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Experimental Investigation of Submerged Arc Welding on Windmill Tower

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Abstract- *Submerged arc welding (SAW) is a high quality, high deposition rate welding process commonly used to join plates of higher thickness. This paper attempts to uncover an important area of quality engineering applied to a critical manufacturing process through Design of Experiments for the Optimization of Submerged Arc Welding Process. Design of Experiments (DOE) is a statistical tool, the USP (Universal sampling Plan) of DOE is that it can establish a functional relation for a complex set of variables which otherwise cannot be related by any empirical formula. The experimental setup is the design of experiments (DOE) where an orthogonal array is constructed for four input process parameters a) Welding current, b) Voltage c) Standoff distance, d)Travel speed to the value of temperature. A Mild Steel (material specification S355/S355 NL+ Z25) is selected for analysis in 09 experiments where ultrasonic testing is performed to find the defect in welded joint. Confirmation experiment was carried out to check the accuracy of the optimized results.*

Keywords-"Submerged arc welding (SAW), Design of Experiment (DOE), Universal sampling Plan (USP)"

I- INTRODUCTION

Welding is a fabrication process that joins materials, usually metals or thermoplastics by causing coalescence. This is often done by melting the work pieces and adding a filler material to form a pool of molten material that cools to become a well-built joint, the process is carried out with pressure sometimes used in combination with heat or only with heat, to produce the weld. Many different energy sources can be used for welding, including a gas flame, an electric arc, a laser beam, an electron beam, friction and ultrasonic frequency. While often an industrial process, Swelding can be done in many different environments, including open air, under water and in outer space. Submerged arc welding is an 'Arc Welding' process in which the arc is concealed by a blanket of granular and fusible flux. Heat for SAW is generated by an arc between a bare, solid metal (or cored) consumable-wire or strip electrode and the work-piece. The arc is maintained in a cavity of molten flux or slag which refines the weld metal and also protects it from atmospheric contamination. SAW is performed using value of these 9 sets and temperature during the welding process is recorded as an output parameter. Ultrasonic test are also performed on all these 9 welded joint to measure the quality of weld joint.

II- EXPERIMENTAL PROCEDURE

EXPERIMENTAL SETUP

Using 'Design of Experiments' approach, significant sets of input variables are identified for experimentation. This section discusses about the procedure adopted to carry out the experiments using submerged arc welding process with 9 selected sets of input parameters.

Selection of Process and Performances Variables

In this study Taguchi's L9 orthogonal array is used to design sets of experiment. After comprehensive study of literature available, internet suffering, industry feedback and discussion with practicing technicians it is found that four process parameters viz. Welding current, voltage, standoff distance and travel speed are dominating performance parameters for submerged arc welding process. The selected input parameters with 3 levels each are mentioned in table I. The performance parameters are Temperature and Quality of welded joint

Table I -Process parameters and their levels

Factors	Process parameters			
		LevelI	Level II	Level III
A	Welding current (amp)	400	500	600
B	Voltage (v)	30	32	36
C	Standoff distance (mm)	25	27	30
D	Travel speed (mm/min)	125	`150	175

- Temperature
- Repair result

These are one of the most important quality characteristics in the welding of thick plate which influences the performance of mechanical parts as well as cost.

Performance parameters: Based on the literature review and discussion with practicing Engineers, following two performance parameters are selected.

Design of Experiments

A fractional factorial design implementing an L9 Taguchi orthogonal array (OA) was established to conduct welding experiments. Fractional factorial design specifics involve the statistical elimination of insignificant parameters, thus reducing experimental runs without the loss of useful information. Following table II shows the L9 Taguchi orthogonal array (OA) for four factorial and their three levels.

Table II- Experiment matrix

Experiment No	In-PutProcessVariables			
	Factor A	Factor B	Factor C	Factor D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table III: Design of Experiment

Experiment No	OrthogonalarrayL9			
	Process Parameters			
	Welding Current (amp)	Voltage (volt) (mm)	Stand of dist .(mm)	Travel speed (mm/min)
1	400	30	25	125
2	400	32	27	150
3	400	36	30	175
4	500	30	27	175
5	500	32	30	125
6	500	36	25	150
7	600	30	30	150
8	600	32	25	175
9	600	36	27	125

Submerged Arc Welding Machine

Welding is carried out with SAW machine. This machine is available in METALFAB HIGHTECHB PVT.LTD., MIDC area Nagpur (M.H.). They allowed to do all the necessary experiments. They also provided the ultrasonic testing facilities on the welded joint to find the failure of welded pipe.

