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Effect of Pulse Frequency and Wire Feed Rate on Grain Size and Penetration of Weld Bead in Double Pulse GMAW

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ABSTRACT

Double Pulse gas metal arc welding is the new technique in which pulse of high frequency current is modulated by weld power source to control transfer of the metal in the form of droplets of liquefied filler material to develop an even and spatter free arc. Experiments are conducted on pulse gas metal arc welding machine in double pulse mode using full factorial design. Pulsefrequency and wire feed rate are considered as input parameters. In this research, the effect of these input parameters on output parameters viz. grain size and bead penetration of weld bead in mild steel plate are investigated. Image analysis software is used to get the microstructure of the weld bead. The penetration, grain area and grain length of weld bead are measured for all specimens. Regression models are developed to predict the grain size and bead penetration. It is noticed that when pulse frequency and wire feed rate increases, depth of penetration also increases. Also grain size is more affected by the pulse frequency compared to the wire feed rate.

KEYWORDS: Pulse frequency, Wire feed rate, Double pulse, Grain size, Microstructure

1. INTRODUCTION

Gas Metal Arc Welding is most widely used technique in which metals are joined by heating them with an arc continuously fed between workpiece and filler metal electrode. In DP-GMAW, the droplet transfer is controlled by thermal pulse and high frequency pulseto develop an even and spatter free arc. Ibrahim et al. [1] studied the effect of different parameters viz. welding current, arc voltage and welding speed on the microstructure and penetration in MIG welding. Sathiya et al. [2] investigated the microstructural characteristics of AISI 904 stainless steel. Experiments were conducted by using Taguchi technique and the Input parameters considered were arc voltage, travel speed, wire feed rate, gas flow rate. Palani and Murugan [3] studied the response of pulse variables on quality of weld. Primary parameters considered for pulsed GMAW are peak current, mean current, peak current period, mean current period duration and pulse frequency. It was concluded that peak current and peak current period plays a dominant part in studying the bead properties.

Liu et al. [4] studied the response of double pulsed GMAW on metal transfer, weld pool profile and other welding properties of aluminium alloy. It was found that droplet transfer and arc profile are influenced by high pulse frequency and thermal frequency simultaneously. By changing the thermal frequency, wave surface of the weld bead can be controlled and the grain size at joint decreases with increase in thermal pulse.

Agrawal and Kumar [5] discussed the preparation of weld joints with good quality and the problems associated with pulse current GMAW Process. It involves additional pulse variables of peak current, base current, pulse on time and pulse off time simultaneously interacting in nature. Mathivanan et al. [6] investigated the austenitic steel weld joint in pulse and DP-GMAW process. It was found that DP-GMAW process produce preferable weld joint properties due to the fluctuation of wire feed rate during the period of thermal pulsation, which reduces total heat involvement and progresses properties of weld joints accordingly.

Peng et al. [7] discussed correlation among the mechanical properties and microstructure for three weld metals. It was observed that ductility of austenite and fine grain size are key aspects to improve the toughness of weld metal. Ramazani et al. [8] investigated the hot rolled DP600 steel microstructure evolution during welding and its impact on ultimate mechanical properties of DP steels. Hong-gang et al. [9] investigated the pores formation in magnesium alloys during GMAW and the effect of porosity on microstructure using scanning electron microscope. It was observed that pores occur on top and bottom parts of the weld which leads to generation of welding cracks. It was concluded that proper matching of travel speed and wire feed rate could reduce the formation of pores.

In the present work, experiments are conducted on pulse MIG welding machine in double pulse mode and the effect of parameters viz. pulse frequency and wire feed rate on grain size and bead penetration is studied.

2. EXPERIMENTAL WORK

Kemppi Pro Evolution 3200 Pulse MIG welding machine is used for conducting the experiment. The experimental setup as shown in Fig. 1 consists of welding machine and welding trolley.For the experimental investigation, mild steel plate having 100mm x 40mm x 6mm size are used as the base metal and the copper coated Fe wire of diameter 1.2 mm as filler wire.

Fig.1 Experimental setup

Contact tip to plate distance is maintained at 15mm and shielding gas is supplied at the rate of 15L/min. The experiment is conducted at welding speed of 25cm/min for all samples. Wire feed rate and pulse frequency are considered as input process parameters and bead on plate technique is used for conducting the experiments. The process parameters range and levels are decided on the basis of initial experiments performed as mentioned in Table 1.

