A REVIEW ON INFLUENCING WELDING PARAMETERS OF SUPER ALLOYS

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Abstract  Manufacturing industries play a vibrant role in economic development and significant growth of a country. Among all different industries, sheet metal industry is irreplaceable in our routine life. Sheet metal applications include in automobiles, aircrafts, computer panels, building roofs etc. Various manufacturing process of sheet metal industry consists of shearing, bending, welding and deep drawing. Welding is one of the vital process in engineering business. Welding is the best operative method of joining similar and dissimilar components together. Choice of influencing process parameters is very much critical in welding for the purpose of obtaining good quality weldments with preferred mechanical properties and enhanced serviceability. This is impossible with single welding method that yields the optimum weld in all conditions. The choice of welding process depends upon the service environment, time, cost, and deposition rate. Superalloy is an alloy having greater mechanical strength and high corrosion resistance in high temperature applications. Superalloys are of, Nickel, Cobalt and Iron built possessing the crystal structure of Face Centered Cubic (FCC) austenitic. Typical examples of super alloys include Inconel, Hastelloy, Waspaloy, Rene alloys, Incoloy. Among these, Hastelloy is a nickel based superalloy containing the major proportion as Nickel 57%, Chromium 15.5% and Molybdenum 16% with the remaining in smaller proportions. Hastelloys are employed by the chemical industries for their Corrosion-Resistant property. The characteristics of Hastelloy include high resistance to localized corrosion in welding and fabrication. Hastelloy are of different grades optimised for specific purpose. Hastelloy alloys of "C-type" alloys are the most versatile. Hastelloy C276 alloy is a nickel alloy engaged in petro chemical and related industries possessing corrosive chemicals. Hastelloy C276 is ductile in nature, suitable for welding, forming and has high resistance to corrosion. Hastelloy C276 alloy is welded by the fusion welding process. The low quantity of carbon existence prevents carbide precipitation to keep resistance to inter granular attack in thermally affected zones. Every industry requires to attain a good quality of weld with great productivity and low processing cost with commanding weld joint.

Keywords: Hastelloy C276, Tensile strength, Microstructure

1. Introduction

Superalloys are alloys that can service in high temperature about 1000°C in rocket engines. They are also termed as thermal-resistant alloys. They possess superior corrosion resistance, mechanical and thermal fatigue (Sims et al. 1987). Superalloys are mentioned to as nickel-base, cobalt-base or iron-base. Major alloying elements are nickel, chromium, cobalt and molybdenum. Nickel-base superalloys contain nickel 38% to 76%; chromium 27% and cobalt 20%. Hastelloy, Inconel, Nimonic, Rene, Udimet, Astroloy and Waspaloy series. Cobalt base superalloys contain cobalt from 35% to 65%, chromium from 19% to 30% and nickel up to 35%. Iron base superalloys contain iron from 32% to 67%, chromium from 15% to 22% and nickel from 9% to 38%. In general, nickel-chromium alloys have excellent oxidation resistance owing to the oxide development of chromium and aluminum.
1.1 DEVELOPMENT OF MATHEMATICAL MODEL FOR WELD BEAD PREDICTION

Yang et al. (2019) proposed an algorithm for weld seam path identification for robot welding process. Improvement of the welding automation level depends on the path extraction and identification of weld seam. In industries, it majorly affects the following characteristics of the workpiece metallic surfaces, textures, and imperfection. To overcome the difficulty, welding robots were taught by the new method of path identification. Feature vectors will be constructed by shape of weld seam. The results show that ANFIS algorithm will improve optimal performance and accurately identify the weld seam.

Bal et al. (2018) made an attempt to investigate the influencing parameters of laser beam welding in penetrated welding zone area. Welding zone has a geometry of throat, crown, neck, and root width. From full factorial design, the regression equation was formed for all the geometrical features. Parameters optimization was conducted to minimize the welding zone area. Minimization of cross-sectional geometry of weld bead was confirmed by conducting experiment. It shows that melt zone shape obtained by formula is same as that of experiment. Output response is mainly affected by scanning speed and laser power.

