Materials and Design 32 (2011) 2165–2171

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

A comparative study of laser-arc double-sided welding and double-sided arc welding of 6 mm 5A06 aluminium alloy

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ARTICLE INFO

Article history:
Received 12 July 2010
Accepted 13 November 2010
Available online 20 November 2010

Keywords:
A. Non-ferrous metals and alloys
D. Welding
E. Mechanical

ABSTRACT

In order to study the interactions between the two heat sources in both laser-arc double-sided welding (LADSW) and double-sided arc welding (DSAW), some welding characteristics including weld configuration, energy efficiency, weld microstructure and mechanical properties of the both processes were contrastively investigated. The results show that the weld cross-section of LADSW within the proper welding parameter takes on the combination of typical weld profiles of gas tungsten arc welding and laser welding, while the DSAW takes on a quasi-symmetrical shape. The energy efficiency of LADSW is higher than DSAW, probably due to the higher heat transfer efficiency in laser welding and stronger effect of laser on the arc. The weld microstructures of the both processes characterized by scanning electron microscope mainly consist of α and β phase, whereas the grain size and second-phase particle size vary a great deal for the different heat input. The tensile strength of LADSW is 91.7% of base metal, compared with that of 82.3% of DSAW, and the elongation is also higher than DSAW. The fracture micromorphology of LADSW indicates a more typical dimple fracture than that of DSAW. It is considered that the better mechanical properties of LADSW are attributed to the finer grain size.

1. Introduction

High productivity with low cost is a major focus for the welding industry and its associated research community, especially in the welding of thick materials. Currently, electron beam welding and laser welding are the primary welding processes to join thick material in a single pass. However, the bad gap bridging ability and high cost are the obvious disadvantages for both laser welding and electron beam welding [1]. In addition, a vacuum chamber is used for electron beam welding, and it is difficult for laser beam to weld the metal of high reflectivity, especially for CO_2 laser [2]. Therefore, the wide application of electron beam welding and laser welding of thick material is somewhat limited. For the traditional arc welding, such as gas tungsten arc (GTA) welding and gas metal arc (GMA) welding, the weld penetration is shallow and welding speed is slow due to the relatively low energy density and unstable arc plasma, thus multipass welding is required to obtain full penetration weld [3,4]. In this case, both welding time and cost for the joint preparation will significantly increase. Some measures have been taken to improve the conventional arc welding, including GMA welding with electromagnetic arc oscillation [5], ultrasonic assisted GTA welding [6] and active flux GTA welding [7]. However, in addition to the process complexity, the weld penetration is not increased drastically.

Researchers have attempted to put forward novel welding processes to increase the weld penetration and decrease cost. Taking advantage of the synergetic effect of two or more heat sources is a very effective technical innovation for welding, and the double-sided arc welding (DSAW) [8–14] and laser-arc hybrid [15–17] welding are the most promising welding methods among them. The recently patented double-sided arc welding process was invented by Y.M. Zhang in University of Kentucky [8]. To date, the DSAW process has been used to produce welds in 6–12 mm thick plain carbon steel, stainless steel and Al alloy plates [9–14], which indicated its high efficiency and low cost. In order to overcome the disadvantages of both arc welding and laser welding, the idea of arc augmented laser welding was first put forward in the late seventies of last century [15], and then extensive interests have attracted to study the laser-arc hybrid welding all over the world [18–21]. However, when the arc current is increased to a certain critical value, the synergetic effect does not exist due to the arc attenuating the laser energy severely in laser-arc hybrid welding, which results in reduction of arc energy density and penetration depth [22]. In view of this fact, an improved laser-arc hybrid welding method called laser-arc double-sided welding (LADSW) was first put into practice by our research group recently [23–25]. In LADSW, laser beam and arc torch are located at the opposite sides of the workpiece, so there is no laser energy loss by the arc. Our

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0261-3069/$ - see front matter
doi:10.1016/j.matdes.2010.11.041