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EFFECT OF PROCESS PARAMETERS ON GRAIN SIZE OF WELD BEAD OF ALUMINUM ALLOY 5083 IN PULSED GAS METAL ARC WELDING WITH ARC ROTATION

SANJAY KUMAR[1*] AND K. KUSUMA [2]

[1]Sanjay Kumar, Gayatri Vidya Parishad College of Engineering (A),
Visakhapatnam-530048, India
[2]K. Kusuma, Gayatri Vidya Parishad College of Engineering (A),
Visakhapatnam-530048, India

Abstract

Pulsed gas metal arc welding is used in industries because of its high weld quality and even better weld quality can be achieved by providing arc rotation mechanism during welding. The quality of the weld joint improves with the refinement in microstructure of the weld bead. In this work, the effect of input process parameters viz. arc rotational speed, ratio of wire feed rate to travel speed and wire feed rate on grain size of weld bead of square butt joint of 5083-H111 aluminum alloy has been studied. The image analysis software is used to obtain the grain size of the microstructure of weld bead. The mean analysis for grain area, grain perimeter, grain length is done at all three levels of input process parameters. It is observed from the investigation that wire feed rate has maximum effect on grain area, grain perimeter and grain length followed by ratio of wire feed rate to travel speed and arc rotational speed.

Key words: arc rotational speed, aluminum alloy 5083, grain area, grain perimeter, grain length.

1 INTRODUCTION

The quality of the weld joint depends on the weld bead geometry and microstructure of the weld bead. It is expected that the grain size of the microstructure of weld bead can be refined by using arc rotation mechanism in pulsed gas metal arc welding. In this mechanism, the arc rotates continuously with certain speed during welding causing flat and broad weld bead and the finger type penetration can also be avoided. Kumar et al. [1] developed arc rotation mechanism and studied the effect of various input process parameters on weld bead geometry viz. bead width, bead height and bead penetration of square butt joint plate in pulsed gas metal arc welding. Wu et al. [2] investigated ultrafine-grained microstructures in the surface layer of aluminum alloy 7075. Xu et al. [3] worked on the microstructure and mechanical properties of butt joint of thick 2219-O aluminum alloy in friction stir welding. It was observed that the microstructure in the weld nugget zone has extremely fine and equiaxed grains. Hong et al. [4] studied the microstructures of Inconel 718 welds by CO_2 laser welding. The analysis of microstructure of welding zone was done by using optical microscope and scanning electron microscope. Qiu [5] observed Interfacial microstructure in the weld joint of aluminium alloy A5052 and austenitic stainless steel SUS304 in resistance spot welding. Sivashanmugam et al. [6] investigated the microstructure and mechanical properties of AA7075 aluminum alloy in GTAW and GMAW.

It was observed that fine and uniformly distributed grains were formed in the welding region. Muruganandam et al. [7] studied micro structural properties of weld joint of dissimilar aluminium alloy 2024 and 7075 in friction stir welding. Kolhe et al. [8] established the correlation between the various parameters and microstructure of V-groove butt joint welding to obtain the weld free defects. Kong et al. [9] studied the microstructure of gas-atomised Al-Sn-Cu alloy powder using scanning and transmission electron microscope. It was observed that the microstructure formed in gas-atomised Al-Sn-Cu alloy powder depend on the Sn particle size. It is observed that literatures are not available for microstructure analysis of weld bead in Pulsed Gas Metal Arc Welding (GMAW-P) with arc rotation. In the present work, the effect of input process parameters of GMAW-P with arc rotation on microstructure of weld bead of 5083-H111 aluminium alloy is studied.

2 EXPERIMENTAL DETAILS

2.1 Experimental process

Fig. 1 shows the photograph of experimental setup which consists of arc rotation mechanism, welding machine and welding trolly. In arc rotation mechanism, provision is made in such a way that the filler wire can be rotated at any speed during welding. Square butt joint plate of Al-Mg alloy 5083-H111 and 5183 filler wire of 1.2 mm diameter are used for conducting the experiments. Kemppi Pro Evolution 3200 welding machine in pulsed mode is used for the experiment. Pure argon gas is supplied at the rate of 17 l/min. The angle between filler wire and work piece is kept at 90^0 and 17mm distance is maintained between contact tip and work piece. The work is fixed on the platform of welding trolly whose speed is controlled by rheostat and moves below the torch.

