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A Review on Taguchi Optimization Technique of Weld Bead Geometrical Parameters using Submerged Arc Butt Weld in Mild Steel

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ABSTRACT

Submerged arc welding (SAW) is usually classified as a pure slag shielded process. It is used extensively in industry to fabricate pressure vessels, pipe lines, marine vessels, bridge girders etc. Weld bead geometry is a critical component in determining weld quality, since it is determined by the mechanical characteristics of the weld metal, particularly tensile strength. Weld metal mechanical strength is influenced not only by metal composition but also by weld bead shape. In the present study attempt has been made to study the optimal process parameters for submerged arc welded mild steel plates for bead geometry and tensile strength. The experimental plan was developed using a design of experiment (DOE) with four parameters (arc voltage, welding current, travel speed, and nozzle to plate distance) and five levels (Taguchi orthogonal design). Twenty-five specimens are made to determine the joint's bead width, penetration, and tensile strength. The analysis of variance (ANOVA) approach is used to determine the model's acceptance. This approach is useful for determining the magnitude of the impact of factors such as welding current, arc voltage, nozzle to plate distance, and trolley speed on bead width, depth of penetration, and weld strength on particular outputs such as bead width, depth of penetration, and weld strength. To see if the models are accurate similar conformity test are conducted for process parameters and the experimental values obtained from confirmation test is compared with the mathematical model predicted.

Keywords: Submerged arc Welding, Weld bead Geometry, Design of experiment, Taguchi approach, Analysis of variance.

I. INTRODUCTION

Welding is the most commonly used method for joining at fabrication workshop. Welding is performed by targeted heating of the base metal and filler, which causes them to fuse together and produce a permanent connection. Welding is a method of joining two pieces of metal by melting them together using heat. Welding provides a number of benefits over other methods of joining processes. This is due to the great strength of the welding process. The high heat in welding fuses the two metal pieces together, making it behave like a single work piece. The welded

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joints cannot be broken easily. These joints can resist a lot of force, without any fear of the joints breaking. The welded joints are also leak proof. For the construction of tanks, the sheet cannot be joined using riveting, but requires welding only.

Classification of Welding: There exist mainly two types of welding. They are:

- Fusion welding
- Solid state welding

Fusion welding: The joining procedure involves melting the two work components and fusing them together to form a single welded joint. The filler metal is fusing as well. This form of welding necessitates the heating of the metals. In this sort of welding operation, the Heat Affected Zone (HAZ) is evident. After the fusion welding process, the properties of the base metals change. Filler material is used. Because of the potential for temperature differences between metal work pieces, joining different types of metals is challenging.

Solid State Welding: There is no melting in this process. The temperature of the work pieces is raised to a high temperature to join them, but without melting. Heating is not required. The pressure applied between the two metal pieces is sufficient for the joining process. HAZ does not appear. There are either no changes or negligible changes in properties of material after welding process. No filler material is required. Joining of dissimilar work pieces is quite easy, because, there is no heat factor related to heating, solidifying, and melting.

Submerged Arc Welding: Submerged Arc Welding (SAW) is welding technique with a high testimony rate. fig.1 shows the schematics of SAW. By the end of the 1930s, issues such as greater deposition rates and the inability to improve SMAW proved to be the reason in developing SAW process. Arc Welding is utilized to weld thick areas in the flat position. SAW is generally worked in two types, i.e., completely motorized or automatic. As the mechanization in the SAW procedure increments, welding parameters are dictated by experimentation.

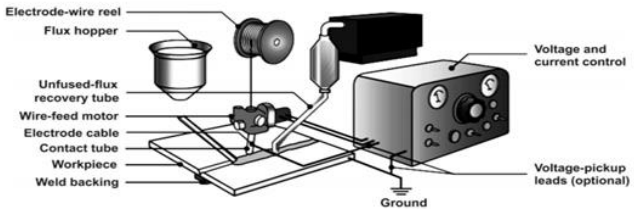

Fig.1: Schematic Illustration of the Submerged Arc Welding

In Submerged Arc Welding, Motorized drive rolls are used for rolling the wire into the mechanically strengthened joint. A layer of granular flux is significant to keep the glint through spared before the Arc. DC current to the range of 2000A can be utilizing single wires on positive terminal or with negative terminal or Alternate Current (AC). Submerged Arc Welding has become the most prominent welding methods with the highest success rate among all the welding techniques. It is regularly utilized for the fusion of heavy/thick territories in the level position. Wire is supported reliably in roundabout portion utilizing rollers run by a motor.

