Effect of ATIG Welding Process Factors on the Wear Behavior of AISI 316L

A.Sivanantham, S. Manivannan, P.Shanmughasundaram*

Abstract: In this study, Activated Tungsten Inert Gas welding (A-TIGW) operation factors welding current, speed and argon gas flow rate (AGFR) were optimized in order to attain the enhanced wear resistance of weldment which is obtained by welding of AISI 316L austenite stainless steel. The levels of welding factors were optimized using Taguchi method. Contribution of welding factors on the wear resistance was determined by using ANOVA technique. Dry sliding wear resistance of weld joint against EN-8 steel was studied employing wear test rig at constant load, sliding velocity and sliding duration at room temperature. The results of the experiments illustrated that as the welding current and speed raises, the wear of the welded joint tends to drop. Experimental results showed that welding factors have to be investigated suitably to attain the enhanced wear resistance.

Keywords: A-TIG welding processes, AGFR welding current, welding speed, wear resistance

I. INTRODUCTION

Welding which is a fabrication process is commonly employed to connect the materials by a fusion route. Metals are joined by employing the various welding methods. Each method has its own benefits and shortcomings which mainly depend on the welding process factors. Various investigators have analyzed the impact of welding factors on the mechanical behaviour of the various materials joints. Stainless steel is employed in industries particularly in marine and petrochemical industries because of superior mechanical properties as well as corrosion resistance. Appropriate process factors have influence on the mechanical as well as wear resistance of the weldment. Halil Ibrahim Kurt et al [1] examined the impact of welding factors using ANN and statistical methods and they concluded that the factors have to be investigated in order to attain the high-quality welding joints. Tribology deals with the friction and wear of the contacting surfaces under dry or lubrication conditions. Tribology decides product quality in addition to reliability of the product. Various investigators have studied the impact of welding process parameters. [2-4]. Davanageri et al [5] analyzed wear modeling of super duplex stainless steel Using ANSYS.

Harb et al [6] studied the impact of TIGW and manual metal arc welding on mechanical behaviour of SS sheets. They reported that 316L steel had better tensile strength compared to AISI304. JamshidiAval et al [7] studied the weld pool geometry and microstructure in GTAW of SS304. Afkhami and Halvaee [8] examined the effects of TIGW process on mechanical behaviour of Nichrome 8020.Vasudevan [9] investigated the influence of a TIGW process of 304LN and 316LN stainless steels. The impact of welding factors on the mechanical behaviourof Al-Mg-Si alloy [10].

Emmanuel O et al [11] reviewed the hybrid welding of 304 austenitic SS and they reported that strength depends on the welding current and speed. Raoand Deivanathan [12] examined TIGW aspects of SS 310.The mechanical properties of 310 SS welds are investigated by using SS filler material of different grades, current and welding speed.

Kumarand Shahi [13] analyzed the influence of heat on the mechanical behaviour of AISI 304 SS TIGW joints. Chuaiphan et al. [14] optimized TIGW factors for the dissimilar welding between AISI 304 and AISI 201 SS. Vasantharaja el al. [15] optimized TIGW process factors such as penetration depth, heat zone and width of the bead were examined for steel employing RSM method. There are a very few works dealing with the influence of welding factors on wear behaviour of welding of dissimilar metals such as austenitic and ferritic stainless steels.

Hence, this study is focused on the influence of the welding current, speed, and AGFR on the wear resistance of the weldment. Factors each at three levels such as welding current 135,140,145 ampere, welding speed 105,110,115 mm/min and GFR 5,10,15 lit/min were considered. In addition analysis was done using Taguchi approach with analysis of variance. The optimal level of welding factors was identified by Taguchi method and significant of factors on the wear resistance of the weld joint were examined using ANOVA analysis.

II. MATERIALS AND METHODOLOGY

A-TIGW was used to join AISI 316L austenite stainless steel with filler materials of SiO_2 and TiO_2.

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The schematic of ATIGW setup is portrayed in Figure 1.

The wear tests were done under a load of 20N, and sliding velocity of 1.5 m/s for a sliding duration of 10 minutes. A pin-on-disc rig is portrayed in Fig 2. The specifications of pin disc friction and wear test rig are given in Table.1. The wear loss was measured in microns with an accuracy 1.0 μm. Pin specimen size of 10 mm diameter and 30 mm height was prepared. Tests were done at ambient temperature of 25°C and relative humidity of 50%. In this study, wear readings were taken at the end of 600 second (10 minutes).

