Parametric Study of Dissimilar Material on Gas Tungsten Arc Welding

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Abstract

Gas Tungsten Arc Welding (GTAW) uses a non-consumable tungsten electrode to produce the weld joint. The properties of the welded joints are affected by a large number of welding input parameter such as welding current waveform, welding current, welding speed and gas flow rate, these parameters plays a very significant role in determining the quality of a weld joint. In this work butt weld joint of Copper and Stainless Steel (SS304) is obtained by using autogenous GTAW process. The trial runs had been conducted to find out optimum range of process parameters. Four parameters such as welding current, welding speed, welding torch angle and gas flow rate are considered. The effect of these parameters on mechanical properties such as tensile strength, impact strength, bend strength and hardness of weld joint is analyzed.

Keywords: GTAW, Dissimilar Metal, Taguchi Orthogonal Array, Tensile, Micro-hardness& HAZ.

1. INTRODUCTION

Welding is a process of permanent joining of two materials (usually metals) through localized coalescence resulting from a suitable combination of temperature, pressure and metallurgical conditions. Depending upon the combination of temperature and pressure from a high temperature with no pressure to a high pressure with low temperature, a wide range of welding processes has been used. The term welding refers to the process of joining metals by heating them to their melting temperature and causing the molten metal to flow together these ranges from simple steel brackets to nuclear reactors. The composition of the autogenous weld metal corresponds to the base metal only. However, autogenous weld can be crack sensitive when solidification temperature range of the base metal to be welded is significantly high (750^o – 1000^oC).

GTAW process, an arc is established between a tungsten electrode and t base metal(s). Under the correct conditions, the electrode does not melt, although the work does at the point where the arc contacts and produces a weld pool. The filler metal is thin wire that's fed manually into the pool where it melts. Since tungsten is sensitive to oxygen in the air, good shielding with oxygen-free gas is required. The arc temperature is typically around 6000^oC. Typical shielding gasses are Argon, Helium, Nitrogen or a mixture of the two. The common weld defects include; Porosity, Lack of fusion, Inclusions, Cracking, Undercut. Wang et al.(2011)studied the joint of dissimilar metal 2205 duplex stainless steel and 16MnR low alloy high strength are welded by using tungsten inert gas arc welding(GTAW). Arivazhagan et al. (2011) studied the microstructure and mechanical properties of AISI 304 stainless steel and AISI 4140 low alloy steel joints by Gas Tungsten Arc Welding (GTAW).Shiri et al. (2012)performed the joining of CP Copper to 304

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stainless steel by gas tungsten arc welding process using 316 SS, Copper filler and Ni-Cu-Fe filler.

2. EXPERIMENTATION

Gas tungsten arc welding may be used for welding almost all metals mild steel, low alloys, stainless steel, copper and copper alloys, aluminum and aluminum alloys, nickel and nickel alloys, magnesium and magnesium alloys, titanium, and others. This process is most extensively used for welding aluminum and stainless steel alloys where weld integrity is of the utmost importance. For high quality welds, it is usually necessary to provide an inert shielding gas inside the pipe to prevent oxidation of the inside weld bead.

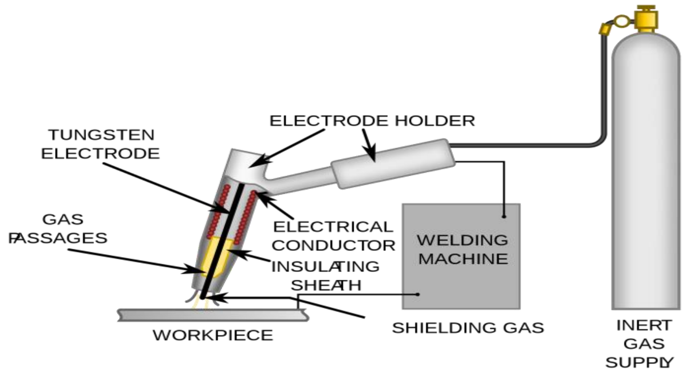

Fig. 1: Schematic Diagram of GTAW System (Wikipedia.org)

The essential components are of Gas Tungsten Arc welding are: Welding Power Source, Electrodes for GTAW Process, Gas Tungsten Arc Welding (GTAW) Torch, Inert Gas Cylinder for Gas Tungsten Arc Welding (GTAW).