2.2 Conducting the experiments

The input process parameters considered for conducting the experiments are arc rotational speed (N), ratio of wire feed rate to travel speed (F/S) and wire feed rate (F). Trial experiments were conducted to obtain the working range of the process parameters. The values of the input process parameters are given in Table 1. The experiments are conducted as per full factorial design of experiment as mentioned in Appendix I and so 27 weld bead samples are obtained.

Table 1 Input parameters and their limits

Input parameters	Units	notation	Factor levels		
			Level 1	Level 2	Level 3
Arc rotational speed	rpm	N	100	500	900
Wire feed rate /travel speed (F/S)	_	X	30	40	50
Wire feed rate	m/min	F	4	5.5	7

These samples are cut at middle position by using circular saw machine to get the metallographic weld bead samples. The emery paper of grade 120, 220,320, 420, 2/0, 3/0, 4/0 and 5/0 in order are used for grinding the transverse face of the weld bead sample and then the specimens are polished by polishing machine. The polished specimens are cleaned with ethyl alcohol and caustic etchant (15 g NaOH+100 g distilled water) solution is applied to reveal the bead geometry and microstructure of the macro-etched samples. The photograph of weld bead of one sample is shown in Fig. 2.

3 MICROSTRUCTURE ANALYSIS OF WELD BEAD

The microstructure of weld bead is observed in the inverted metallurgical microscope with 500X magnification and analysed using metal power image analysis software. The microstructure of weld bead of one sample is shown in Fig. 3. The grain size viz. mean grain area, mean grain perimeter and mean grain length is found as shown in Fig. 4 and Fig. 5 using this software. The value of grain size of all 27 samples are mentioned in Table 2.

Table 2 Grain size of microstructure of weld bead

Sample No.	Rotational speed (rpm)	Wire feed rate/travel speed (-)	Wire feed rate (m/min)	Grain area (μm^2)	Grain perimeter (μm)	Grain length (μm)
1	100	30	4	1.571	4.900	1.60
2	500	30	4	2.180	5.033	1.63
3	900	30	4	2.292	5.400	1.63
4	100	40	4	1.706	4.66	1.50
5	500	40	4	2.072	5.133	1.60
6	900	40	4	2.411	5.333	1.66
7	100	50	4	1.500	6.400	1.43
8	500	50	4	1.973	4.833	1.50
9	900	50	4	2.551	5.133	1.60
10	100	30	5.5	3.053	6.466	1.93
11	500	30	5.5	2.500	3.400	1.90

12	900	30	5.5	2.356	5.566	1.34
13	100	40	5.5	2.813	6.600	1.70
14	500	40	5.5	2.800	6.000	1.60
15	900	40	5.5	2.713	5.000	1.63
16	100	50	5.5	3.045	6.133	1.83
17	500	50	5.5	3.077	5.566	1.70
18	900	50	5.5	3.000	5.966	1.86
19	100	30	7	4.100	9.033	2.26
20	500	30	7	3.381	7.000	1.96
21	900	30	7	1.735	4.600	1.40
22	100	40	7	4.500	8.900	2.56
23	500	40	7	3.273	7.400	2.00
24	900	40	7	2.400	5.800	1.70
25	100	50	7	4.771	7.966	2.13
26	500	50	7	4.000	7.933	2.13
27	900	50	7	3.660	7.066	1.90

4. Results and Discussion

4.1 Analysis of means (ANOM) for grain size

The mean analysis for grain size of microstructure of weld bead is done. It provides the data for the average effect of each factor at different levels.

4.1.1 Analysis of means for grain area

The mean analysis for bead grain area is given in table 3 and its graphical representation is shown in Fig. 6.

Table 3 Mean analysis for grain area

	N	X	F
Level1	3.006	2.574	2.028
Level2	2.808	2.745	2.822

Level3	2.500	3.071	3.539
δ	0.506	0.497	1.511
Rank	2	3	1

These values are found by taking the average of grain area for that factor at that particular level from table 2. δ is the difference between the largest and smallest values of mean grain area within that factor. The effect of each factor is ranked as per the magnitude of δ values. The first rank factor has the largest effect and third rank factor has least effect on grain area.

