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Parametric Optimization of MIG Welding for Dissimilar Metals Using Taguchi Design Method

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ABSTRACT

The present work deals with optimization of welding process variables by using Metal inert gas welding.The aim of my work is to study the hardness that affect the welding joint of dissimilar metals. Stainless Steel 304 was welded to C-25 carbon steel using a metal inert gas welding which also known as gas metal arc is welding with the help of filler wire of stainless steel and 0.8 mm diameter. Argon gas was used as shielding gas in this process. Dissimilar metals welding have great scope in advanced technology now a days owing to their high strenght, hardness, and corrosion resistance properties. The combination of midium carbon steel and austenitic stainless steel has got large number of application in industry such as tublar product, building and costruction, nuclear plant, and heat exchanger assembly etc. Due to the fact that low cost of C-25 carbon steel and corrosion resistance property of stainless steel. All these applications are require welding of the two which can perform the desired service requirement of the industry. In this experiment we got that the hardness depend on the variable parameter and wire feed rate is the main effective parameter.

Keywords: Metal Inert Gas, Hardness, Taguchi Method

I. INTRODUCTION

Joining dissimilar metals is essential nowadays in manufacturing and constructing advanced machineries and equipments. Dissimilar joints can be used to create mechanically robust joints between parts composed of dissimilar metals in marine, automotives, aerospace, boiler and medical applications. Different kinds of metals feature different physical, chemical and metallurgical properties: some are stronger, some have high weldablity, some are high corrosion resistant, some are easily machinable, etc. Dissimilar weld is therefore required to compose different properties of metals in order to minimize material cost, maximize the performance and reduce the vulnerability to failure and maintenance. In recent times there has been an increase in the interest of the use of welding techniques to join dissimilar metals mainly ferrous with non ferrous. Welding is a fabrication process used to join materials, usually metals or thermoplastics, together. During welding, the pieces to be joined (the workpieces) are melted at the joining interface and usually a filler material is added to form a pool of molten material (the weld pool) that solidifies to become a strong joint. In contrast, Soldering and Brazing do not involve melting the workpiece but rather a lower-melting-point material is melted between the workpieces to bond them together.

A. History of MIG / MAG (GMAW)

We know that MIG welding is one of most versatile technique till now in modern production technology and most importantly, it is suitable for both either for thin sheet or thick section components. Basically, in this process, an electric arc is produced between the consumable wire electrode and the workpiece, due to this heat workpiece metal melts and join.GMAW was developed during the early 1940’s and technology was taken from the TIG welding process that was already around at the time. MIG (MAG) welding has the advantage of a particular gas shield that TIG has, and then adds the advantage of a continuous consumable wire electrode. At the time the MIG process was able to increase the production of war manufacturing. It has since become one of the main stages of manufacturing from that time until the present day. Through the years MIG/MAG has undergone changes in the types of wires, gases, and power sources, but the principles remain the same. With the onset of the manufacturing in the 1960's and 1970's the types of wire electrodes have been upgraded to give wire electrodes with higher deposition rates, better finishes and wires more suitable for more modern steel types. The welding gases have also evolved in the same way to make MIG welding faster, more efficient and with a better finish. One of the major changes has also been with power sources and feeders. MIG welding power sources have, over the years, gone from basic transformer types to the highly electronic power sources of the world today.

B. MIG Overview

A MIG welder uses a DC voltage controlled electric power source (different from that of an arc welder), connected to a wire feeder which holds a spool of the type of wire needed to do the job. The feeder will push the wire down which is known as a MIG handpiece. This is done by feeding the wire through a set of rollers. A suitable gas mixture is also fed down the MIG handpiece. Different gases are used for different types of wire.Basically, the MIG process uses a gas or gas mixture to displace the air around the arc that is being formed between the wire being used and the base metal. This is done by using an electric MIG power source. The electrode is still being melted with an electric arc, but in the case of MIG it is a special wire which is mechanically fed into the arc.The feed rate is adjusted depending on the thickness of the material being welded. The voltage of the electric power source is also adjusted depending on the material thickness being welded.

