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A Review on Experimental Analysis on Influence of Process Parameters of GTAW in a Butt Welded SDSS (2205)

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ABSTRACT

Whenever welding procedures are executed, under the influence of heat the grains of material which are close to the weld pool may experience vibration or let's say disturbance of particles and that results in changes in the size of the grains which may eventually alter properties of the material. In this study, the Taguchi method was used to optimize and build relationships between the input parameters and depth of penetration for GTAW of 202 grade stainless steel plates. A mathematical model is also developed to correlate the process parameters like welding current (I), welding speed (V), and shielding gas flow rate (Q) to depth of penetration. The developed model then compares with the result: it is supposed to be found that the deviation falls within the limit of 90% confidence level. Additionally the results obtained also by implementing various testing processes like Micro hardness and Microstructure testing, Magnetic barkhausen noise test etc. and Wire EDM is used in order to cut out the material in desired dimension without forming heat affected zone(HAZ).

Keywords: *Depth of Penetration, Process Parameter, Taguchi Method, Micro Harkness and Microstructure Testing, Magnetic Noise test.*

1.0 Introduction

The gas tungsten arc welding (GTAW) process involves generating a metal coalescence by applying an arc between a non-consumable electrode and base metal. Widely utilized for welding challenging materials like aluminum, stainless steel, magnesium, and titanium, GTAW's quality hinges significantly on the depth of penetration. Shallow penetration can jeopardize welded structures as it directly impacts the stress-carrying capacity of joints.

Selecting appropriate input welding variables is crucial for achieving acceptable weld bead penetration and, consequently, a high-quality joint.

R Sudhakaran [1] Proceed the experiment on a particular material called 202 GRADED STAINLESS STEEL. So firstly regression was used in order to make a relationship between the input parameters which are welding current (I), welding speed (V), welding gun angle (S) and shielding gas flow rate (Q). The results obtained from the mathematical model were more accurate and precise in predicting depth of penetration.

Mostafa.[2] Selected the material called stainless steel 304. The grain growth in austenitic stainless steel plays a major role in metallurgical properties change.In this study the finite element simulation of heat transfer in GTAW was investigated using a double ellipsoidal heat source model of selected material. The simulation result is compared with the ROSENTHAL approach as well as experimental data.

Traidia [3] Developed simplified 2D axisymmetric and comprehensive 3D weld pool models to analyze the factors contributing to asymmetric bead shapes during horizontal Gas Tungsten Arc (GTA) welding of stainless steels.

Our models consider the deformation of the free surface and the addition of filler metal.

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M Yousefieh.[4] The rate of resistance in case of corrosion is high for duplex stainless steel and it is because of elements like, molybdenum and nitrogen.By using potentiostatic polarization test at room temperature corrosion resistance is evaluated in 3.5% of NaCl Solution.The corrosion potential is decrease in the presence of sigma phase and Cr2N.

Shing [5] In pulsed GTAW weld the fusion zone microstructure offset due to cooling rate and large undercooling under the same heat input condition significantly. Final composition of pulse weld metal at 7 degree c, plate comprise plenty of wise intra - granular austenite inside the gamma grain matrix apart from windmann staten austenite and grain boundary austenite.

M. Ravichandran [6] The analysis of TIG welding process parameters was conducted to join plates of duplex stainless steel. Signal-to-noise (SN) ratio and Analysis of Variance (ANOVA) methodologies were employed to explore the chosen welding parameters, which included current (A), gas flow rate (L/min), and speed (mm/min). The primary objective was to create weld joints that exhibit maximum impact strength and hardness.

Shuwan Cui [7] This study successfully employed keyhole tungsten inert gas welding (K-TIG) to weld 8 mm thick plates of 2205 duplex stainless steel (DSS). Utilizing numerical simulations based on the finite element method, three combined heat source models were tested to validate the experimental findings. The simulations, conducted at different welding speeds, focused on calculating the temperature field, molten pool shape, and thermal cycle curve.

Prabhu Paulraj [8]This study investigates the impact of welding parameters on the corrosion behavior of welded duplex stainless steel (DSS) and super duplex stainless steel (SDSS) using Gas Tungsten Arc Welding (GTAW). Examining factors such as heat input, inter-pass temperature, cooling rate, and shielding/back purging gas, the research focused on understanding the corrosion behavior. Welded pipes were non-destructively tested for defects, and subsequent microstructural examinations revealed that low heat input led to desirable microstructures. Corrosion tests, including ASTM G48 for pitting corrosion rate and potentiodynamic and potentiostatic tests, were conducted. DSS weldments exhibited Critical Pitting Temperature (CPT) between 23 °C to 27 °C, while SDSS weldments had CPT between 37 °C to 41 °C in potentiostatic measurements.

The study correlated corrosion results with weldment microstructures, emphasizing the influence of secondary austenite on corrosion resistance.

