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Effect of applying electrical potential to a CO_2 laser welding of different thickness plates

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Abstract

This study was aimed at developing laser welding with an applied voltage potential to increase the bead root width in laser welding. Also, in order to enhance the welding speed and the butt joint gap tolerance, the influences of the experimental conditions: supplied voltage between plate and backside electrode, welding speed, plasma operate gaseous species, and the butt joint gap, on the bead root width were investigated. Although it is necessary to avoid over heating and melting the plates, it is applicable for higher speed and wider gap butt joint welding than a conventional laser welding. In the case of butt joint welding with a thickness of 2.0 and 0.8 mm steel sheets by using 5 kW CO_2 laser system, it is concluded that this method is effective for increasing of the welding speed from 5 to 8 m/min. Knowledge of optimum conditions and configurations has guided to extend this process to more challenging structural materials such as a tailored blank steel sheet.

Keywords: Laser; Plasma; Applying voltage potential; Root bead width; Gap tolerance; Welding speed

1. Introduction

Tailored Blanks (TBs), consisting of different thickness plates or different strength plate, is newly concept material that can reduce total weight of automobile; thus, it is available to decrease amount of exhaust NOx [1–4] gas. To manufacture the TBs, we have investigated some joining techniques. Laser welding is a promising method of applying to the TBs.

The static strength and fatigue strength of welded joint depend substantially on features, such as bead height, smoothness of the bead surface, under-fill, under-cut and so on, that exist because the amount of molten metal, temperature of molten metal, and gravity relate to the bead morphology complexly. A required minimum bead height is considered to be 70% of plate thickness for the same thickness butt joint. The smoothness of the bead surface and penetration depth of the bead, particularly, is fairly sensitive to the gap at the butt joint between two plates. The bead root, however, is so narrow that accurate beam focusing on the plates and precise setting of the beam are required for butt joint laser welding. It must therefore be preferable to widen the bead root for industrial application of laser welding.

A laser welding with an argon gas shielding is that generated plasma on the plate heats itself [5,6]. The injected argon gas is ionized by the energy of the laser beam passing through the plate. Although this plasma can enlarge the width of bead root, its heat input is not sufficient to increase the bead root width significantly. Additionally, because the laser beam generates plasma on the bead root plate surface spontaneously, its width cannot be controlled affirmatively. A further heat source to heat the bead root is a tungsten inert gas (TIG) arc jet [7]. This TIG arc is superposed with the laser beam onto the weld bead root. In contrast to the spontaneous argon shield plasma, with the TIG arc it is possible to control the input power. The problem associated with this technique is that the tungsten cathode of TIG apparatus is consumed at such a rate that endurance of this process might be too short.

To overcome such problems, we have developed laser welding with an applied electrical potential [8]. H.C.Tse has investigated electric and/or magnetic effect fields on plasma control during laser welding [9,10]. This method, however, applied these filed to the plasma on the side of molten metal

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surface not root surface. In our method, during laser welding, an electrical potential is applied between the plates and a copper electrode, which is set below these plates, with plasma operation gases such as argon, helium, and hydrogen being injected into the space between the plates and electrode. Plasma is generated between the point where the laser beam emerges from the plate and the point where this transmitted laser beam strikes the electrode, because those points are heated and thermally excited, and can therefore function as a cathode spot and an anode spot. Previous our study reports that this method is effective in increasing the root bead width and the melting area for bead on plate welding. Also, even though, it is necessary to avoid overheating and melting of the plates, it is applicable for higher welding speed and wider gap butt joint welding in the same thickness plates.

