

An Improvement in Welded Joint Using Vibration Assisted Arc Welding

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Abstract. Welding is one of the important processes in mechanical engineering. In engineering sector, welding is a common phenomenon. To improve the quality of joining process, essential changes are necessary in regular welding process. According to the research in welding process, it has been found that vibration can improve mechanical properties of the joining section. However, welding joint quality varies with different ranges of parameters in different conditions. This study has performed to analyze those ranges of parameters in some selected conditions. Here are some input parameters like vibration amplitude, vibration frequency, welding speed and electrode angle are selected to analyze the variation in welded joint. For analyzing the results, output parameters – hardness and deposition rate are calculated. It can be seen that welding process assisted by vibration increases strength and quality of welding joint.

1 Introduction

A weld is made when distinct pieces of material to be fused and form one piece when heated to a temperature high enough to cause softening or melting. In arc welding, vibration can be applied either during or after the process. For sophisticated fabrication, researchers are now driving their effort to develop the process of arc welding during vibration, i.e. vibration assisted welding (VAW), which can cut most of the costs related to post weld vibrations or heat treatments. Production lead time can be considerably reduced due to the parallel processing of vibration and welding. Moreover, VAW leads to improved microstructure [1] and better mechanical properties [2]. There are different modes in which vibration is applied to workpiece such as longitudinal, transverse, vertical and random vibrations. In their oldest available paper, it is reported that the effect of longitudinal vibration on mechanical properties such as yield strength, ultimate tensile strength and hardness [3]. In another investigation, breaking strength, ultimate tensile strength (UTS) and yield strength of specimen made under longitudinal vibratory conditions registered an improvement of [4] and 2% respectively [5]. Electromagnetic stirring of molten pool was found to be favoring the grain refinement in gas tungsten arc (GTA) welds of thin sheet made of aluminum alloys [6]. A two-dimensional mathematical model was developed to study the effect of electromagnetically oscillated arc on the microstructure and temperature distribution of bead on plate welds on thin tantalum sheets made through GTA Welding [7]. The ultrasonically VAW electrode could produce more arc pressure in TIG welding [8].

The main aim of this study is to study the effect of vibration and other welding parameter on weld joint properties, as necessary study on this area has not done yet. Here, some input parameters like vibration amplitude, vibration frequency, welding speed and electrode angle are selected to analyze the variation in welded joint. For analyzing the results, output parameters – hardness and deposition rate are selected. The results suggest the way to select the vibration welding parameters to get better joint.

2 Experimental Setup and Methodology

2.1 Concept and Setup

Figure 1 and 2 show the experimental setup, where the wooden frame includes a large table over which all the accessories like base table, a large wooden plate for vertically up and down movement, nylon rack and pinion, pulley, and motors are attached. On the wooden plate, there is a pulley, which can move upward and downward and it is controlled by a dc 12V motor. On that plate, there is a pinion made of Nylon. A Nylon rack is set on an aluminum frame which is connected with the wooden frame. Rack and pinion are meshed together, that is why this connection can move back and forth. On that nylon rack, welding holder is joined. The vertical wooden plate has space in front of it, where the small wooden base table is kept. This wooden base table has a square hole where metallic rods are placed. At that place, job piece will be kept for the experiment. Sidewall of the small base table are connected with two springs with main

table. The small base table has four wheels and those wheels can roll on two rail lines. One vibration device is established in front of that small base plate. This arrangement allows the base table and the job piece to vibrate in back and forth direction. The system is made fully automatic by using an Arduino micro-controller and relay circuits.

