Optimization of process parameters for 20MnMoNi55 material in SAW using Taguchi method.

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Abstract

20MnMoNi55 is very critical material to weld, as the material is grouped into the P3 category according to the ASME Code, which has lower weldabilty then other steel. The parameters for the welding of 20MnMoNi55 like Welding current, welding speed, Wire feed rate and stick out should be in optimize range. In this research paper the range of the welding parameters are optimized using Design of experiments with help of Taguchi method. Several experiments were performed for finalize the optimum range using Submerge Arc Welding.

Keywords

20MnMoNi55 material, Taguchi method, SAW

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1 Introduction

Welding is the process of joining different materials. It is more economical and much faster process compare to both casting and riveting. SAW is one of the oldest automatic welding processes introduce in 1930s to provide high quality weld. The quality in SAW is mainly influenced by the independent variables such as welding current, arc voltage, welding speed and electrode stick out. The prediction of process parameter involved in SAW is very complex process. Researchers have made many attempts to predict the process parameters of SAW to get a smooth quality weld. Taguchi method was used to formulate the experimental layout, to analyze the effect of each welding on welding performance, and to predict the optimal setting for each welding parameter. Prediction and optimization of the weld bead volume for SAW, a mathematical model was developed and also studied the weld bead geometry and shape. Taguchi method is the highly popular for the design of experiments, in which according to the level and factor we choose it suggest us the number experiments required for the particular level and factor. Here in this paper L’16 Array has selected for the purpose of the parameter optimization.

Submerge arc welding

The schematic diagram of the SAW process is shown in to the fig. 1. Submerge arc welding involves formation of an arc between a continuous fed bare wire electrode and the work piece. The process uses the flux to generate protective gas and slag, and also helps to control the composition to deposited metal by providing the alloying elements to the weld pool. Prior to welding a thin layer of flux powder is placed on the work piece surface. The arc moves along the joint line with arc fully submerge in to the flux. As the arc is completely covered by the flux, the heat loss is minimum. It provides no visible arc light and spatter free welding. The flux apart from the shielding the arc and the molten poll from atmospheric contamination, plays the following roles:

- The stability of the arc is dependent on the flux.
- Chemical and thus the mechanical properties of the weld metal can be controlled by flux
- The quality of the weld may be affected by the quality and the quantity of the flux used over the arc.

Fig. 1 Submerge arc welding

Taguchi method

The quality engineering method of Taguchi, employing design of experiments (DOE), is one of the most important statistic tools for designing high quality system at reduced cost. Taguchi method provide an efficient and systematic way to optimize design for performance, quality and cost. Optimization of process parameter is the key step in the Taguchi method to achieving high quality without increasing cost. This is because optimization of process parameter can improve quality characteristic and the optimal process parameter obtain from the Taguchi method are incentive to the variable of environmental and other noise factors. Classical process parameter design is complex and not an easy task. To solve this problem Taguchi method uses a special design of orthogonal array to study the entire process parameter space with a small number of experiments only. Furthermore, Taguchi has created a transformation is known as the signal to noise (S/N) ratio. The S/N ratio consolidates several repetitions in to the value, which reflects the amount of variation present. There are several S/N ratio available depending upon the type of characteristic. Lower is better (LB), nominal is best (NB) or higher is better (HB). The S/n ration for each level of process parameter is computed based on the S/N ration analysis. The optimal level of process parameters is the level with the highest S/N ratio. A statistical analysis of variance (ANOVA) is performed to see which process parameter are statistically significant.

2 Experimental design and set-up:

The experiment was conducted with the following set up. Lincoln semiautomatic SAW machine with constant voltage and rectifier type power source with 1000 A capacity was used to join the 20MnMoNi55 low alloy steel plate of 250 mm (L) x 250 mm (W) x 28 mm (T). Copper coated wire spool EF 1 of having 4.0 mm diameter was used to weld the material and UV 420 TTR an agglomerated flux of fluoride basic type was used. Single V groove of 6 mm root face and 0 mm root gap was created using plasma machine for welding and here shown in below figure. As the material is low alloy steel so that preheat, inter pass and post heat temperature must be maintaining before, during and after the welding respectively.