Bal et al. (2018) made an attempt to investigate Ytterbium fiber laser for the failure of Hastelloy C276 weld zone. Failure occurs in Hastelloy weld joint was identified by uni-axial tensile test, which is equal to 50% reduction in length of Hastelloy specimen. The major cause for the failure is due to micro segregation in solidification and cause brittleness behaviour of specimen. Micro segregation was reduced by limiting the required linear heat input to welding. Ytterbium fiber has higher melting efficiency compared to other sources. 3 millimeter thick C276 Hastelloy sheet is welded with Ytterbium fiber, and the tensile strength of welded specimen were studied. It was noted that weld specimen prepared with Ytterbium fiber fails at a base metal. Simultaneously, percentage of elongation was improved twice while compared to the previous C276 Hastelloy specimen.

Moosaviet al. (2014) made an attempt to investigate various welding parameters' influence of strengthened nickel-base superalloy welded by laser beam welding with constant heat input. Vacuum induction melting furnace is used to produce 5 nickel base superalloy with various Nb and Ti content. Six axis anthropomorphic robot used to perform the welding operations at. Experimental results show that porosity formation is directly proportional to velocity and welding power. In 400 W and 1000 W welding power, there is no hot solidification and liquidation crack but in all heat-affected zones, the liquidation phenomenon was observed at the same time that does not alter the hardness of the specimen. Results show that welding power 400 W and 1000 W with velocity of 40 mm/s and 100 mm/s yields defect free welding.

Manikandan et al. (2014) investigated the various mechanical properties and microstructure in laser welding process of alloy C276 by continuous neodymium: yttrium aluminium garnet. Welding trials were conducted with various laser beam scan speed ranging from 550 to 1200 mm/min. EDS analysis is used to predict the extent of segregation in weld joint. Specimen strength will be measured by tensile test. Fine dendritic structure results high hardness in weld zone compared to coarse structure of base metal. Studies indicate that fusion zone micro segregation was acceptable range with the evidence for macro segregation. Defect free weld joint with good tensile strength and ductility produced. Due to narrow heat input, there is no significant heat-affected zone. The author reported on improvement of microstructure and mechanical properties in the year 2014 and 2015.

Kocharet al. (2019) utilized ANN to predict the weld bead shape in Laser welding with the aid of wire feed, joining speed, voltage, current, and laser power as inputs. The bead profiles of the experiments are expressed in polar coordinates \((r,\theta)\). With the various simulation of results, an optimized parameters are find out which captures the physics of the welding process. Among the various parameters, the most influencing parameters, which directly affect the bead shape are welding travel speed and wire feed shape. The results obtained are a high degree of accuracy. The developed algorithms can be utilized for the other welding process too.

Akkaset al. (2013) employed ANN and ANFIS to forecast the relationship between weld bead geometry and the corresponding influencing parameters in submerged Arc welding process. Optimum parameters are find out and the corresponding experiments are performed to check the predictability of both the system. Both the experiment and the developed system imparts that weld penetration is influenced by arc voltage, current, and welding travel speed. Increase of welding thickness depends on arc voltage and arc current. With the minimum of arc current, the welding thickness is minimum with increased arc voltage and Vice versa. With the both systems, ANFIS results are more reliable than ANN.

Chen et al. (2019) developed XGBoost algorithm to forecast the depth of penetration and reinforcement in metal active gas welding. Quality of the joint was assessed by two criteria namely penetration depth to thickness of the plate and reinforcement. On performing various trials, Penetration coefficient provides 11.06% relative error, and reinforcement penetration provides 20.5% relative error. From the above results, it is concluded that XGBoost algorithm can be used for better prediction for accessing the quality of weld.
Kumar (2011) made an attempt to develop a mathematical model for Submerged Arc Welding which has many advantages in welding of pipes. Mathematical model developed establishes a relation among the influencing process parameters and geometry of the bead. The developed model not only predicts the geometry but also the quality of the weld. Response surface methodology has been developed. The developed model controls the geometry of the bead along with the choice of choosing the range of process parameter for the best quality of the weld. The Developed model directly assist the robotic welding in accessing the quality of the Weld. Similar works are reported by Srivastava and Garg (2017).

