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Effect of Welding Parameters Controlling Submerged ARC Welding Process

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Abstract : Submerged arc welding (SAW) process is an important component in many industrial operations. The research on controlling metal transfer modes in SAW process is essential to high quality welding procedures. The SAW parameters are the most important factors affecting the quality productivity and cost of welding joint. Weld bead size and shape are important considerations for design and manufacturing engineers in the fabrication industry. In order to produce good welding or high quality weld, a skilled personal is required and the other reason is the need to select the various welding parameters to provide good quality weld which is identified by the micro structure, grain size, residual stress, the amount of spatter and a quality control system must be developed to eliminate the various predictive works. This is done to specify and establish the interrelation between the mechanical properties and the various weld parameters as well as it also investigates the most ideal combination of the various parameters which gives good weld quality, high strength and durability. This project has been planned to go through a series of phases and tests to specify the interrelation between the weld bead geometry and the mechanical strength. The test also involves the approach for finding the most optimum and the suitable process parameters which is controlling the Submerged Arc Welding.
Keywords: SAW Welding, Parameters, Mechanical properties.

Introduction

Welding is one of the most essential and inescapable process used for major fabrication process in the Manufacturing industries. Various types of Welding process are like Shield metal Arc Welding (SMAW), Gas Tungsten Arc Welding (GTAW), Gas Metal Arc Welding(GMAW), Flux Cored Arc Welding(FCAW) and Submerged Arc Welding(SAW). Welding technology has obtained access in every parts of Manufacturing like rail, roads, ship building, construction of large dams and various projects, pipelines, various power plants and automobile industries. Due to the constant increase in the application of welding in every aspects of manufacturing, it has to be constantly improved, experimented and upgraded.

Now in the presence of modern technologies and increasing demands of quality of products, every manufacturing process must be improved and innovated. Whenever, the welding process comes into the mind, the next moment one thinks of the Arc, Spatter, Weld bead and surface finish.

In order to produce good welding or high quality weld, a skilled personal is required and the other reason is the need to select the various welding parameters to provide good quality weld which is identified by the micro structure, grain size, residual stress, the amount of spatter and a quality control system must be developed to eliminate the various predictive works. One of the other methods to improve the weld quality was investigation of the welding process parameters and the weld bead geometry.

The advantage of the Arc welding enhances due to its wide range of electrode which can be used to weld a number of metals and their alloys. The welding of the joints can be carried out at any positions with highest weld quality and the joints which are difficult to be welded because of their positions by automatic welding machines could be easily welded by Submerged Arc Welding, in which both alternating and direct current can be utilized easily and effectively.

Submerged Arc Welding was not the only automatic welding process developed in the decades of 1920s, but the main problem came into consideration was the spattering of arc, ultraviolet radiations and the poor weld quality in the heavy metal welding. The current used for the arc welding was relatively high which leads to produce a heavy arc and spatter which conversely decreases the weld quality and weld strength as the exact penetration of the weld joint is not achieved which leads to the poor welding strength of the joints. To overcome all these problems the SAW was introduced and patent by Jones, Kennedy and Rothermund in 1935. The process includes continuously feeding electrodes. The molten weld and the Arc zone was prevented by atmosphere by being submerged under the cover of granular fusible flux.

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Submerged arc welding is a form of arc welding process which utilizes AC or DC or combination of both for attaining the maximum metal deposition rate. Here we are dealing with the effects of the various welding parameters controlling the submerged arc welding process. Welding current is a major factor that influences the penetration. Arc voltage and welding speed are also factors that can influence the penetration. Weld width increases with increase in voltage, current and wire feed rate, and decreases with increase in welding speed and nozzle-to-plate distance.

Submerged arc welding (SAW) is an arc welding process in which the heat flow for welding process is supplied by an arc developed between a bare metal (electrode) and a work piece. Among the several arc welding methods, the submerged arc welding is the preferred method for welding thick sections in the industry because of its several advantages which include high production rates, good weld quality, ease of automation and minimum operator skill requirement.Good single bead formation of the root and face surfaces of a weld joint are extremely difficult using the one sided single pass single electrode welding technique. Two electrodes operating simultaneously and arranged in tandem are used in this program because the geometry of the root and face welds can be controlled independently. With a single pass tandem electrode arrangement the lead arc forms the root weld. The trailing arc fills the remainder of the groove and provides sufficient face reinforcement. Both electrodes weld in one pool but are separated sufficiently to allow partial solidification of the root weld.