Groove design:

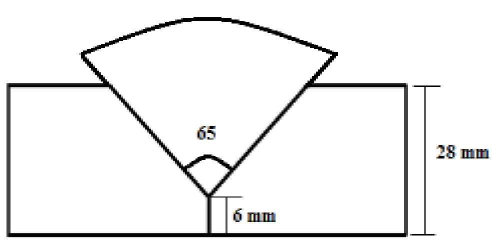
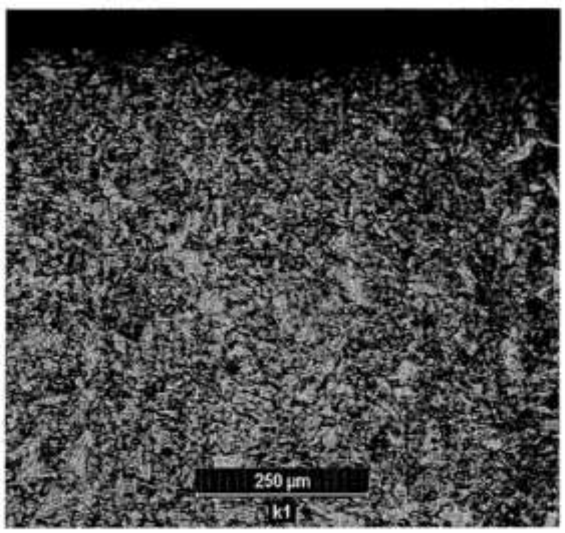


Fig. 2 Groove design

3 Base material detail:

The chemical composition of the investigated steels is listed in below table. In the list Steels A to D are very similar in their composition, except for the sulphur content, which ranges from low to medium values. Special care was taken to minimize phosphorus and sulphur and to refine grain size, thereby enhancing notch toughness.
The sulfur content was expected to possibly have some influence on the susceptibility to SCC in high temperature water. A steel with more than 0.02 wt. % sulfur would have been desirable for a more extended comparison, but modern steel making has reached such a high standard that available alloys are generally very low in sulfur content. However, steels presently in service in older power plants may have still sulfur contents above 0.02%. MnS inclusions may have an important role for stress corrosion susceptibility. A strong influence on the ductility, e.g. the upper shelf toughness and the ductile/brittle transition in impact tests, is also observed. The relative content of manganese and silicon was determined for optimum toughness of welded structures.

Microstructure:



Bainitic structure of 20 MnMoNi 55 in the as received state. Etched with 5 % HNO_3 solution

Mixed bainitic-austenitic structure of 20 MnMoNi 55 after heating and cooling. Etched with 5 % HNO_3 solution

Fig.3 Microstructure of 20MnMoNi55

Table 1: Chemical Composition of 20MnMoNi55:

Base metal	% C	% Mn	% Mo	% Ni	% Si	% P	% S
20MnNoNi55	0.17-0.23	1.2-1.5	0.4-0.55	0.5-0.8	0.15- 0.3	0.012 max	0.01 max

Table: 2 Mechanical Property of 20MnMoNi55:

Mechanical properties	Value

Tensile strength (MPa)	550 - 690
Yield strength (MPa)	345
% Elongation	18
Min. Impact strength (- 10 ˚C)(J)	150 J

4 Experimental work.

Experimental work has been carried out using the submerge arc welding for the purpose of the optimizing the process parameter of 20MnMoNi55 material using the EF 1 wire having 4.0 diameter. The Lincoln electric arc generator machine was used for the power source. For the welding of 28 mm thickness test piece, different processes of welding like GTAW, GMAW, SMAW and SAW were available. But SAW has the higher deposition rate and the bead width and the bead height of the passes in this is much higher than any other process.

Table: 3 welding condition:

Welding process	Submerge Arc Welding (SAW)
Material	20MnMoNi55
Plate dimensions	250 mm X 250 mm X 25 mm # 250 mm X 250 mm X 25 mm
Filler wire	EF 1 , 4.0 Diameter
Flux	UV420TTR
Preheating temperature	150 ˚C
Inter pass temperature	200 ˚C

Welding trials:

Welding parameter for trials of SAW welding process was designed using Design of Experiments – Taguchi Method. 3 Factors and 4 Levels were identified and is as shown in the Table below. Based on this Factors and Levels, 16 trials with different combinations was developed which is known as L16 modified orthogonal array.

Factor	Level 1	Level 2	Level 3	Level 4	Output
current	350	450	550	650	Notch toughness
Travel speed	300	400	500	600	
Voltage	28	30	32	34	hardness

Table: 4 Design of experiments:

Table: 5 Trail number with parameters

Trial no.	Welding current	Travelling speed	Voltage
1	350	300	28
2	350	400	30
3	350	500	32
4	350	600	34
5	450	300	30
6	450	400	28
7	450	500	34
8	450	600	32
9	550	300	32
10	550	400	34
11	550	500	28
12	550	600	30
13	650	300	34
14	650	400	32
15	650	500	30
16	650	600	28

