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Optimization of Tungsten Inert Gas welding using Taguchi and ANOVA

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Abstract: Welding processes are extensively used by manufacturing engineers and production persons to quickly and effectively to obtain desired products. In this research work, bead on bar welds were carried out on EN8 & EN24 solid cylindrical bar using Tungsten Inert Gas (TIG) welding process. The input process variables considered here are - welding current, welding voltage & gas flow rate. A total no of 9 experiments were conducted as suggested by Taguchi method. The analysis for signal-to-noise (S/N) ratio was done using MINITAB-18 software with higher-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 parameter.the experimental values confirm its effectiveness in the analysis of tensile strength of the joint.
Keywords: Tensile strength, EN8 & EN24, Taguchi method, Orthogonal array (L9), ANOVA, TIG Welding

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^{0}C.The schematic diagram of GTAW or TIG welding process is shown in Figure. [1]

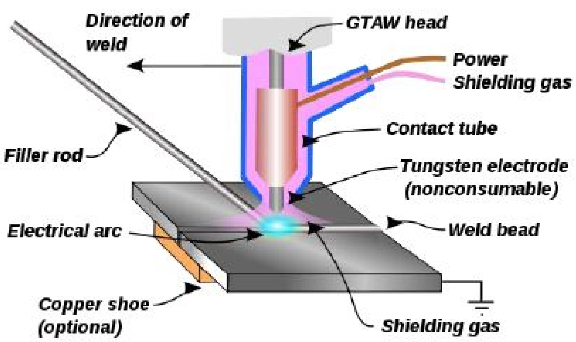

Fig.1-Schematic diagram of TIG Welding

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 GTAW machine

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 work piece. 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
↓
Analyse the data and determining the optimum levels of the control factors
↓
Perform the result operation

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

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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 DETAIL

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 & gas flow rate on tensile strength of dissimilar welded joints.

Table 1 - Welding parameter and their levels

Levels	Current	Voltage	Gas flow rate
1	90	24	8
2	110	26	10
3	130	28	12

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

Experiment No	Current	Voltage	Gas flow rate	Tensile(KN)	S/N Ratios
1	90	24	8	68.4	36.7011
2	90	26	10	72.1	37.1587
3	90	28	12	67.9	36.6374
4	110	24	10	65.2	36.2850
5	110	26	12	64.2	36.1507
6	110	28	8	76.4	37.6619
7	130	24	12	58.4	35.3283
8	130	26	8	58.8	35.3875
9	130	28	10	61.7	35.8057

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

Level	A	B	C
1	69.47	64.00	67.87
2	68.60	65.03	66.33
3	59.63	68.67	63.50
Delta	9.83	4.67	4.37
Rank	1	2	3

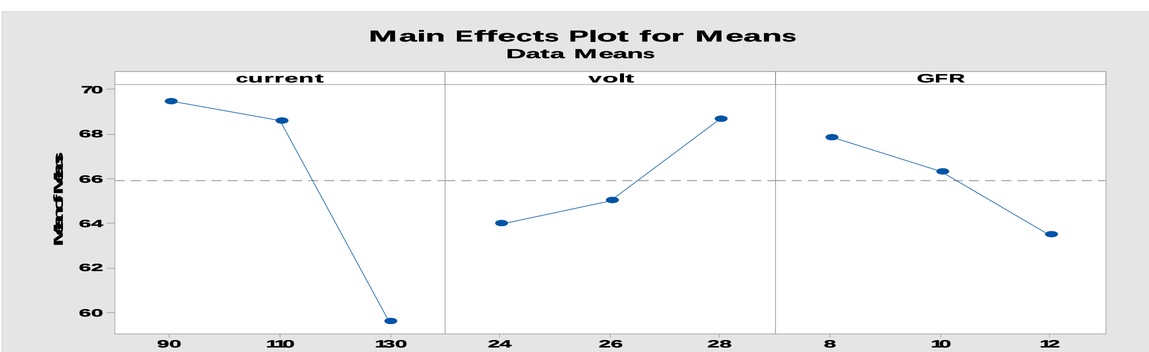

Fig 2 - Means of responce

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

Level	A	B	C
1	36.83	36.10	36.58
2	36.70	36.23	36.42
3	35.51	36.70	36.04
Delta	1.33	0.60	0.54
Rank	1	2	3