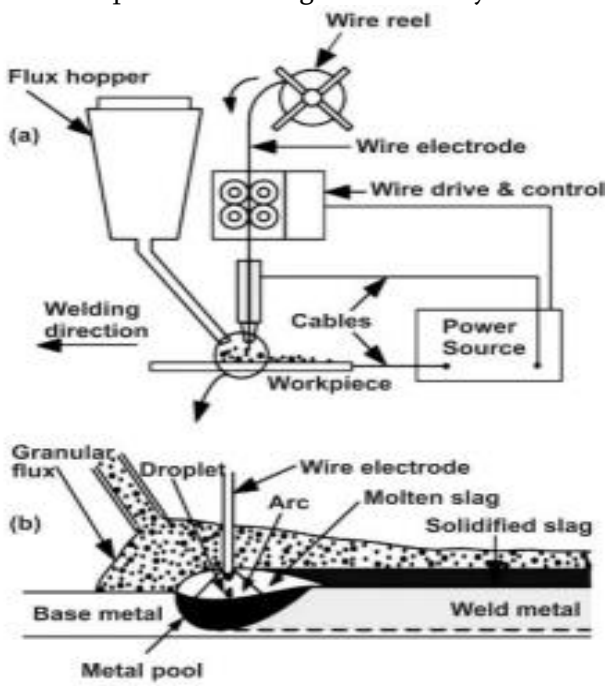

Fig.2: Schematic View of SAW System and its Base Metal Interaction

Importance of SAW: SAW (Submerged Arc Welding) is the most popular form of welding in the world. This type of welding process is very versatile and simple to use. This welding technique is mostly preferred in the maintenance and repair industry.

This type of welding is used in industrial fabrication and construction of steel structures. This method of welding is currently being replaced by gas welding in the industrial sector because of the low cost of the equipment and the comparative easy in use.

Process Variables of SAW: There are necessities of crucial for various process variables before starting SAW for getting extraordinary quality welds

Welding Current: When the current is very high it leads to weld stronghold, expend of more thin plates and gravely fitted joints like restricted beads and undercut. An excessive amount of low current gives arc. SAW control panel is given an ammeter to screen and govern the welding current.

Welding Voltage: The arc voltage is directly related to arc length. Arc length the circuitous arc voltage increments, so in this way more heat has been provided for metal, increment to Arc length causes the arc to widen and volume of reinforcement along with the penetration depth diminishes. The arc voltage changes with welding current causing wire to expel over.

Travel Speed: Welding current as well as voltage, expansion in welding speed result with low penetration, low heat rate. High travel speed diminishes blend amongst the weld store and the parent metal, arc blow, porosity. When welding speed declines penetration and weld bead strength lowers resulting in bad penetration.

Size of Electrode: In any welding current leads to extension in current density. SAW process generally uses wires between 2 and 5 mm. Wire estimation 2 to 3 mm is most proper when more penetration occur during low currents.

Electrode Emerge: This length for cathode from contact tube to arc column or at the end of the day disturbed heating with high current densities used at the same time. More extension in precision rate is combined by a lower in penetration.

Heat Input Rate: The heat input rate is straight forward corresponding to the currents and voltages and conversely relative to the movement speed, which is shown in the equation:

$$\mathbf{HIR} = \frac{V \times A}{S}$$

Where

HIR = Heat Input Rate in j/min

V = Arc Voltage (volt)

A = Welding Current (Amp.)

S = Welding Speed in mm/sec

When heat input rate is higher, cooling rate for weld metal is lowered along with HAZ of parent metal or vice versa. Heat input rate has a very important impact upon microstructure of metal as well as the final microstructure of HAZ.

II. LITERATURE REVIEW

There have been numerous researches that had been performed in this field. The most relevant of those studies have been mentioned below.

Studies on Submerged Arc Welding (SAW) of Mild Steel

Rahman et al. [1] In this paper the capability of current fracture analysis method in pipes undergoing full proper bending when they are subjected to loads as well as displacement along the circumference of the steel sheet having flux welding.

Chandel et al. [2] studied the need for improve the rate of deposition. The researchers performed SAW on IS 432 mild steel bars. The results showed the percentage differences of melting rate, bead height, bead width, as well as bead penetration are impacted by current level and polarity.

Tsai et al [3] utilized for Modelling hard facing processes in SAW. Interactions among process parameters (arc current, arc voltage, welding speed, electrode protrusion, as well as preheat temperature) along with behaviour of welding (deposition rate, hardness, dilution) have been explained briefly.1786 mild steel variant the trials conducted proved that the performance of welding by utilizing this methodology.