In the era of 1920s, various types of welding process and electrodes were developed. Even then the problem of weld contamination has not got its path to success. The atmosphere of oxygen and nitrogen comes in the contact with the weld pool which causes the brittleness of the weld joints and porous joints. After the continuous innovation in the welding research field, the submerged welding process has been introduced in which the arc was submerged in the thick blanket of the granular flux which protects the weld pool and the arc from the atmospheric contact and ultimately leads to the stronger weld joints and the decrease in the brittleness in the weld joints. The problem of porosity and cracks due to various atmospheric gas has been sort out by shielding the arc with the granular flux in order to detach the molten weld from the various atmospheric gases like oxygen and nitrogen which leads to various cracks and defects.

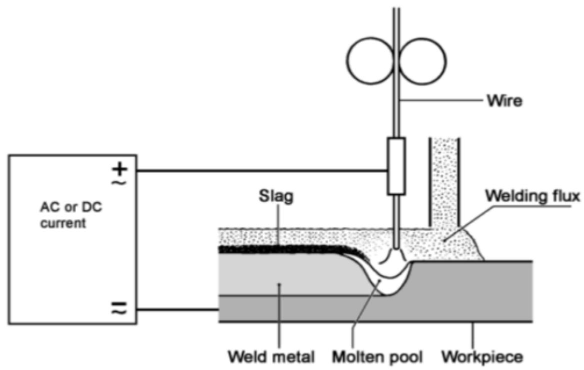


Figure 1 SAW Setup

The principle of operation is based on the technique of arc shielding by the thick granular flux initially consisting of lime, silica, manganese oxide and calcium fluoride as its main constituents and some other components. *The flux is feed in the weld zone through nozzle either by gravity flux feeding mechanism for the horizontal or flat welds and sometimes by pressurized flux feed mechanism for vertical welds and in some other cases.* The flux layer acts as a blanket which completely covers the molten metal and the arc zone which leads to the elimination of the spark and spatters which further reduces the fumes and radiation which is produced in the SAW process to a great extent.

Experimental

In the present study an attempt has been made to investigate the effect of welding parameters controlling submerged arc welding on different bead geometry parameters, including weld penetration, weld bead shape, weld reinforcement, through experiments based on design matrix. The experimental work is planned to be carried out in the following steps:-

- ***Developing the design matrix.***
- ***Conducting the experiments as per the design matrix***
- ***Recording the response parameters.***
- ***Presenting the direct and interaction effects of process parameters on bead geometry.***
- ***Analysis of results.***

Design of experiments

DOE is a systematic method to determine the relationship between factors affecting a process and the output of that process. In other words, it is used to find cause-and-effect relationships. Design of experiments is a powerful analysis tool analyzing the influence of process variables over some specific variable, which is unknown function of these process variables. It is the process of planning the experiments that appropriate data can be analyzed by statistical methods, resulting in valid and objective conclusions.

In submerged arc welding, process parameters interact in a complicated manner that influences various features of quality characteristics of the weld bead.The graphical representations of these equations serve as means for investigating main/direct as well as interaction effects of various process parameters on selected response.

Blocking: When randomizing a factor is impossible or too costly, blocking lets you restrict randomization by carrying out all of the trials with one setting of the factor and then all the trials with the other setting.

Randomization: Refers to the order in which the trials of an experiment are performed. A randomized sequence helps eliminate effects of unknown or uncontrolled variables.

Replication: Repetition of a complete experimental treatment, including the setup.

The Relationship Matrix (RSM) was employed to quantify the relationship between the individual response factors and the input machining parameters of the following form:

$$Y = F\ (A, B, C)$$

Where, Y is the desired response, F is the response function and A, B & C are the variables.

Processing of the DOE:

Enter the High and Low levels for factor A, B and C. Names and Levels are recommended but not required. The various parameters are chosen is shown in table.3.1.

Table 1 Select Factor or Interaction for Weld Bead

PARAMETERS	NOTATION	LIMITS	
		-1	+1
Current (Amps)	**A**	**700**	**900**
Travel Speed in/min	**B**	**11**	**14**
Voltage (volts)	**C**	**38**	**41**

Run each of the eight combinations in random order using the Run Order Column given in Table 3.2.