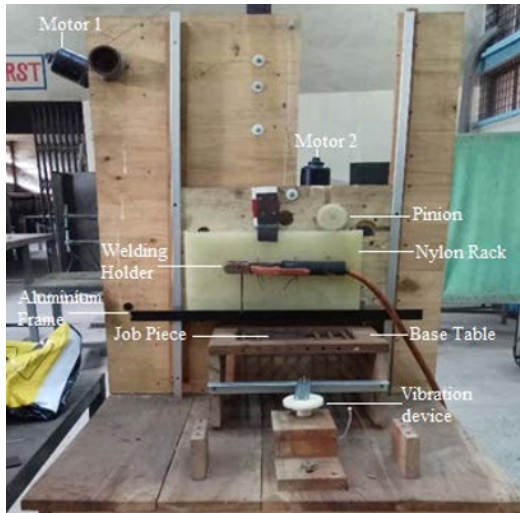


Figure 1. Experimental setup

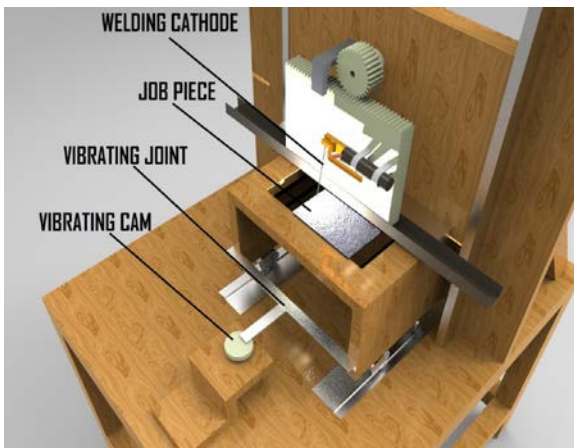


Figure 2. Vibration system designed in CAD Software

Table 1. Process parameters with their values at different levels

Parameters		Levels				
		$-\sqrt{2}$	-1	0	+1	$+\sqrt{2}$
Vibration amplitude (μm)	V_A	12.9	15.0	20.0	25.0	27.1
Vibration Frequency (Hz)	V_F	79.29	100.0	150.0	200.0	220.7
Welding speed (mm/sec)	W_S	1.4	2.0	3.5	5.0	5.6
Electrode Angle ($^\circ$)	E_A	11.9	15.0	22.5	30.0	33.1

Table 2. Experimental results for without vibration

No	Input parameters				Output parameters (Experimental)	
	V_A	V_F	W_S	E_A	Hard. (HRC)	Depo. rate (gm/sec)
1	0	0	1.4	15.0	34.0	0.50
2	0	0	2	15.0	33.0	0.48
3	0	0	3.5	15.0	30.0	0.45
4	0	0	5	15.0	28.0	0.41
5	0	0	5.6	15.0	27.0	0.38
6	0	0	2	11.9	34.5	0.50
7	0	0	2	15.0	33.0	0.48
8	0	0	2	22.5	31.0	0.45
9	0	0	2	30.0	29.0	0.47
10	0	0	2	33.1	28.0	0.48

Table 3. Experimental results using vibration

No	Input parameters				Output parameters (Experimental)	
	V_A	V_F	W_S	E_A	Hard. (HRC)	Depo. rate (gm/sec)
1	15.0	100.0	2.0	15.0	34.54	0.68
2	25.0	100.0	2.0	15.0	41.07	0.70
3	15.0	200.0	2.0	15.0	41.14	0.72
4	25.0	200.0	2.0	15.0	48.00	0.75
5	15.0	100.0	5.0	15.0	29.19	0.48
6	25.0	100.0	5.0	15.0	34.67	0.50
7	15.0	200.0	5.0	15.0	34.40	0.53
8	25.0	200.0	5.0	15.0	41.20	0.55
9	15.0	100.0	2.0	30.0	27.21	0.59
10	25.0	100.0	2.0	30.0	35.33	0.61
11	15.0	200.0	2.0	30.0	34.27	0.63
12	25.0	200.0	2.0	30.0	41.07	0.66
13	15.0	100.0	5.0	30.0	22.13	0.42
14	25.0	100.0	5.0	30.0	29.19	0.44
15	15.0	200.0	5.0	30.0	28.60	0.47
16	25.0	200.0	5.0	30.0	34.40	0.50
17	12.9	150.0	3.5	22.5	28.40	0.57
18	27.1	150.0	3.5	22.5	34.40	0.60
19	20.0	79.29	3.5	22.5	29.19	0.62
20	20.0	220.7	3.5	22.5	34.67	0.65
21	20.0	150.0	1.4	22.5	34.40	0.33
22	20.0	150.0	5.6	22.5	28.79	0.49
23	20.0	150.0	3.5	11.9	34.27	0.57
24	20.0	150.0	3.5	33.1	29.19	0.58
25	20.0	150.0	3.5	22.5	34.80	0.40
26	20.0	150.0	3.5	22.5	34.90	0.39
27	20.0	150.0	3.5	22.5	34.70	0.41
28	20.0	150.0	3.5	22.5	34.60	0.39
29	20.0	150.0	3.5	22.5	35.00	0.40
30	20.0	150.0	3.5	22.5	34.80	0.41