Devakumar et al. (2010) made an attempt to predict the geometrical features of the weld bead in Pulsed GMAW on high strength low alloy steel. The various influencing pulse parameters along with the thermal characteristics influencing the bead geometry has been correlated as mathematical model. The developed model has good agreement with min deviation of 8 to 10% while comparing with the experimental result.

Murugan et al. (1999) made an attempt to predict the Bead Geometry in submerged arc welding by the development of mathematical model that predicts the shape relationships in weld bead geometry. The utilization of response surface methodology with four factor five level design matrix with the regression analysis helps in choosing of optimum parameters for acquiring the expected quality of weld.

Kannan et al. (2018) employed a hot wire gas tungsten arc welding (HW-GTAW) process in joining of T92 steel and S304HCu stainless steel with different filler wires namely. Weld bead depositions are found at two welding currents (130A, 110A) with constant wire feed rate and welding speed. Presence of active surface elements and temperature distribution are main sources for the different shape of weld bead.

Sripriyan and Ramu (2016) proposed a new attempt of defining the weld bead geometry in conventional Gas Metal Arc Welding (GMAW). Varying of the geometry of the filler wire technique is employed in improving the quality of the weld bead. A flat wire has been proposed for investigating the characteristics of weld Bead.

Adak et al. (2015) developed a multiple linear regression model for Gas Metal Arc Welding process to predict output of various input variable to forecast the bead geometry and grain structure on the plate. The responses expected are in decent agreement with the experimental results which shows the acceptability of the developed model.

Murugan et al. (1999b) performed calculations for thermal input and the thermally affected zone for the established model in SAW. Comparative study between the actual joint and bead on trials reveals that the developed model needs to be modified further in accessing the quality of the weld bead. The calculated area for bead on trials is greater that of the joint and the effect of heat input is same for both the joint and bead on plate.

Hedayatiet al. (2017) conducted a heat treatment process of Hastelloy and stainless steel bi metal for microstructural evaluation and interfacial diffusion. The samples were heat treated under different temperature of 800 C, 900 C, 1000 C and 1100 C for a soaking period of 3hrs. Short time exposing to high temperatures develop coarse carbide on the interface, making the weld to failure.

Dhobale and Mishra (2015) made an attempt to study the strength of the weldment which depends upon the thermal input. The weldment hardness increases with increase in thermal input where as it decreases in the thermally affected zone. The Micro constituents are also affected by heat input. The microstructure reveals that the small dendrite structure with less spacing in HAZ zone and vice versa in Weld Zone possessing high thermal input.

Cornacchia et al. (2018) made an attempt to execute a comparative study evaluate the properties of conventional MIG with Cold Metal transfer and hybrid Laser MIG welding process. Mechanical properties like Hardness, tensile strength, and yield strength are found to be superior than the former process. The material used for this investigation was 6005A-T6. Fractographic observations were made using SEM/EDS to analyze microstructural deviations after joining.

Yu et al. (2017) employed an infrared sensing system to monitor the changes during welding. Different process parameter like welding speed, current and nose to tip distance are varied to capture the changes in the weld pool. Defects like undercut, lack of penetration and humping are been used for validation of the proposed system. Experimental results showed that the proposed monitoring system is very much useful in detecting the defects in welding.

Sumeshet al. (2018) proposed an algorithm to monitor the quality of weld bead in automated environment. The process parameter’s like welding current and welding voltage are chosen to define the quality of the weld. Gas metal Arc Welding is employed in welding of carbon plates without the defects like porosity and burn through. Decision tree algorithm are used to classify the defects. The proposed algorithm signatures in defect classification during the welding.

Son et al. (2017) employed neural network to predict the quality of weld with intelligent model Back propagation and Levenberg-Marquardt. The developed model predicts the effects on bead height to access the quality of the Weld in gas metal arc welding process.
Chakiet al. (2015) developed an integrated soft computing model by combining of three different techniques for weld zone’s strength prediction in hybrid CO2 laser–MIG welding of aluminium alloy with the input parameters of travel speed, feed and power of laser. A well trained ANN is employed by the soft computing model to perform the task. The most influencing factor for welding strength is welding speed.

