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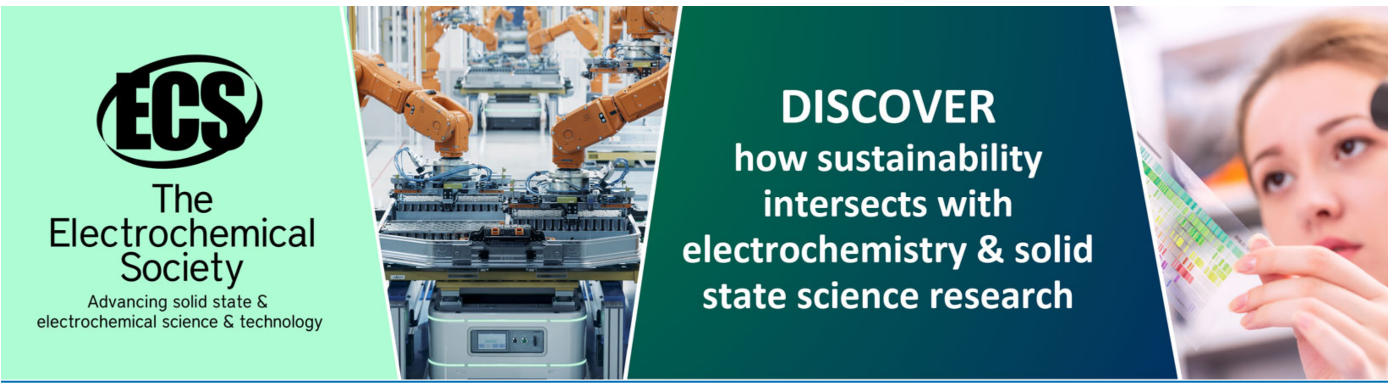

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Optimization of process parameters in welding of dissimilar steels using robot TIG welding

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Abstract: Robot TIG welding is a modern technique used for joining two work pieces with high precision. Design of Experiments is used to conduct experiments by varying weld parameters like current, wire feed and travelling speed. The welding parameters play important role in joining of dissimilar stainless steel SS 304L and SS430. In this work, influences of welding parameter on Robot TIG Welded specimens are investigated using Response Surface Methodology. The Micro Vickers hardness tests of the weldments are measured. The process parameters are optimized to maximize the hardness of the weldments.

1. Introduction

Before age of modern technology anything that required to be welded is done manually. But with the advent of new technologies and using the new innovative methodologies such as robot welding, the welding process has been very much simplified without the need of putting too much effort. The welding that is performed and controlled by robotic equipment and without any human intervention is called Robot welding. It looks like a simple and ordinary system by its appearance or movements but it checks for the knitline and dimensions automatically, and welds the materials. A programmable robot system with a visual sensor for programmed welding is developed. An algorithm for recognizing the welding track and automatic seam-tracking is integrated with the system. 2D vision sensor system has been intended for the welding robot which can identify the localization of the material and coordinate the part position of the welding tip. By analyzing the KRL program, it is been proposed to detect the edges of seam, pool and extract the parameters of welding [1]. Based on the properties of AISI 304L, the process parameters are selected for the Robot TIG welding to improve the performance of system[2].It takes less economy and time by optimizing the welding parameters. So using statistical methods such as DOE (Design on Experiments) to conduct the weld trials is the general tendency of the application [3].To optimize the parameters on weld mechanical properties to achieve appropriate results and to evaluate the instantaneous effects of them, RSM can be used [4].Investigating the welding behavior of SS304L and SS430 in terms of mechanical properties using filler wire ER-309L was performed. Robot TIG welding was done on SS304 and SS430 plate thickness of 5mm.RSM is used to develop mathematical correlations between the welding process parameters like current, wire feed and travelling speed and output of the Micro Vickers hardness test [5].The result point out that the developed models are to satisfactorily predict the responses within the limits of input factors[6].A pool of mathematical and statistical techniques those are apt for analysis and modeling of problems in which a response is affected by many variables, with the goal to optimize the responses is known as Response Surface Methodology [8-9]. The Robot TIG welding factors are optimized by creating 3d response plots, actual and predicted values via design expert software [10].