Balasubramanian et al [4] studied the impact of just two processes thoroughly, shielded metal arc welding (SMAW) as well as flux-cored arc welding (FCAW), for their impact upon the cruciform joints, having lack of penetration (LOP) defects, were investigated. Load-carrying cruciform joints have been manufactured using high strength, quenched, as well as tempered steels of pressure vessel. The results showed for fatigue life for cruciform joints manufactured using SMAW process are comparatively greater as compared to FCAW.

Bayley et al [5] made comparative research among initiation of fatigue crack and predictions in growth

for SAW butt joint in ASTM A517 steel. The S–N values were obtained by the comparison among predicted and trial fatigue lives as well as fatigue crack propagation methodologies have been conservative with strain life assumptions being un-conservative.

Nagesh et al. [6] Studied the most significant physical behavioural traits for bead geometry and penetration. The penetration and bead geometry seems to be impacted by a number of different welding parameters.

Kahraman et al [7] Studied medium-carbon steel which were welded exploitation submerged with moved wires along with motions. The parts which have been welded exposed to inside the hardness and microstructures. The weld hardness as well as wear obstruction have been focused upon substance arrangement of the weld wire and motion.

Nowacki and Rybicki et al [8] studied the effect of heat upon load characteristcics having joints with excess weld heat contribution between 2.5 and 4.0 kJ/mm towards the submerged welded portion in the duplex steel.

Gunaraj and Murugan et al [9] made for penetration, estimation, as well as support, depth of penetration, average width of weld bead moreover the general volume of the weld column regarding input system parameters; voltage, speed, wire sustain rate, along with nozzle to plate independent. So as for performing SAW upon IS 2062 steel.

Basu and Raman et al [10] Performed through movement of the welding stream and welding using simple machine worked at optimum voltage mode. It had been distinguished for various parameters and essentially absolutely differing dependency for particular heat input on the welding current along with speed.

Kaaoglu et al. [11] The affectability of SAW parameters; welding current, welding voltage, and welding speed for perfect weld bead geometry on 1144 medium carbon steel. The weld bead width, height, and penetration have been selected in the form of plan factors. This research concluded that the welding arc has no direct interaction with assortments having voltage as well as speed.

Prasad and Dwivedi et al [12] impact caused by SAW methodology parameters upon microstructure, hardness, as well as in HSLA steel weld joints. The joints in the weld have been HAZ appeared to be harder for the welded area and quality swelled with a decrease in speed for a welding current in a given range.

Sharma et al [13] For driving arcs in twin-wire SAW having assistance of heat exchange. The model was recreated with diverse combinations of show parameters with a fitting heat exchange model. The model was made of 8630 alloys. The recreation demonstrated that the driving arc butt had a maximum share in creating penetration though arc was more of melting.

Ghosh et al [14] utilized system for evaluating the heat influenced zone for SAW type 304 steel plates by investigating the structure of grain. This completely has been over from thinking about HAZ in SAW which has been comparatively lower than measuring the bead thickness in SAW.

Shen et al. [15] studied for SAW plates in ASTM A709 grade 50 steel. Bead support, bead width, bead penetration, HAZ estimate as well as penetration having expanding heat input that as it may the bead contact point with it. The arc voltage is always higher at the start of welding process which is a point remittent with expanding heat input as it may the plate adjusted.

Singh et al. [16] Impact of flux density composition towards behavior and bead geometry. The flux constituent includes major impact on flux nature as well as bead build geometry on type 410 steel.

Shah et al. [17] The characteristics for single groove(v), single-pass welded joints having ASTM A515 grade sixty low-carbon steel undergoing SAW and shielded metal arc securing (SMAW) along with checking the impact of SMAW. Examples were analyzed using – Charpy and Vickers Hardness test and metallographic think about has been performed using magnifier for checking microstructures.

Sridhar et al [18] used double-sided submerged arc welding on austenitic SS plates 12 mm thick to analyze the impact caused by bead profile and mechanical characteristics proportionate to welding current. As the welding current increased, tensile properties also showed a hiked increase. In the fusion zone microstructure, there was however no growth of equated grains.

Studies Based on the Effect of Weld Characteristics

Kim et al [1] have investigated the average impact of electrochemical as well as thermochemical reactions upon the behavioural of weld metal so as for direct current SAW process. The weld metal in electrode-positive (reverse) polarity while welding wire was anodic along with electrode-negative (straight) polarity while welding wire was cathodic.

Pandey et al [2] have mechanical characteristics for weldment is dependent upon chemical composition, solidification history, along with post-weld heat treatment. Weld-metal composition, welding voltage has to be highly efficient in comparison to welding current.

Gunaraj and Murugan [3] have been specimens for strategy factors as well as heat input on different science viewpoints; breadth of the HAZ, weld interface, grain development, as well as grain refinement locales in HAZ. These observations had been ended as heat input along with wire feed rate produce positive impact, in any case, weld speed highlights a negative impact for HAZ properties. The breadth of grain development and grain refinement locales rises even though weld interface locales goes down when voltage is raised.

