OPEN ACCESS

International Journal Of Modern Engineering Research (IJMER)

Modeling and Analysis of Current and Weld Speed on Weld Hardness of Steel-Cu Weldments by RSM Approach

Ramakant Rana[1], Surabhi Lata[1], Alok Shankaran[2], Vinay Sharma[2], Amit Saraswat[2], Roop Lal[3]

[1]*Assistant Professor, Mechanical and Automation Engineering, Maharaja Agrasen Institute of Technology, Delhi, India*

[2,]*Student, Mechanical and Automation Engineering, Maharaja Agrasen Institute of Technology, Delhi, India*

[3]*Assistant Professor, Mechanical Engineering, Delhi Technological University, Delhi, India*

ABSTRACT: *In this paper, Response Surface Methodology (RSM) is used to investigate the effect of two controllable input variables viz. Current and Welding Speed for Weld Hardness of joined surfaces of Steel and Copper. To study the proposed model for Weld Hardness, a Central Composite Design (CCD) is used to estimate the model coefficients of the two factors, which are alleged to influence the Weld Hardness of the weld. Experiments were conducted on Steel and Copper. The response is modelled using RSM on experimental data. The significant coefficients are obtained by performing Analysis of Variance (ANOVA) at 5% level of significance.*

Keywords: *RSM, Welding, Dissimilar Metals, Weld Hardness, Modelling*

I. INTRODUCTION AND LITERATURE REVIEW

Industries have an increasing demand of dissimilar metal joints for various applications, viz. reduction in weight, concern regarding environment, high performance, cost saving and energy saving [Dong et al. (2012), Uzun et al. (2005)]. The transportation industry widely uses aluminium alloys for the purpose of reduction in weight [Chen et al. (2013), Zhang et al. (2007)]. [Korenyuk (1975)] tried to weld Aluminium to Titanium, this combination was not accomplished successfully by conventional arc welding processes. [Gorin (1964), Lv et al. (2012)] welded Titanium to nickel, an attempt to weld Ti and Ni using TIG was not successful. However, they used copper alloy as an insert which, led to a joint without harmful intermetallic compounds. [Mikhailov et al. (1965)] successfully welded Titanium to Copper, their produced joints were with the highest tensile strength and ductility with Ti-30Cb and Ti-3Al-6.5Mo-11Cr. [O'Brien (2011)] welded Copper alloys to Nickel, and found that, the Copper and nickel are mutually soluble in each other. [Shao et al. (2015)] welded Aluminium and Galvanized Steel. Their thermodynamic calculations predicted that the Fe_2Al_5 intermetallic compound layer was formed first in the steel side, when temperature gradually reduced. The joining of steel and copper has become an essential research and application focus [Chen (2015)]. It is nevertheless difficult to join them together due to the differences in physical characteristics such as the melting temperature, the poor metallurgical compatibility and thermal expansion, of these two metals. In this paper, gas metal arc welding (GMAW) method was used to join steel and copper.

II. EXPERIMENTAL SET-UP

A number of experiments were conducted to study the effects of various parameters on joining Steel and Copper with GMAW. These studies were undertaken to investigate the effects of Current, and Welding Speed for Weld Hardness. The selected workpiece material for the research work was steel (composition shown in Table 1) and 100 % Copper. Steel was selected due to its emergent range of applications in the field of manufacturing tools in mould industries. Workpiece materials used were steel square plates of dimensions 100×80 mm and of thickness 6 mm. the welding process is shown in Figure 2 (a) & (b). The test conditions are depicted in Table II.

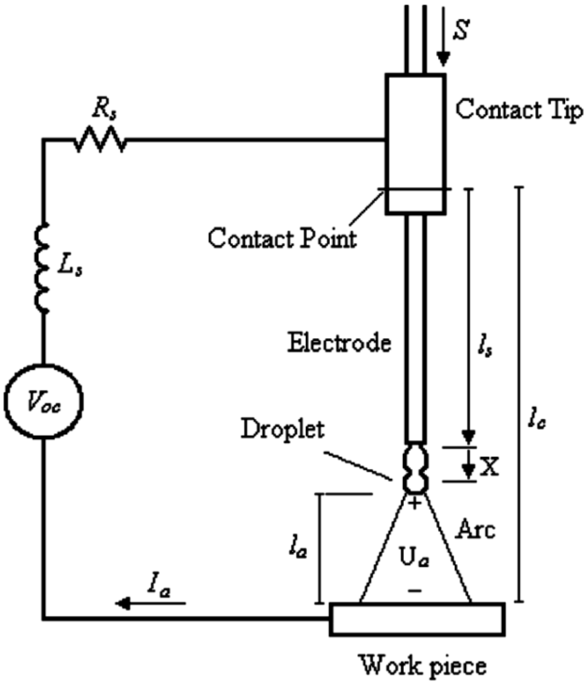

Figure 1: Model of GMAW Process [Shao et al. (2015)]

