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Penetration Control by Monitoring Molten Pool Oscillation in TIG Arc Welding

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ABSTRACT

In automatic butt welding of relatively thin plates, it is important to control welding conditions in order to obtain a sound full-penetration weld. Recently, an intimate relationship was reported between the oscillation of the molten pool and penetration. The vibrating frequency of a molten pool decreases drastically with the transition from partial penetration to full penetration and with an increasing molten pool size. As a result, the vibration of the weld molten pool can be analyzed for an estimation of weld penetration. In this study, a new vibration method is proposed: the Pulse Shielding Gas (PSG) oscillating method. The natural vibration frequency of a molten pool is measured from the molten pool oscillation detected by an arc sensor. A control system is constructed, which controls the welding current on the basis of the measured vibration frequency.

INTRODUCTION

Recently, there has been a wide range of R&D activities in the automation and robotization of welding, and several intelligent welding robots have been developed; these have some sensors, such as arc and visual sensors. Several studies have investigated the adaptive control of welding conditions, in which the welding arc and the molten pool conditions are monitored during welding, and the welding conditions are controlled in real time. For instance, a method has been shown to be effective in controlling and optimizing the penetration of the weld, in which the shape and dimensions of the molten pool are visually monitored for control purposes (Ohshima et al., 1994; Suga et al., 1997, 1999, 2001). However, vision systems are not always reliable due to the interference of the high-intensity light from the welding arc. As an alternative, a relationship between the shape of the molten pool and characteristic vibration has been established for the pulse welding current oscillating method (Xiao et al., 1990, 1993, 1994; Renwick et al., 1983; Madigan et al., 1986; Rokhlin et al., 1993; Suga et al., 2000). Accordingly, a method based on this principle to control TIG arc welding penetration and a new vibration process were developed. In this study, the detection of the molten pool vibration and the penetration control by monitoring the natural frequency are discussed, and the Pulse Shielding Gas (PSG) oscillating method is proposed, in order to increase measurement accuracy and improve the robustness of the monitoring system. Control experiments are performed to confirm the effectiveness of the system in real-time welding control.

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KEY WORDS: Welding, penetration control, oscillation, welding robot, monitoring, pulse shielding gas, PSG method.

WELDING EXPERIMENT SETUP

Fig. 1 shows the welding system setup used in this study. The welding robot system is constructed with a 3-axes Cartesian coordinates robot, TIG arc welding equipment, CCD camera, low pass filter, A/D converter, personal computer (CPU: Pentium II) and so on. A DC electrical source with a drooping characteristic was used. The shielding gas was pure Ar. The TIG torch used an electrode of tungsten with 2% lanthanum-oxide. For automated seam-tracking, a vision characteristic was used. The shielding gas was pure Ar. The TIG torch used an electrode of tungsten with 2% lanthanum-oxide. For automated seam-tracking, a vision sensor was used to detect the weld line (Suga et al., 1997). The arc voltage was stepped down with a voltage transformer before sending as an input signal into the personal computer through a low pass filter and an A/D converter (Suga et al., 2000). The personal computer analyzed the frequency of voltage oscillation to estimate the characteristic vibration of the molten pool. The detection limits

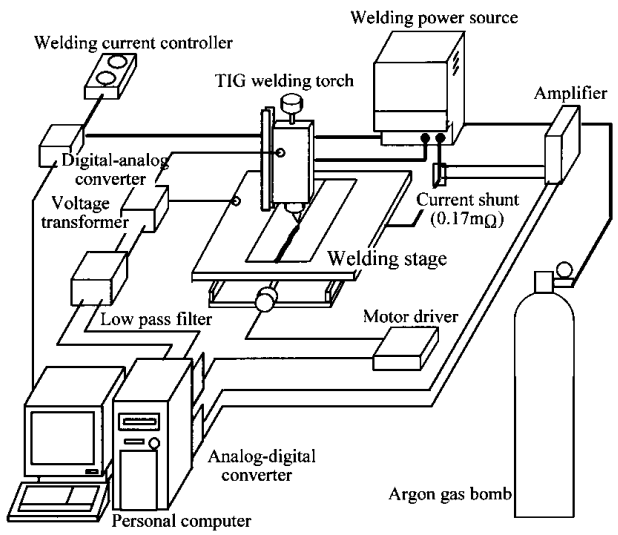

Fig. 1 Experimental setup