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Optimisation of welding parameters of Flux Core Arc Welding (FCAW) of EN 24 & SS409 stainless steel for better Tensile strength and Hardness

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***Abstract*— The dissimilar metal joints have been emerged as a structural material for various industrial applications which provides good combination of mechanical properties like strength, corrosion resistance with lower cost. Selections of joining process for such a material are difficult because of their physical and chemical properties. The stainless steel and mild steel (dissimilar material joints) are very common structural applications. Joining of stainless steel and mild steel is very critical because of carbon precipitation and loss of chromium leads to increase in porosity affects the quality of joint leads deteriorate strength. In order to obtain a good quality weld and control weld distortion, it is therefore, necessary to control the input welding parameters. In this research work, experiments has to be carried out to investigate influence of welding parameters on tensile strength, and hardness of flux cored arc welding (FCAW) by using experimental welding of EN 24 & SS409 stainless steel of 6 mm thick. The research will be applied Taguchi Method on an austenitic stainless steel specimen of dimensions 100 × 100 ×6 mm, which have following interested parameters: various arc current, arc voltage and gas pressure.**

***Keywords*— FCAW, Taguchi Method, EN 24 & SS409 stainless steel, mechanical properties.**

I. INTRODUCTION

Flux Core Arc Welding (FCAW) uses a tubular wire that is filled with a flux. The arc is initiated between the continuous wire electrode and the work piece. The flux, which is contained within the core of the tubular electrode, melts during welding and shields the weld pool from the atmosphere. Direct current, electrode positive (DCEP) is commonly employed as in the FCAW process. There are two basic process variants; self-shielded FCAW (without shielding gas) and gas shielded FCAW (with shielding gas). The difference in the two is due to different fluxing agents in the consumables, which provide different benefits to the user. Usually, self-shielded FCAW is used in outdoor conditions where wind would blow away a shielding gas. The fluxing agents in self-shielded FCAW are designed to not only deoxidize the weld pool but also to allow for shielding of the weld pool and metal droplets from the atmosphere. The flux in gas-shielded FCAW provides for de oxidation of the weld pool and, to a smaller degree than in self-shielded FCAW, provides secondary shielding from the atmosphere. The flux is designed to support the weld pool for out-of position welds. This variation of the process is used for increasing productivity of out-of position welds and for deeper penetration.

II. LITERATURE REVIEW

In a welding world, Flux-Cored Arc Welding (FCAW) process commonly used in different industries to join the metals and alloys. It has a few numbers of benefits such as high deposition rates, more tolerant of rust and mill scale than GMAW, simpler and more adaptable than SAW, less operator skill required than GMAW, high productivity than SMAW and goo surface appearance. For the repairs industry they are performed by used the manual metal arc welding (MMAW), however the flux cored arc welding (FCAW) process are more benefits and have been appreciated by the industry for many years . The process parameters for FCAW should be well recognized and categorized to enable automation and robotization of arc welding. The selection of welding procedure must be specific to ensure the good quality in bead. To obtain the needed quality welds, it is important to have complete control over the relevant process parameters to obtain bead geometry and shape relationship of a weldment based.

Syarul Asraf Mohamat, et.al [1] Flux Core Arc Welding (FCAW) is an arc welding process that using continuous flux-cored filler wire. The flux is used as a welding protection from the atmosphere environment. This project is study about the effect of FCAW process on different parameters by using robotic welding with the variables in welding current, speed and arc voltage. The effects are on welding penetration, microstructural and hardness measurement. Mild steel with 6mm thickness is used in this study as a base metal. For all experiments, the welding currents were chosen are 90A, 150A and 210A and the arc voltage is 22V, 26V and 30V respectively. 20, 40 and 60 cm/min were chosen for the welding speed. The effect will studied and measured on the penetration, microstructure and hardness for all specimens after FCAW process. From the study, the result shown increasing welding current will influenced the value depth of penetration increased. Other than that, the factors that can influence the value of depth of penetration are arc voltage and welding speed.

B. Senthilkumar [2] Weld surfacing with super duplex grade stainless steel found to improve corrosion resistance and functional life of the mild steel components used in the process industries. The properties of the deposited layer were influenced by the process variables that affect the heat input to the process. The influence exerted by the process variables on the responses of super duplex stainless steel claddings were modelled using the response surface models. The response surface models developed by the regression techniques using the data collected from central composite rotatable design of experiments. The data extracted from 32 single bead on the plate welds were deposited by flux cored arc welding process. The developed models can be used to predict and simulate the influence of the process variables on the responses. The insignificant variables found in the full models were removed by the backward elimination technique. Sensitivity analysis performed on the reduced models helps to identify and rank the process variables based on their extent of influence on the responses. Then the ranked variables are closely regulated to tailor the properties of the surfaced layer.