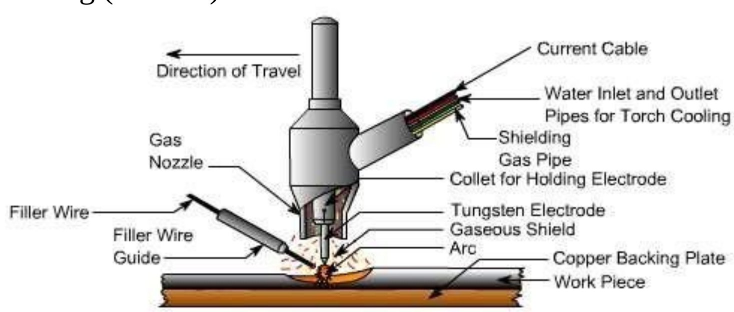

Fig.2: Principle of GTAW (Wikipedia.org)

Gas Tungsten Arc Welding uses a non-consumable, non-melting tungsten electrode which has a melting temperature of 3410˚ Celsius. The rods are manufactured by powder metallurgy techniques of compression and sintering. Tungsten electrodes classified on the basis of composition as described below.

a) Pure Tungsten Electrode.
b) Thoriated Tungsten Electrode.
c) Ceriated Tungsten Electrode.

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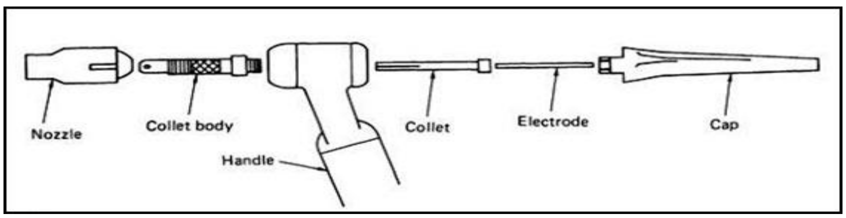
d) Lanthanated Tungsten Electrode.
e) Zirconiated Tungsten Electrode.

Table No. 1 Specifications of Electrodes

S.No.	Electrode type	Color coordination	Use and details of electrodes
1	Pure	GREEN	Provides good arc stability for AC welding. Reasonably good resistance to contamination. Lowest current carrying capacity. Least expensive. Maintains a balled end
2	Ceriated Ce02 1.8% to 2.2%	ORANGE	Similar performance to thoriated tungsten. Easy arc starting, good arc stability, long life. Possible replacement for thoriated.
3	Thoriated Th02 1.7% to 2.2%	RED	Easier arc starting. Higher current capacity. Greater arc stability. High resistance to weld pool contamination. Difficult to maintain balled end on AC
4	Lanthanated La203 1.3% to 1.7%	GOLD	Similar performance to thoriated tungsten. Easy arc starting, good arc stability, long life, high current capacity. Possible replacement for thoriated.
5	Zirconiated Zr02 0.15% to 0.40%	BROWN	Excellent for AC welding due to favorable retention of balled end, high resistance to contamination, and good arc starting. Preferred when tungsten contamination of weld is intolerable.

The function of GTAW torch is to conduct both the welding current and the inert gas to weld zone.



2.1 Materials used in study:

Copper is a good conductor of heat. Copper has 63.564g/moll atomic mass,29 atomic number and 8.9g/cm^3 density,4832W/m*K thermal conductivity at 100^o,melting point 1083^{o}C, boiling point 2595^{o}C. Copper is a reddish metal with a face-centered cubic crystalline structure.

