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Modeling width of Weld in SAW with Adding Nano Material

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ABSTRACT

One of the important methods of welding is submerged arc welding. Special features of this method give it an important position among other ways. Prediction the mechanical features of materials in welding zone is known as an important subjects in mechanical science. As thequality of welding has a direct relation with mechanical properties of materials, studying and predicting the factor of quality is very important. Certainly bead width is one of the effective factors because it shows chemical effects and metallurgical structures and micro structures. The most important property of this research is representing anempiricalformula with high accuracy for modeling the bead width as an factor of quality of welding in submerged arc welding in which the input factors of arc voltage,current, nozzle to plate distant, welding speed, and the thickness of ZnO Nano particles. On this research central composite rotatable matrix method is used in five level-five factor. For achieving this empirical formula with high accuracyRSM is used.

Keyword:

Submerged Arc Welding, ZnO Nano Particles, Bead Width.

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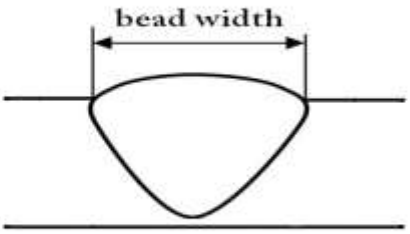
INTRODUCTION

Among the wide variety of welding processes, submerged arc welding, given its particular characteristics, is commonly used in industries.Thedistinguishing advantages of this method are high penetration and sedimentation rate as well as alloy development during welding by creating a cover of desired combinations of elements on the surface of work piece, which improve mechanical, corrosive, fricative and other properties. [1]. Arc welding (SAW) is a process, using an arc established between a consumable wire electrode and the metal, to generate heat for melting and joining metals while The arc is shielded by molten slag and granular flux [2]. McGlone et al. [3] reported the application of curvilinear regression analysis technique for predicting weld bead geometrical features of SAW of square edge close butts. In this welding process the quality of the weld joint can be defined by many characteristics. One of these characteristics is weld width. The width bead is horizontal distance indirection of horizontal line above cross-sectional which is created because of Deposition. The diameter of width is shown in Fig. 1.



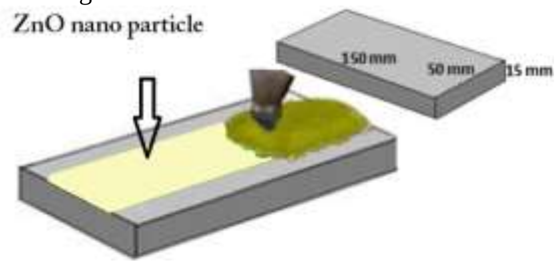
One of the most important characteristic on weldment is weld bead width. It is important to achieve high quality characteristic such as weld bead width in weldment. On some purposes such as cladding and surfacing it is important to maximize weld bead width. width is very important parameter in welding quality that shows mechanical characteristics .As we known in cladding and surfacing when the width increases the welding quality will improved and the welding components have a better mechanical characteristics at welding areas.

Definition and review all possible situations included in a multi-factor is experiment design. The design of experiment purpose is to identify the levels of testing that are necessary and sufficient to achieve the desired response. Design of Experiments, increase efficiency, reduces cost and time and percent of errors. In this study we use a useful method of response surface, central composite rotatable design, which can use five levels-five parameters. Gunaraj et al. [3] utilized response surface methodology (RSM) in SAW of pipes and developed a mathematical model to predict process responses. Murugan et al. [4] developed empirical formula for SAW of pipes using five-level factorial technique to predict critical dimensions of weld bead.

Karaoglu et al. [5] conducted sensitivity analysis of SAW process parameters on weld bead geometry dimensions.

Kim et al. [6] studied the effects of welding process parameters on weld bead width in GMAW processes. Menaka et al [7] estimated the bead width and depth of penetration during welding by infrared thermal imaging. Gunaraj et al. [8] reported that in SAW process dilution increased steadily with increase in arc voltage, whereas weld penetration increased with increase in wire feed rate. Murugan et al. [9] reported that in metal inert gas welding process, weld dilution increased with increase in arc voltage. However, dilution increased with increasing wire feed rate to an optimum value and then decreased. Moreover, dilution was not affected significantly by welding speed. Decrease in dilution was significant when the nozzle-to-plate distance was increased.