The following observations can be made from Fig. 6 and Table 3

(i) Wire feed rate has largest effect on bead grain area. By increasing the wire feed rate from 4 to 7m/min, the mean grain area is increased by 1.511μm^2.

(ii) By increasing the ratio of wire feed rate to travel speed from 30 to 50, the mean grain area is increased by 0.497μm^2.

(iii) By increasing the arc rotational speed from 100 to 900rpm, the mean grain area is reduced by 0.506μm^2.

4.1.2 Analysis of means for grain perimeter

The mean analysis for grain perimeter is given in Table 4 and its graphical representation is shown in Fig. 7

Table 4 Mean analysis for grain perimeter

	N	X	F
Level1	6.788	5.710	5.203
Level2	5.810	6.096	5.633
Level3	5.540	6.332	7.303
δ	1.248	0.622	2.1
Rank	2	3	1

The following observations can be made from Fig. 7 and Table 4

(i) Wire feed rate has maximum effect on grain perimeter. By increasing the wire feed rate from 4 to 7 m/min, the mean grain perimeter is increased by 2.1μm.

(ii) By increasing the ratio of wire feed rate to travel speed from 30 to 50, the mean grain perimeter is increased by 0.622μm.

(iii) By increasing the arc rotational speed from 100 to 900rpm, the mean grain perimeter is reduced by 1.248μm.

4.1.3 Analysis of means for grain length

The mean analysis for grain length is given in Table 5 and its graphical representation is shown in Fig. 8

Table 5 Mean analysis for grain length

	N	X	F
Level1	1.884	1.741	1.573
Level2	1.781	1.773	1.723
Level3	1.637	1.788	2.007
δ	0.247	0.047	0.434
Rank	2	3	1

The following observations can be made from Fig. 8 and Table 5

(i) By increasing the rotational speed from 100 to 900rpm, the mean grain length is decreased by 0.247μm.

(ii) By increasing the ratio of wire feed rate to travel speed from 30 to 50, the mean grain length is increased by 0.047μm.

(iii) By increasing the wire feed rate from 4 to 7m/min, the mean grain length is increased by 0.434μm.

CONCLUSIONS

1. Wire feed rate has maximum effect on grain area, grain perimeter and grain length followed by ratio of wire feed rate to travel speed and arc rotational speed.
2. The grain area, grain perimeter and grain length decreases with an increase in the value of arc rotational speed.
3. Grain area, grain perimeter and grain length are increased when the wire feed rate to travel speed is increased from 30 to 50.

4. When the wire feed rate is increased from 4 to 7m/min, the grain area, grain perimeter and grain length are also increased.

Appendix I Design matrix as per full factorial design

Sample No.	Rotational speed (N)	Wire feed rate/travel speed (X)	Wire feed rate (F)
1	100	30	4
2	500	30	4
3	900	30	4
4	100	40	4
5	500	40	4
6	900	40	4
7	100	50	4
8	500	50	4
9	900	50	4
10	100	30	5.5
11	500	30	5.5
12	900	30	5.5
13	100	40	5.5
14	500	40	5.5
15	900	40	5.5
16	100	50	5.5
17	500	50	5.5
18	900	50	5.5
19	100	30	7
20	500	30	7
21	900	30	7
22	100	40	7
23	500	40	7
24	900	40	7
25	100	50	7
26	500	50	7
27	900	50	7