2.2 Methodology

Experimental design is widely used for controlling the effects of parameters in many processes. For all input parameters vibration amplitude, vibration frequency, welding speed and electrode angle, five levels of data using CCD is used (Table 1). Total thirty experiments are conducted, where, 24 of them are non-center points and 6 of them are center points. Moreover, for comparing the vibration results with non-vibration welding, 10 separate experiments are conducted (Table 2). After completing the welding process, hardness of every specimen is measured with Rockwell Hardness tester. Moreover, the deposition rate is calculated by dividing weight of the deposited metal by the welding time. As a workpiece mild steel bar and 2.5 mm filler rod is used. All the experiments are repeated five times to get an average data. The average hardness and deposition rates for different conditions are shown in Table 2 and 3.

2.3 Mathematical Model

For developing the mathematical model, first the fitness function for the output parameters are calculated. To find out the fitness function the natural log transformation is selected and quadratic type equation is used for this case. By using these conditions, the ANOVA for response surface quadratic model shows significant behavior and for lack of fit is shows non-significant behavior. This proves that, the fitness equation is working with in the reasonable range. The model (Eq. 1 and 2) as suggested for the hardness and deposition rate by the fit and summary tests is shown below:

$$\ln(Hardness) = 3.34656 + 0.018552 \times V_A + 1.71317 \times 10^{-3} \times V_F - 0.055885 \times W_D - 0.011791 \times E_A \quad (1)$$

$$\begin{aligned} \ln(Deposition\ Rate) = & 3.62962 - 0.19605 \times V_A - 0.019767 \times V_F + \\ & 0.10054 \times W_D - 0.10213 \times E_A + 9.14818 \times 10^{-6} \times V_A V_F + \\ & 3.04939 \times 10^{-4} \times V_A W_D + 6.76318 \times 10^{-5} \times V_A E_A + \\ & 1.36819 \times 10^{-4} \times V_F W_D + 1.06895 \times 10^{-5} \times V_F E_A + \\ & 3.56317 \times 10^{-4} \times W_D E_A + 4.90434 \times 10^{-3} \times V_A^2 + 6.54561 \times 10^{-5} \times V_F^2 - \\ & 0.028737 \times W_D^2 + 2.02903 \times 10^{-3} \times E_A^2 \quad (2) \end{aligned}$$

3 Results and Discussion:

3.1 Effect of Vibration Amplitude

In figure 3 (a), it can be seen that with the increase of vibration amplitude, hardness increases. The reason is, amplitude gives the job piece perfect movement range so that the job piece can oscillate smoothly which makes remaining bubble in the welded pole out of the joint, cause the porosity to decreases at the joint. Figure 4 (a) indicates the welded joint is irregular and porous when vibration amplitude has been kept low. Figure 4 (b) shows when the amplitude has been increased then welded joint is in regular shape and less porous. Figure 3 (b) shows that, deposition rate is decreasing with the

increment of amplitude but after a certain period, the curve is going up, as the deposition rate starts to grow after a certain period.

