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EXPERIMENTAL INVESTIGATION OF WELD BEAD HARDNESS OF TIG WELDING OF GRADE SS316

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ABSTRACT

Tungsten Inert Gas Arc 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 (SS316) possessing high strength and toughness is usually known to offer major challenges during its welding. In this work, Taguchi's DOE approach is used to plan and design the experiments to study the effect of welding process parameters on metal deposition rate and hardness of the weld bead. Three input parameters—current, gas flow rate and no. of passes—were selected to ascertain their effect on the weld bead hardness. The results show that during the welding of Stainless Steel (SS316) gas flow rate is the most significant factor followed by current and no. of passes, for hardness of the weld bead as the response. In this paper, the experimentation has been carried out by using L-9 OA as standardized by Taguchi and the analysis has been accomplished by following standard procedure of data analysis on raw data as well as S/N data. It is revealed that all the three selected parameters—current, no. of passes and gas flow rate—affect both the mean value and variation around the mean value of the selected response i.e. hardness of weld bead.

Keywords: TIG Welding, SS316, DOE, ANOVA.

I. INTRODUCTION

1.1 WELDING: The earliest known from of welding called forge welding, date back to the year 2000 B.C forge welding is primitive process of joining metal by heating and hammering until the metal are fused (mixed) together. Although forge welding still exist, it is mainly limited to the blacksmith trade. Today, there are many welding process available. The primary differences between the various welding are the method by which heat is generated to melt the metal. Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant-current welding power supply produces energy which is conducted across the arc through a column of highly ionized gas and metal vapors known as a plasma. GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. A related process, plasma arc welding, uses a slightly different welding torch to create a more focused welding arc and as a result is often automated.

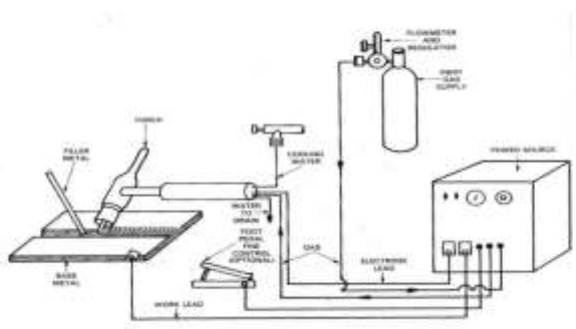

Fig:1.1 Tig Welding

1.2 WELDING PARAMETERS

Regardless of the technology, efficiency or variability, these are the list of parameters that affect the quality and outcome of the weld. When these parameters are improperly configured or out of range for the equipment or materials, this can lead to a variety of problems.

1.2.1 Current: Too much current can lead to splatter and workpiece damage. In thin materials, it can lead to a widening of the material gap. Too little current can lead to sticking of the filler wire. This can also lead to heat damage and a much larger weld affected area, as high temperatures must be applied for much longer periods of time in order to deposit the same amount of filling materials. Current limiting helps to prevent splatter when the tungsten tip accidentally comes too close or in contact with the workpiece. Fixed current mode will vary the voltage in order to maintain a constant arc current.

1.2.2 Welding Voltage: This can be fixed or adjustable depending on the equipment. Some metals require a specific voltage range to be able to work. A high initial voltage allows for easy arc initiation and allows for a greater range of working tip distance. Too large a voltage, however, can lead to greater variability in workpiece quality (depending on the work piece) distance and a greater variation in power and heat delivered to the work area.

1.2.3 Gas Flow and Composition: Various welding or shielding gasses are available including mixtures of argon, carbon dioxide, oxygen, nitrogen, helium, hydrogen, nitric oxide, sulfur hexafluoride and dichlorodifluoromethane. The choice of gas is specific to the working metals and affects the production costs, electrode life, weld temperature, arc stability, welder control complexity, and molten weld fluidity, weld speed, splatter. Most importantly it also affects the finished weld penetration depth and subsurface profile, surface profile, composition, porosity, corrosion resistance, strength, ductility, hardness and brittleness.

II. INPUT (CONTROL) PARAMETERS

To study the effect of input parameters such as current, gas flow rate and number of passes on various response variables like hardness of weld bead. Current, Gas flow rate and number of passes are selected as control parameters. These three parameters are selected because of their ease of control and due to the limitation of available experimental setup. Parameters used for the actual experiment are given below:-

Table: 1.1 Control Parameters

Control Factor	Symbol
Current	Factor A
Gas flow rate	Factor B
Number of Passes	Factor C

III. WORK MATERIAL

Stainless steel is actually a generic referring to a family of over two dozen grade of commonly used alloys. Essentially it is an alloy having of 10.5 percent chromium. In this experimental work, 316 Stainless Steel is used as a work piece. Stainless steel, grade 316 is a versatile "low carbon (0.08%) - Chromium-Nickel steel suitable for a wide variety of welding application. Photographic view of welded sample is shown below.

