STUDY AND PARAMETRIC OPTIMIZATION OF GAS METAL ARC WELDING PROCESS (GMAW) PROCESS

[1]Shweta S. Adayprabhu, [2] Vishal Wankhade, [3] Dr.Pradeep Patil,

[1]ME Student, [2] Assistant Professor, [3]Assossiate Professor

[123] Mechanical Engineering Department, Swami Vivekanand College of Engineering, Indore, India.

Abstract: Welding is widely used by metalworkers in fabrication, maintenance and repair of parts and structures. The arc welding process is a remarkably complex operation involving extremely high temperatures, which produce severe distortions and high levels of residual stresses. These extreme phenomena tend to reduce strength of the structure, which becomes vulnerable to fracture, buckling, corrosion and other type of failures. In gas shielded arc welding, an inert gas is used as a covering shield around the arc to prevent the atmosphere from the contaminating the weld. For the same Taguchi methods are applied to reform the objectives of the study. All these targets are achieved by making an experimental setup.

***IndexTerms* - arc welding, fracture, buckling, inert gas, taguchi method.**

I. INTRODUCTION

The arc welding process is an extremely multifaceted process, needs high temperatures, which results in severe distortions and lasting stresses. These extreme phenomena tend to reduce the strength of a structure, which becomes vulnerable to fracture, buckling, corrosion and other type of failures. The primary goal of any welding operation is to make a weld having the same properties as the base metal. The only way to produce such a weld is to protect the molten puddle from atmosphere. In a gas shielded arc welding process, an inert gas is used for covering shield around the arc to prevent the atmosphere from contaminating the weld. Gas shielding makes it possible to weld metals that are otherwise impartial or difficult to weld by eliminating atmospheric contamination of the molten puddle. In order to weld all kinds of ferrous / nonferrous metals of all thickness, Gas shielded AW is most useful. In general, the controlling factors are the metal types you are using for joining, cost involved, nature of the products you are fabricat8ing, and the techniques used to fabricate them.

II. LITERATURE SURVEY

Chunlin Dong et.al performed Preliminary study on the mechanism of Arc Welding with the activated flux type 304 austenitic stainless steel with different S content. Individual flux compound such as TiO_2, Cr_2O_3, SiO_2, ZrO_2 is used it is found that Weld Penetration depth dramatically increase in presence of some individual Oxides. It is found that fluid flow appear n outward direction in case of ZrO_2.

M Tanaka et.al study Arc constriction and observed during A-TIG welding and this is caused by changes within the arc plasma for the distribution of metal vapors from the weld pool, accompanied by variation in the size and the surface temperature of the weld pool. The constriction of either the arc or the arc root does not play a central role as the deep penetration mechanism during A-TIG welding but cannot be ignored as an auxiliary factor for deep penetration, as seen in high S stainless steel helium TIG welding.

Ugur Esmel et.al study has concentrated on the application of Taguchi method coupled with Grey relation analysis for solving multi criteria optimization problem in the field of tungsten inert gas welding process. Experimental results have shown that the tensile load, heat affected zone and penetration, area of penetration, heat affected zone, bead width and bead height of the weld bead in the TIG welding of stainless steel are greatly improved by using Grey relation analysis in combination with Taguchi method.

III. PROBLEM FORMULATION & OBJECTIVES

The present work "optimization of ATIG Welding process parameter for enhancement of weld penetration" has been undertaken keeping in consideration the following problem.

Inadequate weld bead dimensions such as shallow depth of penetration may contribute to failure of a welded structure since penetration determines the stress carrying capacity of a weld joint.

To avoid such occurrences the input or welding process variables which influence the weld bead penetration must therefore be properly selected and optimized to obtain an acceptable weld bead penetration and hence a high quality joint.

Objective of dissertation work is;

1. Comparative study of coated uncoated sample.
2. Find out the most effective parameter by Taguchi Method.
3. Enhancement of weld Penetration.
4. Study the effect on tensile strength on welded sample.