This paper describes the application of the laser welding with an applied electrical potential to a welding of different thickness plates to increase the bead root width in order to enhance the welding speed and the butt joint gap tolerance. The influences of the experimental conditions: supplied voltage between plate and backside electrode, welding speed, plasma operate gaseous species, and the butt joint gap, on the bead root width were investigated. The difficulty of this method is considered to not only be obtaining the correct energy balance between the transmitted and residual laser beam power and the applied electrical potential, but also plates' arrangements, gap and beam position, for laser welding in different thickness plates. In order to enhance the butt joint properties, the static strength and fatigue strength of welded joint, bead features must be optimized. Also from viewpoint of industrial application, higher welding speed is preferable. Therefore, supplied voltage between plate and backside electrode, welding speed, plasma operate gaseous species, and the butt joint gap, on root bead were investigated on several plate thickness combination. Knowledge of optimum conditions and configurations has guided to extend this process to more challenging structural materials.

2. Experimental details

Fig. 1 shows experimental configurations for laser welding with applied electrical potential. A CO_2 laser (Mitsubishi-Denki, model 50C) operating at 5 kW was used as the laser beam source. The laser beam, with a focal length of 200 mm and focused-spot diameter of 0.45 mm, was irradiated on the surface of the plate 1 whose thickness was thicker than plate 2. Both plates were mild steel SS45 with a thickness of 0.8, 2.0, or 3.2 mm and the performed thickness combinations of those plate were 0.8:0.8, 2.0:2.0, 3.2:3.2, 3.2:2.0 2.0:0.8, and 3.2:0.8 in mm. The focus position was varied in the ranges from −1.0 to 1.0 mm. An insulated copper electrode was located below the sheet and a distance, between plate and electrode, of 5 mm. Electrical power, 0–1.4 kW, was supplied by a TIG power supply (Daihen, model ARGO 300P) connected to the sheet plate and the copper electrode. The plasma gas, a mixture of argon (0–20 l/min) and helium (0–20 l/min), was injected from 17 pairs of holes, of diameter 1.5 mm and pitch 10 mm, symmetrically arranged a short distance from either side of the electrode

The TIG power source operates in current constant power mode; thus, first an applied electrical current value is set between the plates and electrode with the injection of plasma gas. Then, laser beam irradiation is started using the moving plate and electrode. During welding, the voltage between the plates and electrode was measured via a shunt that converted current to voltage (500 A–50 mV). The copper electrode was set as an anode due to the benefit of the stability of the plasma [8]. The welding speed was varied 1–10 m/min and a co-axial shielding argon gas flow rate was 20 l/min. In present work, we expressed a butt gap to be

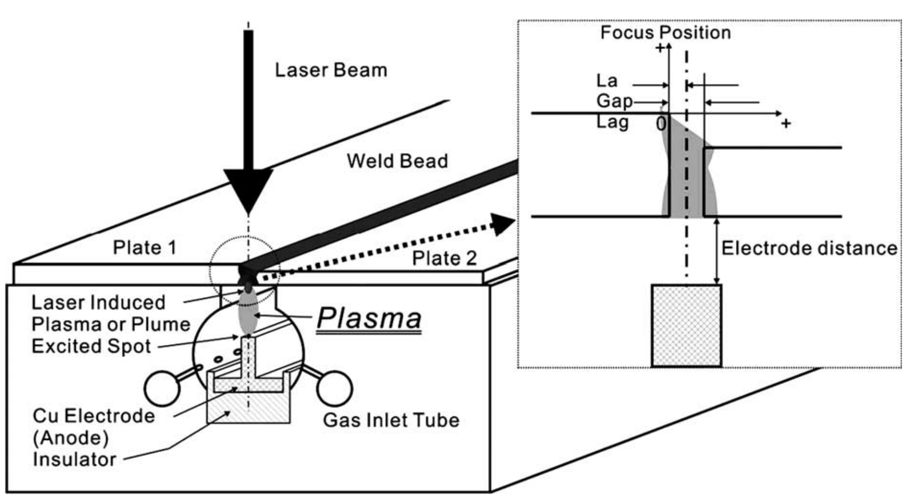

Fig. 1. Schematic experimental configuration for method of laser welding with an applied electrical potential for butt joint welding; during laser welding, electrical potential is applied between plates and copper electrode with injection of argon, helium, or hydrogen plasma gas.