SS304 is a T 300 Series Stainless Steel austenitic. It has a minimum of 18% chromium and 8-10% nickel, combined with a maximum of 0.08% carbon. It is defined as a Chromium-Nickel austenitic alloy.SS304 has 8.03g/cm^3 density, 16.2W/m*K thermal conductivity at 100^o, melting point 1400^{o}C.

By understanding the welding characteristics and utilizing proper procedures Copper and stainless steel could be easily weld. Though Copper and SS304 can be weld by different technique but the most common and commercial method to weld Copper and stainless use a Tungsten Arc Welding.Autogenous welding of this couple is challenging because of a miscibility gap in solid state, in cases where addition of filler material is prohibited or not feasible, the only solution left is to undertake filler-less autogenous welding operation with a objective to obtain a sound weld joint and to investigate the effect of different welding parameters on dissimilar weld joint of Copper and SS304.

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3. DESIGN OF EXPERIMENT

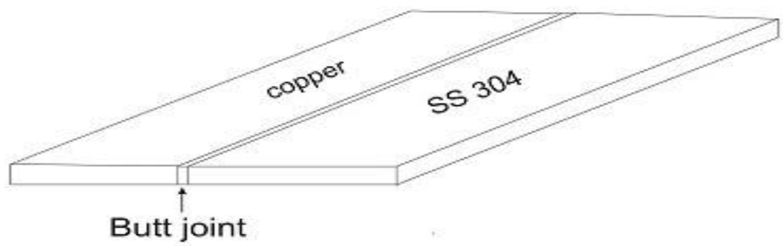
Design of experiments is applicable to both physical processes and computer simulation models. Simply put, DOE helps to pin point the sensitive parts and sensitive areas in designs that cause problems in yield. Designers are then able to fix these problems and produce robust and higher yield designs prior going into production. Factorial designs allow estimation of the sensitivity to each factor and also to the combined effect of two or more factors. Taguchi's loss function can be expressed in terms of the quadratic relationship:

$$L\ (y) = k\ c(\ y - m)2$$

Where y is the critical performance parameter value, L is the loss associated with a particular parameter y, m is the nominal value of the parameter specification, and k is a constant that depends on the cost at the specification limits.

3.1 Experimental Procedure

The validity of proposed process is tested by making a Butt joint as shown in Fig.4



Copper and stainless steel plates of thickness 3mm were selected as workpiece material for the present study, chemical composition of base metals are given in Table 2.

Table 2. Chemical composition of base metals (%)

S.No.	Base Metal	C	Si	Cr	Mn	Fe	Ni	Tb	Cu
1	Copper	3.88	0.82	-	-	-	-	-	95.29
2	SS304	0.08	1.34	18.89	1.07	53.54	8.23	18.61	-

Copper and stainless steel plates were cut with dimensions of 150mm×50mmwiththe help of saw machine for welding purpose.

For the experiment welding parameters selected are shown in Table 3.

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Table-3 Parameters for Experimentation

S.No.	Parameters	Units	Level I	Level II
1	Welding current	Ampere(A)	100	120
2	Welding speed	m/hr	0.3	1.0
3	Torch angle	Degree (^{o})	45	60
4	Gas flow rate	l/min.	6	10

In this experiment work, L_8 (2^{n-1},n=4) Orthogonal Array was used for optimization. There were four input parameters; each parameter had two levels, low and high. Each parameter was assigned to each column of orthogonal array. The four input parameters were welding current, welding speed, torch angle and gas flow rate. Each of them had two levels. Therefore eight experiment runs were required to study the contribution of each parameter using L8 orthogonal array.

