"PERFORMANCE OF GTAW USING ARGON-HELIUM SHIELDING GAS MIXTURE BY GENETIC ALGORITHM ON SDSS MATERIAL"

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ABSTRACT

Gas tungsten arc welding (GTAW) with filler wire addition is a candidate process for welding of UNS S32205 super duplex stainless steel. In GTAW, the quality of the weld is characterized by the weld-bead geometry as it influences the mechanical properties and its performance during service. This work focuses on the development of ANOVA model and optimization using Genetic Algorithm for determining the optimum/near-optimum GTAW process parameters for obtaining the optimum weld-bead geometry during welding of S32205 stainless steel. Parameters selected for study were Welding current, welding speed and welding voltage and the response selected was penetration and hardness. Using the experimental data generated on the influence of process variables on weld-bead geometry. ANOVA Analysis was done to obtain the significant parameters. The optimum values of parameters found using GA optimization tool are welding speed 130, welding current 180, and arc voltage 18. Optimum value of weld penetration was 2.79 and hardness is 200.

Keywords: *GTAW welding, Genetic algorithm, ANOVA, S/N ratio, penetration and hardness.*

I. INTRODUCTION

Tungsten Inert Gas (TIG) or Gas Tungsten Arc (GTA) welding is the arc welding process in which arc is generated between non consumable tungsten electrode and work piece. The tungsten electrode and the weld pool are shielded by an inert gas normally argon and helium. Deforming the surface plastically, under compressive loads. Under this external load, the surface of the component is subjected to cold working. One such SPD process that has gained increasing acceptability in the manufacturing industry is burnishing. Burnishing is a surface modification process which produces a very smooth surface finish cylindrical surface. The tool may consist of one or more ball or roller. This process does not involve the removal of material from the work pieces.

The tungsten arc process is being employed widely for the precision joining of critical components which require controlled heat input. The small intense heat source provided by the tungsten arc is ideally suited to the controlled melting of the material. Since the electrode is not consumed during the process, as with the GTAW welding processes, welding without filler material can be done without the need for continual compromise between the heat input from the arc and the melting of the filler metal.

Fig-1.1 Experimental welding machine

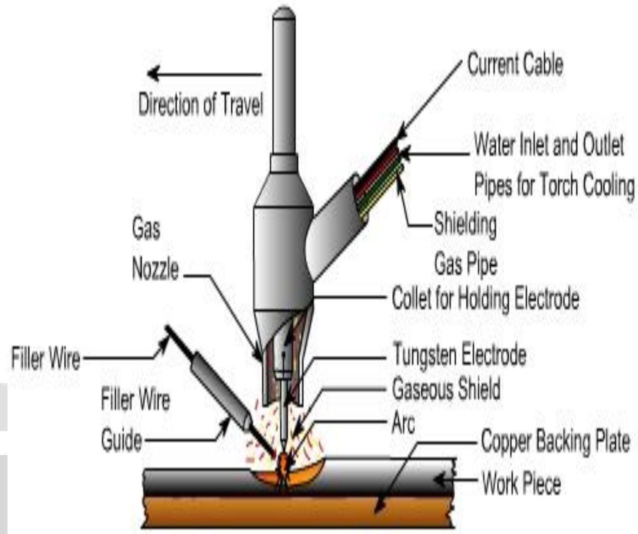

Fig-1.2 Principle of TIG Welding

As the filler metal, when required, can be added directly to the weld pool from a separate wire feed system or manually, all aspects of the process can be precisely and independently controlled i.e. the degree of melting of the parent metal is determined by the welding current with respect to the welding speed, whilst the degree of weld bead reinforcement is determined by the rate at which the filler wire is added to the weld pool. In TIG torch the electrode is extended beyond the shielding gas nozzle. The arc is ignited by high voltage, high frequency (HF) pulses, or by touching the electrode to the work piece and withdrawing to initiate the arc at a preset level of current.

