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Optimization of Welding Parameters of TIG Welding on Welding Strength using Taguchi and ANOVA

Devesh Goyal[1], Pavan Agrawal[2]
[1]*Research Scholars, Department of Mechanical Engineering, VITM, Gwalior*
[2]*Asst. Professor, Department of Mechanical Engineering, VITM, Gwalior*

Abstract: Welding process is widely used by manufacturing engineers and production personnel to obtain desired products rapidly and effectively. In this research work, bead on plate welds were carried out on Stainless Steel 317 plates using Tungsten Inert Gas (TIG) welding process. The input process variables considered here are - welding current, welding voltage & gas flow. A total no of 9 experiments were conducted as suggested by Taguchi method. The analysis for signal-to-noise ratio was done using MINITAB-18 software with considering the 'larger-the-better' criteria. The significance of each parameter was studied by using the ANOVA (Analysis of Variance). Finally the confirmation tests were performed. Thus, with the proposed optimal parameters it is possible to increase the efficiency of welding joint by which tensile strength of joint can be increased with suitable set of parameters. The experimental values confirm its effectiveness in the analysis of tensile strength of the joint.
***Keywords*: Tensile strength, Stainless steel 317, Taguchi method, Orthogonal array (L9), ANOVA, TIG**

I. INTRODUCTION

Welding is a manufacturing process of creating a permanent joint obtained by the fusion of the surface of the parts to be joined together, with or without the application of pressure and a filler material. [7] Tungsten Inert Gas welding is also known as Gas tungsten arc welding (GTAW), is an arc welding process that uses a non-consumable tungsten electrode to produce arc. The welded area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler is normally used to weld thick plate. The electrode is no consumable since its melting point is about 3400^0C.The schematic diagram of GTAW or TIG welding process is shown in Figure.[10]

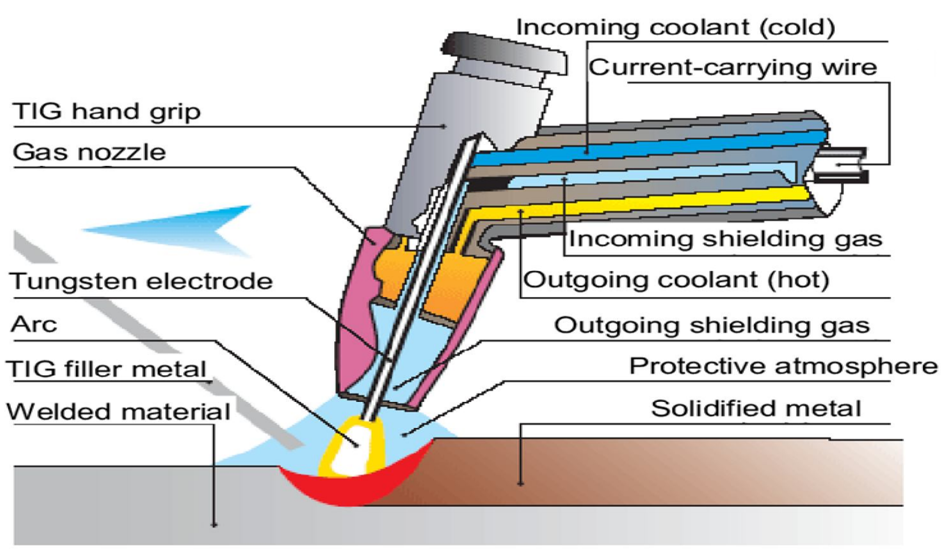

Fig.1 Schematic diagram of TIG Welding

Both the direct current (DC) and alternating current (AC) may be used for TIG welding. When the work is connected to the positive terminal of DC welding machine and the negative terminal to an electrode the welding set up is said to have straight polarity. When work is connected to negative and electrode to positive terminal then the welding set up is said to have reversed polarity.