IV. METHODOLOGY

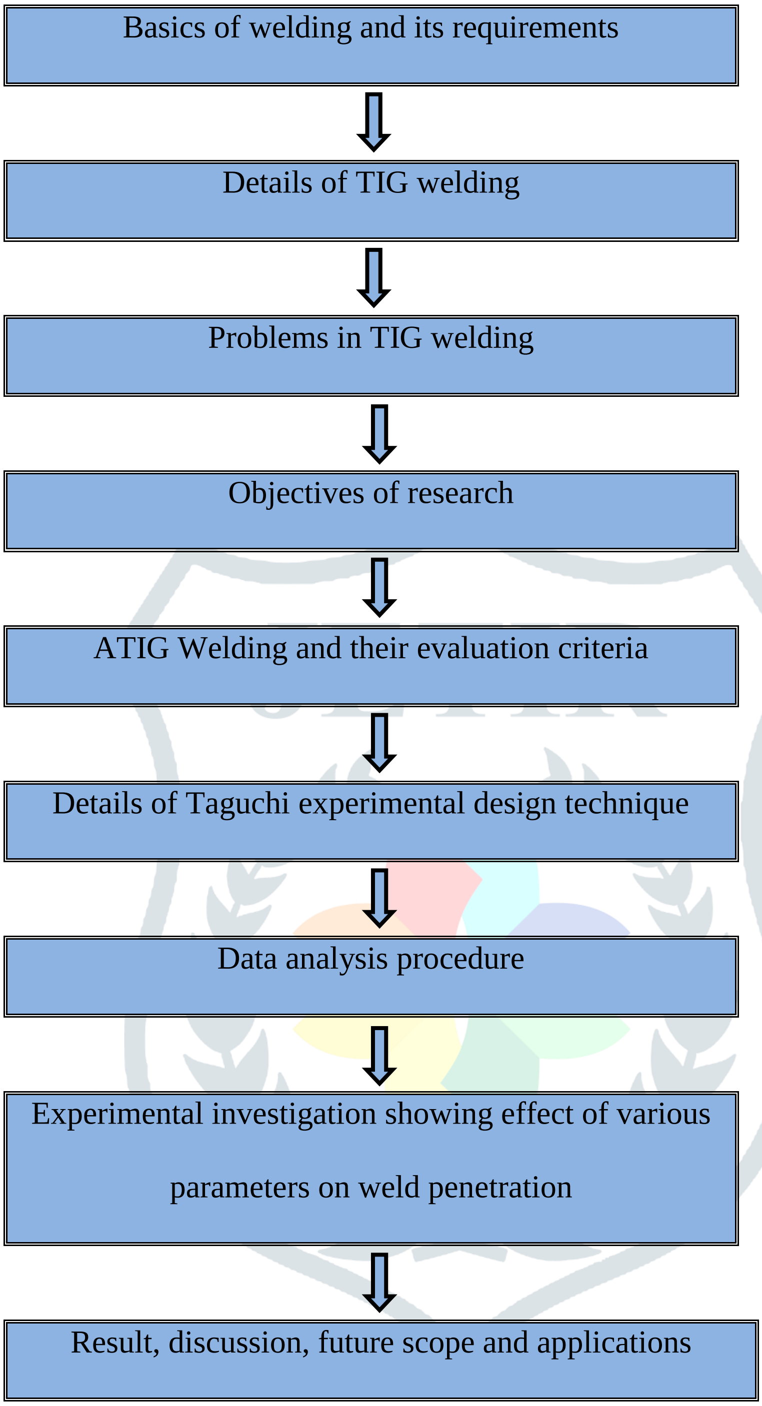

Figure : Methodology

V. SYSTEM DEVELOPMENT

For studying the effects of Welding Process parameters on the weld penetration in the TIG welding heat source is most commonly required. Heat source produces the electric arc which generates the heat for melting the metals and to form the weld for particular purpose which is to be continuous supplied either by direct current or by the alternating electric current. This TIG welding machine has fallowing technical specifications,

1. Input power 18.4 KVA
2. Current range 20A-400 A
3. Duty cycle 60%
4. Weight 43 Kg
5. Input supply 380-440 V
6. Efficiency at full load 89%
7. Power factor 0.95
8. Ambient Temperature 40 degree C

Machine Tool Features:

1. Advanced soft switching inverter Technology and high efficiency.
2. Digital display of current and precise present function.
3. High power factor.