II. LITERATURE REVIEW

A.Karpagaraj, N.Sivashanmugam, K.Sankaranarayanasamy [1] 2015 investigated on Gas Tungsten Arc Welding (GTAW) is a commonly used welding process for welding Titanium materials. Welding of titanium and its alloys poses several intricacies to the designer as they are prone to oxidation phenomenon. The proposed design and arrangement have been employed for joining commercially pure titanium sheets with variations in the GTAW process parameters namely the welding current and travel speed. Bead on plate (BOP) trials were conducted on thin sheets of 2mm thickness by varying the process parameters. Subsequently, the macrostructure images were captured. Based on these results, the process parameters are chosen for carrying out full penetration butt joints on1.6 mm and 2 mm thick titanium sheets. **P. Sathiya, P. M. Ajith and R. Soundararajan [2] 2014** has studied The present study is focused on welding of super austenitic stainless steel sheet using gas metal arc welding process with AISI 904 L super austenitic stainless steel with solid wire of 1.2 mm diameter. Based on the Box - Behnken design technique, the experiments are carried out. The input parameters (gas flow rate, voltage, travel speed and wire feed rate) ranges are selected based on the filler wire thickness and base material thickness and the corresponding output variables such as bead width (BW), bead height (BH) and depth of penetration (DP) are measured using optical microscopy. Based on the experimental data, the mathematical models are developed as per regression analysis using Design Expert 7.1 software. An attempt is made to minimize the bead width and bead height and maximize the depth of penetration using genetic algorithm. **G. Magudeeswaran, Sreehari R. Nair, L. Sundar et al. [3] 2014** has studied the weld bead in the form of aspect ratio i.e. width to depth ratio of Activated TIG welding. The input parameters were Electrode gap, Travel speed, Current and Voltage. L9 (34) OA with 4 columns and 9 rows was used for carrying out readings. Results obtained from ANOVA are: electrode gap is the most significant factor on aspect ratio with contribution of 53.99%, followed by current with contribution of 27.62%. The voltage and travel speed are insignificant with contribution of 14.55% and 3.82% respectively. The optimum welding parameters are found to be electrode gap of 1 mm, travel speed of 130 mm/min, current of 140 A, and voltage of 12 V. The aspect ratio is found to be 1.24 for the joints fabricated using the optimized process parameters and is well within the acceptable range to avoid solidification cracking. **M. Hoseinpoor, M. Momeni, M.H. Moayed, A. Davoodi [4] 2014** investigated critical pitting temperature (CPT) of 2205 duplex stainless steel (DSS2205) was assessed using electrochemical impedance spectroscopy (EIS) in ferric chloride solution. In order to verify the results other methods such as ASTM G 48, potentiodynamic and potentiostatic polarization and zero resistance ammeter (ZRA) were also employed. The results show a strong close relation between the results of this method by those of previous methods. CPT of the alloy is 40 _C based on standard method and 44 C, 49 C according to the ZRA and potentiostatic methods. Both potential dynamic and EIS methods give an almost identical CPT value. **R. Sudhakaran, V. Vel Murugan et al. [5] 2013** has developed a neural network model for predicting depth of penetration and optimizing the process parameters for maximizing depth of penetration using simulated annealing algorithm. The process parameters chosen for the study are welding current, welding speed, gas flow rate and welding gun angle. The chosen output parameter was depth of penetration. The experiments were conducted based on design of experiments using fractional factorial with 125 runs.The percentage of error of the neural network model was calculated as the percentage difference between the experimental and predicted value relative to the predicted value. The results show that the percentage error is in the range of 0.7 to -1.2%. When welding current increases, shielding gas increases and gun angle increases, depth of penetration also increases. **Dongjie Li, Shanping Lu, Dianzhong Li, Yiyi Li [6] 2012** were investigated the A new welding method named double shielded tungsten inert gas (TIG) has been developed to improve the TIG weld penetration. The main principles to increase the weld depth have been discussed. Results show that the critical oxygen content in the weld pool is around 100*10-6 as the temperature coefficient of surface tension changes from negative to positive. The tracer test using pure silver shows that the direction of Marangoni convection changes as the oxygen content increases in the weld pool. The effect of arc constriction on the weld depth has been evaluated on a water-cooled copper plate, and the result indicates that the torch of double shielded can give a more powerful arc. **P. Sathiya, Mahendra Kumar Mishra , B. Shanmugarajan [7] 2011** This paper investigates the bead geometry, microstructure and mechanical properties of AISI 904 L super austenitic stainless steel joint by CO_2 laser–GMAW hybrid welding process. Shielding gas is one of the important parameters for the process stability and efficient synergetic effects between laser and gas metal arc welding (GMAW). A detailed study of CO_2 laser–GMAW hybrid welding with different shielding gas mixtures in different ratio (50%He + 50%Ar, 50%He + 45%Ar + 5%O_2, and 45%He + 45%Ar + 10%N_2) was carried out on AISI 904 L super austenitic stainless steel sheet of 5 mm thickness. The weld penetration of hybrid welding was determined by the plasma shape varying with the shielding gas parameters, especially the plasma height interacting with incident plasma. Finally, hardness test is performed along the longitudinal direction of the weld zone. The results showed that the joint by laser–GMAW hybrid had higher tensile and impact strength than the base metal. The fractrography observation showed the cup-cone shaped fracture while the hybrid welding joint mixed mode of fracture.