A. Principle of Tungsten Inert Gas (TIG) welding

In TIG welding process, the electrode is non consumable and purpose of it only to create an arc. The heat-affected zone, molten metal and tungsten electrode are all shielded room atmospheric contamination by a blanket of inert gas fed through the GTAW torch. Fig. 1 shows schematic diagram of the working principle of TIG welding process. Welding torch consist of light weight handle, with provision for holding a stationary tungsten electrode. In the welding torch, the shielding gas flows by or along the electrode through a nozzle into arc region. An electric arc is created between electrode and the work piece material using a constant current welding power source to produce energy and conducted across the arc through a column of highly ionized gas and metal vapours. The electric arc produce high temperature and heat can be focused to malt and join two different parts of work piece

B. Advantages of TIG welding process

1) Concentrated arc produced for control heat input to the workpiece. It resulting in a narrow heat-affected zone.
2) This process is done without use of flux, therefore no slag formation during welding process.
3) No Sparks or Spatter because of no transfer of metal across the arc during TIG welding.
4) Compared to other arc welding processes like flux cored welding, fewer amounts of fumes or smokes are produced.
5) Welding of thin material is possible.
6) Welding dissimilar type material is possible.
7) Welding of different types of metal and metal alloys are possible by proper control

C. Autogenous TIG welding

A weld joint produced by melting the contact edge surfaces and subsequently solidifying it at room temperature (without addition of any filler metal) is called “autogenous weld”. Thus, the composition of the autogenous weld metal corresponds to the base metal only. However, autogenous weld is crack sensitive when solidification temperature range of the base metal to be welded is significantly high. TIG welding process performed without application of filler material is known as autogenous TIG welding process. Autogenous TIG welding is preferred especially for less than 5 mm thick plate. The advantages of this process are that, it is economical process as compare to heterogeneous or homogenous welding process as no edge preparation and filler material are required.

II. TAGUCHI METHOD

Traditional experimental design procedures are too complex and not easy to use. A large number of experimental works have to be carried out when the number of the process parameters increases with their levels. To solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with only a small number of experiments. The greatest advantage of this method is to save the effort in performing Experiments: to save the experimental time, to reduce the cost, and to find out significant factors fast. Taguchi robust design method is a most powerful tool for the design of a high-quality system. He considered three steps in a process’s and product’s development: system design, parameter design, and tolerance design. In system design, the engineer uses scientific and engineering principles to determine the fundamental configuration. In the parameter design step, the specific values for system parameters are determined. Tolerance design is used to determine the best tolerances for the parameters.

A. The Standard S/N Ratios Generally Used Are As Follows

1) Smaller-The-Better n: - 10 Log10 [means of sum of square of measured data]
2) Larger-The-Better n: - 10 Log10 [means of sum square of inverse of measured data]
3) Nominal-The-Best n: - 10 Log10 (squares of mean/ variance)

Chart 1. Steps to apply Taguchi method [5]

Determining of Quality Characteristics which required for optimization
↓
Identify the noise factor and test condition
↓
Identify the control factors and their different levels
↓
Develop the design matrix (OA)
↓
Conduction of experiments
↓
Analyze the data and determining the optimum levels of the control factors
↓
Perform the result operation

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III. ANOVA

Purpose of the ANOVA is to investigate which process parameters significantly affect the performance characteristics. The ANOVA procedure performs analysis of variance (ANOVA) for balanced and unbalanced data from a wide variety of experimental designs. In analysis of variance, a continuous response variable, known as a dependent variable, is measured under experimental conditions identified by classification variables, known as independent variables. The variation in the response is assumed to be due to effects in the classification, with random error accounting for the remaining variation. In short the basic idea behind analysis of variance (ANOVA) is to breakdown total variability of the experimental results into components of variance, and then assesses their significance. The significance of the variation components associated with factor effects is assessed by comparison with the residual. The optimum level of these significant parameters was found by examining the level averages of the factors. The F-test was utilized for comparing variances for this purpose.