Table 1 Input parameters and their levels

Input parameters	**Level 1**	**Level 2**	**Level 3**
Wire feed rate (F)	4	5.5	7
Pulse frequency (N)	1	2	3

Total 9 experiments are conducted as per full factorial design as shown in Table 2 for wire feed rate and pulse frequency.

After obtaining the welding for all the nine samples, the weld bead is sectioned perpendicular to the direction of weld by using a hacksaw. Different grades of emery papers (120, 220,320,400,4.0,5.0) are used for polishing the cross sectioned weld bead to know the microstructure and bead penetration of weld bead.Then the specimens are etchedby means of 2% nitalsolution to get clear weld zone.

3. MEASUREMENT OF GRAIN SIZE AND PENETRATION

The microstructure analysis is performed on the etched specimens by using empower image analysis software at 500X magnification to know the grain size of the microstructure. Fig. 2 showsthe microstructure of weld bead atwire feed rate 4 m/min and pulse frequency 1 Hz. After following the proper procedure like thresholding, the microstructure of sample 1 as shown in Fig. 3, the software gives the value of grain area and grain length.

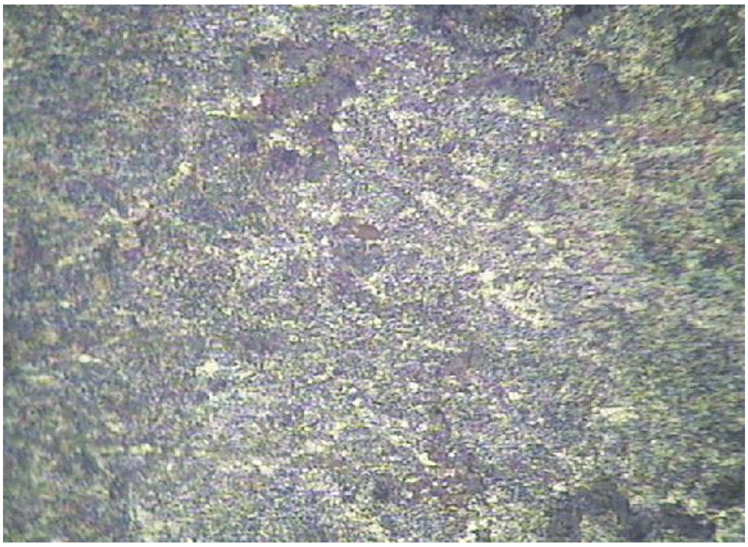

Fig. 2 Microstructure of weld bead

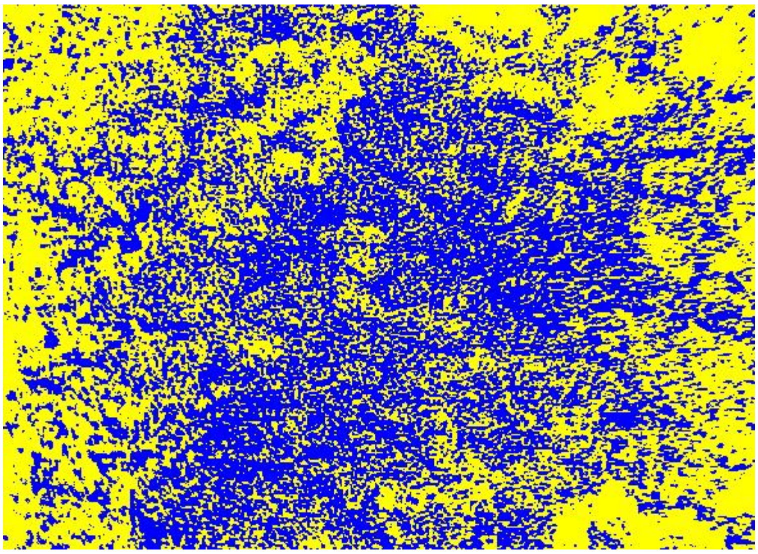

Fig. 3 Microstructure after thresholding of weld bead

The bead penetration is also measured by using standard procedure. The value of these output parameters is mentioned in Table 2.