Table I: Composition of Steel Welded with copper

Carbon	Silicon	Manganese	Phosphorus	Sulphur	Chromium	Molybdenum	Nickel	Copper	Titanium	Cobalt	Vanadium
.352	.178	.61	.035	.037	.243	.033	.080	.089	.007	.003	.003

(a) (b)

Figure 2: Welded Process being conducted

III. RESPONSE SURFACE METHODOLOGY

The collection of statistical and mathematical techniques named Response Surface Methodology (RSM) is useful for modelling and analysis of the problems in several input variables influences the responses. RSM objective is to find the correlation between the variables investigated and the response [Montgomery (2001), Rana et al. (2014)]. Design of Experiments (DOE) was used to estimate an unknown function for which only a few values were computed. Least square error fitting was used to model the generated relations of the response surface. A Central Composite Design (CCD) gives a comparatively accurate prediction of all response variable averages related to quantities measured during experimentation, hence it was used [Mason et al. (2003)]. Central Composite Design (CCD) offers the advantage that certain level adjustments are acceptable and can be applied in the two-step chronological RSM. In these methods, there is a possibility that the experiments will stop with few runs and decide that the prediction model is satisfactory.

Table Ii: Different Variables Used In The Experiment And Their Level

Variable	CODE	LEVELS	
		1	2
Current (A)	A	200	240
Welding Speed (mm/s)	B	1.11	1.44

The Current, and Welding Speed were the variables selected for this investigation. The different levels taken for this study are shown in Table II. Three replications of Weld Hardness were taken, and the average value of Weld Hardness used in the design matrix, is shown in Table III.

Table III: Planning Matrix Of The Experiments With The Optimal Model Data.

Current(A)	Welding speed(mm/s)	Hardness
240	1.11	162
240	1.44	227
200	1.44	160.67
200	1.11	167

The experimental values were analyzed and then a mathematical model was developed which, illustrated the relationship between the process response and the variables. The model in equation 1 explains the behaviour of the system.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \in \quad \ldots 1$$

Where y = Hardness, x_1 = Current (A), x_2 = Welding speed (mm/s) and β_1, β_2= Partial Regressors.

IV. RESULT AND DISCUSSION

Based on the experimental data gathered, statistical regression analysis enabled to study the correlation of process parameters with the Weld Hardness. In this study, a polynomial regression was modelled for two variables under consideration. For simplicity, a quadratic model of Weld Hardness was proposed.

The coefficients of regression model was estimated from the experimental results. The effects of these variables and the interaction between them were included in this analyses and the developed model is expressed as interaction equation:

$$\text{Hardness} = -103 + 0.767 \text{ Current (A)} + 89 \text{ Welding speed (mm/s)} \quad \ldots 2$$

Table IV: Anova Table For Weld Hardness

Term	**Coef SE**	**Coef**	**T-Value**	**P-Value**
Constant	-103	240	-0.43	0.743
Current (A)	0.767	0.892	0.86	0.548
Welding Speed (mm/s)	89	108	0.82	0.562

The unknown coefficients were determined from the experimental data as presented in Table IV. The standard errors on estimation of the coefficients were tabulated in the column 'SE coef'.

It was important to check the adequateness of the model, because under-specified or an incorrect model could have lead us to misleading conclusion. The model adequateness checking included the test for significance of the model coefficients, lack of fit and regression model, which were carried out subsequently using ANOVA on the curtailed model (Table. V).

Table V: Analysis Of Variance Table For The Fitted Models:

Source	**DOF**	**Adj. SS**	**Adj. MS**	**F-Value**	**P-Value**
Regression	2	1800.9	900.4	0.71	0.643
Current(A)	1	940.3	940.3	0.74	0.548
Welding speed(mm/s)	1	860.5	860.5	0.68	0.562
Error	1	1272.0	1272.0	*	*
Total	3	3072.9	*	*	*

Welding Speed and Current improves the weld Hardness with the increase in their values as that is depicted in the figure 3. Even from figure 4 also it is clear that that optimum value of Weld Hardness can be achieved with both the Welding Speed and Current. The surface plot of the Weld Hardness vs Welding Speed (mm/s) and Current (A) is plotted in figure 5.