Francis Davis [9] This study delves into the correlation between ultimate tensile strength (UTS) and yield strength (YS) of a welded joint and four welding input parameters: voltage, current, heat input, and welding speed. Gas Tungsten Arc Welding was utilized to join two super-duplex stainless-steel pipes with specific dimensions.

Employing a factorial design, the study aimed to identify the main and interaction effects of these welding parameters on the UTS and YS of the welded joint.The study determined optimal values for UTS (11.60 V, 30.0 A, 0.71 mm/s, and 0.70 kJ/mm) and YS (9.30 V, 30.0 A, 0.46 mm/s, and 0.70 kJ/mm), providing valuable insights for welding parameter optimization.

Victor Garcia-Garcia [10] This study presents a theoretical-experimental analysis of dissimilar metals, specifically Duplex Stainless Steel (DSS) grade 2205 and Twinning Induced Plasticity (TWIP) steel, joined through pulsed gas tungsten arc welding (GTAW-P).

The welding process involved autogenous mode as well as the use of filler metal (ER2209). Critical regions of the weld were meticulously characterized using metallography techniques like LOM and SEM. Microstructural changes, encompassing the morphology and content of ferritic and austenitic phases, were systematically linked to temperature variations estimated numerically through a finite element (FE) model. The FE model factored in the percentage dilution variation in the fusion zone (FZ), resulting in an average variation of up to 6.75% between experimental and numerical results.

R. Suresh [11] Achieving the required mechanical properties and desired microstructure for marine applications in dissimilar metal welding presents a more challenging and intricate task compared to similar welding processes. The focus of this research is to comprehensively examine the tensile behavior and Tafel polarization of dissimilar welds between Duplex Stainless Steel (DSS) and High-Strength Low-Alloy (HSLA) steel.

C. B. Sekar[12] This study delves into the impact of Gas Tungsten Arc (GTA) welding parameters on the bead geometry of SAF 2507 Super Duplex Stainless Steel.

Autogenous square butt joints, each with a 6 mm thick plate, were created in a single pass. The optimization of process parameters was accomplished through the implementation of a Taguchi L16 Orthogonal experimental design. Key input process parameters included Arc Current, Welding Speed, Shielding Gas Flow Rate, and Arc Gap, while the responses under consideration were the aspect ratio and depth of penetration.

Sukhbir [13] Welding stands as a widely utilized method for joining metals and alloys. This review aims to consolidate existing literature and assess the impact of diverse arc welding process parameters such as welding current, welding voltage, welding speed, and heat input on the corrosion resistance, microstructure, strength, hardness, and toughness of steel welds.

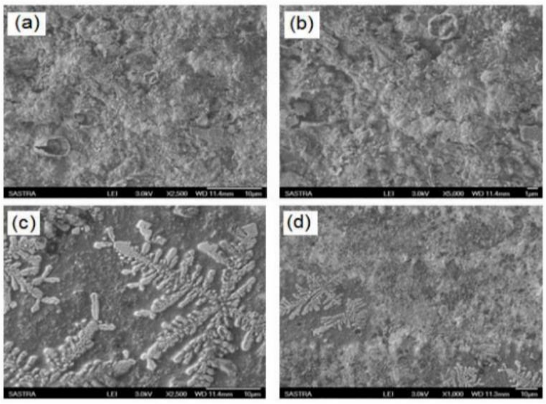
Vedansh Chaturvedi [14] This review paper is primarily focused on identifying the key process parameters and output parameters that significantly influence Tungsten Inert Gas (TIG) welding. A comprehensive analysis of various research papers reveals a predominant emphasis on crucial TIG welding process parameters, including Current, Voltage, Gas Flow Rate, Welding Speed, and Arc Length, treated as input parameters.

Afabor Abraham Martinsa [15] In this study, the Taguchi robust design of experiments (DOE) technique was employed to determine the optimal Gas Tungsten Arc Welding (GTAW) parameters for enhancing the tensile strength of AISI 316L austenitic stainless steel.The obtained results were analyzed using the bigger-the-better criterion for signal-to-noise (S/N) ratio and analysis of variance (ANOVA) with MINITAB 18 software. The analysis revealed that, for optimizing each response, welding current emerged as the most influential factor, contributing to 65% of the outcome.

The maximum tensile strength was achieved at a specific combination of welding parameters: welding current of 100 A, welding voltage of 25 V, and gas flow rate of 20 L/min.

Kora tea sunn[16] Super austenitic stainless steel (SASS), notably AISI 904L, represents a high-grade stainless steel variant renowned for its application in challenging environments. Autogenous activated flux tungsten inert gas (A-TIG) welding stands as a proven technique for crafting robust steel joints, offering numerous advantages. This research endeavors to determine an optimal set of input process parameters for the effective application of A-TIG welding in fabricating 10 mm thick joints using SASS AISI 904L plates through bead-on-plate welding trials.