Fig. 1 Experimental setup

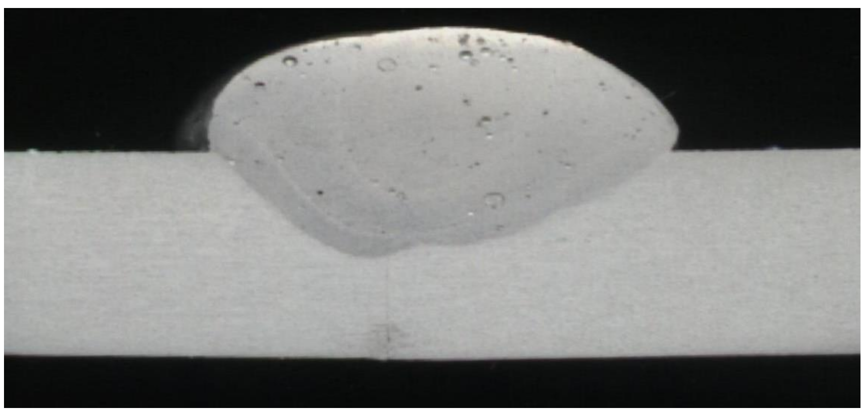

Fig. 2 Weld bead of sample No. 18

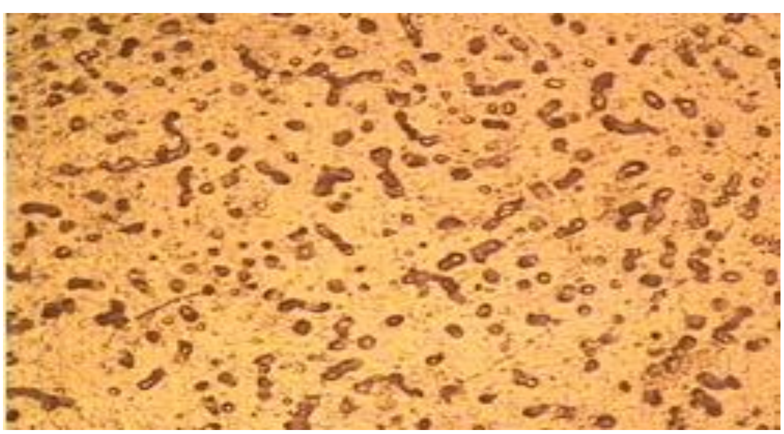

Fig. 3 Microstructure of weld bead sample No. 18

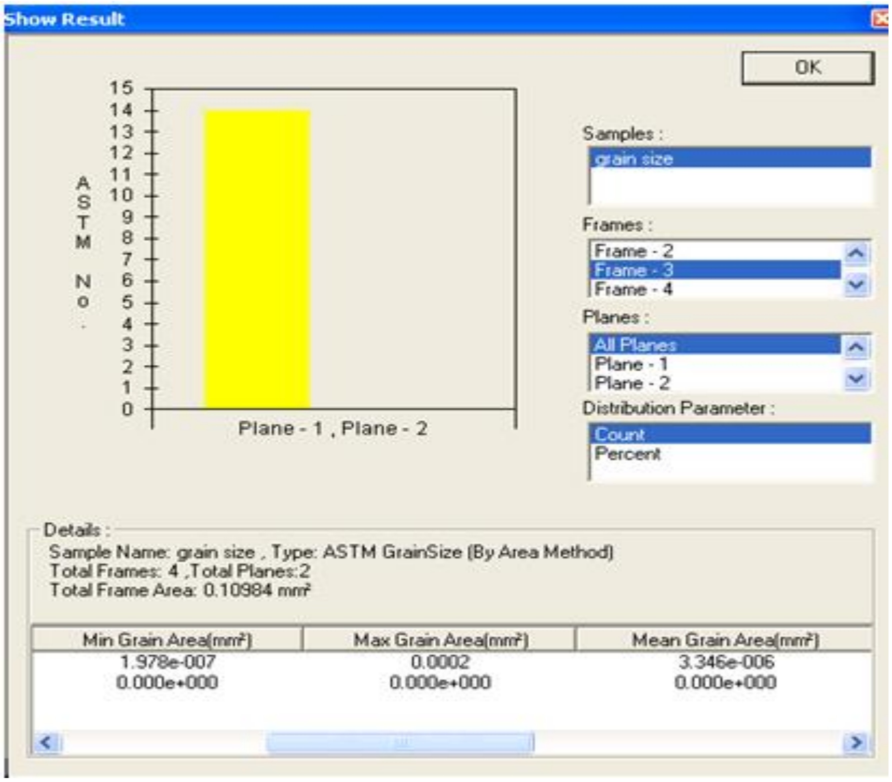