S.No	Run Order	Current (A) Amps	Travel speed (B) in/min	Voltage (C) Volts	AxB	AxC	BxC	AxBxC	Trial 1 (mm)	Trial 2 (mm)	Trial 3 (mm)	Trial 4 (mm)	Trial 5 (mm)	Avg (mm)
1	6	700	11	38	1	1	1	-1	27.2	27.4	27.0	27.6	27.1	27.26
2	8	700	11	41	1	-1	-1	1	45.7	42.9	44.2	45.6	43.2	44.32
3	1	700	14	38	-1	1	-1	1	22.8	22.2	22.6	22.0	22.1	22.34
4	4	700	14	41	-1	-1	1	-1	38.1	37.6	38.6	38.2	35.5	37.6
5	2	900	11	38	-1	-1	1	1	33.0	32.2	33.6	30.4	30.9	32.02
6	5	900	11	41	-1	1	-1	-1	50.8	48.6	50.8	50.2	49.2	49.92
7	3	900	14	38	1	-1	-1	-1	28.6	29.8	31.0	30.6	29.2	29.84
8	7	900	14	41	1	1	1	1	43.2	44.6	44.2	43.0	44.0	43.80

Table 2 Selection of Welding Parameters

Results and Discuussion

In submerged arc welding, the various weld beam characteristics and parameters are taken. These parameters like width, height and Reinforcements are shown in figures. These parameters are obtain by using Design of Experiment Methods.(DOE). These experiments were analyzed and find out the optimized parameters which will useful for welding of railway wagons.

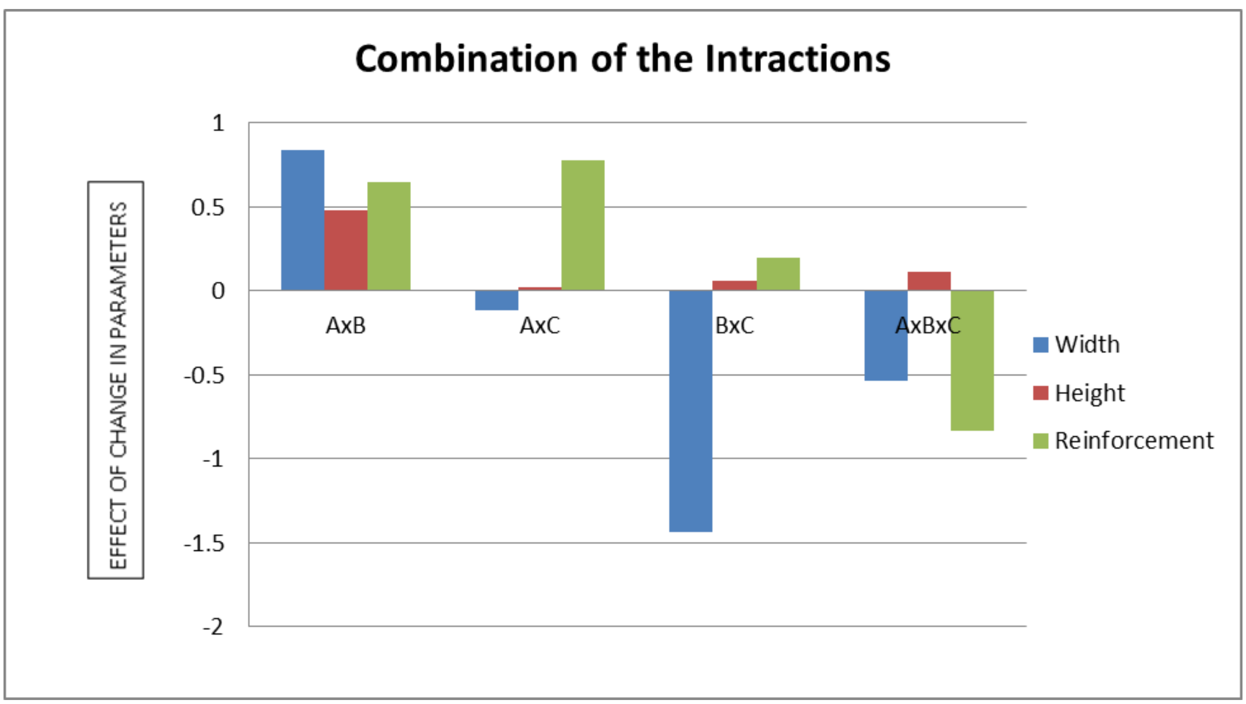
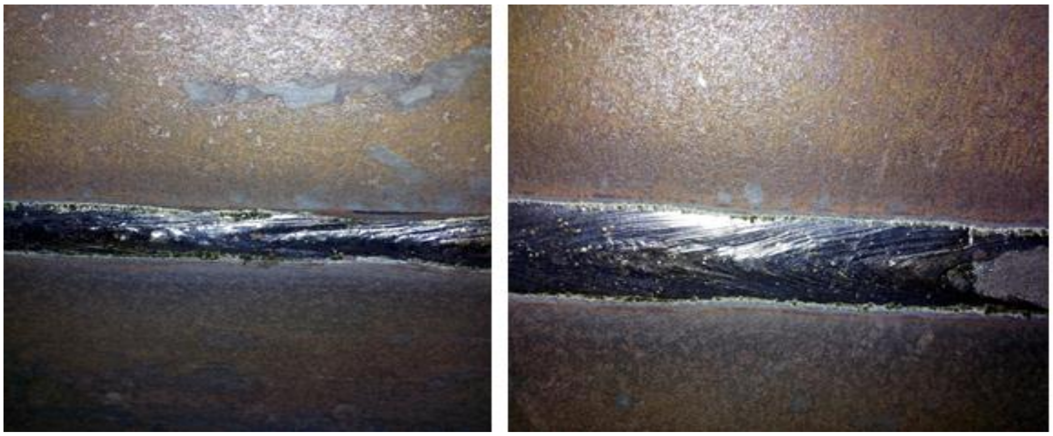