Table 2 Dimensions of grain size and penetration

S. No	Wire feed rate, F(m/min)	Pulse frequency, N(Hz)	Grain area, A (mm^2) * 10^{-5}	Grain length, L (mm)	Penetration,P (mm)
1	4	1	8.579	0.0112	1.80
2	5.5	1	8.786	0.0118	1.75
3	7	1	9.729	0.0121	2.49
4	4	2	7.849	0.0101	1.51
5	5.5	2	7.332	0.0109	1.70
6	7	2	7.273	0.0106	2.18
7	4	3	8.540	0.0109	0.62
8	5.5	3	8.230	0.0117	1.11
9	7	3	8.173	0.0110	1.79

4.RESULTS AND DISCUSSION

Table 2 represents the measured grain size and bead penetration for the respective input parameters and how the grain size is varying with change in wire feed rate and pulse frequency.

4.1 DEVELOPMENT OF REGRESSION EQUATION:

By using data fit software, nonlinear regression equations are generated for each output parameter with respect to two input parameters. These regression equations can be used to predict the value of output parameters at any value of input parameters in the provided range.

The generated regression equations are

FOR GRAIN AREA:

A =1.3128240E-04-6.50370E-06*F-3.72058E-05*N+1.07185E-06*F*F+1.18816E-05*N*N- 2.52833E-06*F*N

FOR GRAIN LENGTH:

L =6.14074E-03+2.79629E-03*F-3.1833E-03*N-2.14814E-04*F*F+9.16666E-04*N*N-1.334E-04*F*N

FOR BEAD PENETRATION:

P =3.8619-0.9137*F-0.0467*N+0.0941*F*F-0.2033*N*N+0.08*F*N

The correlation coefficient of grain area, grain length and bead penetration is 0.92, 0.96 and 0.97 respectively which shows that it can predict these output parameters with good accuracy.

The graph is plotted between input parameters and output parameters using MATLAB software. Fig. 4 indicates the graph between wire feed rate and grain area at different levels of pulse frequency.It is found that grain area is small at pulse frequency 2 Hz andit is maximum at pulse frequency 1 Hz.

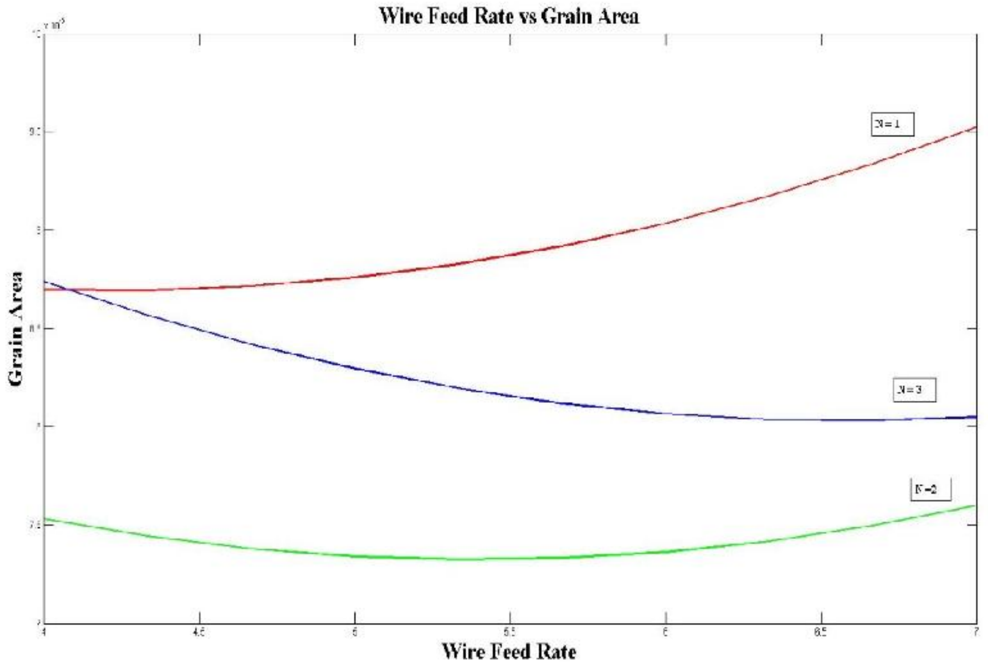

Fig. 4 Wire Feed Rate Vs Grain Area at different pulse frequency

Fig. 5 indicates the graph between wire feed rate and grain length at different levels of pulse frequency. It is observed that first grain length increases and then start decreasing with increase in wire feed rate.

