Laser-MAG hybrid welding of high strength steel using fiber laser and CO$_2$ laser

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1. Introduction

Fiber lasers have many advantages over other laser technologies, which include high processing performance (low beam divergence, no warm up time and no variation in spot size with power), high beam quality, low running cost, maintenance free operation, no diodes or consumables to be replaced, and high efficiency higher than 25%, and a compact and mobile package.

In the present work, a 2.4 kW CO$_2$ laser and 2 kW fiber laser are used for laser welding and laser-MAG hybrid welding of 780 MPa high strength steel. The welding characteristics of CO$_2$ laser and fiber laser are compared. In laser-MAG hybrid welding, the plasma formation during hybrid welding is observed using a high speed video camera, and the effect of laser-arc distance on plasma formation in laser-MAG hybrid welding is discussed.

2. Experimental procedure

2.1 Laser equipments used: A 2 kW ytterbium fiber laser was used in the present work. The wavelength of fiber laser is 1070 nm. Beam parameter product (BPP) is about 4.2 mm-mrad and core diameter of output fiber is 150 μm. The laser beam is collimated by a collimating lens with the 100mm focusing length and focused by a gradiun lens with the focal length of 200 mm.

A 2.4 kW cw CO$_2$ laser with the wavelength of 10.6 μm and beam mode of $TEM_{01}^*$ is also used in the experiment. The parallel CO$_2$ laser beam is focused by a ZnSe lens with a focal length of 200 mm.

2.2 Observation of plasma in laser welding and hybrid welding: A high speed video camera was used for observing the plasma phenomena during laser welding and laser-arc hybrid welding. A digital, high-speed video system records color images at the speed of 4,000 pictures per second (pps).

3. Result and discussion

3.1 Plasma induced by fiber laser and CO$_2$ laser during welding

When the focused laser beam irradiates to the specimen, a part of the radiation is absorbed by the material and the other part is lost by reflection and the plasma absorption. The laser energy absorption by the plasma produced by laser and arc is a problem in laser-arc hybrid welding. Due to the low laser transparent through metal vapor at low vapor temperatures, the laser beam is absorbed strongly if the vapor became plasma at high temperature.

In laser-MAG hybrid welding processes, the plasmas produced by laser and arc were observed by a
high speed video camera at the speed of 4000 pictures per second. The pictures of plasma formation during fiber laser-MAG hybrid welding and CO₂ laser-MAG hybrid welding at laser-arc distance of 5 mm in arc leading processes are shown in Fig.1. The laser plasma produced by fiber laser was not found as shown in Fig.1(a). However, plasma produced by CO₂ laser has very large volume and high brightness as shown in Fig.1(b). The reason is that the different wavelength of fiber laser and CO₂ laser. The role played by the wavelength is important because the characteristics of laser induced plasma are heavily dependent on the processes which take place in the region whose electron density is close to that for cut-off of the radiation.

3.2 Effect of welding process on the weld bead profile

CO₂ laser-MAG hybrid welding and fiber laser-MAG hybrid welding was performed to weld 6 mm thick high strength steel at laser power of 2 kW and MAG current of 100~200A, arc voltage of 14.5~20V. MAG leading laser-MAG hybrid welding process was adopted in these experiments. The macro sections of CO₂ laser-MAG and fiber laser-MAG hybrid welds are shown in Fig. 2. It can be found that the reinforcement height of the weld of CO₂ laser-MAG hybrid weld is too height to be acceptable when the MAG was carried out under the conditions of current of 100A and arc voltage of 14.5V. The wine-cup shape weld bead appeared in CO₂ laser-MAG hybrid weld and fiber laser-MAG hybrid welds when MAG current was 200A and arc voltage was 20V.

The relationship between penetration and MAG current in fiber laser-MAG hybrid welding and CO₂ laser-MAG hybrid welding is shown in Fig.3. With the increase of MAG current, the penetration increased in both hybrid welding processes.

4. conclusion

(1). Fiber laser (λ=1070nm) produces little plasma, however, CO₂ laser (λ=10,649nm) produces a lot of plasma in hybrid welding process.

(2). Bead shape is affected by the laser power density and the MAG power in laser-arc hybrid welding.