III. EXPERIMENTATION

The gas tungsten arc welding (GTAW) process is based on the electric arc established between a non-consumable electrode of tungsten and the work-pieces to be joined. Part of the heat generated by the electric arc is added to the work pieces, promoting the formation of a weld pool. The weld pool is protected from air contamination by a stream of an inert gas (Ar or He) or a mixture of gases. The TIG welding machine that is to be used for carrying out experimental runs is UNITOR UWI 400 Inverter welder machine, DC type. It has a digital display for current. This machine is dual machine that can be used for both Arc welding and TIG welding. It has a current range of 20-300A. This machine fulfills the necessary parameters and levels that are required for experiments. The specifications of the welding setup are as KEEPSAKE ENGINEERING LTD 2-Meldi Estate near Gota Railway Crossing Gota Ahmedabad.

The chemical composition of S32205 or 2205 is provided in the table below:

Cr	**Ni**	**Mo**	**C**	**N**	**Mn**	**Si**	**Cu**	**P**	**S**	**Fe**
22.0-23.0	4.50-6.50	3.0-3.50	0.030 Max	0.24-0.32	2.0 Max	1.0 Max	0.50 Max	0.030 Max	0.020 Max	Balance

Table-3.1 chemical composition

The parameters are the variables that are to be considered for research. Electrode which is to be used is 2% Thoriated Tungsten electrode. Experiment Conducted on Gas Tungsten Arc Welding machine, I had selected Input process parameters & their levels also I had taken some machine constant parameters that I note down here like as below. We have selected the material for experiment runs S32205 as a base metal having size 100*50*5 (mm)

- **Input parameter**

NO	Factor	Level 1	Level 2	Level 3	Unit
1	Arc Voltage	16	17	18	Voltage
2	Welding current	150	165	180	Ampere
3.	Welding speed	130	140	150	mm/min

Table-3.2 Input parameter

- **Response/output parameter**

Hardness and Penetration.

IV. Analysis, Results and Discussion

For optimum parameters selection for GAS TUNGSTEN ARC WELDING design of experiment is done with TAGUCHI Orthogonal Array. This is implemented by MINITAB 17 to construct an experiment design. After performing different experiment with various parameters welding speed, welding current, Arc voltage. The penetration is measured by Stereo zoom microscope.

Experiment No	Welding current (Amp)	Welding voltage (v)	Welding speed (mm/min)	Penetration	Hardness
1	150	16	130	2.18	200
2	165	17	130	2.53	197
3	180	18	130	2.79	200
4	165	16	140	2.22	225
5	180	17	140	2.10	215
6	150	18	140	1.88	208
7	180	18	150	2.65	200
8	165	16	150	2.69	176
9	150	17	150	2.03	194

Table-4.1 experiment and predicted value of penetration and hardness.

A. Analysis of variance (ANOVA)

ANOVA gives us the factors significant in the process. There are different columns in the ANOVA table. They are first Degree of freedom, Sum of Squares (SS), Mean of Squares (MS) or the variance, F-value, P-value.