Fig. 4 Grain area of weld bead sample no.18

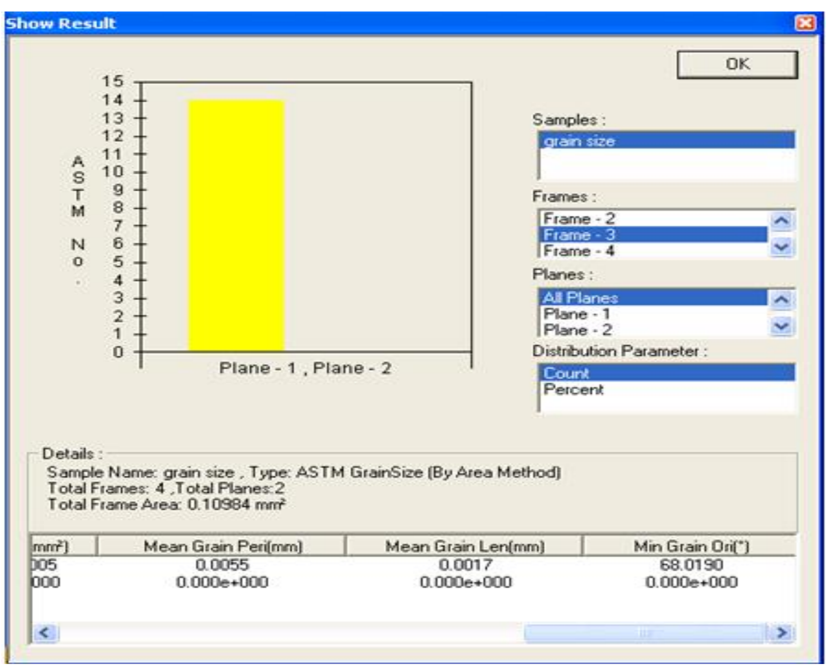

Fig. 5 Grain perimeter and grain length of sample No.18

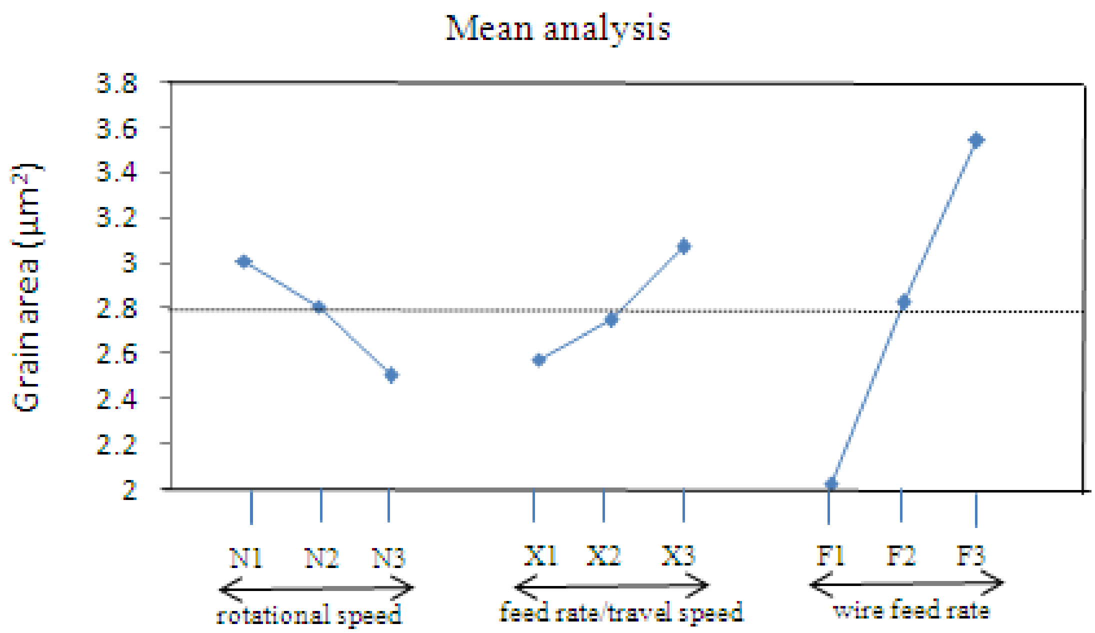

Fig. 6 Effect of factor levels on grain area