Muruganet et al [4] The mechanical quality of welds due to the metal's composition due to weld bead frame in SAW. The factors along with weld bead shape have ended, bead in the plate have taken over plates as weld parameters; voltage, speed, wires nourish rate and nozzle to plate separately.

Bamankar et al [5] have examined in the submerged arc welding (SAW) technique are required for prime quality welding. Parameters viz. arc current, welding speed (trolley speed), as well as arc voltage on the steel for analysing the impact of such parameters upon penetration depth. The current is dominating issue affect the bead broadness. Bead width and penetration will rise with bead voltage and current, but lowers with increase in welding speed.

Chaudhary et al [6] performed for investigating impact caused by input parameters welding voltage, welding speed, nozzle to plate distance, and plate thickness of weld bead geometrical responses i.e., bead width, support, as well as penetration on SAW weldments. Bead on plate method would able to hold weld metal on AISI 1023 steel plates.

Wang et al [7] The surface of H13 steel utilizing natural flux-cored wires using SAW methodology. H13 steel layer had better wear resistance in comparison with the original wear layer.

Saoudi et al [8] have studied the mechanical properties of line pipe steel. Because of the deposited microstructure, the experiment concluded that the fusion zone possessed the highest hardness and the lowest impact strength.

Tarng et al [9] for orthogonal array, the signal-to-noise ratio as well as analysis for understanding behaviour of SAW process. The different parameters such as arc current, arc voltage, welding speed, along with preheat temperature would be individually experimentally analyzed so as to improve their behaviour even in the case of dilution as well as rate of deposition.

Kumanan et al [10] has examined assurance for SAW method parameters using Taguchi procedure taken low-carbon steel plates of 500x50x6mm measurements were examined having welding current and voltage are critical parameters that have an impact on the bead measurement.

Objective: The objective of the present work based on research gaps have been considering the impact in SAW process parameters like arc voltage, welding current, welding speed, and nozzle to plate distance that impact on the weld strength and obtain optimal processes parameters for SAW of IS-2062 steel by application of Taguchi technique on experimental data. Thus we conclude that the review of the literature work for understanding welding parameters that have an impact on the strength of welds in steels.

Conclusion: The thermo-mechanical processing for a number of different alloys particularly the structural steel. The process of SAW in IS-2062 steel has been investigated widely in this research work. The bead geometry and tensile strength for submerged arc welded IS-2062 have been worked on varying combinations of voltage, current, trolley speed and nozzle to plate distance. The correlation of bead geometry along with mechanical properties using unique approach along with process parameters is one of the prime reasons for the success of this research. In mathematical models, the four factor matrix on five levels was established based on the Taguchi orthogonal array. The following conclusions have

been arrived at after analyzing different aspects of submerged metal arc welding of IS-2062 structural steel plates.

- From the ANOVA, it is concluded that voltage which possess the largest influence upon mechanical properties such as tensile strength.
- The optimum parameter obtained for range of parameters used in this study are: voltage as 26 volts, current as 475 ampere, speed as 0.40 m /min, and nozzle to plate distance as 19 mm when the provided set of parameters are taken into consideration.
- With the ascent in welding voltage from 24 volts to 26 volts the mean of penetration increases. An increase in voltage prompts improved welding bead and higher current density, which results in better penetration of the greater volume of the base material.
- When current increase then increasing the bead penetration which leads to decrease in bead width.
- The rise in current leads to rise in penetration when they come in contact with weld pool. When the welding current rises, with the rest of the variables being constant, that leads to improved depth of penetration and higher deposition rate.
- Increase in welding speed produces narrower weld bead. A lot of weld defects are produced because of low speed welding which leads to more melting producing large molten zones.
- It was found that at high nozzle to plate distance, depth of penetration is high because at higher nozzle to plate distance that leads to rise in penetration.
- Tensile strength is one of the best methods for analyzing the sample. It is suggested that the IS-2062 structural steel with plate to plate joint could effectively be used in industrial applications.

III. FUTURE SCOPE

This work can be used as present for a number of different works, which can be performed as the basis for them:

- These works concentrate on butt weld of submerged arc welding process. subsequently this experiment work can be extended to other welding processes such as metal inert gas welding , TIG welding , plasma arc welding , laser welding as well as flux cored welding etc.
- It can be extended to other type of welded joints such as bevel and U-type.
- The present work can be extended which can be done by the selection of parameters.
- It can also be carried out for other material.
- The analysis and development can be extended utilizing various techniques.

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