There is no report which worked on combined effect of ZnO Nano particle and welding input parameters including the arc voltage, welding current, contact tip-to-plate distance, and welding speed on width in SAW process. In this study by modeling of bead weld and developing the formula using RSM. We try to introduce Nano-particles directly into the weld pool. A primary idea was mixing up Nano with SAW flux but because of high cost it was not applicant so a new way was introduced: dispersing in ethanol and Appling the obtained paste on the surface of mild steel plates in different thicknesses as per the design matrix prior to welding, as shown in Fig. 2.



A five-level five-parameter CCRD of experiments was used for gaining data. Then by doing experimental works the results, width, were been measured. The final result of this study is providing an empirical formula for by RSM. This empirical formula is accurate and reliable in optimizing width due to its high correlation coefficient and low error rate.

2. Collecting data

Nowadays DOE is used widely in science and engineering. The major goal of DOE is analyzing the effects of input parameters on output parameters and presenting a model according to repeated and similar experiments also and finally decreasing the cost and time and increasing the efficiency.

One of the most suitable way for identification the relationship between input and output parameters is RSM (respond surface method) the goal of this method is finding a surface which lead to response. RSM is modeled bythe multivariable non-linear regression equation. the effect of first and second order equation regression parameters cover the major part of response and by increasing the order error increased so by decreasing the third order effects in regression equation error decrease and after simplifying the equation throw some stages a second order equation is gained as followed:

$$Y = \beta_0 + \sum_{m=1}^{k} (\beta_m X_m) + \sum_{m=1}^{k} (\beta_{mm} X_m^2) + \sum_{m=1}^{k} \sum_{n=m+1}^{k} (\beta_{mn} X_m X_n) + \varepsilon$$

Where β_0 are the constant term of the empirical formula and coefficients β_m, β_{mm} and β_{mn} are linear, quadratic and two way interactive effects of input parameters on width, respectively.

At first for designing of experiments, parameters and their ranges should be identified. Then DOE help us for gaining the response. Usually full factor and rotatable method is used in analyses.in all these analyses, for gaining the empirical formula, statistical methods are used.in this research, all the calculations are done by statistical software .the surface of input parameters is gained from relation 2 in which X_{max} and X_{min} are the biggest and smallest value of input parameter X and X_i are response levels. Parameters and levels are showed in table1 and table 2 shows the DOE.

Parameter	Notation	Units	Coded values				
			-2	-1	0	+1	+2
Arc voltage	V	Volts	24	26	28	30	32
Welding current	I	Amp	500	550	600	650	700
Contact tip-to-plate distance	N	mm	40	42.5	45	47.5	50
Welding speed	S	mm/min	300	350	400	450	500
TiO2	F	mm	0	0.25	0.5	0.75	1

$$X_i = \frac{2[2X-(X_{max}+X_{min})]}{X_{max}-X_{min}}$$

No.	V	I	N	S	F		No.	V	I	N	S	F
1	0	0	0	0	0		17	0	0	0	0	0
2	0	0	0	-2	0		18	-1	1	1	-1	1
3	-1	1	-1	1	1		19	0	0	0	0	2
4	-1	-1	1	1	1		20	1	1	1	1	1
5	1	1	1	-1	-1		21	1	-1	-1	-1	-1
6	0	2	0	0	0		22	1	-1	1	-1	1
7	1	1	-1	1	-1		23	-2	0	0	0	0
8	0	0	-2	0	0		24	0	0	0	0	0
9	-1	-1	-1	-1	1		25	1	-1	-1	1	1
10	1	1	-1	-1	1		26	0	0	0	0	0
11	-1	-1	1	-1	-1		27	-1	1	-1	-1	-1
12	0	0	0	0	0		28	-1	1	1	1	-1
13	0	0	0	0	-2		29	0	0	0	2	0
14	-1	-1	-1	1	-1		30	2	0	0	0	0
15	1	-1	1	1	-1		31	0	0	2	0	0
16	0	0	0	0	0		32	0	-2	0	0	0

