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"AN ANALYTICAL ASSESSMENT OF WELDING PROCESS PARAMETERS UTILIZING RESPONSE SURFACE METHODOLOGY"

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ABSTRACT

Tungsten inert gas welding (TIG) or gas tungsten arc welding (GTAW) stands as a favored method for joining ferrous and nonferrous metals. The gas tungsten arc welding technique relies on a non-consumable tungsten electrode to initiate the welding arc. Throughout the welding process, an inert gas shield is employed to purge the welding area of air, preventing oxidation of the electrode, weld puddle, and the surrounding heat-affected zone. To accommodate joints requiring additional weld metal, a filler rod is introduced into the puddle. This review paper aims to explore the influence of TIG welding parameters on key output parameters such as weld strength and distortion, employing an analytical approach. Crucial welding parameters, including welding current, gas flow rate, root gap, and bevel angle, are examined for their significant impact on welding outcomes.

Key Words: *TIG, Process Parameters optimization, Taguchi method, Grey Relational Analysis.*

I. INTRODUCTION

Tungsten Inert Gas (TIG): A method of gas tungsten arc welding utilizing a non-consumable tungsten electrode to initiate an arc. An inert protective gas is employed along with a distinct filler metal. In the gas tungsten arc welding process, essential components include a suitable power source, an argon gas chamber, a welding torch connected to a current supply cable, a gas supply tube for shielding, and a water-cooled torch to dissipate heat. The ideal weld, common to all welding types, exhibits storage qualities akin to the base metal; thus, the molten puddle necessitates isolation from the atmosphere. Oxygen and nitrogen in the environment swiftly react with the molten metal, resulting in weak welds. The primary inert gases used include argon and helium. In Tungsten Inert Gas welding, the electrode is solely utilized to initiate the arc and is not consumed during welding. When joining similar metals requiring additional weld material, a filler metal or rod is introduced into the molten puddle. This welding method is often referred to as "Heliarc" (Linde) or "Heliwelding" (Airco), reflecting manufacturer trademarks. Power Supplies: TIG welding employs three fundamental power supplies: direct current straight polarity (DCSP), direct current reverse polarity (DCRP), and alternating current high frequency (ACHF) modified power supplies.

Filler Metal: Proper filler metal selection is primarily based on the composition of the base metal being welded, with filler metals typically closely matched to the base metal composition.

Shielding Gas: The choice of shielding gas significantly impacts weld quality and speed. Argon, helium, and argon-helium mixtures are preferred as they do not react with tungsten electrodes and do not compromise weld quality. Argon is favored for its affordability and its ability to provide a smooth and stable arc, making it suitable for welding aluminum alloy, magnesium alloy, and beryllium copper.

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Electrodes: TIG welding distinguishes itself from other metal arc welding processes by utilizing non-consumable electrodes, which do not supply filler metal. Tungsten, with the highest melting temperature among all metals at 6170°F, is the preferred material for non-consumable electrodes. Three basic types of tungsten or tungsten alloys are used in TIG welding electrodes: pure tungsten, zirconiated tungsten, and thoriated tungsten.

II. Optimization Technique

The Taguchi Method has emerged as a potent optimization technique in contemporary times, particularly for enhancing productivity in research and development endeavors. Its primary objective is to facilitate the production of high-quality products at minimal cost and in a timely manner. The Taguchi Method stands out as one of the most effective approaches for selecting process parameters with minimal experimentation. By integrating design of experiments with optimal welding parameters, the Taguchi Technique strives to yield optimal outcomes efficiently.

Utilizing the Taguchi method allows for discerning the varying degrees of influence among different parameters. This technique employs a specialized design known as an "Orthogonal array" to investigate the entire array of process parameters with a limited number of experiments. Dr. Taguchi's Signal-to-Noise (S/N) ratio, which serves as a logarithmic function of the desired output, acts as an objective function for optimization. It aids in data analysis and prediction of optimal results.

The Taguchi Method utilizes the S/N ratio to identify control factors in the optimization process. First, it seeks to pinpoint those control factors that reduce variability. Second, it identifies control parameters that have minimal or no effect on the signal-to-noise ratio while adjusting the mean to the target. The S/N ratio, under different noise conditions, gauges how the response deviates relative to the nominal or target value. Depending on the experiment's objective, various signal-to-noise ratios are available for selection. Minitab offers S/N ratios for static designs, facilitating the optimization process

There are three Signal-to-Noise ratio of common interest for optimization:

Smaller-The-Better:

$n = -10 \, Log_{10}$ [mean of squares of measured data]

Larger-The-Better:

$n = -10 \, Log_{10}$ [mean of square of the reciprocal of measured data]

Nominal-The-Best:

$n = 10 \, Log_{10}$ (square of mean/variance)

Grey Relational Analysis: In Grey relational analysis, the experimental data i.e. the measured features of quality characteristics are first normalized ranging from 0 to 1.Then, the Grey relational coefficient is calculated, based on normalized experimental data, to represent the correlation between the desired and actual experimental data. Then, the Grey relational grade is determined by averaging the Grey relational coefficient corresponding to selected responses. The overall evaluation of the multiple response process is based on grey relational grade. Hence, with this approach, optimization of the complicated multiple process responses can be converted into optimization of a single grey relational grade. Optimal parametric combination is then evaluated which would result highest Grey relational grade.