Fig. 1.2 Welded Samples 304 Stainless Steel

IV. HARDNESS MEASURMENT

Hardness is a resistance to deformation. The hardness of steel is generally determined by testing its resistance to deformation. There are three general types of hardness measurement.

Scratch Hardness

- The ability of material to scratch on one another
- Important to mineralogists, using Mohs' scale 1=talc, 10= diamond
- Not suited for metal – annealed copper = 3, martensite = 7.

Indentation Hardness

- Major important engineering interest for metals.
- Different type: Brinell, Meyer, Vickers, Rockwell hardness tests.

Rebound or Dynamic Hardness

- The indenter is dropped onto the metal surface and the hardness is expressed as the energy of impact.

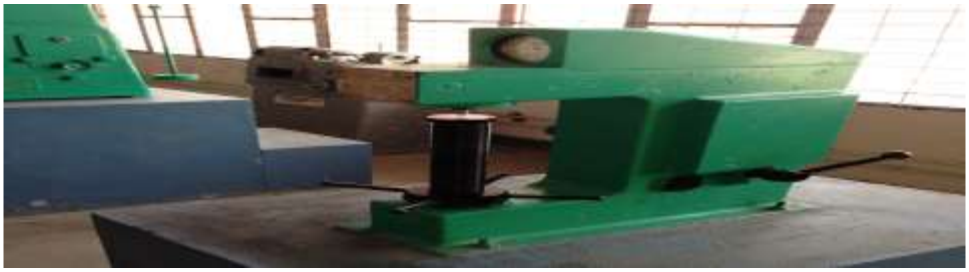

Fig. 1.3 Rockwell Hardness Testing Machine

The hardness was tested by Rockwell hardness -testing machine with 'C' scale. Photographic view of Rockwell hardness-testing machine is shown in Fig. 1.3. Hardness is measured for two runs of each experiment are given below:-

Major Load: - 150kg

Scale: - Rockwell 'C' scales (HRC)

Minor Load: - 10kg

Indenter: - Diamond Indenter

Table: 1.2 Hardness (HRC)

Replication 1

Experiment 1	**Experiment 2**	**Experiment 3**	**Experiment 4**	**Experiment 5**
1st Run=42	1st Run=36	1st Run=30	1st Run=38.5	1st Run=31
2nd Run=20	2nd Run=37	2nd Run=28	2nd Run=40	2nd Run=26
3rd Run=27.5	3rd Run=31	3rd Run=18.5	3rd Run=45.5	3rd Run=26
4th Run=30	4th Run=24	4th Run=29	4th Run=40.5	4th Run=21
5th Run=33	5th Run=32	5th Run=31.5	5th Run=36	5th Run=20
Mean=30.5	Mean=32	Mean=27.4	Mean=40.1	Mean=25.3
Experiment 6	**Experiment 7**	**Experiment 8**	**Experiment 9**	
1st Run=34.5	1st Run=22.5	1st Run=29	1st Run=28	
2nd Run=38	2nd Run=26	2nd Run=29.5	2nd Run=32.8	
3rd Run=33.5	3rd Run=33.5	3rd Run=25	3rd Run=26.8	
4th Run=39	4th Run=31	4th Run=38	4th Run=31	
5th Run=38	5th Run=32	5th Run=29.5	5th Run=23.8	
Mean=36.6	Mean=29	Mean=30.2	Mean=28.48	

Replication 2

Experiment 1	Experiment 2	Experiment 3	Experiment 4	Experiment 5
1st Run=49	1st Run=30	1st Run=27	1st Run=40	1st Run=25.6
2nd Run=29	2nd Run=30	2nd Run=31	2nd Run=42.5	2nd Run=24
3rd Run=25	3rd Run=34.3	3rd Run=20	3rd Run=40	3rd Run=23
4th Run=31	4th Run=20	4th Run=35	4th Run=36	4th Run=29
5th Run=36	5th Run=41	5th Run=23.9	5th Run=35	5th Run=21
Mean=34	Mean=31.06	Mean=27.38	Mean=38.7	Mean=24.52
Experiment 6	**Experiment 7**	**Experiment 8**	**Experiment 9**	
1st Run=30	1st Run=29	1st Run=25.4	1st Run=23	
2nd Run=32	2nd Run=35	2nd Run=31.2	2nd Run=30	
3rd Run=41	3rd Run=40.1	3rd Run=23	3rd Run=23	
4th Run=42	4th Run=29.31	4th Run=34	4th Run=35	
5th Run=36	5th Run=35.2	5th Run=25	5th Run=21.2	
Mean=36.2	Mean=33.722	Mean=27.72	Mean=26.44	

V. RESULT AND DISCUSSION

5.1 Result: After conducting the experiment with different setting of input parameters and the value of output variable were recorded and plotted as per DOF methodology. The analysis of result obtained has been performed according to the standard procedure recommended by Taguchi.