Degree of freedom in ANOVA can be given by total number of factors subtracted by 1. For example, if there are 3 factors then degree of freedom for each factor is 2 and the total degree of freedom will be 6. So, at least 6 experimental values are required for generating an analysis table of ANOVA. The ANOVA analysis for the experimental results is shown in below Table 4.2.

Source	DF	SS	MS	F-Value	P-Value
Welding current	2	0.800	0.400	0.25	0.800

Welding voltage	2	2.133	1.0667	0.67	0.600
Arc speed	2	54.00	27.000	16.88	0.056
Error	2	3.200	1.600		
Total	8	60.00			

Table 4.2: Analysis of Variance

From the Table 4.3 Fisher test or f-test gives that all the factors are significant. For the F-ratio having degree of freedom in numerator as 2 and degree of freedom for denominator 2 at 0.05 significance level has critical value of 1.

The column of p-value also gives the results that all the factors are significant for the process as all the values are lower 0.05 for alpha-level 0.05.

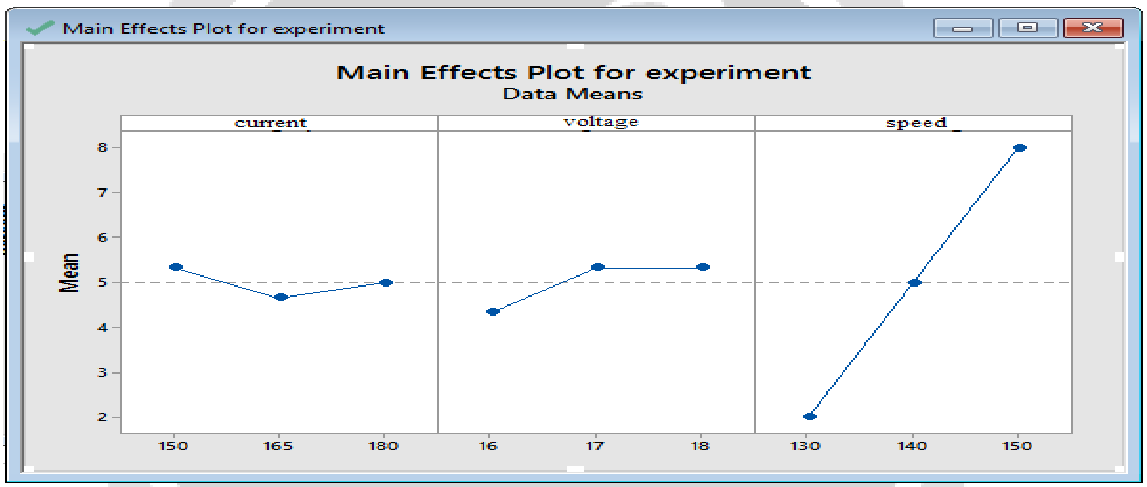

Fig. 4.1 Main Effects plot for parameters.

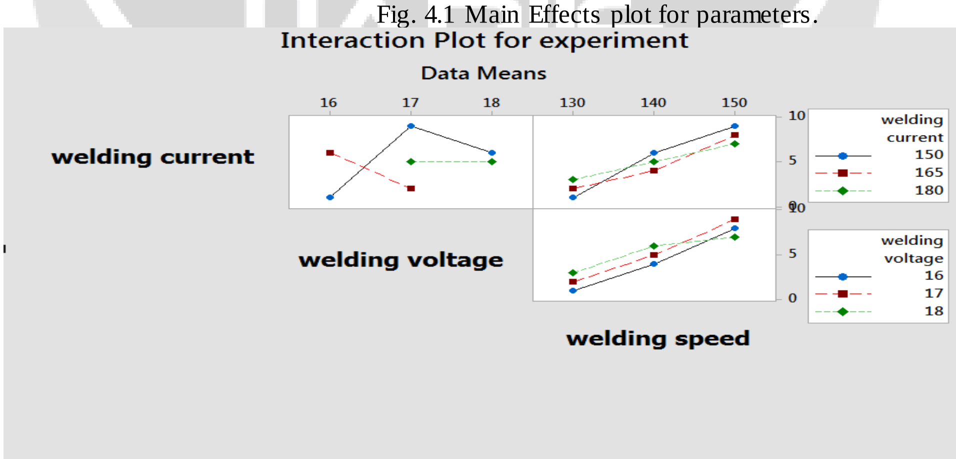

Fig. 4.2 Interaction plot for parameters.