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2. Methodology

2.1. Experimental Design

The experiments are considered based on the three level three factor Box-Behenken design with 5 center points. Current, Wire feed, travelling speed are choosing input parameters for the ROBOT TIG welding. The Box –Behenken design is chosen because it avoids the all corner points and the star points. Based on the trial runs the process parameters are chosen for the experimentation.Table.1shows the welding input parameters for welding experimental design levels. RSM is useful for experimentation via Design Expert 9 statistical software. Linear model and quadratic polynomials are fixed to the experimental data to obtain the regression equation. The sequential F-Test, lack of fit test and other adequacy procedures are used in order to select the finest models.

Table 1. Independent factors and Experimental design levels

Variables	Low	High
Current(amps)	120	180
Wire Feed(mm/min)	0.62	0.82
Travelling Speed(mm/min)	0.070	0.080

2.2 . Robot **TIG Welding**

The dissimilar joining metals used in this work exists SS304L and SS430 stainless steel. The chemical composition of metals is given in Table 2 and Table 3.Both metals are cut into equal sizes of 204*102*5 mm which are to be welded by butt joint using KUKA Robot. The welding power has been taken as Magic 3000 and gas flow rate is maintained as constant. After the welding, test samples are cut by the wire EDM cutting machine to test the hardness of the weld zone.

Table 2. Chemical conformation of SS304L (wt %)

Element	C	Cr	Mn	Mo	Ni	N	P	Si	S	Others
Composition	0.030	18-20	2.00	-	8-12	0.10	0.045	0.75	0.030	Rem

Table 3. Chemical conformation of SS430 (wt %)

Element	C	Cr	Mn	Ni	P	Si	S	Others
Composition	0.044	16.36	0.560	8-12	0.031	0.270	0.012	Rem

3. Results and Discussions

3.1 Optimization

Fig.1shows that the optimum solution plot for desirability of current, wire feed and travelling speed to maximize Vickers hardness. Optimum conditions predicted for the Micro Vickers hardness are current at 120 amps, wire feed at 0.82 mm/min and travelling speed at 0.0780 mm/min. The predicted Micro Vickers hardness is under these optimum conditions 231.079 HV with composite desirability is 1. Table 5.shows the optimum conditions for Micro Vickers hardness by minitab 17.0 software.