Ibrahim et al. (2012) investigated the effect of welding current, Arc voltage, and welding speed to predict the depth of mild steel plate of thickness 6mm in Metal inert gas welding. Depth of penetration increases with the increase in current and vice versa in welding speed and arc voltage. Changes in the boundaries of grains were observed for different level of parameters.

Kumar et al. (2013) investigated the process parameter influenced in welding of two different metals by using Taguchi’s technique. GMAW process is employed to join the low carbon and AISI 304 steel plates. L9 orthogonal array is used to prepare the no of weldment required for the investigation. Welding current, voltage and gas flow rate are considered as input parameters. Design of experiment is used to find the controllable factor to calculate the signal to noise ratio. Also he identify and conclude the significant input parameter for tensile strength and hardness of metal by ANOVA technique.

1.2 OPTIMIZATION IN WELDING PROCESS

Narwadkar and Bhosle (2016) made an attempt to address the major problem of angular distortion in butt welded joints. It was overcome by optimizing the input parameter by taguchi technique. Gas flow rate and welding current, voltage are considered as controllable input parameter. Three levels and factors are consider for DOE. L9 orthogonal array is formed and the different butt weld sample was produced by MIG welding process. After ANOVA technique is used to calculate the distortion angle of the samples. Results were validated by confirmation test.

Malviya and Pratihar (2011) made an attempt to discover four approaches for tuning of neural networks for MIG process. PSO for both forward and reverse mapping. Performance of four approaches were identified and compared with each other to solve the problem caused during MIG welding. First two approaches is used to tuning of multi layer forward mapping and the rest two approaches used to decide the network structure. Third and fourth approaches are provide better results compared to first two approaches. Similar work has been carried out by Nageshet al. (2002)

Meenaet al. (2017) made an attempt to study the influence of input process parameters in preparation of weld bead geometry to determine the load carrying capacity of weldments. Weld bead geometry was examined with various thickness of shielding gas. Strength of weldments is purely depends on the weld bead geometry and metal composition and bead shape relationship. Also the metallurgical investigation carried out to find hardness of weldment in base metal, heat affect zone and weld metal zone. Results was correlated with process variables. Similar works were reported by Kumar et al. (2019) Response-Surface Methodology (RSM)

1.3 MECHANICAL AND METALLURGICAL PROPERTIES OF WELDMENTS

Ganjigattiet al. (2007) attempted to study the regression analysis of input–output relationship of MIG welding in cluster wise and global approaches. The study was carried out by data obtaining from full factorial design of experiments. Comparison results of above two approaches indicates that regression analysis of cluster wise approach perform better than other one.

Patel et al. (2016) made an attempt to investigate the importance of hard facing operation in metal to metal seal creation by MIG welding process. Input process parameter and bead geometry plays major role in weld quality. Influence of process parameter in weld height was analysed in this study. Different modelling techniques like ANN, Fuzzy and Regression are employed to determine the optimal weld height. Results from different techniques was compared with experimental data to predict the best modelling technique.

Chaudhariet al. (2018) made an attempt to investigate the influence of oxide flux in MIG welding process. SiO2 and Cr2O3 are the different fluxes used in weld bead. Specimens were prepared with different process parameters. L9 orthogonal array is used to prepare the samples with SiO2, with Cr2O3 and without flux. ASRS and AHP-MOORA methods used to optimize the process parameter and results illustrate that superior penetration obtained with flux coating. Metallurgical characteristics of weldment was evaluated.

Khanna and Maheshwari (2018) made an attempt to promote the mathematical model for predicting the shape relationship of weld bead geometry in MIG welding. Design matrix for experiments were carried out by using statistical technique. Significance and capability of the model was analysed by t-test and F-test. Newly developed mathematical model is more helpful to predict the optimal process parameter and weld bead dimensions.
Bal et al. (2019) made an attempt to investigate the fracture mechanism of Hastelloy sheet welded by LBW process at weld zone in different heat input condition (60 and 120 J/mm). After PHWT of AW-Hastelloy it was witnessed that the sample prepared at 60 Joules per mm failed at the fusion zone, while the other sample prepared at 120 Jules per mm fractures at the parent metal. AW and PWSHT samples, XRD and SEM results indicate the occurrence of chromium carbide in base metal of sample welded at 120 Jules per mm, compared to AW sample hardness is significantly increasing in PWSHT samples.