C. Introduction to Dissimilar Metal Welding

All welding processes have a component of dissimilar metal welding about them. Dissimilar metals welding are defined in which weldaments are made from metals of different compositions. A successful weld between dissimilar metal is one that is as strong as the weaker of the two metals being joined, i.e., possessing sufficient tensile strength and ductility so that the joint will not fail in the weld. Nowadays, joining dissimilar metals are indispensable in manufacturing and constructing advanced equipment and machinery. Different kind of metal features, different chemical, physical, and metallurgical properties: some are more resistible to corrosion, lighter, and some are stronger. Joining dissimilar metals are, therefore, to compose different properties of metals in order to minimize material costs and at the same time maximize the performance of the equipment and machinery. The problem of making weld between dissimilar metals related to the transition zone between the metals and the intermetallic compound formed in this transition zone. For the fusion type welding process it is important to investigate the phase diagram of the two metal involved. If there is mutual solubility of the two metals the dissimilar joints can be made successfully. If there is little solubility between the two metals to be joined the weld joint will not be successful. The intermetallic compounds that are formed, between the dissimilar metals, must be investigated to determine their crack sensitivity, ductility, susceptibility to corrosion, etc. Another factor involved in predicting a successful service life for dissimilar metals joint relates to the coefficient of thermal expansion of both materials. If these are widely different, there will be internal stresses set up in the intermetallic zone during any temperature change of the weldment.

D. Introduction to Gas Metal Arc Welding (GMAW)

We know that MIG welding is one of most versatile technique till now in modern production technology and most importantly, it is suitable for both either for thin sheet or thick section components. Basically, in this process, an electric arc is produced between the consumable wire electrode and the workpiece, due to this heat workpiece metal melts and join.The GMAW welding process is easily found in any industry whose product require metal joining in a large scale. It establishes an electric arc between a continuous filler metal electrode and weld pool, with shielding from an externally supplied gas, which may be an inert gas, an active gas or a mixture. The heat of the arc melts the surface of the base metal and the end of the electrodes. The electrode molten metal is transferred through the arc to the work where it becomes deposited weld bead.The quality of the welded material can be evaluated by many characteristics, such as bead geometric parameters (penetration, width and height), hardness, residual stress and deposition efficiency. These characteristics are controlled by the number of welding parameters, and, therefore, to attain good quality, is important to set up the proper welding process parameters. Out of these properties hardness is most important property because hardness determines the impact strength, toughness and crack susceptibility of welded joint. Traditionally, it has been necessary to determine the weld input parameters for every new welded products to obtain a welded joint with the required specifications. To do so, requires a time-consuming trial and error development effort, with weld input parameters chosen by the skill of the engineer or machine operator. Then welds are examined to determine whether they meet the specification or not. Finally the weld parameter scan is chosen to produce a welded joint that closely meets the joint requirements. Also, what is not achieved or often considered is an optimized welding parameters combination, since weld scan often be produced with very different parameters. In other words, there is often a more ideal welding parameters combination, which can be used if it can only determined.

II. LITERATURE REVIEW

Several researchers and academicians of international repute have probed into the topic of study of effect of welding parameters whose name and work abstract has been given below:

KayaDeveli, Nizamettin et al. (2006) **"**The Hardness values were studied on parameters like shielding gas composition and welding current. A Griffiths, B roebuck, A turn bull in 2004 studied the hardness profile in welding of 16 Cr stainless steel welds .It was found that the hardness was maximum at 4 to 6 mm far from the weld Centre**." [**16]

Prakash Ahirwar et al. "Welding is an efficient and economical method forjoining of metals. Welding has made significant impact on the large number of industries by raising their operational efficiency, productivity and service life of the plant and relevant equipment. The advantages of welding, as a joining process, include high joint efficiency, simple set up, flexibility and low fabrication costs. Because of its high reliability, deep penetration, smooth finish and high productivity, arc welding has become a natural choice in industries for fabrication. Welding involves large number of interdependent variables that can affect product quality, productivity and cost effectiveness. Many studies and researches have been made so far to determine the effect of welding parameters on weld properties and quality. For example, studied the effect of heat input on weld mechanical properties. Effect of current and voltage on strength of Lap-joints produced by submerged welding process. The weld bead geometry plays an important role in determining the mechanical properties of the weld. Residual stresses have a strong influence on weld deformation, fatigue strength, fracture toughness and buckling strength. Welding current, weld geometry and welding speed seems to be an important process parameter in arc welding with its direct significant effects on bead quality as well.