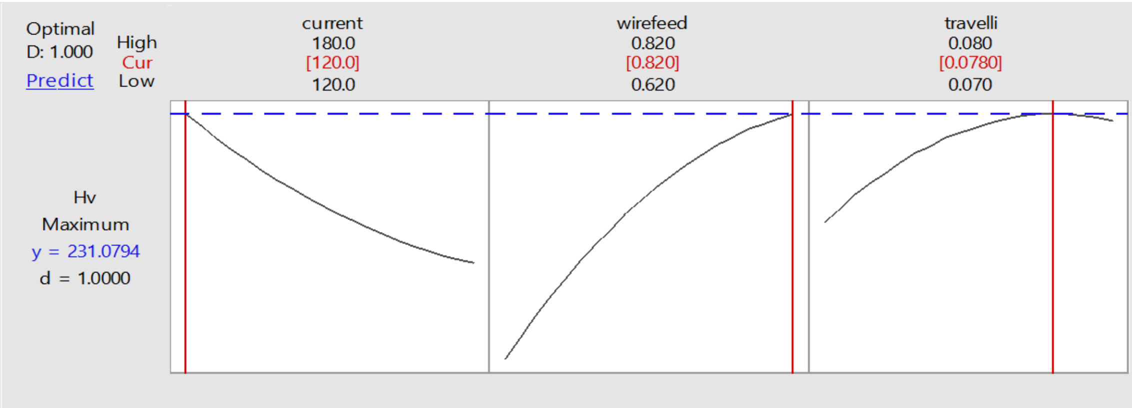

Figure 1. Optimal condition plot for Vickers hardness

Table4. Design matrix, experimental responses measured

Std. order	Run Order	PtType	Blocks	Current (amps)	Wire feed (mm/min)	Travelling Speed(mm/min)	Micro Vickers hardness HV
17	1	0	1	150	0.72	0.075	220.67
6	2	2	1	180	0.72	0.070	222.67
8	3	2	1	180	0.72	0.080	220.97
13	4	0	1	150	0.72	0.075	220.66
11	5	2	1	150	0.62	0.080	210.33
14	6	0	1	150	0.72	0.075	223.66
7	7	2	1	120	0.72	0.080	220.66
16	8	0	1	150	0.72	0.075	221.66
1	9	2	1	120	0.62	0.075	203.67
4	10	2	1	180	0.82	0.075	216.67
2	11	2	1	180	0.62	0.075	225.33
10	12	2	1	150	0.82	0.070	211.67
9	13	2	1	150	0.62	0.070	208.67
5	14	2	1	120	0.72	0.070	212.67
15	15	0	1	150	0.72	0.075	220.77
12	16	2	1	150	0.82	0.080	218.33
3	17	2	1	120	0.82	0.075	230.66

Table5. Optimal conditions for Micro Vickers hardness test

Solution	Current(amps) A	Wire Feed(mm/min) B	Travelling Speed(mm/min) C	Micro Vickers hardness HV Fit	Composite Desirability
1	120	0.82	0.0780	231.079	1

3.2 Analysis of Variance for Micro Vickers hardness test

The regression models are tested its significance using P-value and F-value on individual model coefficients and lack of fit test are done by using same statistical Table 6. For assigning the linear model terms and full quadratic models are summarize by using polynomial values to analyze the analysis of variance of Micro Vickers hardness and show the major terms at confidence level of 0.95. The measured

R^2 and predicted$R^2$are shown in table 6.The ANOVA for the Micro Vickers hardness test indicates that Wire feed (B) is the most significant model term. Besides, the two level interactions of robot TIG welding current and wire feed (AB)is more significant model term followed by the quadratic level of the second order interaction level of wire feed (B^2)is more significant. Fig.2represents the predicted Vs actual Vickers hardness. The group of points around the diagonal line shows a satisfactory correlation between the experiment data, the predicted values and confirming the vigor of model. Represents the three dimensional response surface plots for the Micro Vickers