Effect of welding direction on weld bead formation in high power fiber laser and MAG arc hybrid welding†

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KEY WORDS: (High power fiber laser) (MAG arc) (Hybrid welding) (T-joint fillet weld) (Welding direction)

1. Introduction

For many structural materials, it is required to establish high-speed, highly-efficient, and high-quality welding methods. As one of them, attention is being paid to hybrid welding method which combines laser welding and arc welding [1]. In this research, a hybrid welding method which has a high power fiber laser and a pulsed MAG arc has been applied to T-joint fillet welding of SS400 steel plate.

The effect of welding direction, which means laser-leading or arc-leading, on the weld bead formation has been revealed by parametric study of hybrid welding conditions and direct observation of weld pool behavior by using an infrared high- speed video camera.

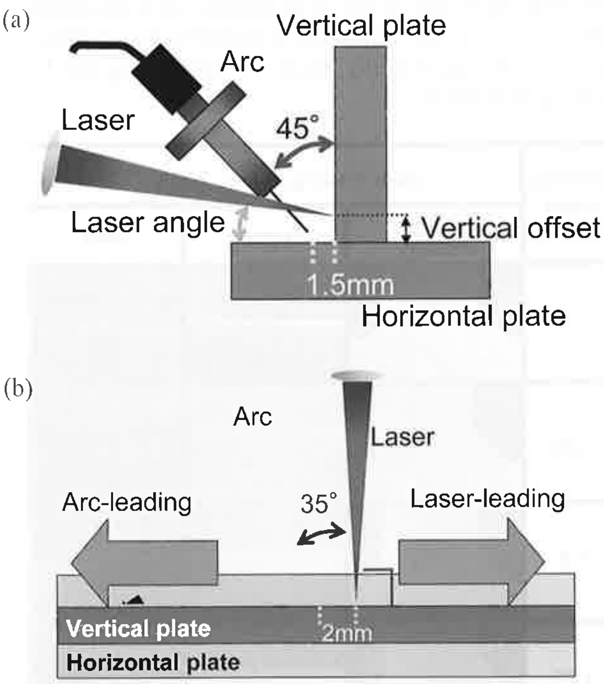

Fig. 1 Schematics illustration of the setup of a hybrid welding
(a) Horizontal view , (b) Vertical view

Table 1 Hybrid welding conditions

Laser power	Defocus distance	Laser angle	Arc current	Wire extension	Arc torch angle
9kW	±0mm	7°	200A	15mm	45°
Distance/ laser and arc	**Arc offset**	**Welding speed**	**Vertical offset**	**Angle/ laser and arc**	**Shield gas**
2mm	1.5mm	1.0~2.0 m/min	1mm	35°	$CO_2$20% +Ar80%

Table 1 shows hybrid welding conditions used. Fiber diameter was 0.3mm and focal point of the laser beam was fixed on the plate surface. Distance between laser and arc was fixed to 2mm [2].

2. Experimental procedure

Horizontal T-fillet welding of SS400 steel plate with the dimension of 150mm x 50mm x 12mm in thickness was cond ucted in T-fillet joint by using 10kW class high power fiber laser and pulsed MAG arc as shown in **Fig. 1** (a) and (b), which shows the schematic illustration of the setup of a hybrid welding. During welding, the behavior of molten metal flow in the weld pool was observed by using an infrared high-speed video camera with 2000 frames/s. After the welding, the welded specimens were cut, polished and etched to reveal the microstructure and weld defect.

3. Results and Discussions

In hybrid welding, welding direction which means laser-leading or arc-leading is one of the important and special parameters for hybrid welding. **Figure 2** shows the typical bead appearance and cross-section of 1 pass-1 side fully penetrated T-fillet weld beads in each welding direction at the same welding condition. Comparing two weld beads large differences were easily observed. In laser-leading, a smooth weld bead was obtained, while a humping and undercut bead with pit and void was observed in the arc-leading, which was caused by different types of molten metal flow. In order to reveal this, the behavior of molten metal flow in the weld pool was observed. **Figures 3 and 4** show typical frames of weld pool surface during hybrid welding in laser-leading and arc-leading, respectively. In the laser-leading molten metal flew forward to the front end

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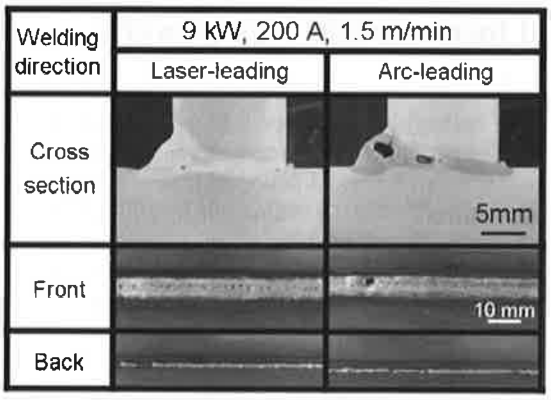

Fig. 2 Appearance and cross-section of hybrid weld bead of SS400 at different welding directions