Fig.1 Schematic of TIG welding setup

Figure 2: Schematic of pin-on-disc friction and wear testing rig

Table 1 Specifications of Pin Disc Friction and Wear Test Rig

Sl.No	Setting Parameters	Range
1.	Normal Load Range	Up to 200 N
2.	Frictional Force Range	Up to 200 N with a resolution of 1 N with tare facility
3.	Wear Measurement Range	+/- 2 mm with tare facility
4.	Sliding Speed	026 to 12 m/s
5.	Disc Speed	100 to 2000 rpm
6.	Present Time Range	Up to 99 hrs: 59 min: 59 sec
7.	Wear Disc Diameter	165 mm, Thk-8mm (E31 disc 58-60 HRC)
8.	Wear Disc Track Diameter	10 mm to 140 mm
9.	Specimen Pin Diameter / Diagonal	3 mm to 12 mm
10.	Pin Length	25 mm to 30 mm
11.	Data Acquisition System	Up to 8 channel with NI USB DAQ card
12.	Pin Heating System	Up to 250°C

III. TAGUCHI METHOD AND ANALYSIS OF VARIANCE (ANOVA)

Design of experiment is a scientific method of performing tests and helps to get inferences based on the output. Taguchi's technique can be easily employed to resolve the many engineering complex issues. In this work, It was done to choose the optimum level of welding factors on the wear resistance of the welded materials.

Moreover this method identifies which one of the factors has the most effective on the output of the process. It describes three classes of quality uniqueness. Lower is better" S/N ratio is selected to find the optimal level of factors as a lower wear loss was enviable. It is represented in the equation (i).

$$\frac{S}{N} = -10\text{Log}\left(\frac{1}{n}\sum_{i}\frac{1}{y_i^2}\right) \quad \text{------------Eq. 1}$$

In the present investigation, nine tests were performed based on L9 array. The factors and the related levels are provided in Table 2. Experimental values and S/N ratios are given in table 3.S/N ratio helps to identify the factors that reduce the unevenness caused by the noise factors.

Table 2: Factors and levels

Level	Welding current Ampere (A)	Welding speed (mm/min) (B)	Gas flow rate (Lit/min) (C)
I	135	105	5
II	140	110	10
III	145	115	15

The signal to noise ratio for each factor level is estimated by taking an average of the S/N ratios at the related level of the factors. Delta is calculated by subtracting the highest and lowest average response values for each factor.

Response table for S/N Ratio is given in table 4which revealed that the welding current is the dominant factor followed by speed and AGFR for the wear loss of the weldment.

Table 3: Measured values and S/N ratios

Exp .No	Welding current Ampere(A)	Welding speed (mm/min) (B)	Gas flow rate (Lit/min) (C)	Wear loss	
				Measured Values	S/N ratio
1	135	105	5	134	-42.5421
2	135	110	10	103	-40.2567
3	135	115	15	94	-39.4626

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4	140	105	10	90	-39.0849
5	140	110	15	85	-38.5884
6	140	115	5	82	-38.2763
7	145	105	15	95	-39.5545
8	145	110	5	78	-37.8419
9	145	115	10	46	-33.2552

Table 4: Response table for Signal to Noise Ratios - Smaller is better (wear loss)

Level	Welding current (A)	Welding speed (mm/min) (B)	Gas flow rate (Lit/min) (C)
1	-40.75	-40.39	-39.55
2	-38.65	-38.9	-37.53
3	-36.88	-37	-39.2
Delta	3.87	3.4	2.02
Rank	1	2	3

Diagram of S/N ratio is shown in Figure 3 and it is identified that the optimal level of the factors were found to be current (145A), speed (115 mm/min) and flow rate of the gas (10 lit/min) for the minimum wear loss of the weldment. The wear loss of the weldment at the optimal level of the parameters I shown in Fig 4.

In addition, the analysis of variance was made to investigate the importance of the factors that are influenced on the wear resistance of the weldment and the resulting data is given in Table 5.

It is found that welding speed has highest F-value (34.88) which represents that it is the most crucial factor which affects the wear loss of the weldment.

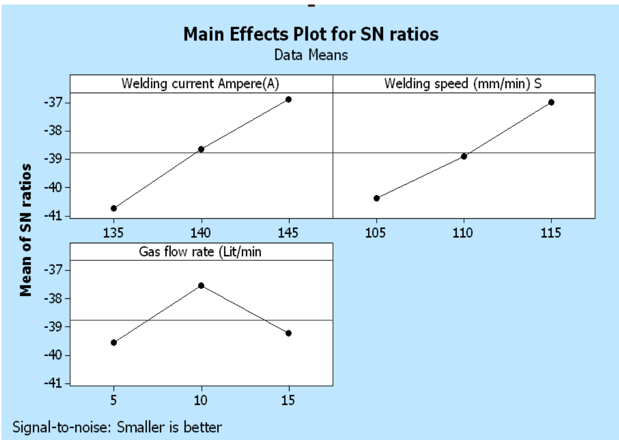

Fig.3 Response diagram of S/N ratio for wear loss

Table 5: ANOVA analysis for wear loss

Factor	DoF	SSS	Value F	Value P	Pc
Welding current Ampere (A)	2	2162.67	34.88	0.028	50.13
Welding Speed (mm/min)(B)	2	1572.67	25.37	0.038	36.45
Gas flow rate(Lit/min)	2	516.67	8.33	0.107	11.97
(C)					
Error	2	62			1.437
Total	8	4314			100