hardness acquired from the regression model [7]. Fig (3) shows that as current increases, hardness increases and as wire-feed increases, the hardness increases. From Table6, the interaction between the current and wire-feed is significantly influencing the hardness. Fig (4) shows that as wire-feed increases, hardness increases initially and then decreases, as travelling speed decreases, hardness increases initially and then decreases. From Table6, the interaction between wire-feed and travelling speed is not influencing much on the hardness of the weld. Fig (5) shows that as current increases hardness increases and as travelling speed increases hardness increases. From Table6, the interaction between current and travelling speed is significantly influencing on the hardness of the weld. Table 6. Shows that the result of ANOVA.

The mathematical model for prediction of hardness is given in equation (1)

$$\mathrm{HV} = -1418.0 + 2.660 \times A + 9771.15 \times B + 28209.75 \times C - 2.97083 \times A \times B - 16.1500 \times A \times C + 2500 \times B \times C + 2.55056E - 003 \times A^2 - 469.70000 \times B^2 - 1.81480E + 0.005 \times C^2 \quad (1)$$

Table6. Anova for Micro Vickers hardness test Model

ANOVA for Response Surface Quadratic model						
Analysis of variance Table [partial sum of squares-Type III]						
Source	Sum of squares	Degrees of freedom	Mean square	F-value	p-value	Model
Model	725.067	9	80.56	38.32	<0.0001	Considerable
Linear	174.623	3	58.208	27.69	0.0000	Considerable
A	40.41	1	40.41	19.22	0.0032	Considerable
B	107.53	1	107.53	51.14	0.0002	Considerable
C	26.68	1	26.68	12.69	0.0092	Considerable
2-way interaction	374.455	3	115.818	55.08	0.000	Considerable
AB	317.73	1	317.73	151.10	<0.0001	Considerable
BC	6.25	1	6.25	2.97	0.1284	Non-Considerable
AC	23.47	1	23.47	11.16	0.0124	Considerable
Square	202.990	3	67.663	32.18	0.000	Considerable
A^2	22.19	1	22.19	10.55	0.0141	Considerable
B^2	92.89	1	92.89	44.17	0.0003	Considerable
C^2	86.67	1	86.67	41.22	0.0004	Considerable
Residual	14.72	7	2.102			
Lack of Fit	8.102	3	2.701	1.63	0.3162	Non-Considerable
Pure Error	6.617	4	1.65			
Cor. Total	739.79	16				