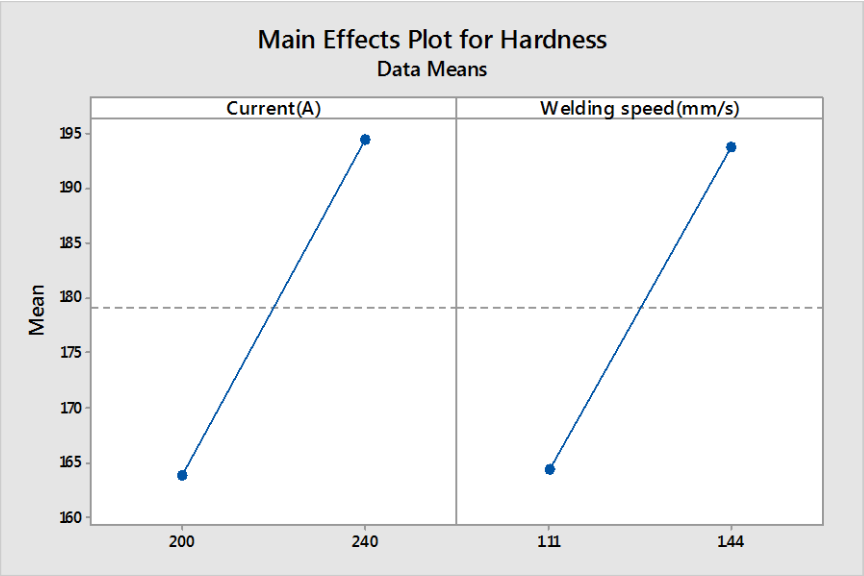

Figure 3: Effect of Current and Welding Speed on Weld Hardness

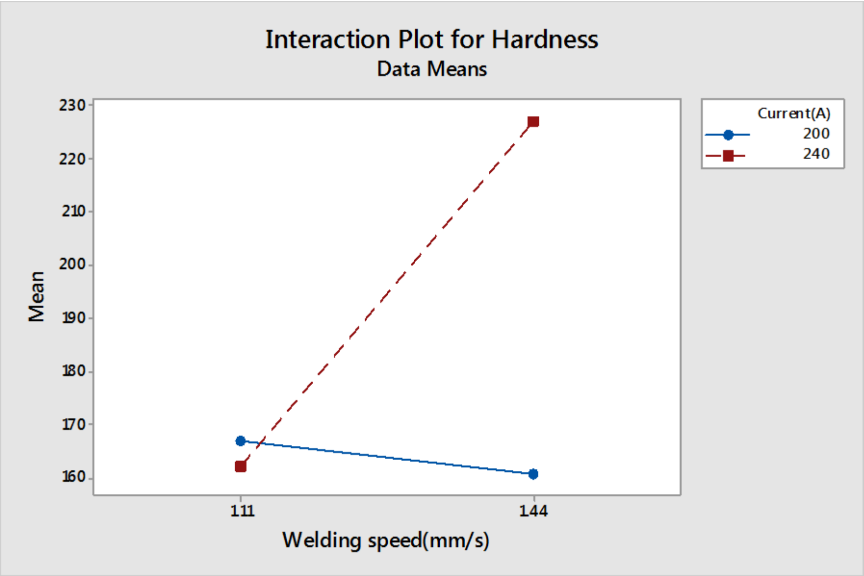

Figure 4: interaction plot of Current vs Welding Speed

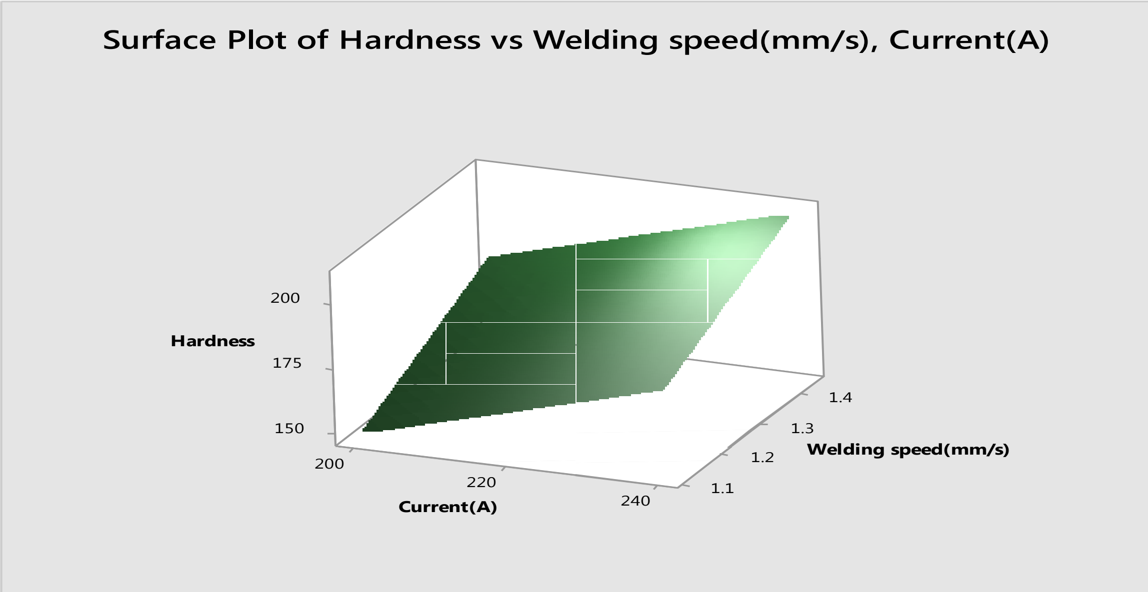

Figure 5: Surface plot of the Weld Hardness vs Welding Speed (mm/s) and Current (A)