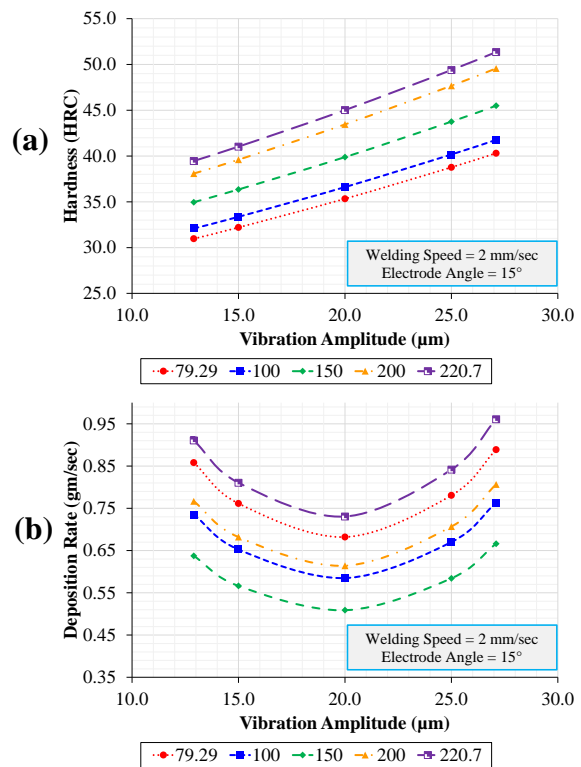


Figure 3. Effect of vibration amplitude for different vibration frequency on (a) Hardness (b) Deposition Rate

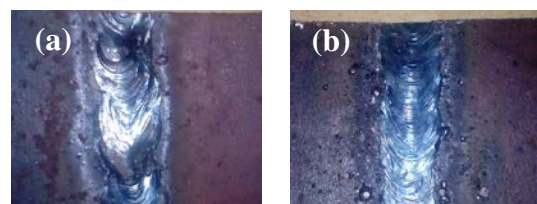


Figure 4. Porosity in welded joint with the change of vibration amplitude (a) high porosity (b) less porosity

3.2 Effect of Vibration Frequency

Figure 5 (a) shows hardness of the joining point is improving with the increase of frequency. Frequency helps the joining point to release its bubble from the molten metal. In figure 6 (a), if low frequency is provided with low amplitude then high amount of porous welded joint is seen with irregular shape but in figure 6 (b), high frequency with high amplitude is given then it shows better result because now those bubbles are not there for vibration. Figure 5 (b) represents deposition rate is decreasing first but after a certain point it is increasing with the increase of frequency and amplitude.

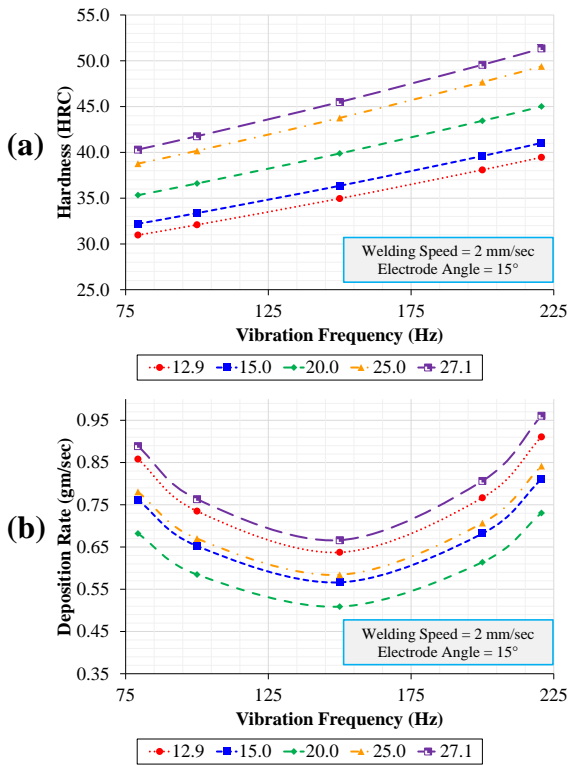


Figure 5. Effect of vibration frequency for different vibration amplitude on (a) Hardness (b) Deposition Rate

