Parametric study during SMAW welding of dissimilar metals

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Abstract

The systematic approach carried out towards the optimization on the joint of carbon steel and stainless steel SMAW welding. The quality of the welding is depended upon the various parameters which are used in welding. In current work by changing parameters like voltage, polarity and bevel angle, we can easily find the effect on weld joint which is made from carbon steel and stainless steel. The Levels of parameters derived from design of experiment procedure (DOE). The tensile specimen prepared as per the ASTM and tested on the universal testing machine. Response surface methodology has been used to develop the mathematical model for tensile strength. The effect of the different parameter on the tensile strength has been evaluated. The ultrasonic method has been used for finding internal defects like cracks, porosity, etc. The results indicated that electrode diameter current and bevel angle play vital role welding strength. The maximum strength has been achieved by using maximum electrode diameter and current, but bevel angle should be accurate. Very high and very low bevel angle may decreases welding strength.

Keywords: SMAW welding; dissimilar metals; welding parameters; Taguchi method.

1. Introduction:

Shielded metal arc welding (SMAW), also known as manual metal arc welding (MMA or MMAW), flux shielded arc welding or informally as stick welding, is a manual arc welding process that uses a consumable electrode coated in flux to lay the weld. An electric current, in the form of either alternating current or direct current from a welding power supply, is used to form an electric arc between the electrode and the metals to be joined. As the weld is laid, the flux coating of the electrode disintegrates, giving off vapours that serve as a shielding gas and providing a layer of slag, both of which protect the weld area from atmospheric contamination. Shielded metal arc welding is one of the world's most popular welding processes, accounting for over half of all welding in some countries. Because of its versatility and simplicity, it is particularly dominant in the maintenance and repair industry, and is heavily used in the construction of steel structures and in industrial fabrication. In recent years its use has declined as flux-cored arc welding has expanded in the construction industry and gas metal arc welding has become more popular in industrial environments. However, because of the low equipment cost and wide applicability, the process will likely remain popular, especially among amateurs and small businesses where specialized welding processes are uneconomical and unnecessary [1-5]. SMAW is often used to weld carbon steel, low and high alloy steel, stainless steel, cast iron, and ductile iron. While less popular for nonferrous materials, it can be used on nickel and copper and their alloys and, in rare cases, on aluminium. The thickness of the material being welded is bounded on the low end primarily by the skill of the welder, but rarely does it drop below 1.5 mm (0.06 in). No upper bound exists: with proper joint preparation and use of multiple passes, materials of virtually unlimited thicknesses can be joined. Furthermore, depending on the electrode used and the skill of the welder, SMAW can be used in any position [6-12].

Design engineers are increasingly faced with the need to join dissimilar materials as they are seeking creative new structures or parts with tailor-engineered properties. Sometimes a part needs high-temperature resistance in one area, good corrosion resistance in another. Structures may need toughness or wear resistance in one area combined with high strength in another location. Improving the ability to join dissimilar materials with engineered properties are enabling new approaches to light-weighting automotive structures, improving methods for energy production, creating next generation medical products and consumer devices, and many other manufacturing and industrial uses. In this paper, designs of experiment technique applied to selecting most effective parameters and optimize total number of experiment. Here, the selected process parameters are current, bevel angle and electrode diameter.

2. Design of Experiment:

The statistical tools like design of experiments (DOE) were used in order to get the better results. The use of design of experiments will eventually give the mathematical strength model for the welded carbon steel and stainless steel based on the variation of process parameters during welding procedure. The input parameters as selected in previous parts of this report were current, bevel angle and electrode diameter will be used in finding out the better response which is the ultimate tensile strength to frame the strength model and behaviour of welding. A well designed experiment can substantially reduce the number of trials. In classical methods of experimental planning a large number of experiments have to be carried out as the number of the process parameters increases, which is difficult and time consuming and also results in higher cost.

2.1.Taguchi method:

Taguchi methods are statistical methods developed by Genichi Taguchi to improve the quality of manufactured goods, and more recently also applied to engineering, biotechnology, marketing and advertising. Professional statisticians have welcomed the goals and improvements brought about by Taguchi methods, particularly by Taguchi's development of designs for studying variation, but have criticized the inefficiency of some of Taguchi's proposals [12].

Taguchi's work includes three principal contributions to statistics:

- A specific loss function
- The philosophy of off-line quality control and
- Innovations in the design of experiments.

Definition: Taguchi has envisaged a new method of conducting the design of experiments which are based on well defined guidelines. This method uses a special set of arrays called orthogonal arrays. This standard array stipulates the way of conducting the minimal number of experiments which could give the full information of all the factors that affect the performance parameter. The crux of the orthogonal arrays method lies in choosing the level combinations of the input design variables for each experiment.