The Above Fig. 4.1 gives the main effect plot of the all the parameter. In main effect plot if the line is horizontal i.e. parallel to X-axis then there is no effect of that parameter. If the line is not horizontal then there is effect of changing that factor, more the line is steeper more the effect of that parameter is found.

The Fig. 4.2 gives the interaction of the hardness and penetration. If the lines are parallel, then there is no interaction between the factors and if the difference in the slope of the line is high then there is large interaction between the factors.

B. Signal-to-noise ratio (S/N ratio)

Signal-to-noise ratio is defined as the ratio of the power of a signal (meaningful information) and the power of back-ground noise (unwanted signal)

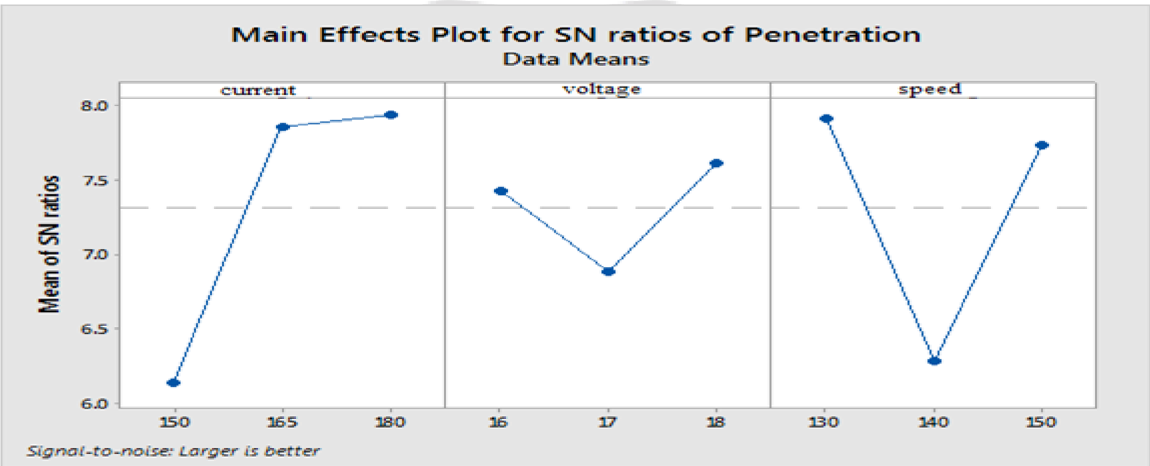

Fig. 4.3 main effects plot for S/N ratio of penetration

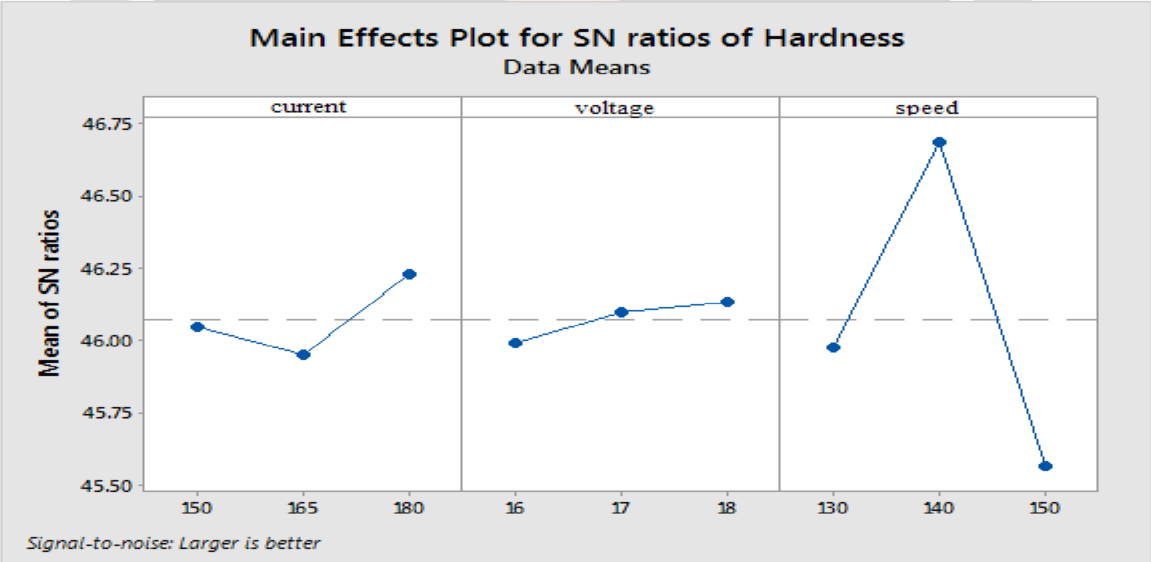

Fig. 4.4 main effects plot for S/N ratio of Hardness

C. Genetic Algorithm

A genetic algorithm is a search algorithm based on natural selection and the mechanisms of population genetics. It is inspired by Darwin's theory- "Survival of the Fittest". Performs a random search within a defined search space to solve a problem. The searching procedure starts with an initial set of random solution. Fitness function is used to optimize the solution. Fittest individual has highest probability to survive and reproduce in each iteration or generation. GA uses two strategies first exploration in which it investigate unknown and new areas in search space and exploitation here it makes use of knowledge of solution that was found previously in search space to help to find new and better solutions. Different operators used in the Genetic Algorithm are Reproduction, Crossover, and Mutation. Reproduction is the first applied. In this the individuals are copied to the mating pool according to their fitness level.