Nano materials are one of the best parts of nano technology. Metal oxides are one of the important nano materials in manufacturing process. Because of the high corrosion resistance, Zno is very particular. Table 3 shows the Zno properties

Shape	color	Melting point	boiling point	morphology
Powder	white	1975 °C	2360°C	spherical

3. Performing the experiments

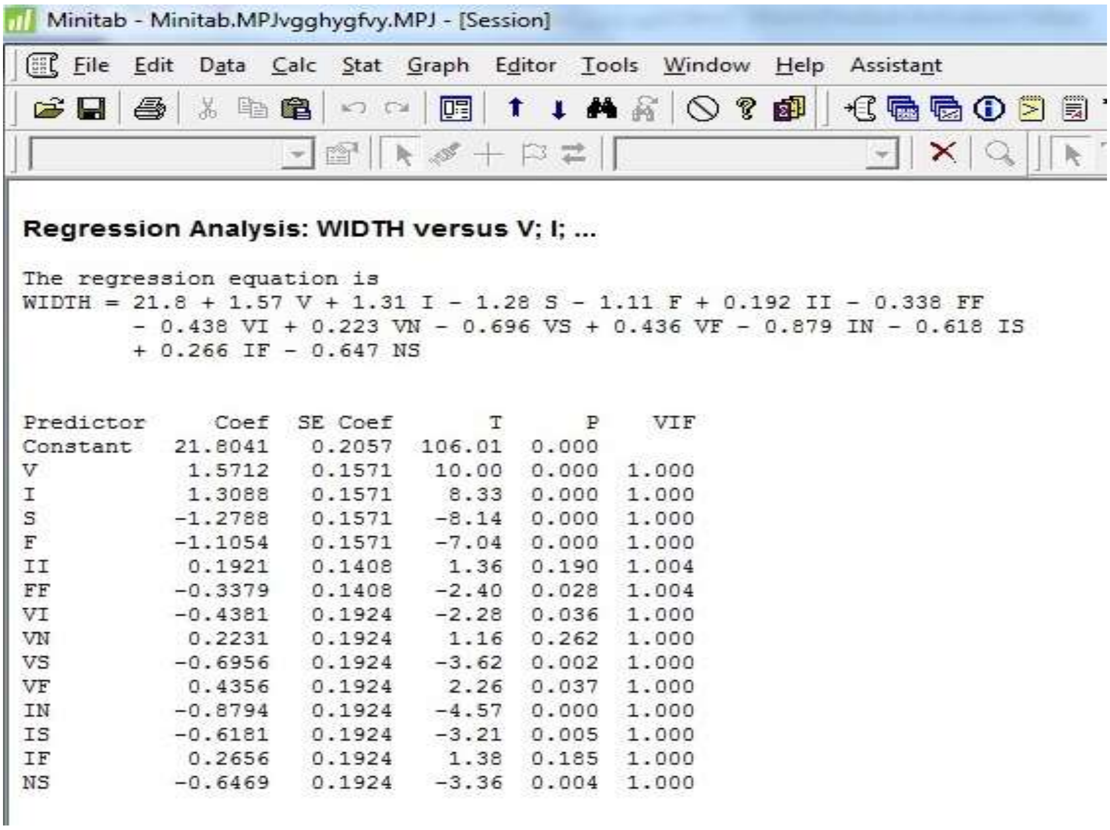
At the first 32 pieces are selected, after cleaning the surface and according to the DOE on central composite rotatable matrix, the ZnO nano particles with required thickness on pieces by the method mentioned before. In the next step according to DOE the welding processes are done, then the pieces are taken to the laboratory and are cutting, they are polished and etched with nital 2 %. Then the pieces are taken to the laboratory for microscopic measuring. The results of this measurement are shown in table 4.