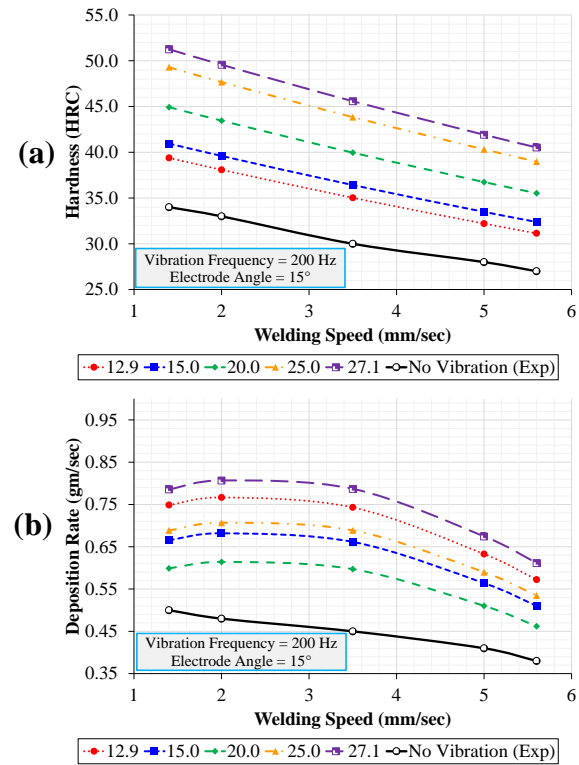


Figure 7. Effect of welding speed for different vibration frequency on (a) Hardness (b) Deposition Rate

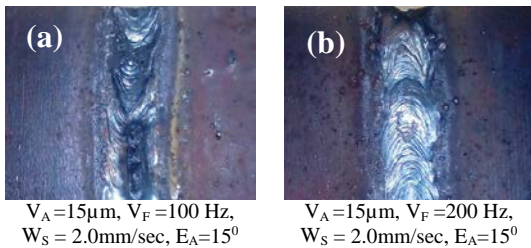


Figure 6. Change of porosity in welding joint with the variation of frequency (a) high porosity (b) less porosity

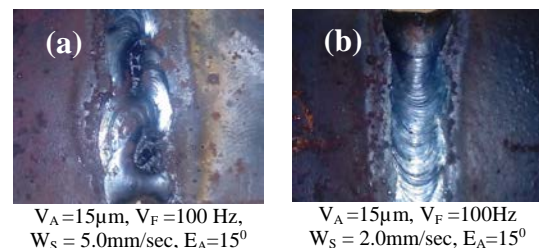


Figure 8. Change of Porosity in welding joint with the variation welding speed (a) high porosity (b) less porosity

3.3 Effect of Welding Speed

Figure 7 (a) shows less welding speed is beneficial to the joining point because if welding speed is high then less amount of molten metal will enter into the joining point so obviously joining point will be weak. Here different coloured lines of amplitude show how hardness is varying with the decrease of welding speed. In figure 7 (a), there is black line which represents non-vibration line and it shows it is also decreasing with the increase of welding speed. Figure 8 (a) shows high welding speed produces welding joint with high amount of porosity. Moreover, figure 8 (b) less welding speed produces welding joint with less amount of porosity. Figure 7 (b) shows the amplitude is decreasing with the increase of welding speed that means deposition rate is decreasing.

3.4 Effect of Electrode Angle

Figure 9 (a) shows less electrode angle is good for the joining point because if electrode angle is high then molten metal will enter into the joining point in less amount so joining point will be weak. With high frequency, high amplitude, less welding speed and less electrode angle, molten metal will enter more into the joining point and release bubble from the joining point. Figure 10 (a) shows the porosity amount is higher when electrode angle is higher, which is not good for the welding joint. In figure 10 (b), the porosity amount is lower when electrode angle is lower so for better welding joint electrode angle should be maintained lower. Figure 9 (b) shows that with the decrease of electrode angle, having high vibration frequency and amplitude and less welding speed, and deposition rate gets higher. Because high frequency and amplitude provides less porosity and

high penetration. As the porosity becomes lower in the molten material and metal is entering more into the joint.

joining section, which provides the better joint than regular cases.