After reproduction operator, the population has good strings. Now crossover operator is applied to create better strings. Crossover is controlled by crossover rate which is a ratio total mating strings to population size. The two strings participating in the crossover operation are known as the parent strings, and the resulting strings are known as children strings. Mutation ensures no important genetic material is lost. Mutation is the occasional random alteration of the value of a string position. This means changing 0 to 1 or vice versa on a bit-by-bit basis and with a small mutation probability of 0 to 0.1. The need for mutation is to maintain diversity in the population.

GA optimization toolbox was used to obtain the optimum results. The parameter selected for optimization ware population size: 40, Selection Function: Roulette, Fitness Scaling: Rank, Elite count: 2, Generation: 100, Crossover rate: 0.8, Mutation rate: 0.01. The optimum values of parameters found using GA Optimization Tool are Welding speed 180, Welding current 18, and Arc voltage 130. Optimum value of weld penetration was 2.79 and hardness is 200. Optimum values found at 51^{th} Generation.

V. Conclusions

This research work has presented an investigation on the optimization of "INVESTIGATION OF GTAW USING ARGON-HELIUM SHIELDING GAS MIXTURE BY GA ON SDSS MATERIAL". Input parameters selected for study were Welding speed, Welding current and Arc voltage the response was weld penetration and hardness. The level of importance of the welding parameters on the weld penetration and hardness is determined by using ANOVA. The model was optimized using Genetic algorithm optimization toolbox. Experimental validation of the model was also performed. Various conclusions obtained were:

- Best Result of weld penetration and hardness are found which is 2.79 and 225 respectively.
- Genetic algorithm will provide the best optimization on 51th generation and which is quite fast.
- F-value and p-value shows that all the factors are significant.
- Increasing Welding current & welding speed and low welding voltage then increases the penetration and hardness.
- Genetic Algorithm has given optimum result at lowest value of welding voltage and highest value of Welding current & welding speed.
- The optimum values of parameters found using GA Optimization Tool Are Welding speed 130, Welding current 180 and Arc voltage 18. Optimum value of weld penetration is 2.79 and hardness is 200 which is best possible result of those weld.

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