M.D. Mathew et al.(2006) "The characterized the creep properties of the base metal, weld metal and weld joint for 316L(N) SS welds at 873 and 923K at stress levels of 100–325MPa with rupture lives in the range of 100–33,000 h. The creep strength reduction factors for the weld joints were found to be higher than the RCC-MR values implying that the actual creep strength of the weld joints is higher than the design values and that the difference between the strengths of base metal and weld metal is low. Weld strength reduction factors based on the strength of the weld metal is more conservative at 873 while at 923K at long term conditions; WSRF based on weld joint seems to be more conservative. Higher rupture life of the weld joint as compared to the weld metal is suggested to be resulting from the formation of a metallurgical notch**".**

Jounghoon Lee et al. (2007) "The studied the mechanical properties for inconel 82/182 dissimilarmetal weld. Dissimilar metal welds composed of SA508 Gr.3, inconel 82/182 weld, and TP316 stainless steel were prepared by gas tungsten arc welding and shielded metal arc welding technique. The tensile properties were increased as the test region was changed from the top to bottom in the inconel 82/182 welds. While the tensile properties were decreased as the test temperature was increased, the ultimate tensile strength of SA508 Gr.3 was not changed at the test strain rate and 320°C because of the dynamic strain aging effect**."** [3]

S. R. Patil et al. "Optimization Of MIG Welding Parameters For Improving Strength Of Welded Joints'This paper presents the influence of welding parameters like welding current, welding voltage, welding speed on ultimate tensile strength (UTS) of

AISI 1030 mild steel material during welding. A plan of experiments based on Taguchi technique has been used. An Orthogonal array, signal to noise (S/N) ratio and analysis of variance (ANOVA) are employed to study the welding characteristics of material & optimize the welding parameters. The result computed is in form of contribution from each parameter, through which optimal parameters are identified for maximum tensile strength. From this study, it is observed that welding current and welding speed are major parameters which influence on the tensile strength of welded joint.**'** [12]

V.Ravishankar et al.(2013) "They studies to weld dissimilar metal of Aluminum alloy AA1050 and low carbon steel through the TIG welding. The process can be explained as a self brazing process in which low carbon steel is heated to melting point of the Aluminum which is sufficient for fusion of Aluminum with low carbon steel. They finding with the 135A, 16V and 305 mm/sec yielded better strength and hardness when compare to other welding condition. But optimize the speed we can increase the depth of penetration as well as strength of the joint."

M. Sireesha et al.(2000) "They studied the transition joints in power plants between ferrites steels and austenitic stainless steels which suffer from a mismatch in coefficients of thermal expansion (CTE) and the migration of carbon during service from the ferrites to the austenitic steel. The study shows the use of a trimetallic combination with an insert piece of intermediate CTE (coefficient of thermal expansion) provides for a more effective lowering of thermal stresses. In this work a trimetallic joint involving modified 9Cr+1Mo steel and 316LN austenitic stainless steel as the base materials and Alloy 800 as the intermediate piece. Nickel-based consumables produce welds exhibiting better tensile properties and improved thermal stability in relation to the austenitic steel filler materials. The absence of microstructural deterioration at high temperatures is considered particularly important in view of the usual operating conditions for these joints. From a consideration of thermal expansion coefficients also, the Inconel filler materials are seen to be superior to the stainless steel consumable**".** [2]

III. METHODS AND MATERIAL

Gas Metal Arc Welding

Gas Metal Arc Welding (GMAW) is defined by an arc welding process which produces the coalescence of metals by heating them with an arc between a continuously filler metal electrode and the work. The process uses shielding gas from an externally supplied gas to protect the molten weld pool.

GMAW Equipment and Supplies

Gas metal-arc welding equipment basically consists of four units: the power supply, the wire feeding mechanism, the welding gun (also referred to as the torch), and the gas supply.

