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Pulsed current and dual pulse gas metal arc welding of grade AISI: 310S austenitic stainless steel

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Abstract

The transverse shrinkage, mechanical and metallurgical properties of AISI: 310S ASS weld joints prepared by P-GMAW and DP-GMAW processes were investigated. It was observed that the use of the DP-GMAW process improves the aforementioned characteristics in comparison to that of the P-GMAW process. The enhanced quality of weld joints obtained with DP-GMAW process is primarily due to the combined effect of pulsed current and thermal pulsation (low frequency pulse). During the thermal pulsation period, there is a fluctuation of wire feed rate, which results in the further increase in welding current and the decrease in arc voltage. Because of this synchronization between welding current and arc voltage during the period of low frequency pulse, the DP-GMAW deposit introduces comparatively more thermal shock compared to the P-GMAW deposit, thereby reducing the heat input and improves the properties of weld joints.

Keywords: Pulsed current; Dual pulse; Weld joint

1. Introduction

The gas metal arc welding (GMAW) process has been widely investigated and reported since 1950s [1]. A number of variants of GMAW have been developed in an attempt to improve the performance and productivity of the process [2]. In this regard, John Norrish et al. [2,3] reported the evolution of the GMAW process starting from standard operating modes, such as surface tension, globular and spray, of metal transfer behavior to waveform control technology up to the various hybrid techniques. From these literatures, it is well understood that the conventional GMAW process can be modified to enhance productivity and quality by manipulating the operating parameters, such as the electrical extension of wire/polarity, and the improved process control can be achieved by modifying the current waveform. Dual pulse is also introduced in the GMAW process to improve the energy transfer efficiency in comparison to the conventional and pulsed GMAW processes. Praveen et al. [4] reported that the dual pulse GMAW (DP-GMAW) process operates at low heat input. In the DP-GMAW process, the low frequency current pulsation is superimposed on high frequency pulsed current for better control of arc and metal transfer behavior as reported by Anhua Liu et al. [5] in the case of welding of AA5754 aluminum alloy. Celina Leal Mendes da Silva et al. [6] concluded that DP-GMAW technique maintains the capability of porosity minimization in aluminum weldment attributed to the pulsed current GMAW (P-GMAW) technique. The process characteristics of inverter type GMAW process under static and dynamic operating conditions were reported by Devakumaran et al. [7]. It was concluded that the DP-GMAW process operates at low heat input compared to the

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Table 1
Chemical compositions of base and filler materials.

Materials	C	Si	Mn	Cr	Ni	P	S	Fe
Base material AISI: 310S ASS	0.026	1.28	1.49	25.06	19.75	0.025	0.01	Bal.
Filler material E309L	0.05	0.35	1.80	24.51	13.91	0.023	0.01	Bal.

conventional and pulsed GMAW processes, which is in agreement to the earlier work reported by Praveen et al. [4]. From the above literature, it is understood that very little work has been carried out with respect to the process characteristics of DP-GMAW process, but the utilization of DP-GMAW process for various applications is not well known to the users because of the limited understanding of the mechanism of DP-GMAW and its influence on weld joint quality. Hence, it is felt that a systematic understanding of the DP-GMAW process in welding of various ferrous and nonferrous materials are very much important.

In this context, the present investigation describes the superiority of DP-GMAW process in welding of AISI: 310S austenitic stainless steel in comparison to the conventional P-GMAW process. The grade AISI: 310S austenitic stainless steel (ASS) is designed for high temperature service due to excellent high temperature properties and good ductility [8]. It resists oxidation in continuous service at the temperatures up to 1000 °C [9]. However, it is reported that the welding of high chromium grade AISI: 310S material is critical since it is susceptible to Intergranular corrosion attack because of chromium depletion near the fusion line of HAZ [10]. It is generally known that the increase of heat input enhances the chromium depletion. Thus, special attention should be taken in welding of grade AISI: 310S ASS material. From the literature review, it is well understood that there is limited published literatures about welding of grade AISI: 310S ASS [11]. Hence, it is felt that the dual pulse GMAW process is one of the welding techniques which may improve the weld joint characteristics of grade AISI: 310S ASS material.

2. Experimental

2.1. Welding

10 mm-thick AISI: 310S austenitic stainless steel (ASS) plate having a chemical composition in Table 1 were used in this investigation. The plate was butt-welded using single V-groove with included angle of 60°. The plates were welded by using 1.2 mm-diameter filler wire in P-GMAW and DP-GMAW processes. The chemical compositions of the filler wires used for AISI: 310S ASS materials are also given in Table 1. The shielding gas used for present investigation is commercial pure argon (99.97%) with a gas flow rate of 15 lpm, and the distance between the contact tip and work piece was maintained at 14–16 mm. The welding of the plates was carried out using mechanized torch travel at direct current electrode positive (DCEP) (Kemppi-ProMIG-530). The welding parameters used in the welding of AISI: 310S ASS plate are shown in Table 2. In order to ensure the quality of the weld joints, studies were carried out by keeping the different welding parameters with respect to the wire feed speed, mean current and arc voltage. To maintain the reliability in the study, three weld joints were made for each welding process.

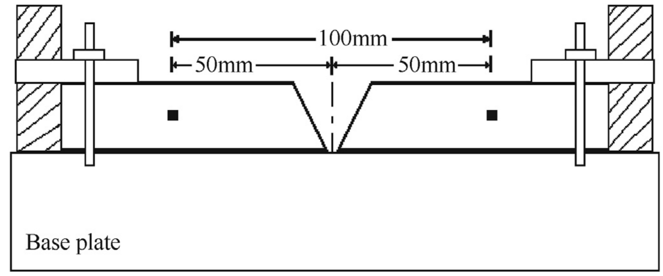

Fig. 1. Schematic diagram showing the technique of measurement of transverse shrinkage.

2.2. Studies on the weld joints

During welding the transverse shrinkage of the weld joint per weld pass was measured using a Vernier caliper having least count of 0.01 mm at a given distance (straining length) of 100 mm from weld centerline (Fig. 1), which was referred to the center of the weld groove. After each pass of welding at a given heat input, the transverse shrinkage of the plate at its initial position was measured.

The metallurgical characteristics of weld joints prepared by P-GMAW and DP-GMAW processes were studied under optical microscope with respect to the microstructure of weld and heat affected zone (HAZ) as revealed in its metallographic polished and etched transverse section. The mechanical properties such as tensile, *C*v impact toughness and hardness of both welds were studied as per ASTM: E8M, ASTM: E23 and ASTM: E384 standards, respectively.

3. Results

The present section describes the advantage of DP-GMAW process over the P-GMAW process in welding of AISI 310S ASS in reference to the improved mechanical and metallurgical properties of the weld joint.

Table 2
Welding parameters used for preparation of weld joints.

Welding processes	Heat input/(kJ · cm^{-1})	Welding parameters			
		Wire feed rate/(m · min^{-1})	Mean current I_m/A	Arc voltage/V	Travel speed S/(cm · min^{-1})
P-GMAW	5.06–6.05	4–5	174–196	19.4–20.6	40
DP-GMAW	4.92–6.23	6–6.5	170–188	19.3–22.1	40