R^2=0.9801, Adjusted R^2=0.9545, PredictedR^2=0.8108

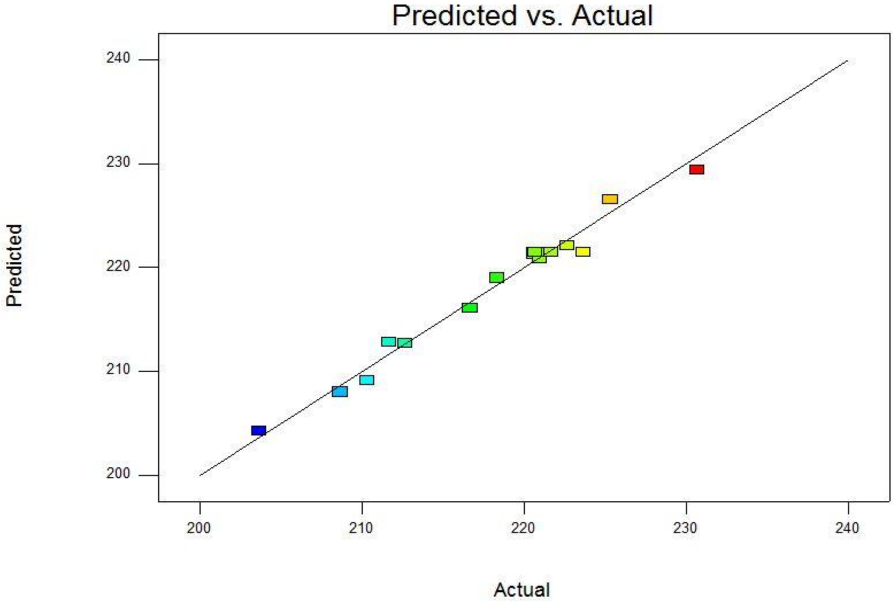

Figure 2. Predicted VS Actual plot of Vickers hardness

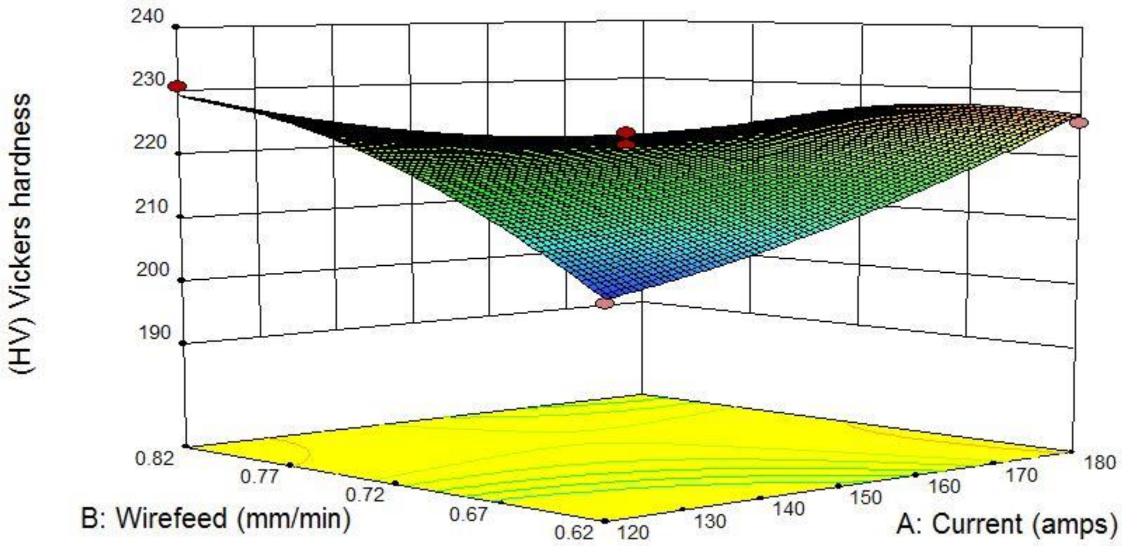

Figure 3. 3D Surface plot presenting the interactive effect of current and wire feed on Vickers hardness

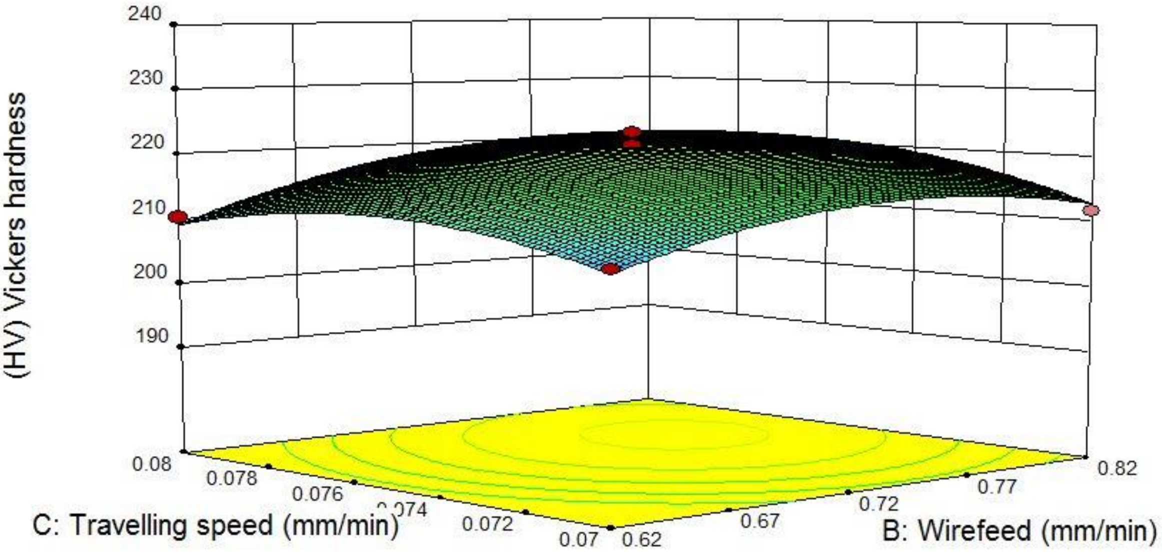

Figure 4. 3D Surface plot presenting the interactive effect of wire feed and travelling speed on Vickers hardness

