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RESEARCH STATUS OF PHYSICAL FIELD-ASSISTED LASER WELDING

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Abstract: To review the current research status at home and abroad of different physical field -assisted laser welding, looking forward to the future of physical field-assisted laser welding technology The future direction of development. Method Discussion Electric Field, magnetic field, ultrasonic field and other different physical fields on the laser welding process Mechanism of influence, right than not Same thing Advantages and Disadvantages of Physical Field Effect. Results and conclusions based on the development status of physical field-assisted laser welding, refer to out of work Art optimization, equipment integration, Challenges faced by theoretical foundations and other aspects, and looked forward to the future development trend of this technology.
Keywords: Electromagnetic field; LASER welding; Development trend

1 THE INFLUENCE OF ELECTRIC FIELD ON THE WELDING PROCESS

The characteristics of fast welding speed, low heat input, It has the characteristics of small residual deformation and good flexibility[1] , and is widely used In aerospace, automobile, shipbuilding and other industrial fields. Because laser energy The mass density is high, and the metal will be vaporized and evaporated during the welding process, forming into small holes. The formation of small holes is caused by the reaction of metal vapor The result of the dynamic balance between punching force, liquid metal static pressure and surface tension, it is extremely susceptible to interference from the external environment and causes fluctuations, thus forming pores, undercuts, Splash etc[2]. Welding defects reduce the quality of laser welding.

In order to improve the quality of laser welding, physical fields such as electric field, magnetic field Fields, ultrasonic fields, etc. are introduced into the welding process to increase the laser absorption rate and increase the penetration depth;at the same time, the stirring effect of the electromagnetic field and ultrasonic vibration will affect the flow of the molten pool and the heat and mass transfer behavior, which can eliminate pore defects, Refine the welding structure, improve weld formation, and improve welding quality. Since physical fields can significantly improve the quality of laser welding, physical field-assisted laser welding technology has become Current research hotspots. This article reviews the working principles of different physical fields on laser welding and the corresponding latest research results, and looks forward to the future development direction of physical field-assisted laser welding technology.

In the welding process, convert DC electricity Connect the positive and negative poles to the test Both sides of the board form additional Electric field, controlled by the size of the applied current field strength. Electric fields can affect the plasma formed during laser welding The body density increases the laser absorption rate and the penetration depth.

Li Xueyuan[3]It was found that the applied electric field affects the plasma formed by arc welding. The daughter density has little effect on the plasma formed by laser welding. Density has a greater impact, and laser welding penetration varies with Increase in electric field strength And increase. Xiao Rongshi et al[4-5] Study on the effect of electric field on aluminum alloy laser The influence law of welded joints, it was found that large electric field intensity can not only Add access head of melt deep and and able change good weld seam become shape. TSE et al[6]The influence of electric field on laser welding plasma density was analyzed. Response law (see the electric field-assisted laser welding device[6]), Discover Electric fields can reduce plasma during welding density, reducing the excitation Light shielding effect increases welding penetration. plum Xiaoquan et al. [7] studied the effect of electric field on laser welding seam formation, and the results showed that electric field can eliminate undercut defects to a certain extent.

2 EFFECT OF MAGNETIC FIELD ON WELDING PROCESS

The magnetic field is mainly divided into 2 major categories, one is steady-state magnetic field, using Permanent magnets or constant current flowing through the coil generate. The other type is It is an unsteady magnetic field, such as rotating magnetic field, alternating magnetic field, etc.

2.1 Effect of Steady-State Magnetic Field on Laser Welding

A steady-state magnetic field can hold a magnet N pole and S pole respectively fixed on Weld both sides to form size He Fang remain unchanged magnetic field[8]. Steady-state magnetic field plays a role in laser welding molten pool 2 aspects of Usage:On the one hand, the steady-state magnetic field can suppress the flow state of the molten pool and change the welding The heat and mass transfer behavior during welding improves the stability of laser welding;another

On the other hand, due to the Seebeck effect, the molten pool heat will be generated in current, and Steady-state magnetic field interaction produces electromagnetic force, which affects the molten pool flow. Therefore, the influence of steady-state magnetic field on laser welding molten pool 2 The effects of aspects are mutually restrictive.

CHENet al[9]Study on the effect of steady-state magnetic field on laser welding 301 stainless steel and 5754 aluminum alloy dissimilar metal joint quality Impact, Stable magnetic field found to improve weld formation. LI et al[10]in laser welding A constant magnetic field was introduced into the 316L stainless steel process, and it was found that increasing the magnetic field intensity could reduce welding spatter. ZHAN et al[11]Experiments on laser welding of aluminum alloys, after applying a steady-state magnetic field, it was confirmed that the steady-state magnetic field can increase the penetration depth, but coarse grains were formed near the welding line.. Zhang Xun et al[12]Research steady state magnetic field pair 316L Effect of microstructure on stainless steel laser welded joints found As the magnetic field intensity increases, the microstructure of the joint is refined.