IV. EXPERIMENT DETAILS

A number of experiments were conducted to study the effect of various machining parameter on welding process. These studies have been undertaken to investigate the effects of current, voltage and gas flow on tensile strength of welded joints.

Table 1 - Welding parameter and their levels

Levels	Current	Voltage	Gas flow
1	90	20	10
2	120	27	12
3	160	35	14

Table 2 - Experiment result of Tensile strength and S/N ratio

Experiment No	Current	Voltage	Gas Flow	Tensile(KN)	S/N Ratios
1	90	20	10	154.20	43.761
2	90	27	12	200.70	46.051
3	90	35	14	235.70	47.447
4	120	20	12	211.45	46.504
5	120	27	14	280.45	48.957
6	120	35	10	381.80	51.636
7	160	20	14	221.50	46.907
8	160	27	10	299.40	49.525
9	160	35	12	397.70	51.991

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Table 3 - Mean response table for Ultimate Tensile Strength (UTS)

Level	A	B	C
1	196.9	195.7	278.5
2	291.2	260.2	269.9
3	306.2	338.4	245.9
Delta	109.3	142.7	32.6
Rank	2	1	3

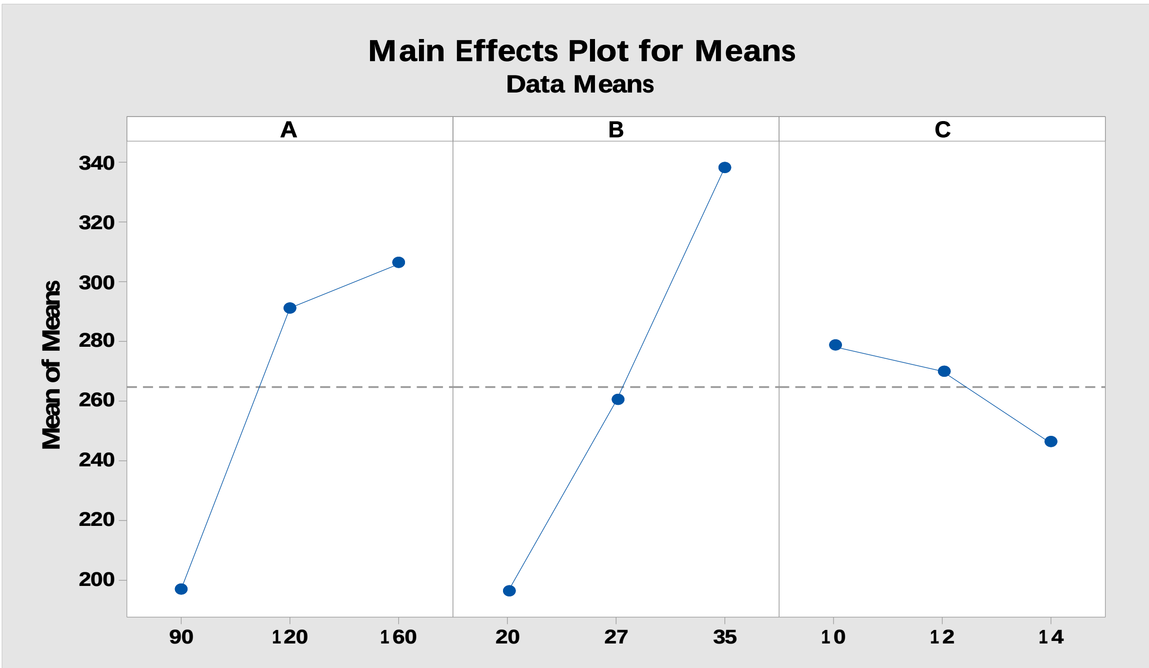

Fig 2 - Means of responce

Table 4 S/N Ratio response table for Ultimate Tensile Strength (UTS)

Level	A	B	C
1	45.75	45.72	48.31
2	49.03	48.18	48.18
3	49.47	50.36	47.77
Delta	3.72	4.63	0.54
Rank	2	1	3