Figure 2 Effect of change in parameters due to interaction combination

Here we can see from the Combination of Interaction Graph that "The Interaction AxB has the Maximum Positive Effect on the geometry of the Weld Bead i.e. Weld bead Width, Height and its Reinforcement."



(a) (b)

(c) (d)

Figure 3 (a) Run 1, Width = 22.34 mm (b) Run 2, Width = 42 mm (c) Run 3, Width = 29.84 mm (d) Run 4, Width = 37.6 m

(a) (b)

Figure 4 (a) Run 5, Width = 49.92 mm (b) Run 8, Width = 44.32 mm

Conclusion

The economical layout of welding experiment is optimized by the factorial method assisted by the graphical method. The result is from the experiments which is optimized and analyzed by the Design of Experiment tool and Design Expert 9.0 software. The result obtained by the graphical method is based on pure experimental observations and validated by the DOE. The result acquired indicates the welding current, travel speed and the welding voltage are the key factor which determines the weld quality and the weld bead geometry.

The weld bead geometry is the significant factor which manipulates the weld strength. This project has been gone through a series of phases and tests to specify the interrelation between the weld bead geometry and the mechanical strength. The test also involves the approach for finding the most optimum and the suitable process parameters which is controlling the Submerged Arc Welding.

There are various interactions found and based on their positive effects on the weld bead geometry the most suitable interaction is found. The interaction is again taken into consideration for further experimental analysis of the mechanical strength of the bead. This is done to specify and establish the interrelation between the mechanical properties and the various weld parameters as well as it also investigates the most ideal combination of the various parameters which gives the good weld quality, high strength and durability.

The result obtained from the various series of the experiments shows the most acceptable weld bead condition and the most suitable combination for the good welding bead geometry.

Table 3 Most Acceptable Weld Bead Condition

Current (A) Amps	Travel speed (B) in/min	Voltage (C) volts	AxB	Weld Bead Width (mm)	Weld Bead Height (mm)	Reinforce-ment (mm)	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)	(%) increase in the Yield Strength	(%) increase in the Ultimate Tensile Strength
900	11	41	-1	49.92	11.38	14.94	65.1	89.4	16.996 %	13.6578 %

The welding parameters are chosen by the welders or the engineers based on the experimental trails and error methods. After conducting the experimental trail welding, the joint is inspected to confirm the joint requirements. Since the weld geometry depends on the welding parameters, it is very important to study the essentiality of the welding parameters and its adverse and direct effect on the weld bead geometry.

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