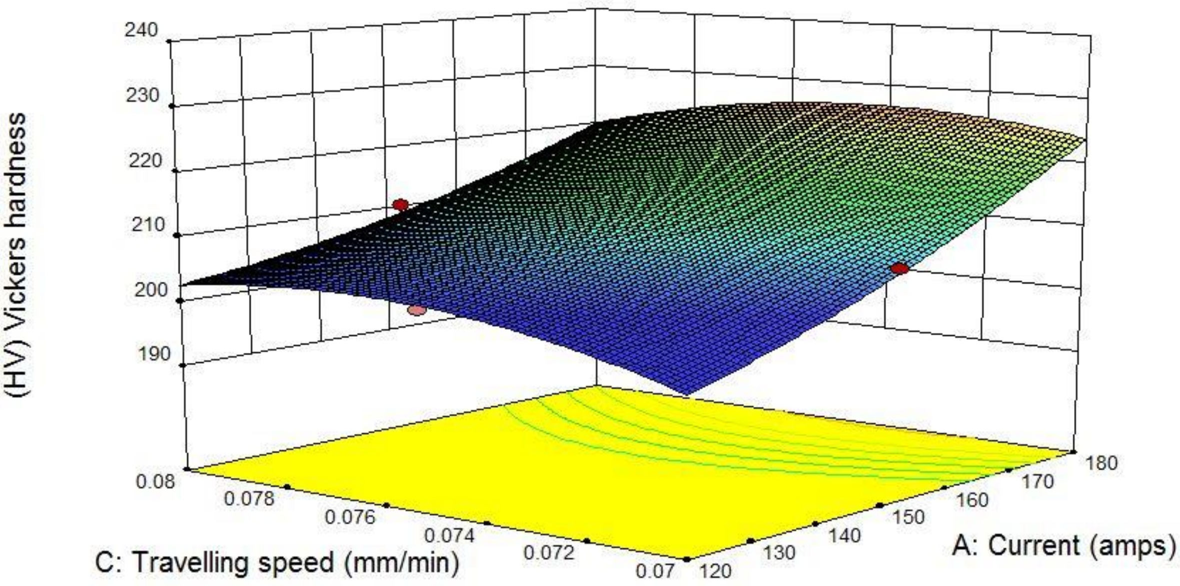

Figure 5. 3D Surface plot presenting the interactive effect of current and travelling speed on Vickers hardness

4. Conclusions

1. A mathematical ideal is developed to predict the Micro Vickers hardness test of Robot TIG welding of dissimilar steels SS304L and SS430 joints with 95% of confidence level. The model is developed to predict the Micro Vickers hardness with input parameters.
2. The optimum process parameters to maximize the Micro Vickers hardness are current at120 amps, wire feed is0.82mm/min and travelling speed is 0.0779 mm/min. The predicted hardness under optimum conditions is 231.079 HV.
3. The Analysis of Variance shows that the process parameters of the linear regression model are significant and wire feed is highly influencing the hardness.

References

[1] Yanling Xu, Huanwei Yu, Jiyong Zhong, Tao Lin, Shanben Chen 2012 *Real-time seam tracking control technology during welding robot GTAW process based on passive vision sensor*, Journal of Materials Processing Technology**212**pp1654– 1662.
[2] S.A.A. Akbari Mousavi, R. Miresmaeili 2008 *Experimental and numerical analyses of residual stress distributions in TIG welding process for 304L stainless steel*, Journal of materials processing technology**208**pp383–394.
[3] Antony J.2003 *Design of experiments for engineers and scientists.* Oxford: Heinemann.
[4]Correia DS, Gonçalves CV, da Cunha SS, Ferraresi VA, 2005 *Comparison between genetic algorithms and response surface methodology in GMAW Welding optimization*, J Mater Proc Technol**160**pp70–6.
[5] Hussain Zuhailawati, Muhammad Afiq Jamaluddin, Anasyida Abu Seman, Suhaina Ismail, 2016,*Welding Investigation and Prediction of Tensile Strength of 304 Stainless Steel Sheet Metal Joint* by Response Surface Methodology Procedia Chemistry**19**pp217 – 222.
[6]Nikhil Kumar, Manidipto Mukherjee, AsishBandyopadhyay, 2017*Comparative study of pulsed Nd: YAG laser welding of AISI 304 and AISI 316 stainless steels*Optics &Laser Technology**88**pp24–39.
[7] A. Razal Rose, K. Manisekar, V. Balasubramanian, S. Rajakumar 2012 *Technical Report Prediction and optimization of pulsed current tungsten inert gas welding parameters to attain maximum tensile strength in AZ61A magnesium alloy*, Materials and Design**37**pp334–348.
[8] Montgomery DC 2009, *Introduction to statistical quality control*, Jefferson, John Wiley & Sons.
[9] Montgomery DC 2001, *Design and Analysis of Experiments*. New York, John Wiley & Sons.
[10] G. Vairamani1 T. Sandhill Kumar, S. Malarvizhi, V. Balasubramanian, 2013 *Application of response surface methodology to maximize tensile strength and minimize interface hardness of friction welded dissimilar joints of austenitic stainless steel and copper alloy*, Trans. Nonferrous Met. Soc. China **23**pp2250−2259.

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