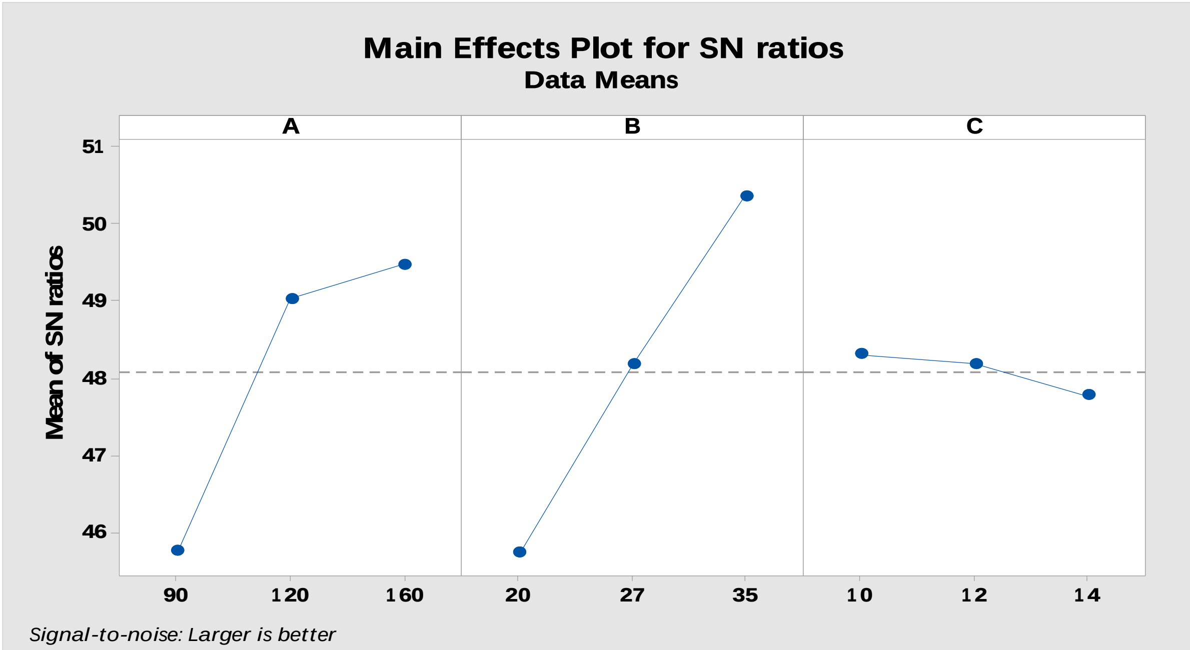

Fig 3 Means of S/N Ratio

V. THE ANOVA ANALYSIS

The ANOVA analysis for ultimate tensile strength verses gas presser, current and voltage by using Minitab 18 software are shown in Table

Table 5 – ANOVA Table

Source	DF	Adj SS	Adj MS	F	P
Current	2	20373	10187.6	15.54	0.059
Voltage	2	31082	15541.8	22.92	0.043
Gas Flow	2	1521	762.5	1.07	0.464
ERROR	2	1327	659.7		
TOTAL	8	54303			

The ANOVA analysis shows the percentage contribution of given input parameters on measurable output parameter with help of Minitab 18 software.

Table 6 Percentage contribution of input parameter on Tensile strength

Input parameter	Percentage contribution (%)
Current	18.10
Voltage	74.56
Gas flow	1.65
Error	5.69

VI. CONCLUSION

TIG welding is one of the best welding technique by which we can join two similar and dissimilar materials. Analysis of variance (ANOVA) helps to find out the significance level of the each parameter. The optimum value was determined using MINITAB-18 software.