4. High Switching frequency, hence low volume and weight.
5. 2/4 Track functions in TIG.
6. Adjustable Down slope function in TIG.
7. Can be used with extended welding cable in MMA.
8. Basic outfits Power source, Remote socket for Torch trigger.
9. Optional TIG welding, Argon regulator, water circulating system, wired remote controller.

AISI304 Steel materials plates are used, having large scale application in process industry. Sample of 100mm×70mm×5mm size has been used as a work piece material and bead on welding is done for present experiments. The SS304 sheet was changed into the desired work pieces sizes by shearing operation application. After shearing the work pieces are straighten by holding them in a press. The burr from the cut edges of the work pieces is removed by manual filing.

Activated flux can increase the joint penetration, mainly because the surfactant (surface-active element) in the molten pool switches the surface tension gradient, and consequently reverses the Marangoni convection pattern, resulting in a deep-penetration weld. To clear this concept, the following studies are used for flux powder.

The SS304 sheet is converted in to the desired 100mm×70mm×5mm size by using shearing operation. After shearing the work pieces are straighten by holding them in a press. The burr from the cut edges of the work pieces is removed by manual filing the plate surface was ground using 400 grit (silicon carbide) flexible abrasive paper to remove the impurities, and then clean the surface with acetone . The different types of flux powders were mixed with acetone for obtaining paint-like consistency. A brush to apply the mixture over joints of the surface to be welded. The coating density of flux powder application was 4.3 mg/cm2.

Table: List of Specimen Plate for Welding

Sr.No	1	2	3	4	5	6
Sample	TiO2 Coated	Cr2O3 Coated	Al2O3 Coated	Uncoated	CaO Coated	SiO2 Coated

Figure : Preparations and Application of Activated Flux Powder

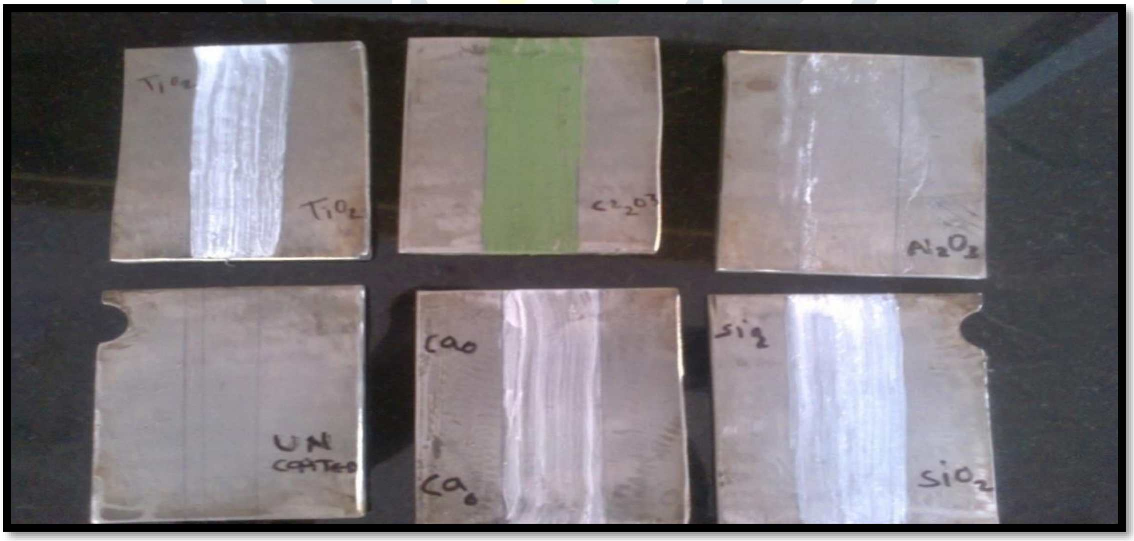

Figure : Activated Flux Powder Coated Sample

The primary goals of designed experiments are to:

- Determine the variables and there magnitude that influences the response.
- Determine levels of these variables.
- Determine how to manipulate these variables to control the response.