A. Aloraier et.al [3] Post weld heat treatment (PWHT) is the most common technique employed for relieving residual stresses after general repair welding. Besides, the primary purpose of reducing the effect of stresses induced by welding, PWHT is also intended to temper the metallurgical structure of the heat affected zone (HAZ). Unfortunately, there are significant difficulties in carrying out post weld heat treatment such as; the complexity of weld geometry, the possibility of distortion in the case of any mechanical loads, difficulty in heating symmetrically, and also PWHT may cause degradation of the material properties (especially creep and tensile strength in the case of multi PWHT cycles). Most of the repairs in industry are performed with manual metal arc welding (MMAW), however, the benefits of the flux cored arc welding (FCAW) process have been appreciated by industry for many years. Guidelines in the current welding standards in addressing the issue of temper bead welding (TBW) when fully automated flux cored arc welding is used are very limited. This paper reports research work carried out to investigate; whether a fully automated flux cored arc welding process with bead tempering can be used in repair welding instead of manual metal arc welding in order to eliminate the use of post weld heat treatment. The paper also examines different percentages of bead overlaps and studies their effects on the mechanical properties as well as the microstructures. The results show that desirable microstructures and hardness values can be obtained using flux cored arc welding when 70% bead overlap is used.

N.B. Mostafa[4] This paper describes prediction of weld penetration as influenced by FCAW process parameters of welding current , arc voltage , nozzle-to-plate distance, electrode-to - work angle and welding speed .Optimization of these parameters to maximize weld penetration is also investigated. It deals with the statistical technique of central composite rotatable design to develop a mathematical model for predicting weld penetration as a function of welding process parameters. The constrained optimization method is then applied to this model to optimize process parameters for maximizing weld penetration. The result obtained from the developed model indicates that the model predicts the weld penetration adequately. The optimization result also shows that weld penetration attains its maximum value when welding current, arc voltage, nozzle-to-plate distance and electrode-to-work angle are maximum and welding speed is minimum. The statistical technique of developing a model for prediction of weld penetration is valid only within the specified limits of welding process parameters and hence maximization of penetration is also valid within these limits. This technique can be modified to include other parameters such as plate thickness affecting penetration

LI YAJIANG, et al [5] carried out the distribution of the residual stress in the weld joint of HQ130 grade high strength steel was investigated by means of finite element method (FEM) using ANSYS software. Welding was carried out using gas shielded arc welding with a heat input of 16 kJ/cm. The FEM analysis on the weld joint reveals that there is a stress gradient around the fusion zone of weld joint. The instantaneous residual stress on the weld surface goes up to 800 ~ 1000 MPa and it is 500 ~ 600 MPa, below the weld. The stress gradient near the fusion zone is higher than any other location in the surrounding area. This is attributed as one of the significant reasons for the development of cold cracks at the fusion zone in the high strength steel. In order to avoid such welding cracks, the thermal stress in the weld joint has to be minimized by controlling the weld heat input.

J. Dutta,et al[6] investigated reveals an elaborate analysis of variation of thermal properties of high carbon steel plate butt joints formed by DC Gas Tungsten Arc (GTA) welding. Experiment has conducted to predict the two dimensional temperature cycle developed. To find out the heat flux distribution, Gaussian Heat source model has been implemented. Carslaw-Jaeger's mathematical model has been incorporated to estimate the variation of thermal conductivity. To portray the change in specific heat at different locations from the fusion boundary at experimental temperatures, Thin plate model has been utilized. Heat losses due to convection, radiation and evaporation have been studied. To estimate total heat loss from weld joint at different locations a method has been proposed and Vinokurov's empirical correlation has been used for validation. At very close region (36mm from fusion boundary) to heat affected zone all thermal properties have shown significant variation based on experimental results. From the analysis of heat loss an optimum temperature has been observed and it is helpful to define the range of convection and radiation heat loss phenomena.

2.1 Problem Identification

Problem Identification in many cases the welder needs only to know the techniques of actual welding and does not need to be concerned about the type or grade of steel being welded. This is because a large amount of steel used in fabricating a metal structure is low Carbon or plain carbon steel (also called mild steel). When welding these steels with any of the common arc welding processes like Stick MIG or TIG there are generally few precautions necessary to prevent changing the properties of the steel. Steels that have higher amounts of Carbon or other alloys added may require special procedures such as preheating and slow cooling, to prevent cracking or changing the strength characteristics of the steel. The welder may be involved in following a specific welding procedure to ensure weld metal and base metal has the desired strength characteristics.