2.1.1. Minimum number of experiments to be conducted:

The design of experiments using the orthogonal array is, in most cases, efficient when compared to many other statistical designs. The minimum number of experiments that are required to conduct the Taguchi method can be calculated based on the degrees of freedom approach.

$$N_{Taguchi} = 1 + \sum_{i=1}^{NV}(L_i - 1) \quad (1)$$

For example, in case of 8 independent variables study having 1 independent variable with 2 levels and remaining 7 independent variables with 3 levels (L18 orthogonal array), the minimum number of experiments required based on the above equation is 16. Because of the balancing property of the orthogonal arrays, the total number of experiments shall be multiple of 2 and 3. Hence the number of experiments for the above case is 18.

2.1.2. Parameters to be used in experiment:

The various values of current, bevel angle and electrode diameters are mentioned on table 1. The selected range of the current is between 50 to 100 ampere whereas the bevel angle is consider between 30° to 60° angle. The diameter of the electrode is between 2 mm to 3.15 mm.

Table1: Standard parameters selected for the experiment

Current(amp)	50	75	100
Bevel angle	30	45	60
Electrode Dia.(mm)	2	2.5	3.15

By Taguchi method from Minitab software we got best selected experiment do. It got reduced to nine experiments which will give best suitable result. The combination of the current, bevel angle and electrode diameter was shown in table 2.

Table 2: Experiments by Taguchi method

Sr. No.	Current	Bevel Angle	Electrode Dia.(mm)
1	50	30	2
2	50	45	2.5
3	50	60	3.15
4	75	30	2.5
5	75	45	3.15
6	75	60	2
7	100	30	3.15
8	100	45	2
9	100	60	2.5

3. Experimentation

Experimental setup being as always started with the material selection and acquisition for work piece, fixtures, electrodes and other things to get the work started. All the details for the same are being explained below.

3.1.Material selection:

Work piece Material: As a great share in market, Carbon steel IS2062 and SS304 were always a demanded work piece for the project. Generally running in the market, these metals were a favourite choice of all the metal corporations in the city and even locations outside. The major reason behind selecting this metals and welding together is that, where we want higher strength, carbon steel give work and where we want corrosion free metal, stainless steel is give work. Hence, in this project, the effect of process parameters for SMAW welding was carried out on these dissimilar metals (stainless steel and carbon steel). The chemical and mechanical properties of CS IS2062 and SS304 are shown in table 3 and table 4.

Table 3: chemical composition and mechanical properties of CS IS2062

Chemical composition of CS IS2062					
GRADE	C%	Mn%	S%	P%	Si%
	Max.	Max.	Max.	Max.	Max.
B	0.22	1.5	0.045	0.045	0.04
Mechanical properties					
GRADE	UTS(MPa) Min.	Y.S(MPa) Min.	BEND TEST		
B	410	230-250	2T*&3T*		
***2T <=25mm** ***3T >25mm**					

Table 4: chemical composition of SS304

Chemical composition							
C% (Max.)	Mn% (Max.)	P% (Max.)	S% (Max.)	Si% (Max.)	Cr%	Ni%	N% (Max.)
0.08	2.00	0.045	0.030	0.75	18-20	8-12	0.10
mechanical properties							
HARDNESS(BRINELL)	UTS (MPa)	Y.S(MPa)	Modulus of Elasticity(GPa)	DENSITY(Kg/m^3)			
123	505	215	193-200	7999.49			

A. Electrode:

E309 electrodes are used for the welding of similar alloys in wrought and cast form, as well as for dissimilar metals such as stainless steels to carbon or low alloy steels. They also can be used for a barrier layer before cladding. The chemical composition of E309 is shown in table 5.

Table 5 chemical composition of E309

C%	**Mn%**	**Si%**	**Cr%**	**Ni%**	**S%**	**P%**	**N%**
0.08	1.70	0.52	23.5	12.3	0.021	0.024	0.05

B. Welding fixture material:

Due to the running properties of Mild Steel as its yield strength (250 MPa) and versatile usability, it was the standard choice as the fixture material which could easily handle the welding vibrations and would let the weld strength unaffected during welding & after it. Clamps and bolts will also be used of the same material that is mild steel. Choosing mild steel also had one more reason that being heavier; it would definitely resist vibrations and shock loads easily depending upon its design.