Experimental design is used to:

i) Improve process by increasing its performance and eliminate troubles.

ii) Establish statistical control of a process variable that is to identify the variables to control the process.

iii) Improve the existing product or develop a new product.

Guidelines for designing of an experiment are :

- Recognition and statement of the problem
- Selection of the response of the problem
- Choice of the factors, levels and ranges
- Performing the experiments
- Statistical analysis of the data
- Conclusions and recommendations

Generally, the steps 2 & 3 are usually performed simultaneously, or in the reverse step.

Requirements for Experimentation,

- Materials – stainless steel
  Shearing saw
- Chemical – HCL,H2SO4,Aceton
- Activated flux powder
- Metallurgical Microscope with photographs attachment
- Optical emission Spectrometer for chemical analysis
- Digital weight m/c, Vernier calliper, micrometer and height gauge.
- Stopwatch
- Stirrer and beakers
- Rubber gloves, goggles, plastic bags, jars, plastic trays
- ATIG Welding machine.

Table: List of Fixed Process Parameters

Sr. No.	Fixed Parameters	Level at which it is fixed
1	Welding current (A)	200
2	Gas flow rate(LPM)	15
3	Welding speed (second)	60
4	Torch angle	60 degree
5	Nozzle tip to work piece distance	3 mm
6	Work Piece size	100 mm × 70 mm × 5mm

Table: Preliminary Test Results of Various Activated Flux Powder

Activated Flux Powder	Weld penetration(mm)
Uncoated	2.0
Cr2O3 Coated	4.10
TiO2 Coated	2.70
Al2O3 Coated	2.20
CaO Coated	2.50
SiO2 Coated	3.00

Table: Effect of Welding Current on Weld Penetration

Sr.No	Welding current(A)	Weld penetration in mm
1	150	2.5
2	200	3.1
3	250	4.1
4	300	5.0