II. Literature Review

Deepak Malik, Sachin Kumar, and Mandeep Saini conducted a study to explore the significant issue of angular distortion in butt weld plates. They found that restraining this distortion could potentially lead to higher residual stress levels. To mitigate initial angular distortion in a negative direction, the study applied restraint, aiming to reduce predictable distortion magnitudes. The optimization of weld parameters was achieved using ANOVA. The investigation focused on the transverse direction of TIG welding processes, considering key input parameters such as welding current, filler rod diameter, plate length, and time gap between passes. Experiments were conducted using SS 302 and MS samples of varying dimensions, employing V-groove designed plates and butt weld types. Distortion was measured using a dial gauge attached to a height gauge, with welding currents ranging from 70 to 100 Amps and carbon steel filler rods of 1.5 to 2.5 diameter. The L9 orthogonal array was selected for designing experiments to optimize distortion caused by welding, with MATLAB 16 software used to develop source code for optimization. The study analyzed the direct and interaction effects of process parameters, presenting findings in graphical form. It concluded that the diameter of the electrode had the greatest impact on angular distortion, while the time between successive passes had the least effect.

Lalit S. Patel and Tejas C. Patel analyzed welding parameters to determine their significance on thin 304L SS plates. They utilized the Taguchi method in designing experiments to observe tensile strength and distortion responses. ANOVA was employed to analyze the experimental results, identifying the root gap as the most significant parameter for weld strength and current for distortion. The error associated with weld strength and distortion fell within acceptable ranges.

Ugur Esme, Melih Bayramoglu, Yugut Kazancoglu, and Sueda Ozgun conducted investigations on the multi-response optimization of TIG welding processes using Grey relational analysis and the Taguchi method. The study aimed to derive optimal parametric combinations for favorable bead geometry of welded joints. Sixteen experimental runs were performed based on an orthogonal array of the Taguchi method to optimize objective functions related to TIG welding parameters. Grey relational analysis in conjunction with the Taguchi approach facilitated multi-response optimization, with ANOVA used to evaluate the significance of factors on weldment quality characteristics. The optimal results were verified through additional experiments.

Mukesh and Sanjeev Sharma examined the influence of welding current, gas flow rate, and welding speed on the mechanical properties in TIG welding. They conducted experiments using an L9 orthogonal array, analyzing microstructure, hardness, and tensile strength responses of weld specimens. ANOVA analysis revealed that current was the most significant parameter affecting tensile strength and micro-hardness, with the microstructure of the weld metal showing delta ferrite. The highest tensile strength was obtained under specific welding conditions.

Dheeraj Singh, Vedansh Chaturvedi, and Jyoti Vimal researched optimum welding parameters for gas tungsten arc welding using the Taguchi method with an L16 orthogonal array. They focused on achieving optimal TIG welding process parameters for 304 stainless steel plates, utilizing the grey relational theory. The study identified the best combination of process variables, with the predicted optimal parameters verified using ANOVA.

J. Pasupathy and V. Ravisankar investigated the influence of welding parameters like welding speed and current on the strength of low carbon steel on AA1050 materials during welding. They employed the Taguchi method to obtain data and utilized ANOVA, orthogonal arrays, and S/N ratios to investigate welding characteristics and optimize process parameters. Their study observed optimal welding parameters resulting in specific strengths and S/N ratios.

Mallikarjun Kallimath, G. Rajendra, and S. Sathish discussed the extensive use of TIG welding in industry and emphasized the importance of selecting optimum combinations of input variables for achieving required welding qualities. The study utilized the Taguchi method, designing a 3-factor and 2-level orthogonal array with full replication. Experiments were conducted using AA6160 base metal with a filler metal of 4043, with gas flow rate identified as a major contributing factor.

S. Akella and B. Ramesh Kumar investigated the control of transverse distortion in TIG welding using the Taguchi method and ANOVA. They identified welding current, root gap, gas flow rate, welding speed, and weld voltage as critical parameters for distortion control. An L8 orthogonal design was employed for process parameter optimization, with experiments conducted on MS plates of specific dimensions. The study assessed the contribution of each parameter to distortion control.

III. CONCLUSION

The literature review underscores TIG welding's significance in joining various alloys and materials across industries. Several studies have employed optimization methods such as the Taguchi method, ANOVA, and factorial design to analyze mechanical properties like tensile strength, hardness, and distortion control. Parameters including root gap, welding current, bevel angle, gas flow rate, and welding speed are pivotal in TIG welding optimization. Researchers have commonly used ferrous metals like SS202 and SS304, with methods like the Taguchi method and S/N ratio aiding in result acquisition.

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