4. Design and manufacturing of Fixture:

4.1. Process Parameter Selection:

The most important and the centre point of the whole paper was to decide the process for parameter which should be selected to show most desired post welding properties with the demanded variation. It was one of the most tedious works as we had to select the parameter based on the constraint of the availability of variation, their behaviour on and after welding as well as on analysis post welding. it was when all the literature review done and came into the help again for selecting proper and simpler parameters to eliminate mathematical work and heavier calculation. Hence the selected parameters were,

i) Current, ii) Bevel angle, iii) Electrode (different diameter). The basic design of welding fixture is shown in figure 1.

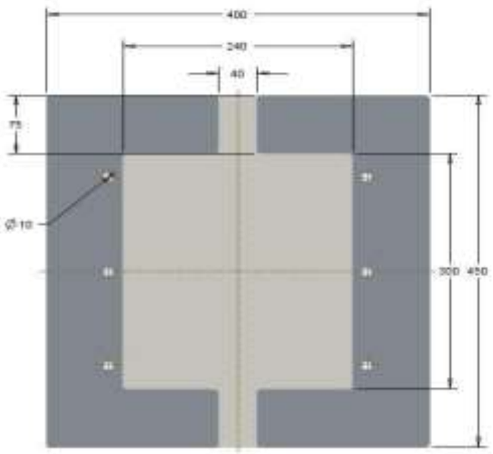


Figure 1: Basic Design of welding fixture

5. Experimental Design:

5.1. Design of experiments

The main aim of the project is to find out the optimized values of the process parameters and their effects on strength of weld and its defects like porosity. For carrying out the design of experiments, it was very important to understand the effects of all the three parameters and decide levels for the variation in carrying out the required amount of experiments. The three parameters of process will be the factors for the experiments and the response would be the tensile strength. The basic SMAW setup is shown in figure 2.

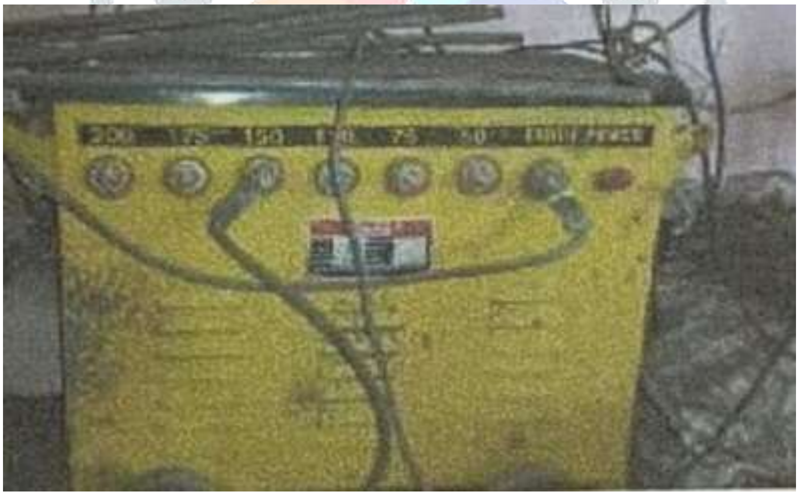
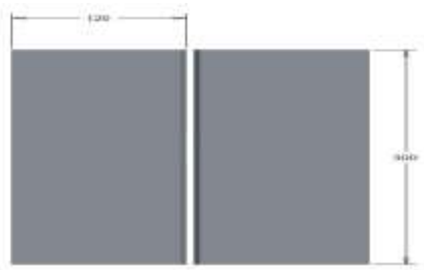


Figure 2: Basic SMAW setup.

5.2. Design of work piece:

The design of work piece was shown in figure 3. The work piece size was 300mm x 120mm x 6mm. One side of plate will be carbon steel and other side will be stainless steel.



(a)

(b)

Figure3: work piece size (a) line diagram of the work piece (b) final work piece

5.3.Universal Testing Machine (UTM)

We used Universal Testing Machine to measure ultimate tensile strength which was shown in figure 4. Machine can take load up to 60 KN.

Figure 4: Universal Testing Machine

5.4.Experimental procedure

The 300mm x 120mm x 6mm specimen were prepared by gas cutting method. These Specimen were fitted on fixture which was shown in figure 1.After all setup was completed we joined two plate by using SMAW welding method. we used various combination to weld by varying different current, bevel angle, and electrode diameter we performed welding. The joining process was derived from design of experiments levels. We also used Taguchi method to evaluate the best optimum number of parameters. We used ultrasonic method to find any internal defects like cracks, porosity, etc. After ultrasonic test we did test of plates on UTM (Universal Testing Machine) to measure universal tensile strength. The measured values of ultimate tensile strength were recorded and were put in Minitab software for further analysis. Various types of test like Taguchi analysis, ANOVA were used. In ANOVA response surface method was used.