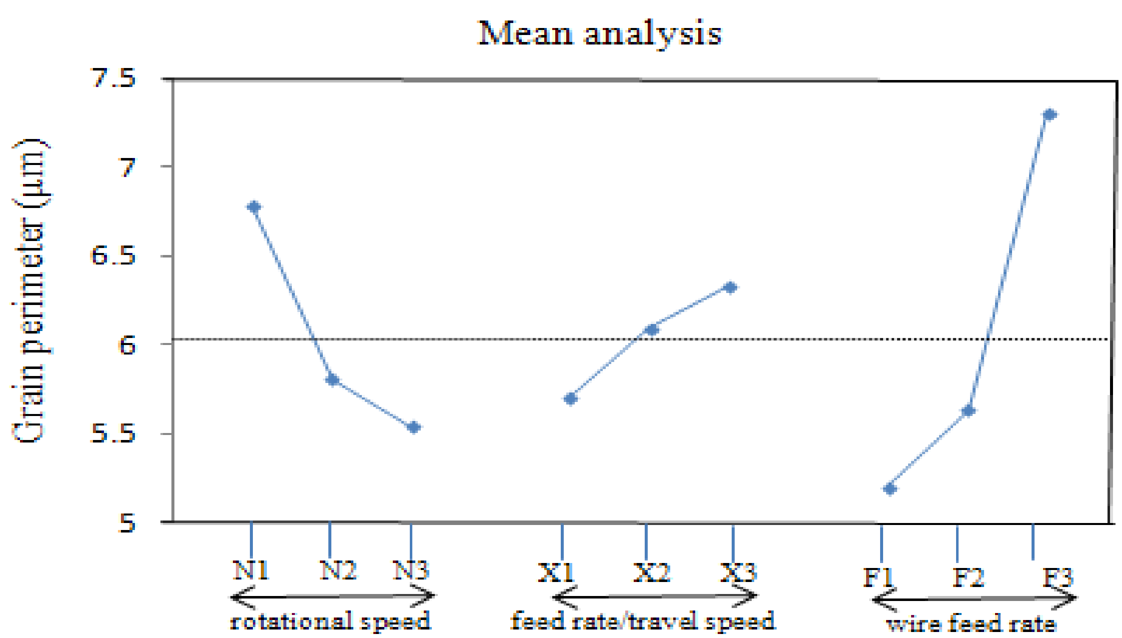

Fig. 7 Effect of factor levels on grain perimeter

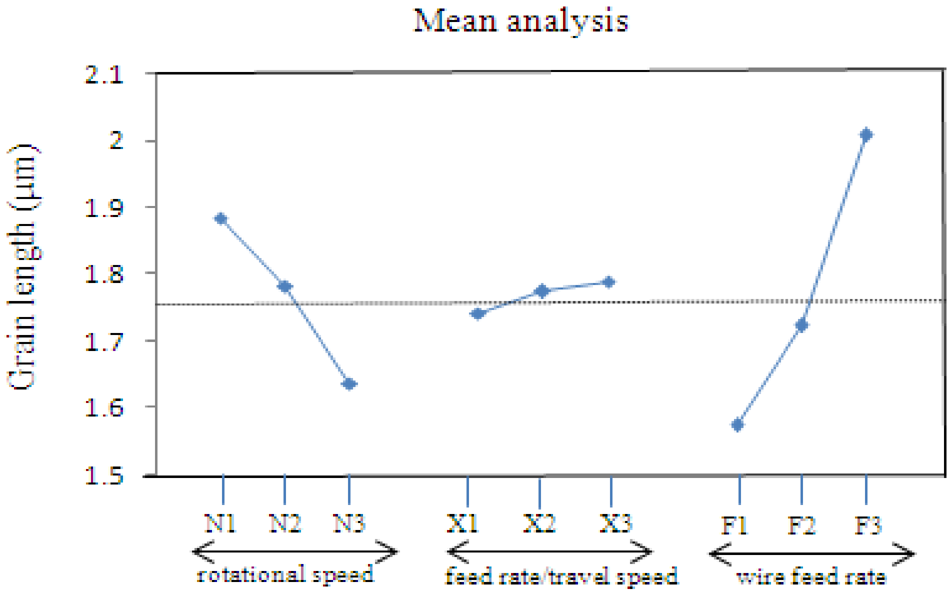

Fig. 8 Effect of factor levels on grain length

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