V. CONCLUSION

In the present study, the process parameters with significant influence on Weld Hardness was determined by using RSM. A response model of these parameters were developed and found that Current, Welding Speed, and interaction term of Current with Welding Speed significantly affect the Weld Hardness. Weld Hardness is directly proportional to the linear effect of Current and Welding Speed. The higher value of Weld Hardness is achieved with I = 211 A, and Welding Speed = 1.18 mm/s within the experimental domain. The research findings of the present study is based on RSM models, and can be used effectively in joining of Steel with Copper, in order to obtain best possible strength of weld. This research can also help researches and industries for developing a reliable and robust knowledge base along with early prediction of Weld Hardness without experimenting with joining of materials.

REFERENCES

[1]. Chen Shuhai, Huang Jihua, Xia Jun, Zhao Xingke, Lin Sanbao, "Influence of processing parameters on the characteristics of stainlesssteel/copper laser welding", Journal of Materials Processing Technology, Vol. 222, 2015, pp. 43–51

[2]. Chen Y, Weyland M, Hutchinson CR. The effect of interrupted aging on the yield strength and uniform elongation of precipitation-hardened Al alloys. Acta Mater 2013;61:5877–94.

[3]. Cook, LA, & Stavish, MF. (1956). Welding aluminium to copper using the inert gas metal arc process. Welding Journal, 35(5), 348–355.

[4]. Dong HG, Liao CQ, Chen GQ, Dong C. Butt jointing of aluminum to steel by arc brazing process. Mater Manuf Process 2012, 27:1392–6.

[5]. Gorin, LG. (1964). Welding titanium alloys to nickel-base alloys. Welding Products, 11(12), 46–53.

[6]. Korenyuk, YM. (1975). Interaction of liquid aluminium and solid titanium in fusion welding [J]. Welding Production, 22(6), 3–5.

[7]. Lezovskaya, AV, & Rabkin, DM. (1966). Fusion welding aluminum to copper. Automatic Welding, 19(7), 65–66.

[8]. Lv, SX, Jing, XJ, Huang, YX, Xu, YQ, Zheng, CQ, & Yang, SQ. (2012). Investigation on TIG arc welding–brazing of Ti/Al dissimilar alloys with Al based fillers. Science and Technology of Welding and Joining, 17(7), 519–524.

[9]. Mason R. L., Gunst , R. F., Texas D. and Hess J. L., "Statistical Design and Analysis of Experiments With Applications to Engineering and Science", 2nd Edition, A John Wiley & sons publication, 2003.

[10]. Mikhailov, AS, Slonimaky, EV, Senic, AM, & Sukhorukov, AP. (1965). Welding titanium to copper and its alloys. Weld Product, 12(8), 1–6.

[11]. Minitab14, Minitab User Manual Release 14 MINITAB Inc, State College, PA, USA,, 2003.

[12]. Montgomery D. C., "Design and analysis of experiments," John wiley and Sons Inc., 2001.

[13]. Murray, JL. (1982). The magnesium-aluminum phase diagram. Bulletin Alloy Diagrams, 3, 60–74.

[14]. O'Brien, A. (2011). Welding handbook, volume 4 - material and application. Part 1, 9th edn. Doral: American Welding Society (AWS).

[15]. Rana Ramakant, Rajput Kunal, Saini Rohit, Lal Roop, "Opimization of Tool Wear: A Review", International Journal of Modern Engineering Research, Nov, 2014, vol. 4, Issue 11.

[16]. Shao L., Shi Y., Huang J.K., Wua S.J., "Effect of joining parameters on microstructure of dissimilar metal joints between aluminum and galvanized steel", Materials and Design, Vol. 66,2015, pp. 453–458.

[17]. Uzun H, Donne CD, Argagnotto A, Ghidini T, Gambaro C. Friction stir welding of dissimilar Al of 6013-T4 to X5CrNi18-10 stainless steel. Mater Des 2005, 26:41–6.

[18]. Zhang HT, Feng JC, He P, Hackl H. Interfacial microstructure and mechanical properties of aluminum–zinc-coated steel joints made by a modified metal inert gas welding–brazing process. Mater Charact, 2007, 58, pp. 588–92.