A. Based on the investigations following conclusions can be made

1) TIG welding process is very successful to join stainless steel 317.
2) Based on S/N ratio analysis and ANOVA, the process parameters which significantly affects the ultimate tensile strength was voltage and welding current.
3) The effect of parameters on the ultimate tensile strength can be ranked in decreasing order as follows: Voltage > current>gas Flow

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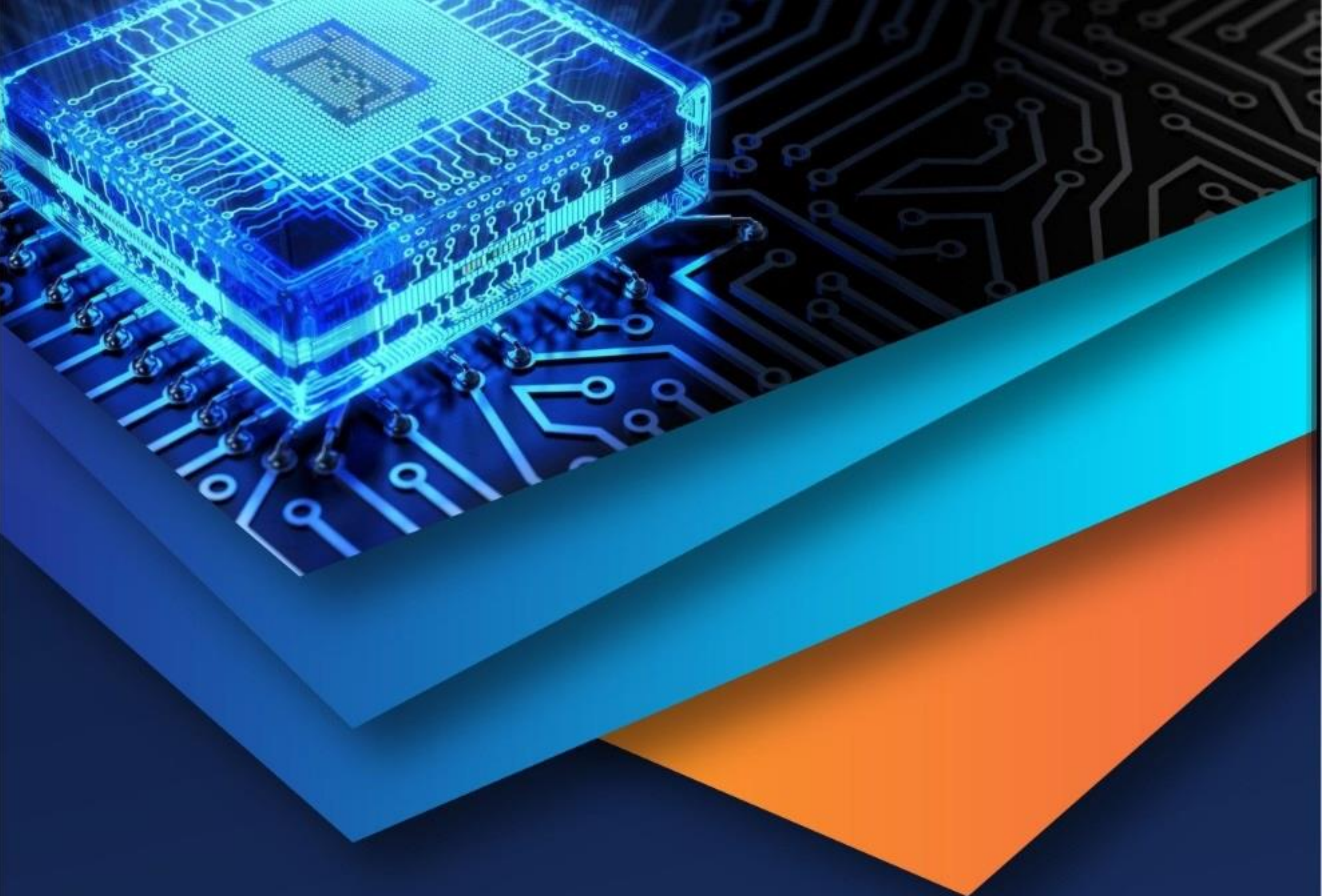

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