6. Results and discussion:

6.1.ANOVA for ultimate tensile strength Analysis

Figure 5 shows the response surface diagram for ultimate tensile strength. It can be seen from figure that if current was increased then tensile strength would increase initially, but after certain value of current tensile strength would decrease. And with the increase of bevel angle tensile strength was decreases and with the increases of electrode diameter ultimate tensile strength was increases

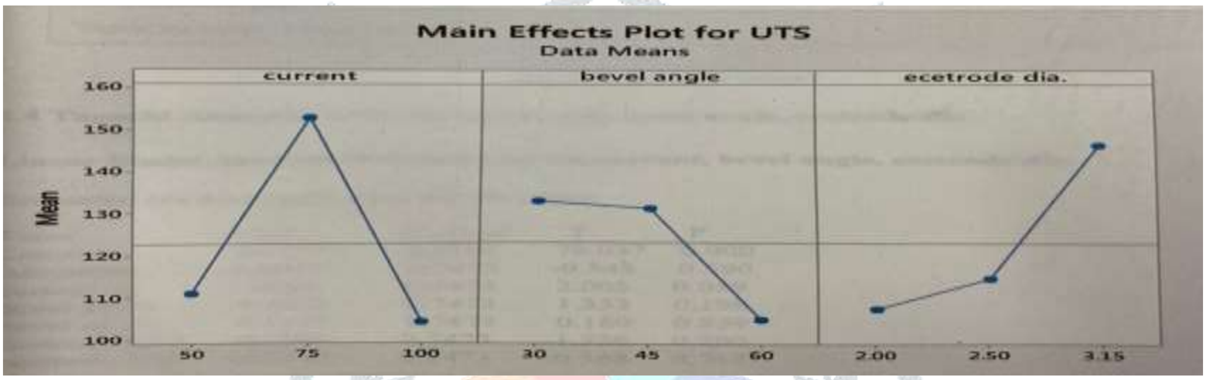


Fig 5 Main effects plot for UTS

6.2.Contour Plots

6.2.1. Contour plot of UTS vs. bevel angle, electrode diameter

As seen from the contour diagram 6 at lower electrode diameter and higher bevel angle ultimate tensile strength was lower which was shown in lighter green colour was contour plot. With increases in electrode diameter ultimate tensile strength increased which shown in dark green portion in contour plot.

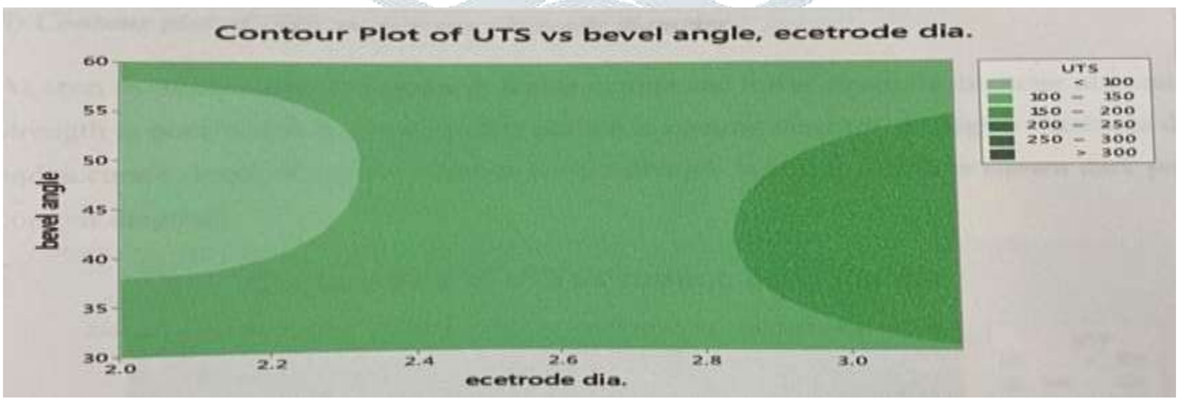


Fig 6 Contour plot of UTS vs bevel angle, electrode diameter

6.2.2. Contour plot of UTS vs. current , bevel angle

As seen from the contour diagram 7 ultimate tensile strength was increased with the increase in current and bevel angle. After certain value tensile strength was decreased with the increase in current and bevel angle.