A. Naveen Sait[17] The SN ratio analysis reveals that, for achieving high impact strength, the ideal welding parameters are a current of 150 A, gas flow rate of 14 L/min, and welding speed of 210 mm/min. Conversely, for attaining high hardness, the optimal parameters are a welding current of 190 A, gas flow rate of 12 L/min, and welding speed of 175 mm/min. Further analysis through ANOVA indicates that the gas flow rate stands out as the most influential factor affecting both the impact strength and hardness of the joints.



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E.V. Morales [18] In this study, we conducted a comprehensive review of the austenite microstructural evolution within simulated Heat Affected Zones (HAZs) in duplex stainless steel. Quantification of the different morphological forms of austenite was carried out for each simulated heat input. A meticulous examination of the microstructural parameters in our investigation provided a basis for justifying the impact of volume fractions associated with three austenite morphologies on HAZ mechanical properties and resistance to pitting corrosion.

Nanda Naik [19] This study employs response surface methodology to analyze the impact of activated tungsten inert gas welding parameters on the depth of penetration in super duplex stainless steel alloy 2507. Using a central composite rotatable design, experiments varied input parameters like current, torch speed, and arc gap at five levels. Bead-on-plate welds were created on 10-mm-thick super duplex stainless steel plates, and the depth of penetration served as the response. A second-order response surface model was developed, and optimization for maximum depth of penetration was achieved through the desirability approach. Model validation demonstrated good agreement between predicted and actual depth of penetration values.

A.Balaram Naik,[20] This study employed the TIG (Tungsten Inert Gas) welding technique, a widely adopted method in rail car manufacturing, automotive, and chemical industries. The material of focus was Duplex Stainless Steel (2205), known for its exceptional corrosion resistance, higher yield strength, and hardness. The objective of this paper is to explore the impact of varying input process parameters—specifically, gas flow rate, welding speed, and welding current—on crucial mechanical properties like the strength of the weld joint, microstructure, and hardness. The Taguchi technique (L9 orthogonal array) was utilized for a systematic investigation.

A. N. Chapgaon [21] The quality of weldments in Gas Tungsten Arc Welding (GTAW) is influenced by various process parameters. Higher welding current is linked to increased deposition rates but leads to a reduction in hardness. Employing Direct Current Electrode Negative (DCEN) polarity facilitates deeper penetration compared to Direct Current Electrode Positive (DCEP) and Alternating Current (AC) polarity. Modulating welding speed has a direct impact—increasing it results in narrower bead width and reduced depth of penetration. Additionally, higher welding voltage is associated with decreased depth of penetration and deposition rates. Elevated voltage extends arc length, resulting in a wider bead width. The choice of shielding gas, with their unique properties such as electrical conductivity, molecular weight, and ionization temperature, induces distinct effects on arc plasma.

Vikram A. Patel [22] This study aims to investigate the impact of several process parameters specifically, welding current, filler materials, and groove design on the aspect ratio, hardness, and impact strength of SS304L welded joints using Tungsten Inert Gas (TIG) welding. The aspect ratio, representing the ratio of bead penetration to bead width, is a key indicator of weld joint quality. Bead dimensions, measured with vernier calipers, are highly dependent on welding current, making the aspect ratio a crucial response parameter.

The Rockwell hardness test setup assesses hardness in the fusion zone, heat-affected zone, and base metal zone. Impact strength, indicative of a material's resistance to suddenly applied loads, is temperature-dependent. SS304L is widely used in various industrial fields, including steam power generation, automotive engineering, biomedical engineering, dairy industry, petrochemical engineering, and chemical engineering. Consequently, understanding and optimizing the mechanical properties mentioned above are essential.

Bolarinwa Johnson Kutelu [23] Paper delves into welding as a crucial fabrication process, serving as a vital production route for numerous manufacturing industries. The selection of a welding process for specific applications involves considering factors such as the compositional range of the material, thickness of the base materials, and the type of current used. Molten metals tend to oxidize rapidly, necessitating protection of the weld area from atmospheric contamination. Gas Tungsten Arc Welding (GTAW) addresses this challenge by employing shielding gasses like argon, helium, or nitrogen. GTAW is a prominent technique for joining austenitic stainless steels (ASS) and ferritic stainless steel (FSS) in fabrication. However, the microstructural changes occurring during welding and at weld joints pose significant challenges, impacting both corrosion resistance and mechanical properties. This paper critically reviews past research findings on Gas Tungsten Arc (GTA) welding of ASS and FSS. The results highlight that the amount of heat input, controlled by welding parameters such as speed, voltage, and current, plays a crucial role. Welded joints, particularly the heat-affected zones (HAZs) of both steel grades, can undergo mechanical failure and become susceptible to corrosion if not produced with an optimal combination of welding parameters.