No.	width	No.	width
1	20.49	17	21.22
2	23.83	18	21.16
3	21.07	19	17.81
4	16.55	20	20.08
5	27.53	21	23.63
6	25.12	22	24.94
7	23.34	23	19.23
8	21.88	24	23.23
9	15.29	25	20.13
10	26.7	26	21.75
11	21.55	27	24.94
12	22.19	28	19.69
13	22.46	29	19.69
14	19.99	30	23.79
15	22.48	31	20.76
16	22.32	32	19.39

4. Approach to the empirical formula

Eq 1. Is improve as Eq 3 for five parameters as followed that $\beta_0$is a constant value $\beta_m$is linear factor and $\beta_{mm}$is the square and $\beta_{mn}$is the interactive factor between two factors on width .Empirical equation is developed as Eq 4 as followed. Fig 3 shows the effects of each parameter on width.

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_{11}X_1^2+\beta_{22}X_2^2+\beta_{33}X_3^2+\beta_{44}X_4^2+\beta_{55}X_5^2+\beta_{12}X_1X_2+\beta_{13}X_1X_3+\beta_{14}X_1X_4+\beta_{15}X_1X_5+\beta_{23}X_2X_3+\beta_{24}X_2X_4+\beta_{25}X_2X_5+\beta_{34}X_3X_4+\beta_{35}X_3X_5+\beta_{45}X_4X_5$$



Regression Analysis: WIDTH versus V; I; ...

