Research on Leveling Technology of Tailored Laser Welding

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Abstract. Mismatch is one of the main defects of tailor welded blanks (TWB), and leveling technology is a new method which can solve this problem. The structures, force analysis and flange morphology of the leveling mechanism are studied in this paper, and a three-dimensional prototype is designed. The results have practical significance for improving welding quality of TWB.

Introduction

Laser welding is a modern processing technique with the advantages of high efficiency, small weld deformation and simple post processing [1-3]. Tailored laser welding has become an important manufacturing process for automobile industry. TWB are defined as two or more steel sheets with same or different thicknesses, mechanical properties or surface coatings welded together by laser before stamping [4]. TWB is the link between high safety requirements and affordable weight reduction. They are lighter, require less material and consolidate production operations [5, 6].

In the process of laser welding, there is a relative motion between laser beam and weld seam. However, it is difficult to eliminate mismatch even if the precision of the welding system is pretty high. An idea is to only keep high position accuracy near the welding position, if the idea comes into truth, it will reduce the mismatch during laser welding. Based on the idea above, the leveling technology comes into being. Leveling technology is defined as pressing the suspension side of blanks near the welding position to reduce the position error, especially mismatch.

Leveling technology was applied in pipe welding in 1930s[7, 8], and then appears in the stitch welding and butt welding[9, 10]. Leveling rolls press the suspension side of blanks near the welding position to form a standard round or plane, so, the accuracy of the welding joint is improved, and the welding quality is enhanced.

Leveling technology has a long history, but there are still many problems to be solved before it is applied in automated laser welding equipment, such as pressing angle, flange morphology, pressing position, etc.

Structure of Leveling Mechanism

As TWB are usually composed of blanks with different thicknesses, one side of TWB will be uneven and the other side will be completely even. Mismatch occurred at the side which must be even along the thickness direction. Leveling mechanism may be applied at the welding position to reduce mismatch. Generally leveling mechanism is composed of three or four rollers. leveling rollers press the suspension side to adjust the position error.
There are two modes of leveling mechanism. The first mode is composed of three rollers (fig.1), leveling rollers 3, 4 are tension rollers, supporting roller 5 is a fixed roller. The lower surface of blanks 1, 2 is leveled by the three rollers. The second mode is composed of four rollers, leveling rollers 3, 4 are still tension rollers, there are two supporting rollers 5, 6 under it, and the Z coordinate of supporting roller 5 is adjustable, so two form of welding joints can be realized(fig. 2).

Although the adaptability of the second mode is better, its structure is complex, and the vertical position of sustain roller 5 need to be adjusted precisely. The first mode can only realize one form of welding joint, but its structure is simple and its accuracy is easy to control. It can adapt to the requirements of current production line and is the way we recommend.

Structure of Leveling Rollers

Leveling mechanism and welding unit work at the same position, so the operating space determines the structure of leveling rollers, the operating space includes the influence range of laser beam and the space of tracking system and detection system. Vertical pressing mode(Fig.3) has advantage of good mechanical properties, But in order to avoid the space of welding unit, the leveling rollers will be made into little structure(Fig.3a) or hollow structure(Fig.3b), which is difficult to manufacture. The mechanical properties of inclined pressing mode(Fig.4) is poor, but its structure is simple, so this mode is a good choice to automatic laser welding production line with integrated welding unit.

Calculation of Leveling Force

Leveling force is an important data for leveling mechanism design, if the leveling force is too small, the mismatch can not be corrected, and too large leveling force will leading to a bulky design. So to determine a proper leveling force is the first job. Factors influencing leveling force are shown in fig.5.
Fig. 5 Factors influencing the leveling force

The force analysis of leveling mechanism is shown in Fig. 6, according to the force equilibrium conditions,

\[-F + F_f \cdot \frac{L_1}{L_1 - L} + \frac{M}{L_1 - L} = 0\]  \hspace{1cm} (1)

Where

- \( F \) = leveling force (N)
- \( F_f \) = friction between blanks (N)
- \( M \) = flexibility torque (N)
- \( N \) = pressure (N)
- \( L_1 \) = pressing position (m)
- \( L \) = suspension length (m)

leveling force can be estimated by Eq. 1.

Theoretically, the closer the distance between the pressing position and the weld seam, the better its leveling effect becomes, however, due to the high temperature, the position of leveling rollers is at least beyond the width of heat affected zone. The Fig. 5 below demonstrates our consideration about the width of weld seam and the width of heat affected zone in our experiment, i.e. the distance between them should larger than 1.5 mm. Also, it is necessary to think about the laser beam radiation heat and the heat effect given by heat conduction to the leveling rollers, thus, the proper pressing position given here is about 5mm near the weld seam center.

\[ \geq 1.5\, \text{mm} \]
\[ 0.5-2\, \text{mm} \]
\[ 0.2-0.5\, \text{mm} \]

Fig. 7 Width weld seam and heat affected zone
Flange Morphology Design

Designing the different flange morphology of leveling rollers, diverse contact types can be made such as point contact, line contact, and bi-point contact. The flange morphology of point contact can form indentation easily on the material surface shown in Fig. 8(a). In Fig. 8(b), although it is line contact, but considered the existence of mechanical error, it still a type of point contact after the angle changed. As shown in Fig. 8(c), the reliable two-point contact or line contact is possible due to the flexible joints designed in the end of the contact.

![Fig. 8 Flange morphology](image)

Implementation Structure

According to the analysis above, an implementation structure is given in Fig. 9, the two upper leveling rollers are driven by cylinders, a supporting roller underneath is fixed, there are grooves in the middle of support roller to realize suction and slagging, meanwhile the splashing impurities will stick on the surface of the entire leveling rollers and support roller, thus the cleaning device is considered.

![Fig. 9 Implementation Structure](image)

Conclusion

The leveling technology has outstanding effect to the quality of tailored laser welding, especially in the reduction of mismatch. The inclined pressing mode is proper to the welding production line integrated with tracking system and inspection system. The flange morphology with flexible joints is a better way.
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