Sumeet Singh [24] Indicated that exposure at 850 °C for 2 hours led to the maximum reduction in ferrite content, inducing pronounced hardening and significant embrittlement in both the weld metal (203

J → 2 J) and heat-affected zone (HAZ) (204 J → 3 J) regions, along with substantial degradation in pitting corrosion resistance. Under the aging condition of 475 °C/20 h, ferrite content reduction was less apparent, yet a notable increase in microhardness and a severe reduction in weld metal toughness (203 J → 6 J) were observed. Surprisingly, the HAZ region exhibited greater tolerance to toughness loss (204 J → 54 J). Overall, the impact and corrosion properties displayed high sensitivity to degradation at 850 °C. The study concludes that the extent of ferrite content reduction does not linearly correlate with the degree of hardening, toughness reduction, and corrosion resistance. These changes are primarily influenced by the type of secondary precipitation, which depends on temperature and exposure duration in the case of DSS welds.

Francis Davis [25] Results demonstrated significant interactions between voltage, current, welding speed, and heat input for UTS, and between welding speed and heat input for YS. Notably, an increase in voltage from 9.3 V to 11.6 V resulted in a 2.69 MPa decrease in UTS, but a substantial 24.25 MPa increase in YS. Similarly, an increase in current from 30 A to 38 A led to a UTS increase of 10.81 MPa and a YS increase of 4.25 MPa. Adjusting welding speed from 0.46 to 0.71 mm/s resulted in a UTS decrease of 7.94 MPa but a significant YS increase of 33.25 MPa. Moreover, an increase in heat input from 0.54 to 0.70 kJ/mm led to a UTS decrease of 15.06 MPa, while YS decreased significantly by 35.25 MPa.

Optimal values for UTS were found to be 11.60 V, 30.0 A, 0.71 mm/s, and 0.70 kJ/mm for voltage, current, welding speed, and heat input, respectively. For YS, the optimal values were 9.30 V, 30.0 A, 0.46 mm/s, and 0.70 kJ/mm, respectively. Rajeev Kumar [26] Weld joints of super-duplex stainless steel (UNS S32750) were created using continuous current gas tungsten arc welding (CCGTAW), CCGTAW with superimposed high-frequency current, pulse current gas tungsten arc welding (GTAW-PC), and superior advanced GTAW-PC with superimposed high-frequency current, employing a super duplex-grade electrode alloyed with 2%–3% nickel (ER2594).

This research introduces a novel technique of associating high frequency with GTAW or GTAW-PC, effectively restricting the arc with nearly equal root and projected diameter. Characterization of the weld joints focused on the mechanical and metallurgical properties, revealing the superior performance of GTAW-PC with superimposed high-frequency current compared to other CC GTAW types. The incorporation of high-frequency current in GTAW and GTAW-PC resulted in a reduction of the weak section of the weld joint's Heat Affected Zone (HAZ) width, coupled with a significant enhancement of associated properties. The rationale behind the superior properties attributed to the involvement of high-frequency current is explained and justified based on the underlying scientific principles. Ghusoon Ridha Mohammed [27] This delves into the impact of varying input heat in different welding processes on the microstructure, corrosion resistance, and mechanical properties of welded duplex stainless steel (DSS). While austenitic stainless steel (ASS) typically benefits from low-heat inputs during welding, caution is warranted for DSS due to distinct physical metallurgy differences between the two. The examination focuses on contrasting solidification modes and transformation characteristics related to heat input in welding processes for ASS and DSS. Numerous studies are scrutinized, specifically addressing the influence of heat energy input on pitting corrosion, intergranular stress, stress-corrosion cracking, and mechanical properties of DSS weldments.

3.0 Figures

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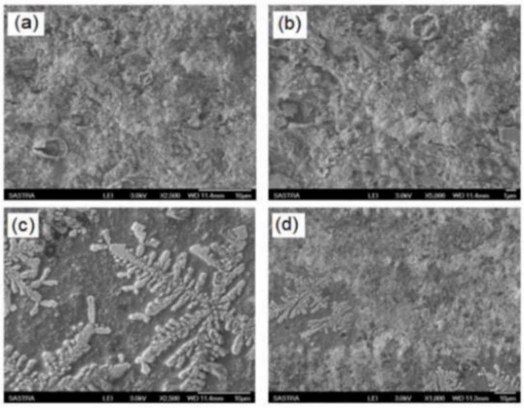

4.0 Conclusions

By implementing the 3 input parameters (welding current (I), welding speed (V), and shielding gas flow rate (Q)) and further applying the L9 approach in this way we can reduce the numbers of experiment trails without ripping the quality of the results.

On the other hand we use beat welding instead of the butt joint and at the time cutting of the material minimum heat affected zone takes place because the material is cut with the help of the Wire EDM.

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