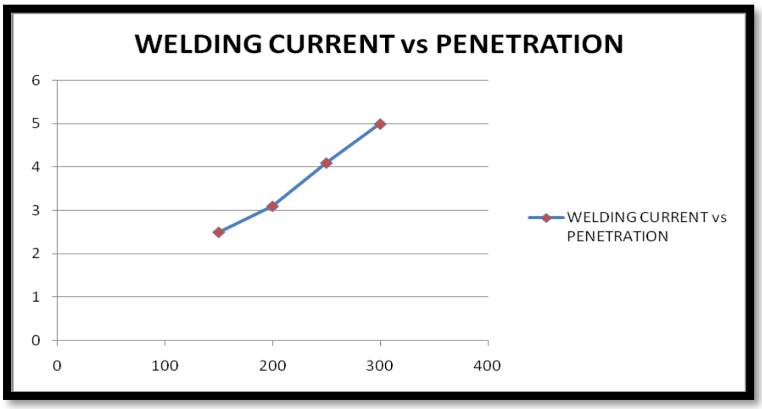

Figure: Graph Effect of Welding Current on Weld Penetration

Table: Effect of Welding Current on Weld Penetration

Sr.No	Gas flow rate(LPM)	Weld penetration in mm
1	5	3
2	10	3.5
3	15	5.0

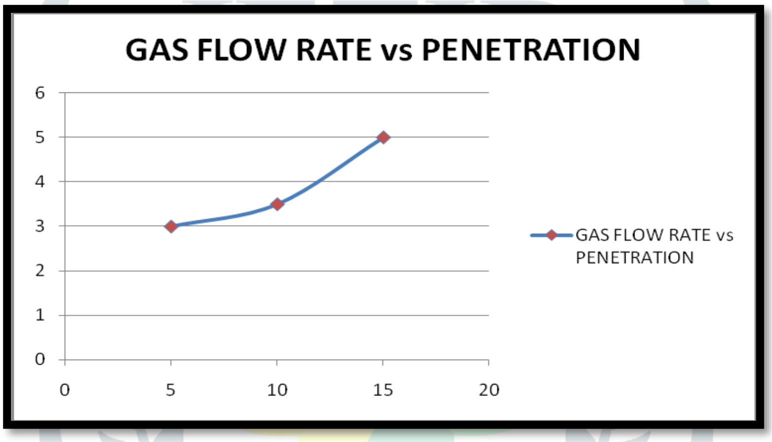

Figure: Graph Effect of Welding Gas Flow Rate on Weld Penetration

Table 5.9: Effect of Welding Speed on Weld Penetration

Sr. No	Welding speed	Weld penetration in mm
1	6.66	3
2	3.33	3.5
3	1.66	5.0

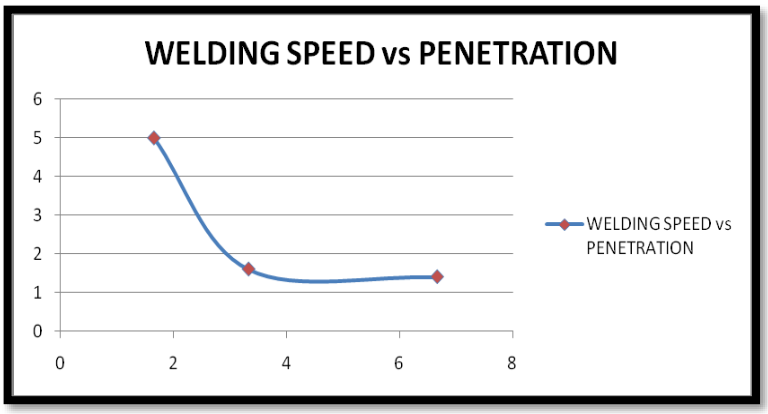

Figure: Graph Effect of Welding speed on Weld Penetration

Table: Effect of Torch Angle on Weld Penetration

Sr.No.	Torch Angle in degree	Weld penetration in mm
1	60	5
2	75	3
3	90	1.6

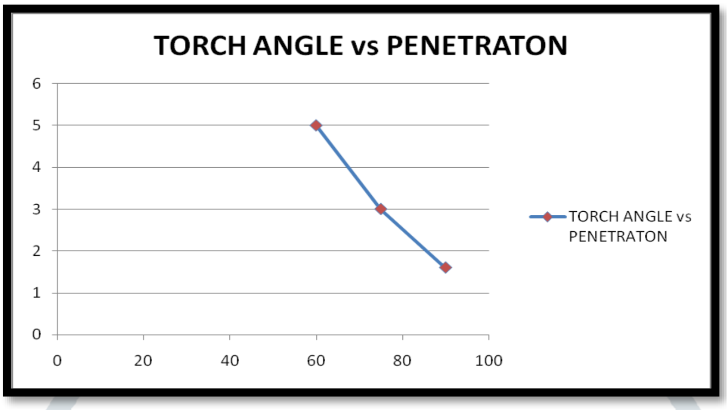

Figure: Graph Effect of Torch angle on Weld Penetration

VI. PERFORMANCE ANALYSIS

Design of Experiments

I) Purpose of Experimentation

The purpose of the product or the process development is to improve the performance characteristics of the product or the process relative to the customer needs and the expectations. The purpose of experimentation should be to understand how to reduce and control variation of a product or process; subsequently, decision must be made concerning which parameters affect the performance of a product or process. The loss function quantifies the need to understand which design factors influence the average and variation of a performance characteristic of a product or process. By properly adjusting the average and reducing variation, the product or process losses can be minimized.

II) Basis of Experimentation

This approach is based on the use of orthogonal array (Taguchi) to conduct small, highly fractional factorial experiments up to larger, full factorial experiments. The orthogonal array is basically used to design an experiment, but it's the most flexible in accommodating a variety of situations and also is easier for statistically oriented people to execute on the normal practical basis.