2.2 Conclusion

From the above literature survey it is found that the mechanical behaviour analysis and microstructure analysis of dissimilar carbon steels is not yet analysed. Hence, in this investigation an attempt has been made to study the process parameter Analysis on medium and stainless steels during the Flux core arc welding. This Experimental study is very useful for carrying out further studies on dissimilar structure materials.

III. METHODOLOGY AND EXPERIMENTAL DESIGN

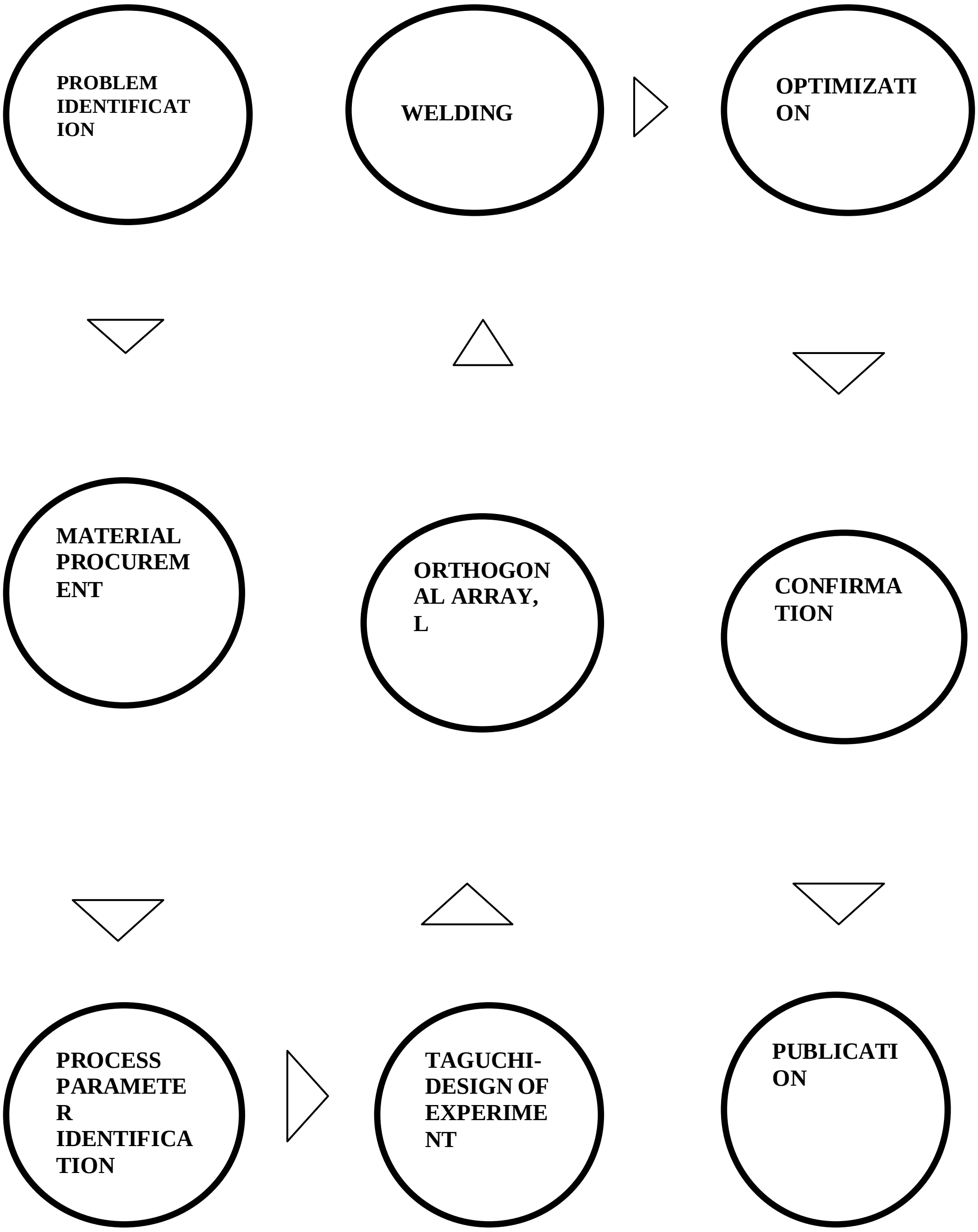

Fig1. Methodology of research work

Design of experiment

Welding current in Amperes, Arc voltage in Volts and Torch angle in degree are the three chosen process parameters and the various levels we considered for the research work is listed below