Table IV Specifications for submerged arc welding machine

Design	Technical data
Welding speed	120mm/minto1800mm/min
Wire feed speed	2.5to10m/min
Wire diameter	2.4mmto6.3mm
Welding current range	150ampto1200amp
Capacity of flux container	5.0kg(min)
Welding head adjustment • Vertical traverse • Horizontaltraversetowelddseam	 Min 250 mm Min 250 mm
Angular Displacement • Angle the vertical axis • Vertical plane traverse • Verticalplaneparalleltoweldseam	 360° 45° 45°
Opening circuit voltage	72volts (DC)
Welding voltage	20to46volts (DC)
Input Power supply	415±10%V,50±HZ,3phaseAC,3wire system

Selected performance parameter and their measurement

The output parameters measured in this research work is temperature and welding quality in form of a percentage. To get the desired performance of a welded structure the temperature is determine by the IR thermometer and quality of the welds determined by the ultrasonic test.

Temperature measuring instrument

During welding process heat generation takes place which increase temperature of welded plate. During the experimentation, temperature is measured by infra-red thermometer.

Mild Steel (material specification S355/S355 NL+ Z25) is used as a work piece material for the present experiment. The calculated average industry grade mild steel density is 7861.093 kg/m3. Its Young' modulus (a measure of its stiffness) is around 210,000MPA.

Figure 1: Image during submerged arc welding of tower

Orthogonal array was established to conduct welding experiments according to process parameter table I

Exp. No 01(WC=400amp,V= 30volt, SD= 25mm TS = 125mm/min, Temp = 1928)

Exp. No 02 (WC=400amp, V= 32volt, SD= 27mm, TS = 150mm/min, Temp = 1860)

Similarly total 9 experiments performed and their temperature and repair result to be measured.

RESULT

After selecting input process parameter as well as performance parameters, welding operations have been performed. The experimental data obtained after welding operation is present in Table V. The table also shows the fractional factorial design of experiment (L9, Orthogonal Array) for input parameters as mentioned in column 1 to 4. Column 5, 6 and 7and 8 provides the temperature and repair result. Corresponding signal to noise ratio using Larger the better for temperature and repair result is selected as Taguchi quality characteristics. The work piece material is mild steel. Table V shows the Input, Output and SN ratio for all performed experiments.

CONCLUSION

The objective of this work is to perform experimental investigations followed by optimization of the process parameters during CS and LS welding of MS tower using Submerged Arc Welding. To achieve this in total 9 experiments are conducted according to Orthogonal array L9. Taguchi's design of experiment has been employed for experiment design. Taguchi's method has been employed as single objective optimization technique to find optimal combination of input parameters for each performance measures. In this work, process parameters (Temperature) is investigated by varying the four process parameters (welding current, voltage, standoff distance, travel speed) on MS plate of thickness 28 mm. The optimum parameters value combination was found which would yield maximum temperature.

Table V: Shows the fractional factorial design of experiment(L9,OrthogonalArray)

Inputprocessvariables				**Outputvariables**		**SNratio**	
WeldingCurrent	**voltage**	**StandoffDistance**	**TravelSpeed**	**Temp.**	**Repairresult**	**SNTemphigh**	**SNResulthigh**
400	30	25	125	1928	88	65.7021	38.88
400	32	27	150	1860	92	65.3902	39.27
400	36	30	175	1728	31	64.7508	29.82
500	30	27	175	2680	24	68.5626	27.60
500	32	30	125	2530	89	68.0624	38.98
500	36	25	150	2700	93	68.6272	39.36
600	30	30	150	3024	36	69.6116	31.12
600	32	25	175	3240	80	70.2109	38.06
600	36	27	125	2900	89	69.2479	38.98

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