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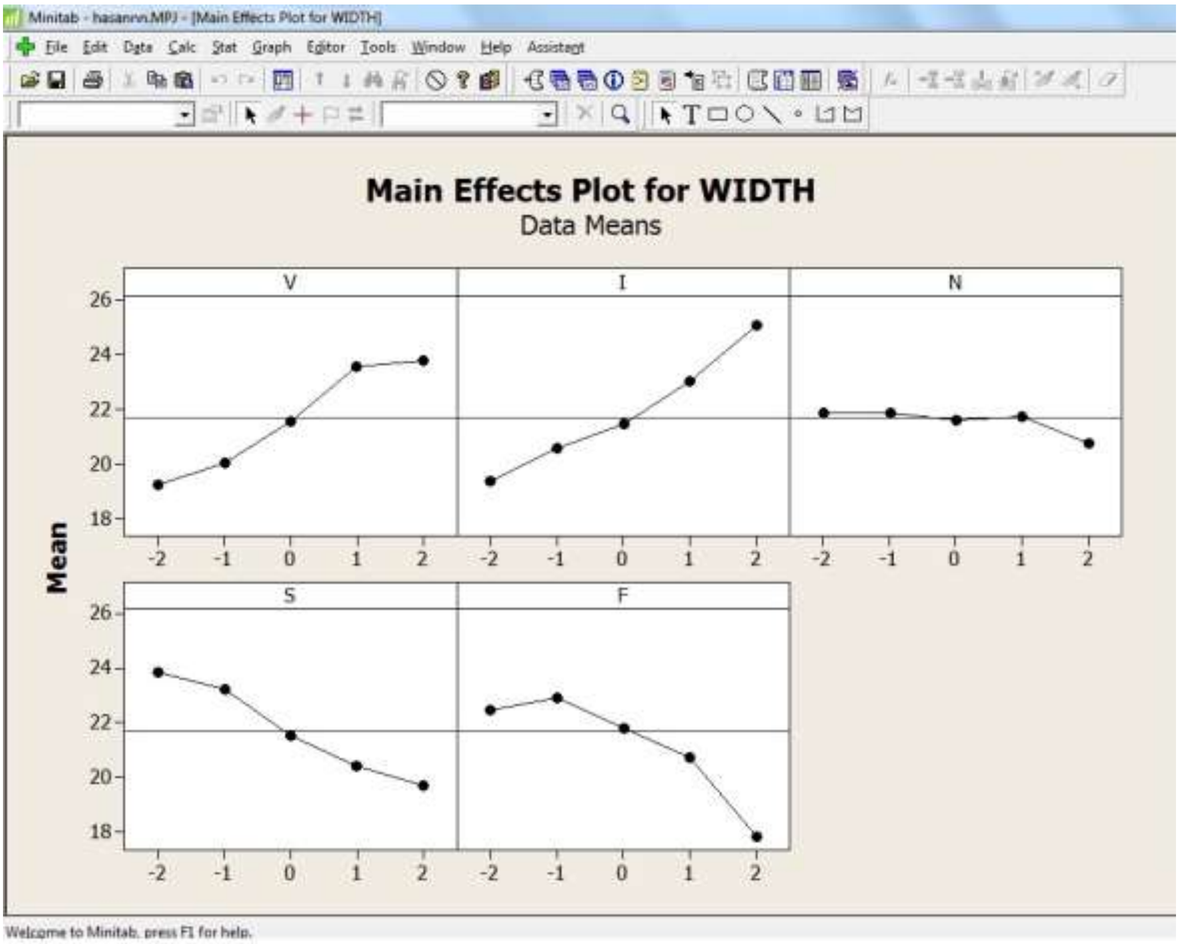
The regression equation is
WIDTH = 21.8 + 1.57 V + 1.31 I - 1.28 S - 1.11 F + 0.192 II - 0.338 FF
        - 0.438 VI + 0.223 VN - 0.696 VS + 0.436 VF - 0.879 IN - 0.618 IS
        + 0.266 IF - 0.647 NS
```

Predictor	Coef	SE Coef	T	P	VIF
Constant	21.8041	0.2057	106.01	0.000	
V	1.5712	0.1571	10.00	0.000	1.000
I	1.3088	0.1571	8.33	0.000	1.000
S	-1.2788	0.1571	-8.14	0.000	1.000
F	-1.1054	0.1571	-7.04	0.000	1.000
II	0.1921	0.1408	1.36	0.190	1.004
FF	-0.3379	0.1408	-2.40	0.028	1.004
VI	-0.4381	0.1924	-2.28	0.036	1.000
VN	0.2231	0.1924	1.16	0.262	1.000
VS	-0.6956	0.1924	-3.62	0.002	1.000
VF	0.4356	0.1924	2.26	0.037	1.000
IN	-0.8794	0.1924	-4.57	0.000	1.000
IS	-0.6181	0.1924	-3.21	0.005	1.000
IF	0.2656	0.1924	1.38	0.185	1.000
NS	-0.6469	0.1924	-3.36	0.004	1.000

Bead width: 21.8+1.57 V +1.31 I-1.28 S – 1.11 F + 0.192 II – 0.338 FF – 0.438 VI + 0.223 VN -0.696 VS + 0.436 VF-0.879 IN – 0.618 IS + 0.266 IF – 0.647 NS

Predictor	Coef	SE Coef	T	P
Constant	21.804	0.206	106.010	0.000
V	1.571	0.157	10.000	0.000
I	1.309	0.157	8.330	0.000
S	-1.279	0.157	-8.140	0.000
F	-1.105	0.157	-7.040	0.000
II	0.192	0.141	1.360	0.190
FF	-0.338	0.141	-2.400	0.028
VI	-0.438	0.192	-2.280	0.036
VN	0.223	0.192	1.160	0.262