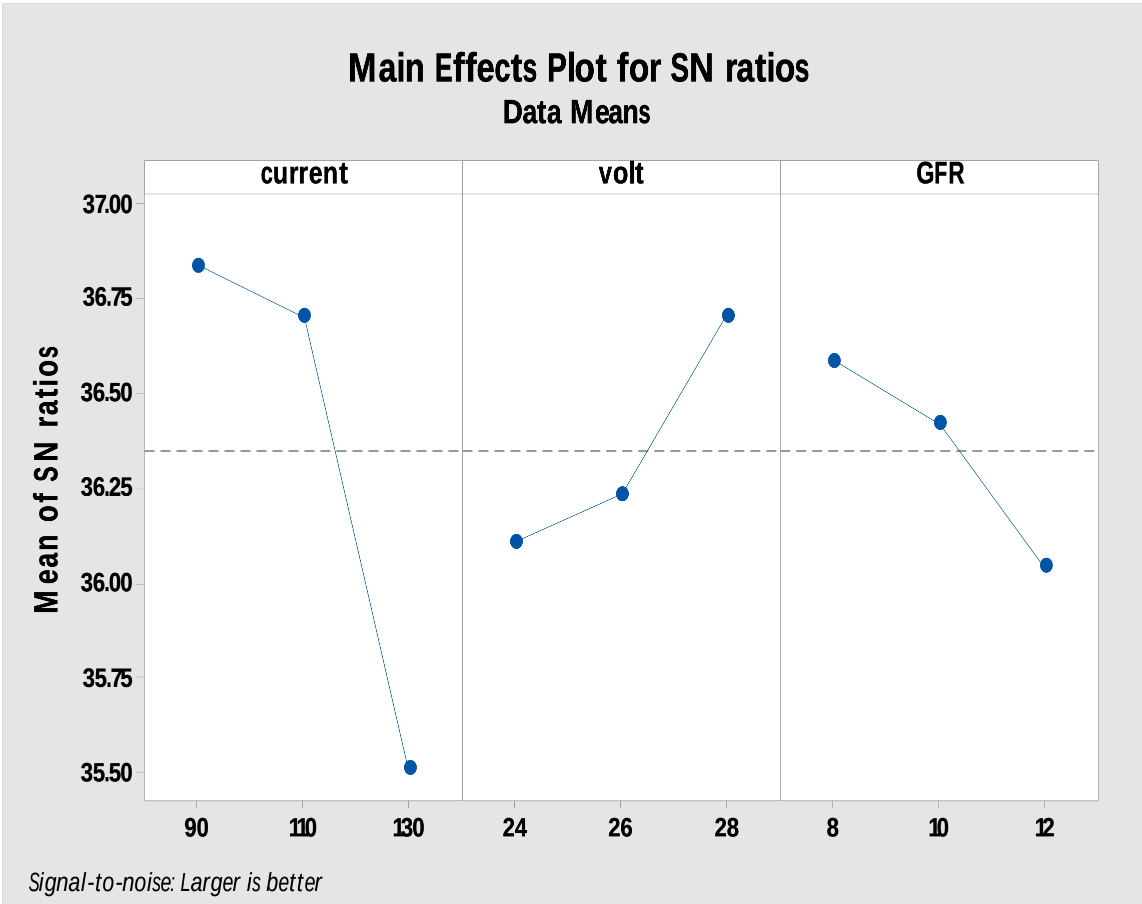

Fig 3 - Means of SN Ratio

Table 4 - ANOVA Table

Source	DF	Adj SS	Adj MS	F	P
Volt	2	36.05	18.02	0.83	0.546
GFR	2	29.45	14.72	0.68	0.595
current	2	177.85	88.92	4.11	0.196
Error	2	43.28	21.64		
Total	8	286.62			

V. RESULTS OF ANOVA

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

Percentage contribution of input parameter on Tensile strength

Input parameter	Percentage contribution (%)
Gas pressure	1.65
Current	18.10
Voltage	74.56
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.

