054892	0.04986	0.1152	0.027	0.294	0.031	0.096	**5**
S9	0.059114	0.05485	0.1083	0.321	0.018	0.298	0.942	**4**
V+	0.050669	0.05984	0.1238	0.321				
V-	0.059114	0.04986	0.0842	0.024				

VII. NDT Testing

NDT Testing is done for extracting information of chemical, mechanical, physical, metallurgical or mechanical properties. These methods have a wide range from simple to most intricate. NDT has various methods out of which few are Radiography Test, Visual Inspection, Ultrasonic Test and etc. It helps in verifying the internal structure of the specimen. Radiography test can be done with the help of either Gamma rays or X-rays. The properties of these electromagnetic rays is that they have short wavelength which helps them to penetrate, travel through and exit through various materials. In order to inspect a variety of materials, iridium-192 and cobalt-60 which are the sources of Gamma rays are commonly used. Metallic components such as pressure vessels, high capacity storage containers, pipelines, welder test materials and other structural welds are tested by Radiography testing. Ceramics used in aerospace engineering are also normally tested by radiography testing method.

VIII. Applications

Tungsten Inert Gas welding is the process which is best for materials ranging from 4mm to 6mm.TIG welding can be used for thicker materials but it requires a number of weld passes resulting in high heat input, causing distortion and reduction in properties of base material. TIG Welding gives greater control over the weld area. The filler addition and heat input has to be controlled properly in order to achieve high quality welds. TIG Welding can be carries out in various positions and it is mostly preferred for small, thin component and tube and pipe work.

IX. Conclusion

This work deals with TIG Welding of material SS304 and SS304L. TIG Welding can be successfully used for joining both the above materials. The specimen hardness and depth of penetration were dependent on the input process parameters. It was found that the best weld obtained was for voltage at 120 volts with a gas pressure of 10 kg/sq.cm. The hardness and depth of penetration values were nominal at these input parameters.

References

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