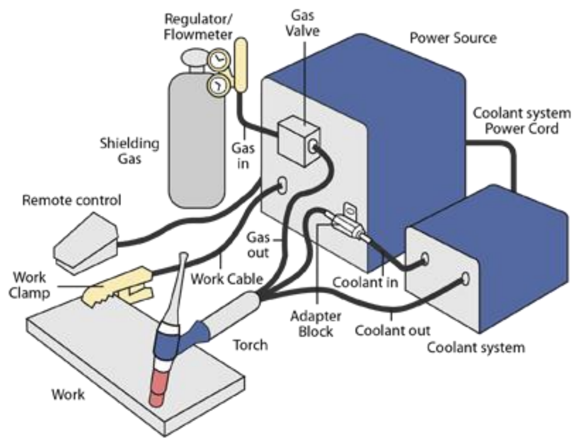

Figure 1. Figure of GMAW Machine

When a conventional type of welding machine is used for GMAW the voltage varies depending on the length of the arc. The arc length and the voltage changes accordingly whenever the nozzle-to-work distance changed. The only way to produces the uniform welds with this type of power source is to maintain the arc length and voltage at a constant value. Besides producing non-uniform welds, this inconsistent voltage can cause the wire to burn back to the nozzle. [12]

Specimen Preparation

The sheet of stainless steel and C-25 carbon steel is cut by shaper machine. And the surface of work piece is grind by grinder and emery paper to get mirror image of work piece. After getting very good surface machining is possible.

Specimen	Size(In mm)
Length	80
Width	30
Thickness	5

Grinding Machine

A grinding machine often shortened to grinder is any of various power tool or machine tool used for grinding which is a type of machining using an abrasive wheel as the cutting tools. Each grains of abrasive on the wheel's surface cuts a small chip from the workpiece via shear deformation.

Grinding is used to finished workpieces that must shows high surface quality (e.g., low surface roughness) and high accuracy of shape and dimension. As the accuracy in dimensions in grinding is of the order of 0.000025 mm in most application it tends to be a finishing operation and removes comparatively little metal, about 0.25 to 0.50 mm depth. However, there are some roughing applications in which grinding removes high volumes of metal quite rapidly.With the help of grinding machine we form the V- groove on the materials. Which is shown in the fig.

Figure 2. Figure of Specification of work piece during grinding

Figure 3. Figure of original Specimen of work piece with V Groove

Figure 4. Figure of Specification of work piece

Design of Experiment

In this experiment the input parameters considered are current, voltage and wire feed rate. Since three factors are chosen the design becomes a 3 level 3 factorial Taguchi design. L9 orthogonal array was chosen for the experiments to be conducted.

Parameter	Level 1	Level 2	Level 3
Current(Amp)	160	170	180
Voltage(Volt)	20	22	24
Wire Feed Rate(imp)	400	410	420

Machining parameters and levels

Overview of Taguchi Method

Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. Taguchi developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied; it allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources. Taguchi design method is to identify the parameter settings which render the quality of the product or process robust to unavoidable variations in external noise. The relative “quality” of a particular parameter design is evaluated using a generic signal- to noise (S/N) ratio. Depending on the particular design problem, different S/N ratios are applicable, including “lower is better” (LB), “nominal is best” (NB), or “higher is better” (HB).

STEPS IN TAGUCHI METHOD

To achieve desirable product quality by design, Taguchi suggests a three-stage process:

i. System design.

ii. Parameter design

iii. Tolerance design.

System design

It is the conceptualization and synthesis of a product or process to be used. The system design stage is where new ideas, concepts and knowledge in the areas of science and technology are utilized by the design team to determine the right combination of materials, parts, processes and design factors that will satisfy functional and economical specifications. To achieve an increase in quality at this level requires innovation, and therefore improvements are not always made. In parameter design the system variables are experimentally analyzed to determine how the product or process reacts to uncontrollable "noise" in the system; parameter design is the. main thrust of Taguchi's approach

Parameter design

It is related to finding the appropriate design factor levels to make the system less sensitive to variations in uncontrollable noise factors, i.e., to make the system robust. In this way the product performs better, reducing the loss to the customer.

