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Review

Selection of parameters of pulsed current gas metal arc welding

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Abstract

Pulsed welding is a controlled method of spray transfer, in which the arc current is maintained at a value high enough to permit spray transfer and for long enough to initiate detachment of a molten droplet. Once the droplet is transferred the current is reduced to a relatively low value to maintain the arc. These periods of low current allow the average arc current to be reduced into the range suitable for positional welding, while periodic injection of high current pulses allows metal to be transferred in the spray mode. Parameters of these current pulses, such as I_p I_b, T_p and T_b have a distinct effect on the characteristics viz., the stability of the arc, weld quality, bead appearance and weld bead geometry. Improper selection of these pulse parameters may cause weld defects including irregular bead surface, lack of fusion, undercuts, burn-backs and stubbing-in. Therefore, it is important to select a proper combination of parameters of the pulsed current for welding, which will ensure that the process gives proper results in all the above aspects. However, arriving at such a combination of parameters without a rational base would be only a matter of chance with a fairly low probability for achieving desirable weld properties, since the complexity and interdependence of pulse parameters involved in this process. These difficulties of setting-up the welding conditions correctly has been one of the main reasons for the lack of popularity of pulsed GMA welding in industries. Hence, a detailed study is essential to arrive at a method of predicting the conditions that will give a good weld and this paper reviews various aspects of the pulsed GMA welding, the effects of pulse parameters and different methodologies adopted for selecting these parameters to obtain better quality welds.

Keywords: Peak current; Peak time; Base current; Base duration; Pulse frequency; Detachment parameter

Contents

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Nomenclature

A	area of cross-section of the wire, mm^2
d_d,	wire diameter, mm
d_e	electrode diameter, mm
D	load duty cycle, %
D_d	droplet volume, mm^3
dc	direct current, A
e	$I_p - I_b$ = excess current, A
F	frequency, Hz
I	dc steady current, A
I_{av}	average current, A
I_m	mean current, A
I_p	peak current, A
I_b	base current
k	intercept, A
K_c	detachment parameter, A^n/s
L	electrode extension, mm
M_m	melting rate in terms of mass, kg/s
M	mass of the droplet, kg
m	electrode melting rate, kg/s
m_d	electrode melting rate with pulsing, kg/s
S_m	slope, A/(m/min)
t_d	detachment time, ms
T	cycle time, ms
T_p	peak current duration, ms
T_b	base current duration, ms
V_{drop}	volume of droplet, mm^3
W_f	wire feed rate, m/min
W	wire feed rate, mm/s
x	fractional duration of peak

Greek symbols

α	factor accounting for localized arc heating, mm/(A s)
β	factor accounting for resistance heating along the wire length, A^{-2}/s
δ	$T_p F$ = detachment parameter, A^n/s
φ	droplet volume, mm^3
ρ_d	density of the droplet, kg/mm^3

1. Introduction

The gas metal arc welding is increasingly employed for fabrication in many industries. The process is versatile, since it can be applied for all position welding; it can be easily automated and can easily be integrated into the robotized production centers. These advantageous features of this process have motivated many researchers to study the GMAW process in detail.

Despite its wide application, the gas metal arc welding (GMAW) process has some limitations regarding the control of metal transfer. Although GMA welding was initially developed as a high deposition, high welding rate process facilitated by continuous wire feed and high welding currents, susceptibility to porosity and fusion defects, limited its use to applications where weld quality was not of paramount importance [1]. However, in recent years, as the industries have striven to become more efficient, there has been renewed interest to improve quality and to overcome the limitations of conventional GMA welding which led to the development of pulsed arc technologies.

The pulsed GMAW process works by forming one droplet of molten metal at the end of the electrode per pulse. Then, just the right amount of current is added to push that one droplet across the arc and into the puddle. Unlike conventional GMAW, where current is represented by a straight line, pulsed GMAW drops the current at times when extra power is not needed, therefore cooling off the process. It is this “cooling off” period that allows pulsed GMAW to weld better on thin materials, control distortion and run at lower wire feed speeds [1].

However, it is not so easy to select the values for these pulse parameters, since for each welding condition (base material, electrode material and diameter, shielding gas type, etc.) there is an optimum parameter combination [2,3]. Also, robotics and automated applications are demanding greater consistency from the welding process, which in turn necessitates more insights into the effects that operating parameters have on weld bead shapes and extent of fusion [4,5]. Taking the above facts into consideration, this paper attempts to review the various aspects of pulse parameters and their selection to obtain good quality welds.

2. Features of pulsed GMAW

1. The main feature of pulsed GMAW is a spray type metal transfer at low average currents, which would produce globular metal transfer under steady current conditions [6].
2. Pulsed GMAW, a modified spray transfer process provides the best of both short-circuiting and spray transfer.
3. Pulsing reduces overall heat input, yet provides the fusion associated with spray transfer [4,7–9].
4. Pulsed GMAW provides good bead appearance because tiny molten droplets do not cause spatter [7,10,11].
5. Welders have better directional control over the weld bead because the weld puddle cools in between pulses and freezes faster. This minimizes puddle sag or an excessive convex bead during out-of-position welding.
6. It requires less skill to obtain good welds with GMAW-P than it does with GTAW [7].

3. Pulse parameters

The primary parameters of pulsed GMAW welding are: (1) peak current, (2) background current, (3) peak current duration, (4) background current duration, (5) pulsing frequency and (6) load duty cycle.

1. Peak current (I_p): Higher of the two current levels in the pulsing waveform (Fig. 1). It is the current level at which the spray transfer is achieved. The peak current pinches off a spray transfer droplet and propels it towards the weldment for fusion [7].