Fig.4 welding trial set-up

5. Result and discussion:

Table: 6 Parameters with output result

Trial no.	Welding current	Travelling speed	Voltage	Impact	Hardness	Signal to noise ratio
1	350	300	28	123	303	41.798
2	350	400	30	136.5	252.5	42.702
3	350	500	32	144.5	228	43.197
4	350	600	34	156.5	243.5	43.890
5	450	300	30	128.5	346.5	42.178
6	450	400	28	134.5	335	42.574
7	450	500	34	166.5	235.5	44.428
8	450	600	32	129	225	42.211
9	550	300	32	122.5	317.5	41.762
10	550	400	34	136.5	324.5	42.702
11	550	500	28	173	272	44.760
12	550	600	30	151.5	306	43.608
13	650	300	34	108	354.5	40.668
14	650	400	32	117.5	347	41.400
15	650	500	30	131	324	42.345
16	650	600	28	141.5	305.5	43.015

Here from the above table we can say that the trial number 11 is giving the better value of the impact so that for the better result in the mechanical properties like toughness the welding essential parameter like welding current, travelling speed and the voltage should be according to the trial number 11.

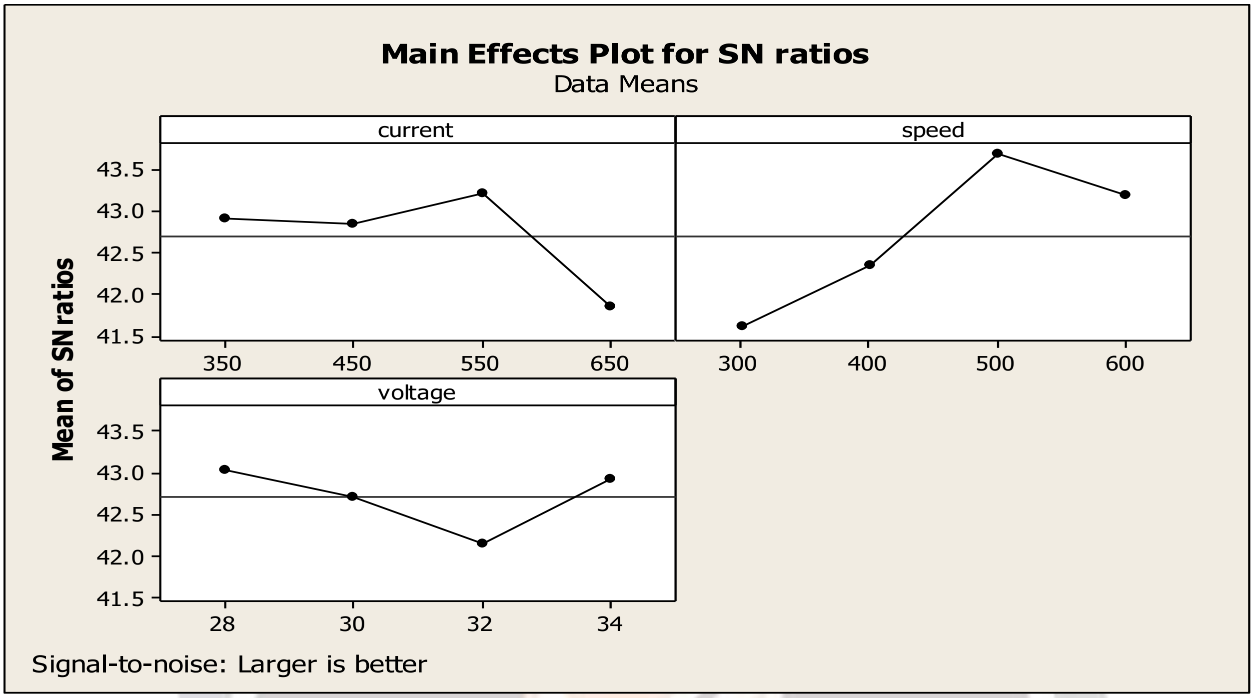


Fig. 5 Main plot of S/N ration for impact

The above graph shows the value of the impact test where it shows that the best value of impact is come at 550 amp. Welding current, 500 mm/min. travelling speed and 28 V voltage.

Main Effects Plot for SN ratios

Taguchi Analysis: Impact versus current, speed, voltage

Response Table for Signal to Noise Ratios
Larger is better

Level	current	speed	voltage
1	42.90	41.60	43.04
2	42.85	42.35	42.71
3	43.21	43.68	42.14
4	41.86	43.18	42.92
Delta	1.35	2.08	0.89
Rank	2	1	3

The effect of the parameter on the impact is comes in the way like

1) Travelling speed
2) Welding current
3) Voltage

So from the above we can conclude that the effect of voltage on the toughness property is lower and the effect of travelling speed on the toughness is maximum.

6. Conclusion:

After performing 16 experiments with changing the variables Conclusion come up with effects of parameter on the mechanical properties.

As the heat input increases it will make the material more harden and more harden material is comparatively brittle. The material which has higher hardness will not sustain the impact load and it will fail in the impact test.

After performing ANOVA welding speed and the welding current this two parameters has higher significant on the output.

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