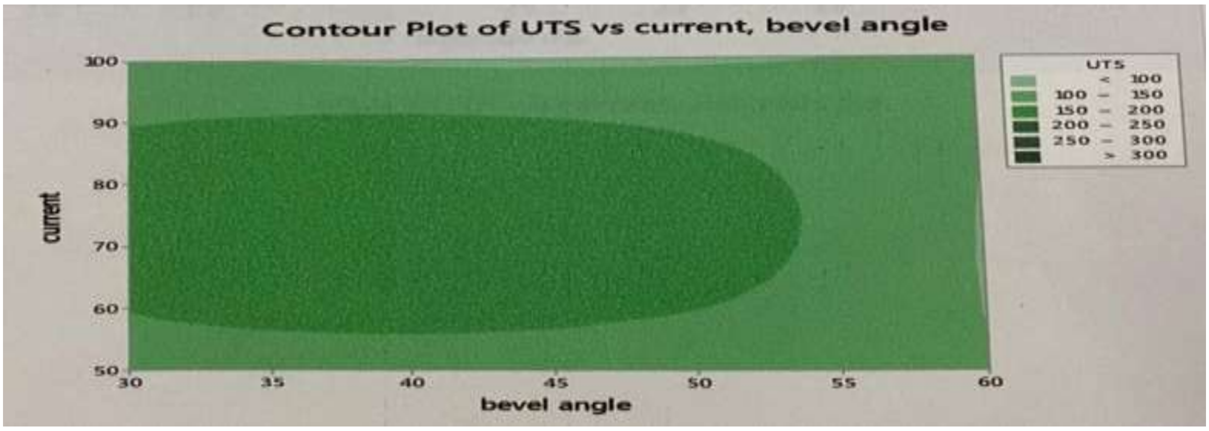


Fig 7 Contour plot of UTS vs current, bevel angle

6.2.3. Contour plot of UTS vs. current , electrode diameter

As seen from the contour diagram 8 at higher current and lower electrode diameter ultimate tensile strength was poor which was shown lighter portion in contour diagram. At higher electrode diameter and accurate level of current ultimate tensile strength was higher which was shown dark portion in contour diagram

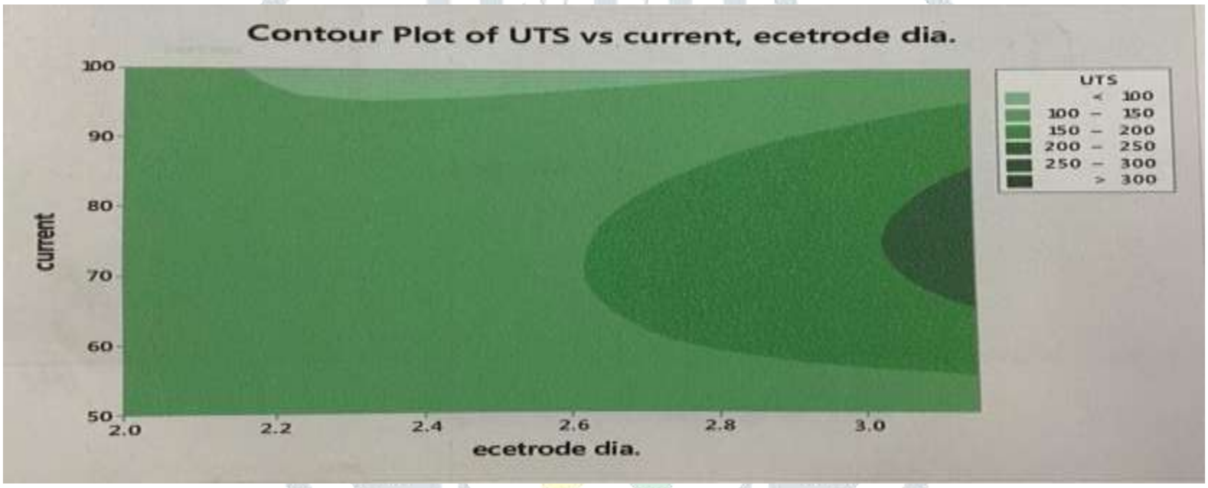


Fig 8 Contour plot of UTS vs current, electrode diameter

7. Conclusion:

In the present work, the effects of various parameters have been evaluated in welding of two different types of materials such as stainless steel and carbon steel. The experimental investigation has been done different welding parameter combination. Based on experimental observation graphs are plotted and results are critically discussed. The results indicated that with maximum electrode diameter, we get better strength and with lesser diameter of electrode get lesser tensile strength. The electrode diameter should kept maximum when we increase current. The bevel angle selection played important role in welding strength. The result shows that very high and very low bevel angle may decreases welding strength. The current selection also played vital role in welding strength. Very high and very low current may decreases welding strength. After developing the mathematical model and analyzing the parameters and their effects on the welding process, the observation came out that the selected parameters and their levels are widely accepted around the industries for welding the carbon steel and stainless steel under different welding processes.

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