Tolerance design

It occurs when the tolerances for the products or process are established to minimize the sum of the manufacturing and lifetime costs of the product or process. In the tolerance design stage, tolerances of factors that have the largest influence on variation are adjusted only if after the parameter design stage, the target values of quality have not yet been achieved. Most engineers tend to associate quality with better tolerances, but tightening the tolerances the cost of the product or process because it requires better materials, components, or machinery to achieve the tighter tolerances as we discussed in earlier chapters. Taguchi's parameter design approach allows for improving the quality without requiring better materials or parts and makes it possible to improve quality and decrease (or at least maintain the same) cost.

IV. RESULTS AND DISCUSSION

Taguchi Design

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Taguchi Orthogonal Array Design
L9(3^3)
Factors:  3
Runs:     9
Columns of L9(3^4) Array
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S.N	Current	Voltage	Wire Feed Rate	Hardness	SNRA1	MEAN1
1	160	20	400	86	-38.6900	86
2	160	22	410	84	-38.4856	84
3	160	24	420	85	-38.5884	85
4	170	20	410	82	-38.2763	82
5	170	22	420	84	-38.4856	84
6	170	24	400	87	-38.7904	87
7	180	20	420	84	-38.4856	84
8	180	22	400	83	-38.3816	83
9	180	24	410	82	-38.2763	82

Taguchi Analysis: hardness versus current, voltage, wire feed rate

```
Response Table for Means
Level       c      v      w
1       85.00  84.00  85.33
2       84.33  83.67  82.67
3       83.00  84.67  84.33
Delta    2.00   1.00   2.67
Rank        2      3      1
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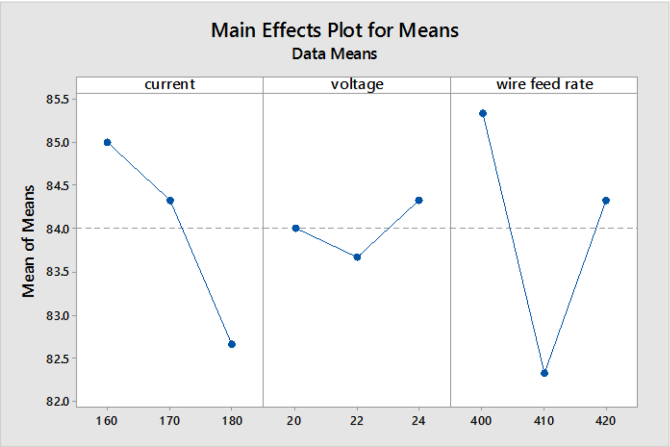


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Response Table for Signal to Noise Ratios
Smaller is better

Level       c       v       w
1      -38.59  -38.48  -38.62
2      -38.52  -38.45  -38.35
3      -38.38  -38.55  -38.52
Delta    0.21    0.10    0.27
Rank        2       3       1
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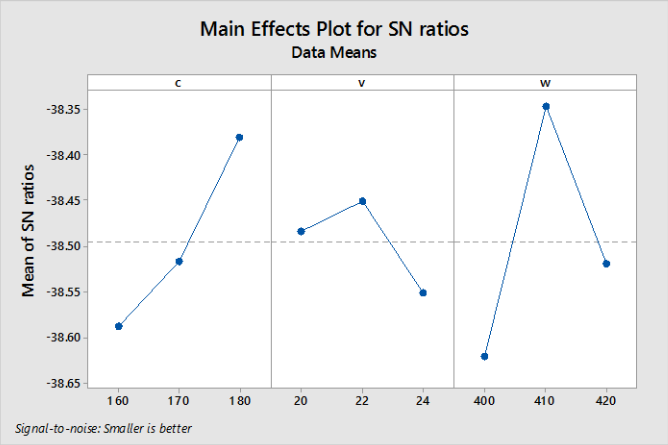

V. CONCLUSION

After the experiment we find that the current, voltage and wire feed rate as a input parameter create a significant effect. In this experiment we got that the wire feed rate is the first parameter whist affect the hardness first then currenr and voltage.

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