Table3.1. Process parameters and their levels

S.No	WELDINGCURRENT (A) I	ARC VOLTAGE (V)	TORCH ANGLE (DEG)
1	140	18	30
2	160	20	45
3	180	22	60

Table 3.2 L9 Array formation

WELDINGCURRENT (A) I	ARC VOLTAGE (V)	TORCH ANGLE (DEG)
140	18	30
140	20	45
140	22	60
160	18	45
160	20	60
160	22	30
180	18	60
180	20	30
180	22	45

I. RESULTS AND DISCUSSIONS

Hardness test of welded specimen

TABLE 4.1: Hardness value of FCAW specimen

Materials	WELDINGCURRENT (A) I	ARC VOLTAGE (V)	TORCH ANGLE (DEG)	HARDNESS	
				SS409	EN24
SS409 & EN24	140	18	30	82	90
	140	20	45	90	95
	140	22	60	86	87
	160	18	45	82	90
	160	20	60	87	94
	160	22	30	90	92
	180	18	60	84	95
	180	20	30	89	87
	180	22	45	87	89

Tensile Strength Test

The friction welded specimens were prepared as per the ASTM standards. The test was carried out in a universal testing machine (UTM) 40 tones FIE make. The test specimen's tensile strength value and their corresponding S/N ratio by Taguchi Analysis are listed in table below.

Table4.2TENSILE STRENGTH RESULT

SL.NO	TENSILE STRENGTH KN	S/N RATIO
T1	58	18.8897
T2	22.4	26.8485
T3	24	24.0824
T4	56	20.8279
T5	58.2	23.5218
T6	56	23.9731
T7	23	18.0618
T8	32	22.2789
T9	56.2	28.0967

Table: 4.3 Response Table for Signal to Noise Ratios Larger is better

Level	**WELDINGCURRENT AMPS I**	**ARC VOLTAGE VOLT**	**TORCH ANGLE º**
1	29.96	32.49	33.45
2	35.08	30.80	32.32
3	30.78	32.52	30.05
Delta	5.12	1.72	3.40
Rank	1	3	2

Table4.4 Analysis of Variance for TENSILE TEST, using Adjusted SS for Tests

Source	**DF**	**Seq SS**	**Adj MS**	**F**	**P**	**% OF CONTRIBUTION**
WELDINGCURRENT (A) I	2	873.0	436.49	0.89	0.528	38
ARC VOLTAGE (V)	2	128.1	64.05	0.13	0.884	7
TORCH ANGLE (DEG)	2	295.4	147.72	0.30	0.768	12
Error	2	977.9	488.97			43
Total	8	2274.5				100

Regression equation: TA = 42.87 - 8.1 CURRENT_140 + 13.9 CURRENT_160 - 5.8 CURRENT_280 + 2.8 VOLT_18 - 5.3 VOLT_20 + 2.5 VOLT_22 + 5.8 ANGLE_30 + 2.0 ANGLE_45 - 7.8 ANGLE_60

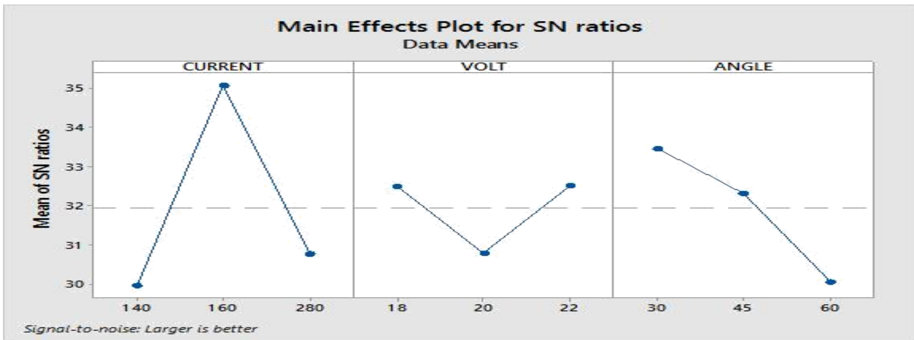

Fig 4.1 Main effect plot for S/N ratio

According to the Taguchi design, optimal parameters value for the 6 mm plate of dissimilar structure steel were AMPS 160 VOLT 22 TORCH ANGLE 30º.

I. CONCLUSIONS

FCAW welding can be used successfully to join SS409&EN24. The processed joints exhibited better mechanical and metallurgical characteristics. The specimen failures were associated depending upon the improper changes of heat value. Experimentally found that the input parameter value Current Rating 160 A, Voltage 18V and Torch angle 45º was the best value and it did not create any major changes and failures in the testing process and it was comparatively higher tensile value than other values. Finally optimized through Taguchi design,the optimum parameter value for 6mm bimetallic joints was 160 A, Voltage 22V and Torch angle 30º for the Tensile properties.

Percentage Of Contribution

Tensile strength was most influenced with current rating of 38%.

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