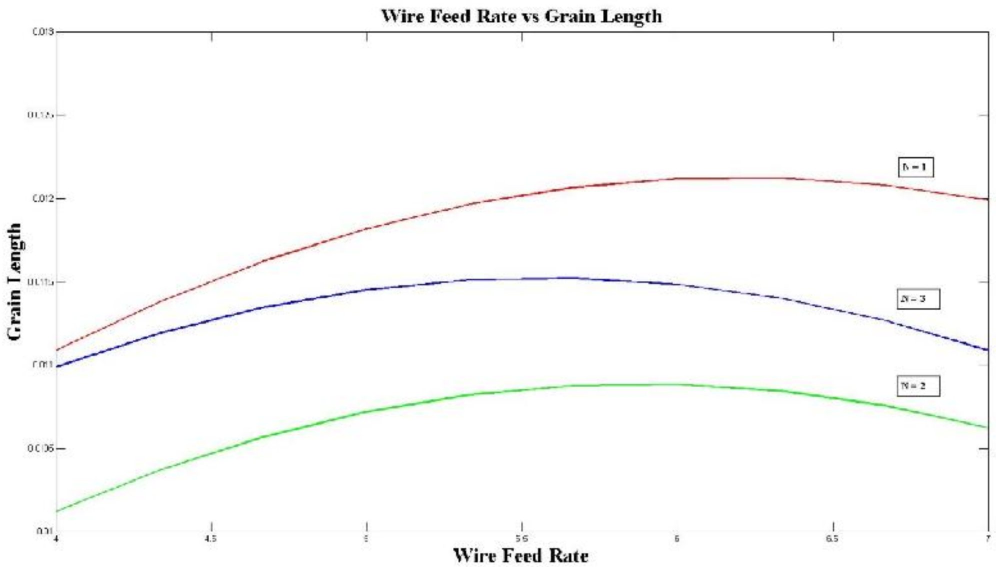

Fig. 5Wire Feed Rate Vs Grain Length at different pulse frequency

Fig. 6 indicates the graph between wire feed rate and penetration at different levels of pulse frequency. It is found that with an increase in wire feed rate, bead penetration also increases at all levels of frequency.

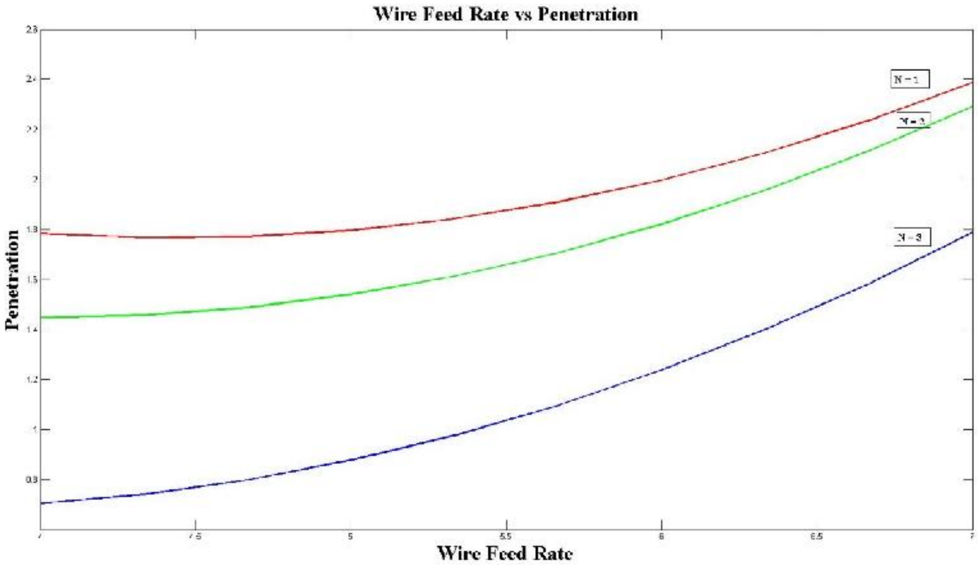

Fig. 6Wire Feed Rate Vs Penetration at different pulse frequency

5.CONCLUSIONS

1. Pulse frequency has more effect on grain area compared to wire feed rate andsmallergrain area is observed at pulse frequency 2 Hz.
2. With increase in wire feed rate from 4 to 7 m/min, first grain length increases and then start decreasing.
3. Bead penetration is increased with increase in wire feed from 4 to 7 m/min at all levels of pulse frequency.
4. Correlation coefficient for regression model of grain area, grain length and bead penetration is 0.92, 0.96, 0.97 respectively which shows that it can predict the output parameters with good accuracy.

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