VS	-0.696	0.192	-3.262	0.002
VF	0.436	0.192	2.260	0.037
IN	-0.879	0.192	-4.570	0.000
IS	-0.618	0.192	-3.210	0.005
IF	0.266	0.192	1.380	0.185
NS	-0.647	0.192	-3.360	0.004

S = 0.769555 R-Sq = 95.5% R-Sq (adj) = 91.08%



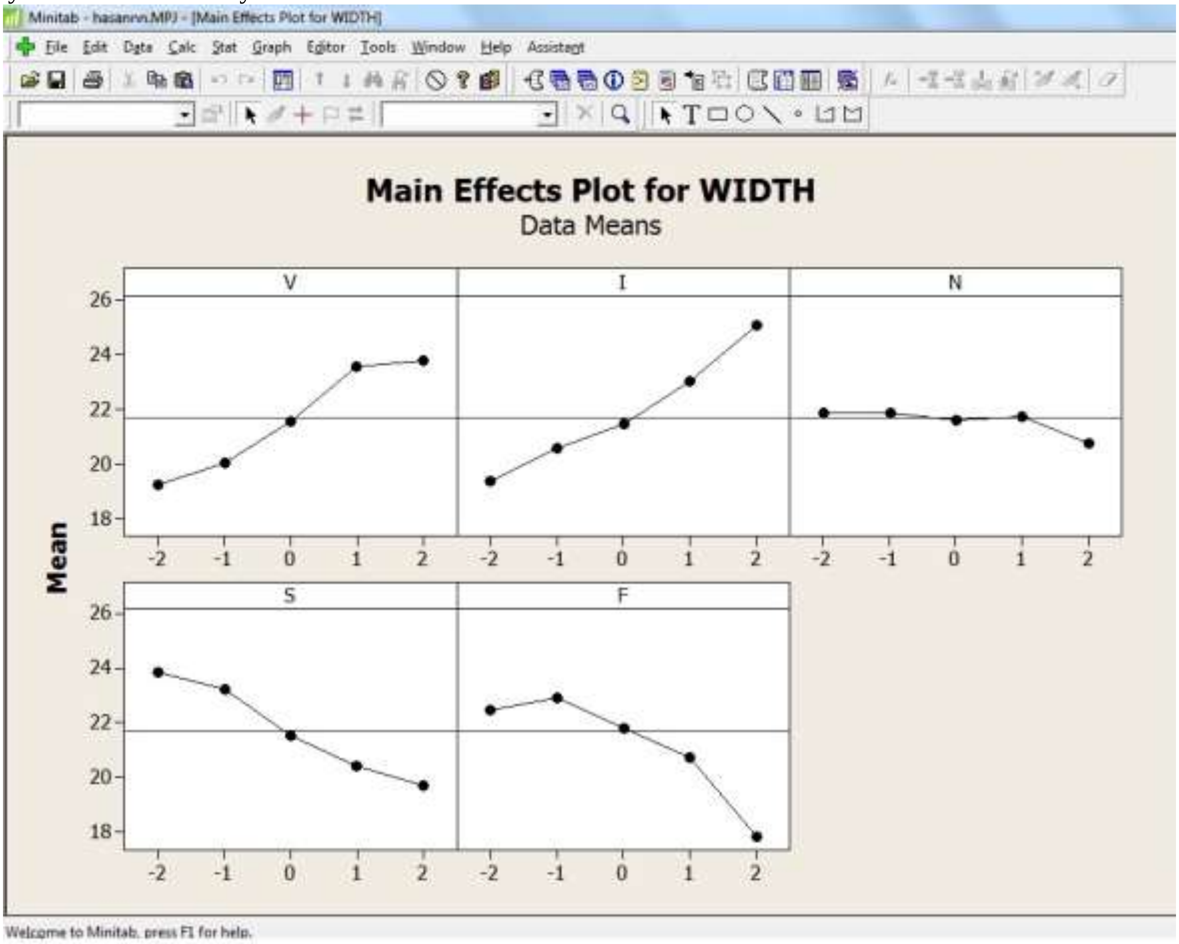
Testing the adequacy of the empirical formula

Source	DF	SS	MS	F	P
Regression	15	4542.38	302.83	22.86	0.000
Residual Error	16	16	13.25		
Lack of Fit	11	114.06	10.37	0.53	0.824
Pure Error	5	97.93	19.59		
Total	31	4754.3			

For testing the adequacy of the empirical formula analysis of variance and F test is used. In the table analystof variance is seen which P factor is less than 0.05 which shows 95% reliability. Table 6 shows analyze and F test.

5. Conclusion

According to the output charts of MATLAB software following results is gained:



1- By increasing the voltage, the width increases continually.
2- By increasing the current which is related to wire feed rate directly, width increases continually.
3- By increasing the speed , the width decreases continually
4- By increasing the nozzle to plate distant, the width has not any considerable change.
5- By increasing the thickness of Nano particles to 0.25 mm the width increases then from 0.25 to 1 mm decreases continually.

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