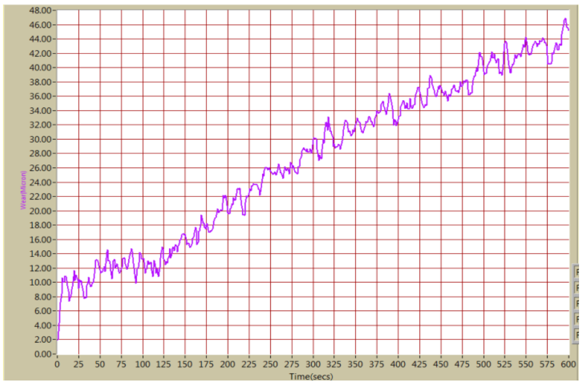

Fig.4 Wear loss of the weldment at the optimum level of the parameters

The P-value shows that the process factors are highly important in affecting the wear loss of the material. It can be noted that the welding current has the most contributing factor on the wear resistance of the material (i.e., 50.13 %) followed by welding speed (i.e., 36.45 %) and gas flow rate (i.e., 11.97 %).

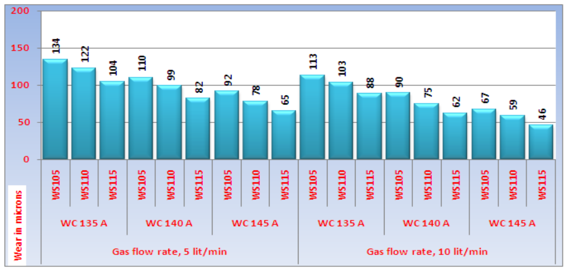

Fig.5. Wear loss of the weldment with respect to welding current, welding speed, and gas flow rate

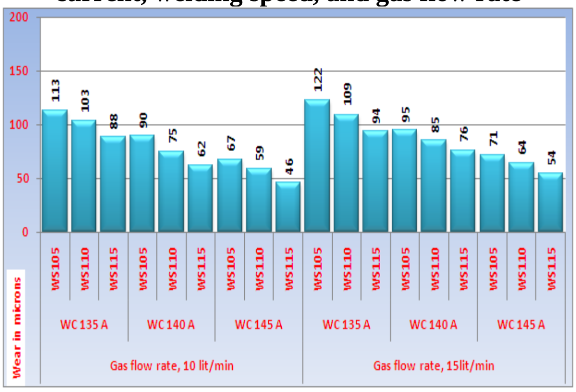

Fig.6 Wear loss of the weldment with respect to welding current, welding speed, and gas flow rate

Fig 5 shows that the wear resistance of the weldment with varying three levels of welding current, three different welding speeds and two different gas flow rates.

It can be observed from the figure that, when the current was raised from 135 A to 145 A wear loss of the weldment tends to decrease from 66µm to 46µmat the constant speed of 115 mm/min and gas flow rate of 10lit/min. It can also be seen that, when the welding speed was increased from 105 mm/min to 115 mm/min wear loss tends to drop from 67µm to 46µmat the welding current of 145 A and gas flow rate of 10 lit/min.

Fig 6 illustrates the wear loss of the weldment with respect to current, speed, and flow rate of the gas. On the other hand the wear is increased from 46µm to 54µm when the gas flow rate was increased 10 lit/min to 15 lit/min at the welding current was about 145 A and speed of 115 mm/min. Welding current as well as speed together enhances the wear resistance of the weldment. Because too low heat input leads more weld defects. It infers the wear resistance increases with gas flow rate upto10 lit/min. Shielding gas prevents atmospheric contamination which improves the quality of the weld joint. As welding current increases, weld penetration end to increase and improves liquid flow in the weld zone.

IV. CONCLUSION

Stainless steel was welded employing the TIGW and tested for wear resistance. The wear of the material was investigated employing the pin-on-disc test rig. The results display that the wear depends on the welding process factors i.e., welding current and speed. With the increment in the welding current, the wear resistance of the weld joint tends to increase. The optimum combination of process factor were found to be welding current (145A), welding speed(115 mm/min) and AGFR (10 lit/min) for the minimum wear loss of the weldment. The welding current (50.13%) was the key factor subsequently welding speed (36.45%)and finally gas flow rate (11.97%) influencing the wear resistance of the weldment.

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