How to reasonably optimize the direction and intensity of the steady-state magnetic field to ensure stable The effect of the state magnetic field on the molten pool It is difficult to achieve the optimal state of the two functions. 2.2 The influence of unsteady magnetic field on welding

Unsteady magnetic fields can change the strength and direction of the magnetic field towards, to melt The pool produces strong stirring, promotes heat transfer behavior inside the molten pool, and changes the flow behavior of the molten pool, thereby eliminating welding defects and fine particles. The role of weld structure. Its principle is shown in Figure 1[13].

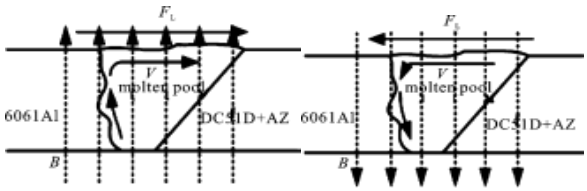
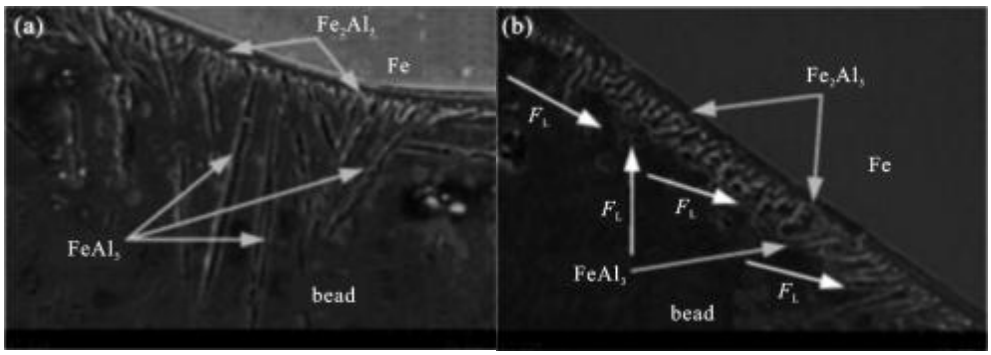


Fig. 1 Schematic diagram of electromagnetic stirring

Wang Yunpeng et al.[14]Study on the effect of rotating magnetic field on pure nickel laser welding Joint microstructure shadow sound, experimental results show that due to the rotation magnetic field of lead into, weld of crystal grain bright show quilt thin change. Zhao Ze foreign etc[15] The effect of alternating magnetic field on stainless steel laser welding joints was studied. The influence of the connection quality, the test results show that the alternating magnetic field can refine the connection quality head group weave, suppress system Got it weld catch hour of fly splash. FRITZSCHE et al.[16] introducing gravity into the welding process of stainless steel thick plates.

The opposite magnetic field force offsets the hydrostatic pressure of the molten pool during welding, showing that Significantly improved weld collapse[17].

AVILOV et al[18]It is proved that applying an alternating magnetic field when laser welding aluminum alloy can suppress the flow of the molten pool, improve the weld shape, and reduce the number of pores. CHENet al[19] When performing aluminum alloy laser welding, it was found that the direction of the magnetic field has an impact on the flow of the molten pool. Obviously, when a magnetic field perpendicular to the material surface is added, the Marangoni convection of the molten pool is suppressed and the weld formation is improved. Ding Hao et al[13]Research Study on the pore defects of steel/aluminum dissimilar metal laser welding joints caused by magnetic field Impact, It was found that after an external magnetic field is applied, the Fe/Al interface The compound layer becomes narrower, FeAl compound structure refinement (see Figure 2[13]). Compared with not introducing a magnetic field, the strength of the joint can be improved after introducing a magnetic field. twenty four%.



(a) When no magnetic field is added (b) After adding magnetic field

Fig. 2 Weld morphology and microstructure

Although magnetic field-assisted laser welding can improve welding quality, Matching relationship and mechanism between magnetic field intensity and laser welding parameters It has not yet been fully understood, which limits its further widespread application.

3 EFFECT OF ULTRASONIC FIELD ON WELDING PROCESS

The mechanism of action of ultrasound on metal melt has 4 effects, i.e.sound Cavitation effect, acoustic flow effect, mechanical vibration and thermal effect. melting Introducing ultrasound during the welding process can refine the weld structure and eliminate welding Porosity and crack defects.

ZHOUet al[20] and KIMet al[21] In ultrasound-assisted stimulation During the light welding test, it was found that the ultrasonic effect made the weld smooth in appearance, significantly reduced the porosity of the weld, improved the tensile strength of the joint, and reduced the grain size of the weld. The refinement effect is obvious. Figure 3 is a schematic diagram of the device[20].