III) Definition of Design of Experiment

The designed experiment is continuous result of the two or the more factors (parameters) for their ability to affect the resultant average or variability of particular product or process characteristics. To get this in an very effective and statistically exact manner, the levels of the factors are managed in a proper manner, the results of this particular test combination is observed to be, and the complete set of results is analyzed to determine the influential factors and preferred levels, and whether increases or decreases of those levels will potentially lead to further improvement. It is important to note that this is an iterative process; the first round through the DOE process will many times lead to subsequent round of experimentation.

The DOE process is divided into three main phases which encompass all experimentation approaches. The three phases are:

1. Planning Phase
2. The conducting phase
3. The analysis phase

Steps in Experimental Design and Analysis

I) Selection of orthogonal array (OA)
II) Assignment of parameters and interaction to the OA
III) Selection of outer array
IV) Experimentation and data collection
V) Data analysis
VI) Parameter design strategy

Table 6.3: Experimental Results

Sr. no.	Welding Current(Amp)	Gas flow rate(LPM)	Welding speed(mm/s)	Weld Penetration(mm)
1	150	10	6.66	1.6
2	150	12.5	3.33	2.5
3	150	15	1.66	2.7
4	175	10	3.33	3.0
5	175	12.5	1.66	5.0
6	175	15	6.66	3.0
7	200	10	1.66	2.5
8	200	12.5	6.66	2.5
9	200	15	3.33	2.0

VII. CONCLUSION

The best result for welding penetration by the Taguchi Method is given as below;
According to Taguchi methods, an attempt is made to determine set of values of process variable at their selected levels.
Predicted optimum value of the welding penetration 4.89 mm but the actual value for the welding penetration is 5.00 mm at the conditions of confidence interval as shown in table where conclusions are according to the Taguchi method.

Table 7.1: Predicted Value Vs Actual Value of Welding Penetration

Response	Predicted Value	Actual Value
The welding Penetration Set for the optimum value of the process parameters are as below, 1. Welding Current 175 Amp 2. Gas flow rate 12.5 LPM 3. Welding Speed 1.66 mm/sec	4.89 mm	5.0 mm

Adding advantage to welding Penetration is that one additional test is performed which analyze the tensile strength. The standard value of tensile strength for 5mm AISI304 Plate is in the range of 540 to 750 N/mm2 and when the Specimen is welded with Cr_2O_3 Coating. Optimum Parameter in addition of full Weld Penetration the tensile strength obtained to be 707 N/mm2 which is supposed to be within the Standard range of Tensile strength.

VIII. APPLICATIONS

The major constraints of the TIG welding for the austenitic stainless steels are because of the limited thickness of the material which can be welded in a single pass, the poor tolerance to cast variations and the low productivity. The thickness of austenitic stainless steel that has to be welded in single pass is normally limited to 3 mm with argon as the shielding gas. Therefore, improvements in weld penetration have long been sought in austenitic stainless steel welds produced by TIG welding process because TIG welding result in high quality welds besides providing for exact control of the heat input and the low cost of the equipment. A novel variant of the TIG welding process called A-TIG is known to overcome the limitations. This process includes applying a thin coating of the activated flux on the joint before welding. The Cr_2O_3 activated flux has been used in the present work for enhancing the penetration during autogenously TIG welding of type 304LN steels. The use of activated flux produced a significant increase in penetration of 5.0 mm in single pass TIG welding of 304LN as compared to 1.2mm penetration of uncoated 304LN Steel plate.

IX. FUTURE SCOPE

A Penetration Enhancing Activating Flux (PEAF) in paste form for autogenously TIG welding of austenitic stainless steels adapted for ready application with a brush on top weld surface prior to conducting autogenously TIG welding to favor single weld pass, of austenitic stainless steels of AISI 304LN and AISI 316LN varieties with weld bead penetration up to a section thickness of 12 mm. Importantly, the (PEAF) paste based TIG welding of the invention achieves an increase in weld bead penetration of about 300% over the conventional TIG process without activating flux. The PEAF paste based TIG welding also favors higher productivity and high quality apart from being cost-effective due to fewer requirements of consumables and controlled heat input to arrest deformation, making it extensively acceptable for the variety of industrial applications for welding of the austenitic stainless steel.

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