Table 4: Standard Experiment Run of L8 Orthogonal Array

Exp. No.	Welding Current	Welding Speed	Torch Angle	Gas flow rate l/min.
1	1	1	1	1
2	2	1	1	2
3	1	2	1	2
4	2	2	1	1
5	1	1	2	2
6	2	1	2	1
7	1	2	2	1
8	2	2	2	2

To evaluate the impact behavior of weld joint, charpy impact test notch specimen were used. To investigate the bending strength of weld joint , specimen was cut transverse to the welded joint with dimensions 100mm ×10mm ×3mm as per standard ASTMa370-2014.2T method of bend testing is used. Metallurgical tests are performed to investigate the Metallurgical properties of

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weld joint. .Micro-hardness was measured with Vickers micro-hardness tester HV1000B. Load of 100gm applied on the work piece.

4. RESULTS & DISCUSSIONS

The main objective of this experimental work was to evaluate the properties of dissimilar weld joint between Copper and SS304 by autogenous GTAW process. Four parameters namely welding current, speed of welding, torch angle and gas flow rate were considered. The effects of these parameters on mechanical properties like tensile strength, impact strength, bend strength and hardness of butt joint is analyzed. Results for tensile test are shown in Table 5

Table No.-4 Experimental Results for various Runs

Exp. No.	Heat Input kJ/min.	Elongation (%)	Maximum Force (N)	Tensile strength (MPa)
1	10	20	4500	200
2	12	22	4320	190
3	2	23	4600	210
4	4	21	4020	176
5	10	23	4500	192
6	12	23	4080	181
7	2	25	4480	192
8	4	10	4300	194

Experimental data is analyzed by Taguchi method, signal to noise ratio is calculated for each response variable under the investigation. For Tensile strength "larger is better" signal to noise ratio is chosen. It has been shown that current has maximum contribution 51.8% in the tensile strength of weld joint according to ANOVA. It can be inferred that with increase in the level of current the tensile strength of joint also decreases.

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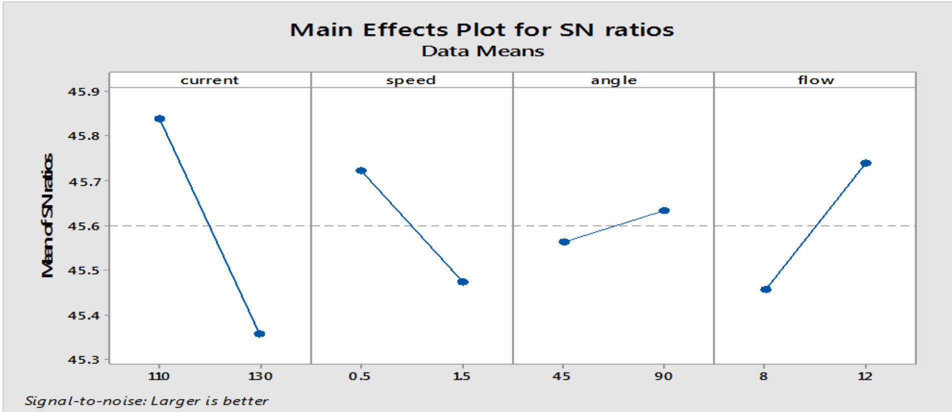

Fig. 3. Main effects plot for SN ratios data means

Table No.-5 Result for ANNOVA

Analysis of Variance					
Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**% Contribution**
Welding Current	1	200.615	210.815	8.61	53.8%
Welding Speed	1	54.54	58.584	2.16	12.1%
Torch angle	1	3.167	3.687	0.18	0.74%
Gas flow rate	1	73.725	71.707	3.10	16.7%
Error	3	66.703	20.968		
Total	7	421.404			

5. CONCLUSIONS

From the experimental procedure of joining Copper and SS304 using autogenous GTAW process, the following conclusions are drawn:

- Welding current has maximum contribution to tensile strength of weld joint followed by welding speed.
- From the above result it can be conclude that with increase in the level of speed the impact strength of joint decrease as the welding speed is directly proportional to the heat input.
- With the change in cooling rate and solidification sequence of weld pool, the grain size changes, and with the change in the grain size micro hardness number changes.

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