VENKANNAH et al[22]in ultrasound-assisted laser reactor During the welding of low carbon steel, it was found that ultrasound can promote the uniform distribution of molten metal in the molten pool and increase the joint penetration. KIM et al[21] Research ultrasonic versus laser spot welding Al-Mg and Al-Mg-Si alloy The influence of surface cracks, test results show that the use of ultrasonic-assisted excitation Light spot welding method can reduce the size of solder joint cracks. Zhu Zongtao et al[23] Proven laser on aluminum alloys -MIG Caused during composite deep penetration welding Ultrasonic injection can reduce the number of pores in the weld, refine the weld structure, and improve the mechanical properties of the joint.. LEI et al[24-25] conduct magnesium alloy Research on ultrasonic-assisted laser welding and found that ultrasonic shadow Noisy molten pool flow and chemical element distribution[24]. Liu Haodong et al.[26]ested ultrasonic to laser welding Influence of TC 4 thermal cycle curve, it is found that the most The high temperature and high temperature residence time first decreased and then increased as the ultrasonic power increased. reduce the rules. LIU et al[27] Use ultrasound When studying aluminum alloys using assisted laser welding, it was found that with the ultrasonic power enlargement, hole The gap first decreases and then increases, and the grain size decreases., the grain area fraction increases significantly.

Under ultrasonic vibration, the welding quality is significantly improved, but for laser The influence mechanism of welding It has not yet been revealed clearly that the welding parameters involved Too many, and process optimization is complicated.

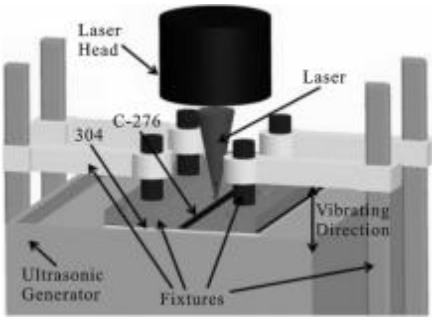


Fig. 3 Ultrasonic vibration-assisted laser welding device

4 THE IMPACT OF COMPOSITE FIELDS ON WELDING

Although a single physical field acting on the laser welding process can to improve welding quality, but there are still limitations. A single electric field can increase the welding penetration by affecting the plasma density, but it cannot change the heat and mass transfer behavior of the molten pool;a single magnetic field can affect the heat and mass transfer of the molten pool, Refine grains, but cannot effectively increase penetration. Coupling the electric field and the magnetic field can simultaneously act on the plasma and molten pool formed by laser welding, thereby refining the weld structure on the basis of increasing the penetration depth.

Wang Liang et al[28]Research The impact of the synergistic effect of electromagnetic composite fields on the laser welding process It is found that the synergistic effect of electromagnetic fields is greater than the effect of a single electric field or magnetic field, and can significantly refine the welding structure.. LINDENAU et al[29]During the laser filler wire welding of aluminum alloys, it was found that the electromagnetic composite effect can eliminate pore defects and make the weld well formed. This shows that the electromagnetic composite effect makes the laser welding process stable.. AMBROSY et al[30]Comparative study on the effects of single electric field, single magnetic field and electromagnetic composite field on aluminum alloy laser welding function, test results table Bright, relatively single field, electromagnetic complex combine can significantly improve the weld seam become shape quality quantity.

SCHNEIDERet al [31] and FRITZDCHEet al [32] research When studying aluminum alloy laser welding, it was also found that electromagnetic fields help reduce gas The formation of holes and the formation of weld seams are improved. Composite physical fields improve the stability of laser welding Obviously, but the synergistic effect of multi-field coupling affects the welding process The mechanism of action is complex, Lack of corresponding theoretical support makes welding process optimization complex.

5 SUMMARY AND OUTLOOK

During the laser welding process, due to the instability of the small hole, the gas Defects such as holes, undercuts, and splashes are easy to form, and the introduction of physical fields can cause To increase penetration, eliminate welding defects, refine the structure, etc., improve High welding quality. Especially the impact of composite physical fields on laser welding quality The improvement is more obvious and can achieve effects that cannot be achieved by a single physical field. fruit. Although physics-assisted laser welding has gained widespread research, but to achieve industrial application, we still face the following problems:

(1) The interaction mechanism between multiple physical fields is relatively complex and related to the exciting Plasma, pinhole fluctuations and molten pool flow behavior of light welding The mechanism of action is still unclear and corresponding theoretical support is urgently needed.

(2) There are many parameters involved in physics-assisted laser welding. The optimization of process parameters is more complex than single laser welding. The establishment of a physical field-assisted real-time monitoring system for laser welding status can simplify the optimization process. However, the system is currently not perfect and requires further development and research.

(3) How to couple a physics-generating device to laser welding Automated integrated equipment to achieve large-scale industrial application is currently A new direction for the development of laser equipment integration.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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