Based on the investigations following conclusions can be made

A. TIG welding process is very successful to join EN8 & EN24.

B. Based on S/N ratio analysis and ANOVA, the process parameters which significantly affects the ultimate tensile strength was voltage and welding current.

C. The effect of parameters on the ultimate tensile strength can be ranked in decreasing order as follows: voltage > current>pressure

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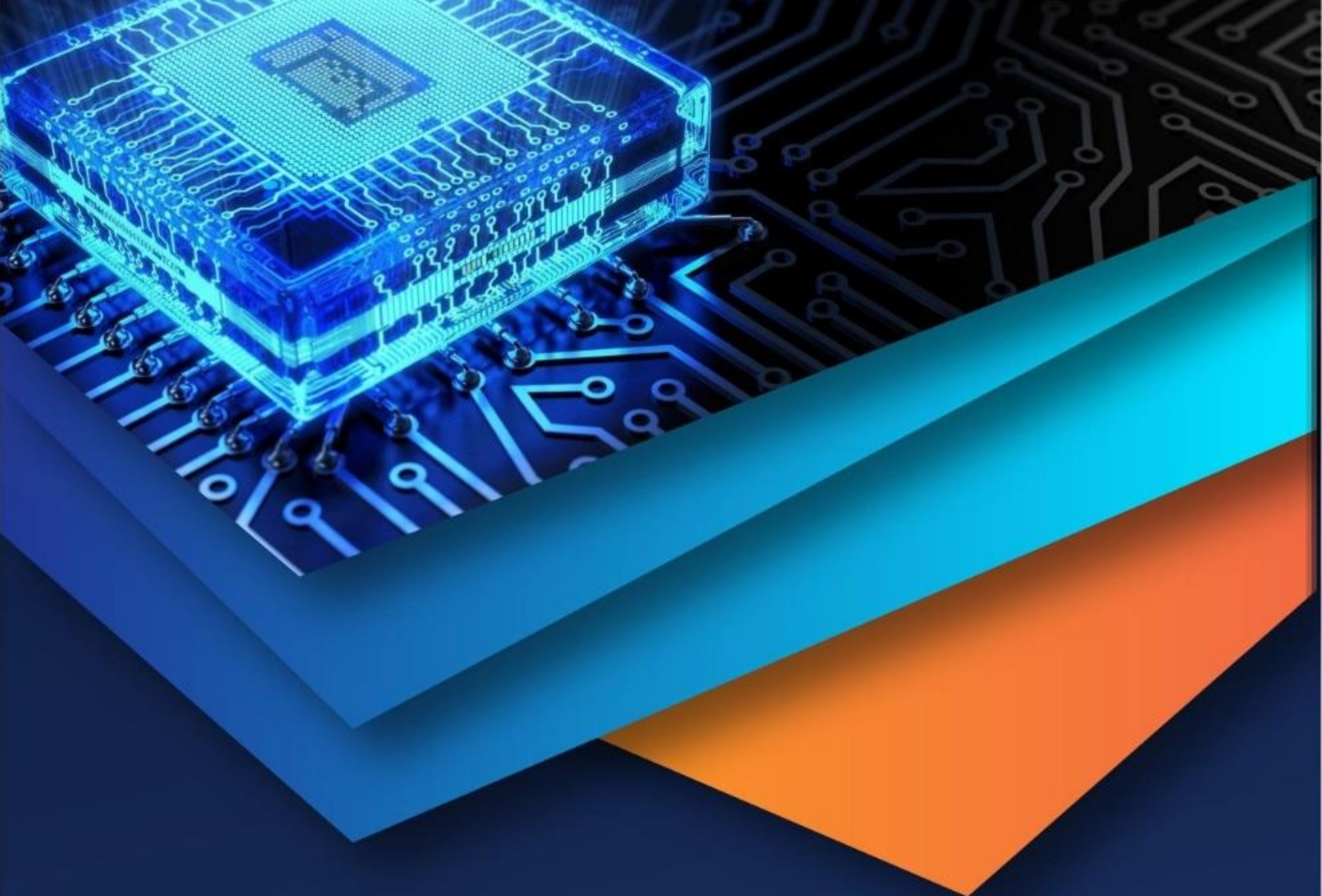

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