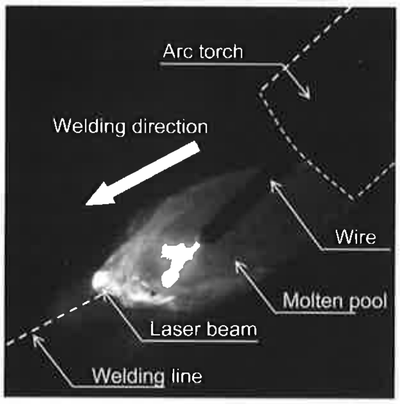

Fig. 3 Typical frame of weld pool surface during hybrid welding in laser-leading by high speed camera

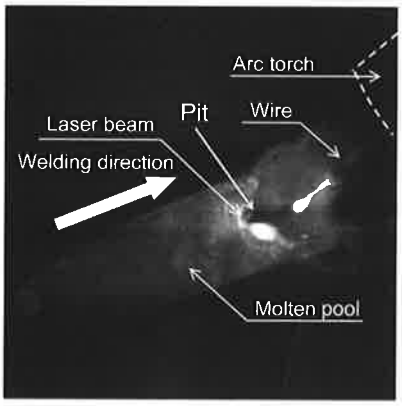

Fig. 4 Typical frame of weld pool surface during hybrid welding in arc-leading by high speed camera

of the weld pool, and then went rearward along the edge of the weld pool. On the other hand, molten metal flew continuously and rapidly rearward to the rear end of the weld pool in the arc-leading and in addition, opening of a pit was observed. **Figure 5** shows schematics of these obvious differences in molten metal flow comparing in laser-leading and arc-leading, which is caused by the strong plasma gas flow of arc and its flow direction related to the inclination of GMA arc torch. In high speed arc welding, it is well known that a humping or undercut weld bead is easy to form due to elongated shape of weld pool and strong molten metal flow to rearward in the weld pool, and in addition the plasma gas flow promotes it [3].

Therefore, in this experiment conducted at the condition as shown in Fig.1, the welding direction of laser-leading is obviously better than that of arc-leading.

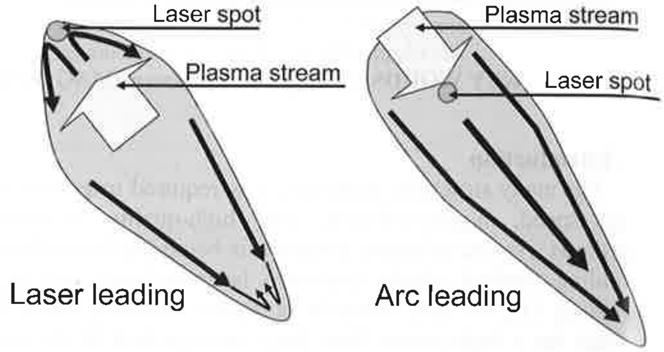

Fig. 5 Schematics of molten metal flow in the weld pool laser-leading and arc-leading conditions

Figure 6 shows the effect of the welding speed of laser-leading on the weld bead formation. At higher welding speed than 1.25m/min, solidification cracking was observed at the middle to lower part of the penetration, and in addition, a lack of fusion at the fusion boundary of horizontal plate was observed at the upper part. At 1.0m/min, however, these weld defects were not observed. Thus, a 1pass-1side fully-penetrated horizontal T-fillet weld bead can be successfully made by optimizing the hybrid welding parameters.

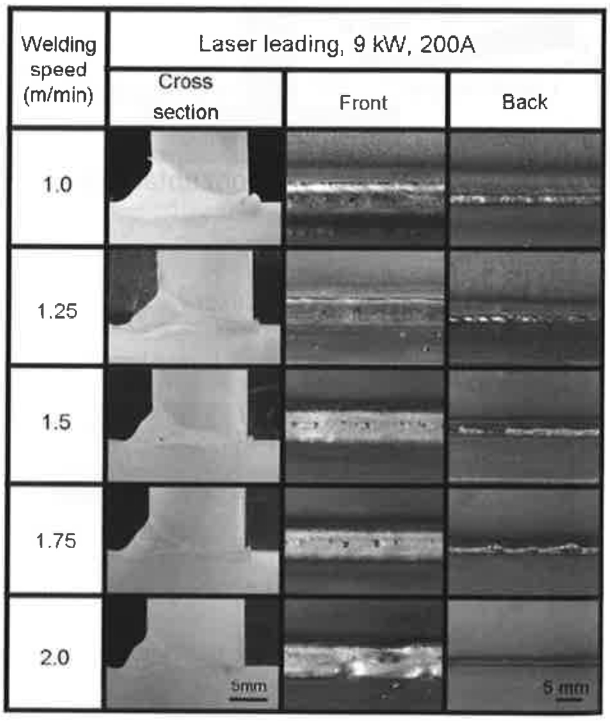

Fig. 6 Appearance and cross-section of hybrid weld bead of SS400 with different welding speeds at laser-leading

4. Conclusions

The conclusive remarks are summarized as follows.

(1) 1 pass-1 side fully-penetrated horizontal T-fillet weld bead can be successfully made by optimizing the fiber laser and pulsed GMA arc hybrid welding parameters.

(2) Different molten metal flows are observed in laser-leading and arc-leading, which caused differences in appearance and cross-sectional shape of weld bead as well as weld defect formation.

(3) Laser-leading in the welding direction is beneficial to make a smooth weld bead without weld defect at a hybrid welding with horizontal T-fillet joint.

Acknowledgment

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