Table: 1.3 Test Data for Hardness (HRC)

Experiment No.	Hardness		Hardness Mean Value	Hardness S/N Ratio
	1st Mean value	2nd Mean value		
1	30.500	34.000	32.250	30.132
2	32.000	31.060	31.530	29.972
3	27.400	27.380	27.390	28.752
4	40.100	38.700	39.400	31.906
5	25.300	24.520	24.910	27.924
6	36.600	36.200	36.400	31.222
7	29.000	33.722	31.361	29.854
8	30.200	27.720	28.960	29.212

9	28.480	26.440	27.460	28.756
Average			31.073	29.748
Maximum	40.100	38.700	39.400	31.906
Minimum	25.300	24.520	24.910	27.924

Optimal Combination of Plot $A_2B_1C_2$

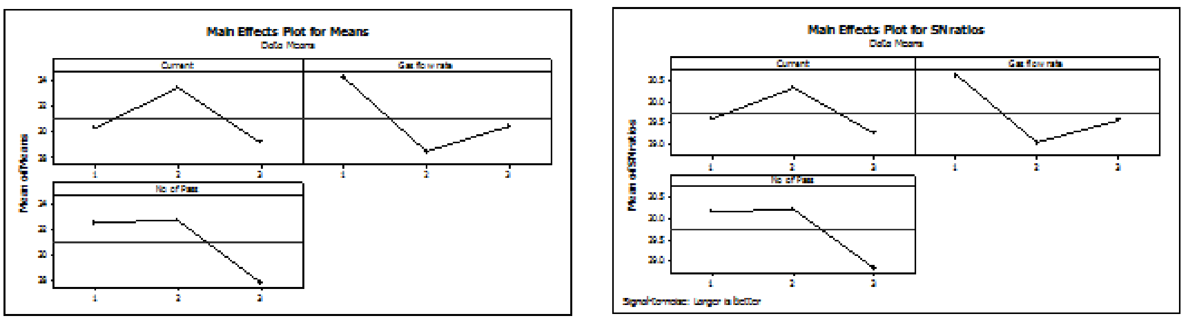

Figure 5.2: Effect of Process Parameters on Hardness – Raw data and S/N Ratio

Table: 1.4 ANOVA: A Test Summery for Hardness

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% contribution
Current	2	59.924	59.294	29.962	3.22	0.079	16.59
Gas flow rate	2	107.265	107.265	53.632	5.76	0.019	29.70
No of Passes	2	91.584	91.584	45.792	4.92	0.030	25.35
Error	11	102.381	102.381	9.307			
Total	17	361.153					
S = 3.05080 R-Sq = 71.65% R-Sq(adj) = 56.19%							

5.2 Discussion: After performing experiment and analyzing the results, the discussion for the effect different input parameters on response variables is described below

5.2.1 Effect on Hardness: It can be seen from the figure number 5.2 that the current and no. of passes are the most significant factor that are affecting the hardness. The different input parameters used in the experimentation can be ranked in order of increasing effect as current, gas flow rate and no. of passes From the figure 1.3 it is conclude that gas flow rate effect less to hardness as compared to effect of current and no. of passes. It can be concluded that with increase in current their decreases in hardness. It was observed that increasing the welding current caused the decreasing in mechanical properties of welded metal. These phenomena can be related to metallurgical behavior of weld melt during solidification and chance of formation the defects in different conditions of welding. It related when increasing in arc voltage and welding current or reducing in welding speed increases the welding heat input. With increasing the input energy, grain size in welded microstructure increases and grain boundaries are reduced in the background. Reduction in grain boundaries as locks for movement of dislocations, increases possibility and amount of dislocation movement as line defects in structure. It will cause a reduction in strength and hardness of welded metal. In graph plotted of no. of passes versus hardness, we can see there is increase of hardness with increase in no. of passes. This result can be compared to the phenomenon that melting metal is settled in weld zone layer by layer with shielding layer in between so that a good strength weld is formed.

5.2.2 ANOVA Results: From table 1.4, we can observe that the following parameters are statically significant at 5% level of Significance for their effects on hardness; gas flow rate, no of passes, and current. The percentage contribution of their parameters in the variation of hardness is 29.70, 25.35 and 16.59 respectively. The order of significance is- gas flow rate, no of passes, and and current, on the basis of the observed p value, which is less than the significance level (0.005 for all these parameters**.**

VI. CONCLUSION

Based on the experiment conducted the Following conclusions have been drawn:

- Current and no. of passes significantly affected the hardness of the weld bead. It was observed that increasing the welding current caused a decrease in the hardness of welded metal. This may be explained on the basis of the higher probability of occurrence of line defects under the effect of increased current.
- $\mathbf{A_2\,B_1C_2}$ Has been identified as the optimal input parametric setting for deposition rate. The values of various input parameters corresponding to the optimal setting are:-

  A_2= 120 Amp
  B_1= 5 litre/min
  C_2= 2

VII. REFERENCES

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