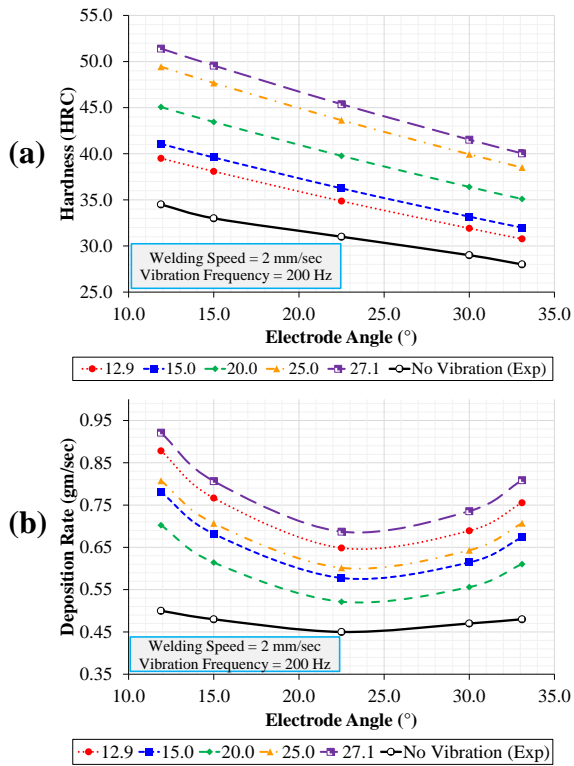


Figure 9. Effect of electrode angle for different vibration frequency on (a) Hardness (b) Deposition Rate

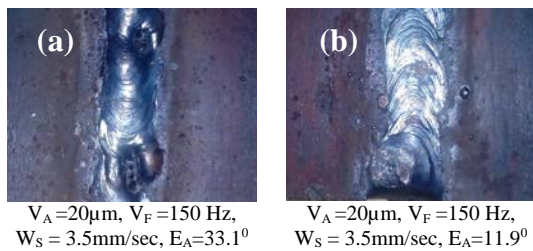


Figure 10. Change of Porosity amount with the change of electrode angle (a) high porosity (b) less porosity

4 Conclusions

The input parameters- amplitude, frequency, welding speed and electrode angle have a very significant effect on welding process. These model equations have been used to find out the relation between input and output parameters through graphical analysis. Graphical analyze of input and output parameters shows that hardness of a welded joint increases when the amplitude, frequency, welding speed and electrode angle in a selected range. Hardness differs with the amount of porosity in welding section. If porosity amount is higher in welded section, hardness becomes low and if this porosity amount is lower, hardness of the joint gets higher. This study also shows the similar improvement phenomenon with the deposition rate, which gives an increase in production rate as well. The controlled input parameters in some specific ranges helps to get complete penetration in

References

1. W. Wu, Micro- and Nano. Tech: Mat., Processes, Packaging, and Systems II **5650**, 438 (2005)
2. S. P. Tewari, ISIJ International **39**, 570 (1999)
3. S. P. Tewari, Shanker, Proc. IMechE B **207**, 173 (1993)
4. A. S. M. Y. Munsif, A. J. Waddell, C. A. Walker, Strain **35**,139 (1999)
5. S. P. Tewari, Thammasat Int. J. Sci. Technology **14**,17 (1999)
6. M. Fukuhisa, N. Hiroji, N. Kazuhiro, A. Ritsu, Transactions of JWRI **7**, 111 (1978)
7. A. Grill, Metall. Trans. B **12B**, 667 (1981)
8. S. Qingjie, L. Sanbao, Y. Chunli, F. Yangyang, Z. Guoqing, China Welding **17**, 52 (2008)