Ramkumar et al. (2014) made an attempt to investigate the behavior of nickel alloys (Monel 400, Hastelloy C276) joint by PCGTA welding. ERNiCrMo-3 filler is used to join the dissimilar metals of nickel alloy. Study indicates that Monel 400 subjected to tensile failure due to the absence of unmixed zone in both sides of HAZ. Better ductility was observed in dissimilar metal in bend test. Metallurgical and mechanical properties of dissimilar metals are associated with the use of current pulse.

Panditel et al. (2014) made an attempt to study the need of bimetallic (Monel 400, Hastelloy C276) combinations in high temperature applications were studied. GTA weld technique used to join these metals by employing ERNiCrMo-3 filler. Weldments characterization was carried out to observe the metallurgical and mechanical properties of weldments. Results obtained from tensile test prove that the hardness of weld zone in bimetallic combination metals is greater than that of parent metals. EDAX/SEM and optical microscope techniques are used to predict the structural property.

Wu et al. (2014) made an attempt to investigate the requirement of Hastelloy C276 in nuclear industry. Studies indicates that weldment less than 1 mm width produce the defect free joint. Fracture mechanism of Hastelloy C276 was studied from SEM analysis at different temperatures (200, 300, 400°C). Results shows that few sample were broken in weld zone and some samples were broken in base metal. AS welded samples have higher strength compared to the base metal.

Saravanan et al. (2019) made an attempt to correlate the laser butt weld microstructure of Hastelloy C276 joint by experimental and numerical method. Joints are made at different process parameters viz., pulse energy and duration, welding speed. Experiment was done in 600 W Nd: YAG LWM, FEA is used to find the numerical microstructure of Hastelloy. Results indicates the temperature variation, distribution of heat in weld zone and hardness of weld zone.

Bal et al. (2019) made an attempt to investigate the welding zone, adjacent HAZ and unpretentious base metal correction rate and consequently measure the weakness to correction of weldment without preparing a separate samples by implementing the laser displacement sensor scanning technique in EBW process. Corrosion test indicates that weld zone corrosion rate is greater than corrosion rate of base metal and HAZ.

Bal et al. (2019) made an attempt to optimize the influencing process parameter to increase the quality of weld bead area in Hastelloy C276. Optimisation technique is used to prepare the full factorial design with the various parameters to prepare the required number of samples and the output responses are the various bead geometry. The regression equation was established to optimise the process parameter after validating the experimental result with conformation test. Corrosion occurred in the bead geometry, weld zone and base metal are studied by conducting the potentiodynamic-polarization test.

Guo et al. (2014) made an attempt to develop the 3D model by ANSYS code to disclose the behaviour of Hastelloy C276 butt joint by pulsed laser welding. Experiment were conducted and compared with the simulation result to check the residual distortion and welding temperature of weldments. Finite element method used to investigate the influence of cooling distance in residual distortions and stresses in weldment. Cooling distance plays the vital role in residual distortion and stress distribution compared to traditional PLW and better results were obtained during reducing the cooling distance.

2. Conclusion

From the literature review, many researchers have focus on the welding of superalloys. Since superalloys find it’s working in very high temperature. Different welding techniques have been applied on the superalloys. Large number of works have focused on the side of automating the welding. In order to automate the welding process, the most influencing process parameter which affects the quality of the weld has to be determined. Generally the weld quality depends upon the geometry of the bead and the composition of the weld. Each process parameter has influence on the various geometry of the bead. Geometry of the Bead include width of the bead, depth of penetration and height of reinforcement. From the bead’s geometry, the weld quality without any defects can be assed manually. Defects like lack of penetration, lack of fusion, spatter, large reinforcement, more depth of penetration, undercut, dilution etc. can be visualized by naked eye. Therefore it is necessary to choose the combination of the better parameter to obtain good quality of the weld. For to obtained the best combination, large of trials are been made on the plate to quantify the range of the parameter. Lot of work described on establishing the relationship among the process parameter to improve the quality of weld.
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