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Research Status of Laser Welding Technology for Thin Metal Plates

Ningkang Bian [a*], Pengyan Guo [a], Hao Xing [a], Wanxiang Yin [a], Jiabao Wei [a] and Jiale Peng [a]

[a] *North China University of Water Resources and Electric Power, Zhengzhou -450002, Henan, China.*

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ABSTRACT

Thin metal sheets have always been one of the core materials in the mechanical industry, and laser welding technology is an important technique for connecting thin metal sheets. This article analyzes the current research status of laser welding technology for metal thin plates, discusses the problems existing in laser welding technology for metal thin plates, points out the development direction of laser welding technology for metal thin plates, solves some problems in the welding process of metal thin plates, and provides reference for future thin plate welding technology.

Keywords: Thin plate; laser welding; connect.

1. INTRODUCTION

Laser welding technology for metal sheets is one of the rapidly developing advanced manufacturing processes in recent years. Its principle is to use high-energy density laser beams as heat sources to perform precision welding on metal sheets. This technology

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**Corresponding author: Email: bianningkang8929@outlook.com;*

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originated in the 1960s, and with the breakthrough of laser technology, especially the mature application of fiber lasers and carbon dioxide lasers, laser welding gradually became an important means in metal sheet processing.

Compared with traditional welding methods, laser welding has multiple advantages: it has low heat input, high welding accuracy, small deformation, good weld quality, and is suitable for high-speed automated production. Therefore, laser welding is particularly suitable for welding metal sheet materials with a thickness between 0.1mm and a few millimeters, and is widely used in fields such as automotive manufacturing, aerospace, electronic equipment, home appliances, and micro mechanical processing.

At present, laser welding technology has made significant progress in industrial manufacturing, especially in the automotive industry, where laser welding is widely used for welding body structural components and manufacturing parts. Other fields, such as packaging and welding of new energy batteries and precision welding of medical devices, are increasingly relying on laser welding technology.

This article analyzes the current research status of laser welding technology for metal thin plates, discusses the problems existing in laser welding technology for metal thin plates, points out the development direction of laser welding technology for metal thin plates, solves some problems in the welding process of metal thin plates, and provides reference for future thin plate welding technology.

2. LASER WELDING TECHNOLOGY FOR METAL THIN PLATES

Danny et al. [1] used a YAG laser beam to weld 60 μ m AISI 304 (a type of austenitic stainless steel) stainless steel sheet. The results show that compared with resistance welding, laser welding requires nearly three times less heat input, produces a 50% narrower weld seam, reduces porosity by 15%, and increases strength by 25%. It overcomes obstacles such as excessive deformation, formation of discontinuities (pores, voids, and thermal cracks), uncontrolled melting, and poor aesthetics.

Brady et al. [2] also used laser welding in the design of advanced metal bipolar plate connections. In this design, 0.1 mm thin foils of Fe-20Cr-4 V and Fe-23Cr-4 V are processed through stamping technology and then laser welded under argon protection to produce metal bipolar plate components for the anode and cathode, including cooling channels. Then, the laser welded plate is subjected to surface treatment through pre oxidation and nitriding.

Nawi et al. [3] used an ultra short pulse Nd: YAG laser with a wavelength of 1064 nm to perform spot welding on 304 stainless steel. We studied the effects of laser welding parameters, including peak power of the laser beam, pulse duration, incident angle, focal position, and number of shots, on the size of the weld seam (penetration depth and weld width). The results show that the penetration depth and width increase with the increase of welding power, pulse duration, and number of shots. However, as the laser defocusing amount and incident angle increase, the penetration depth and width decrease.

Liao et al. [4] used pulsed Nd: YAG laser to weld stainless steel samples. The laser energy range is 0.6~1.2 J, and the incident angle (the angle at which the laser beam is incident on the surface of the plate) is 30-75 °. Research has found that with the increase of laser energy, the penetration depth, weld bead length, and weld bead width of the molten pool all increase. As the laser incidence angle increases, the melting depth and width also increase.

Venturella et al. [5] used a YAG laser to weld 100 μ m AISI 316L stainless steel plates. The laser pulse energy ranges from 1.0 J to 2.25 J, with increments of 0.25 J, and the pulse duration is 4 ms. The results indicate that pulse energy control is of great significance for the welding quality of thin plates, as it can generate good mechanical properties and reduce the discontinuity of welded joints. As the pulse energy increases, the maximum tensile strength of the welded joint first increases and then decreases.

Vicente Afonso Venturella et al. [6] studied the effect of pulse energy on the weld characteristics of ultra-thin stainless steel plates during laser lap welding with a thickness of 0.1mm. In the study, the pulse energy was varied from 1.0J to 2.25J in increments of 0.25J, with a pulse duration of 4ms. Analyze the weld seam through tensile shear testing and microstructure observation. The results show that the ultimate tensile strength of the welded joint increases first and then decreases with the increase of pulse energy, which is very sensitive to the distance between the two plates. Pulse energy control can ensure good mechanical properties of the welded joint and reduce its discontinuity.

Patrizia Perulli et al. [7] established a simulation model for the hybrid laser MAG (metal active gas) welding process of dual phase (DP) steel and austenitic stainless steel (AISI316). The simulation model was built using Simufact Welding, and two different models were coupled to simulate the thermal input of laser and arc. At the same time, continuous cooling transformation (CCT) diagrams and calculated cooling rates were used to evaluate the metallurgical transformation of DP steel. The reliability and correctness of the established simulation model were verified through the shape of the weld seam, thermal cycling, and geometric deformation of the butt weld seam.

Jae et al. [8] conducted thermal elastoplastic simulation on the laser welding process of I-core sandwich panels. In the welding simulation, an improved conical heat source model was first proposed, and the reliability of the heat source model was verified through welding experiments. Then, the improved heat source model was used to study the effects of welding power, welding speed, and other factors on post weld deformation. The results showed that welding power was positively correlated with post weld deformation, while welding speed was negatively correlated with post weld deformation.

Pakmanesh et al. [9] used response surface methodology to optimize the parameters of pulsed YAG laser welding for 316L stainless steel foil lap joints. They studied the effects of peak power, pulse duration, and frequency on weld seam undercutting and incomplete welding, and proposed improved conditions for obtaining defect free welds.

Moraitis et al. [10] used Ansys software to simulate laser lap welding on a 2mm thick 6061-T6 aluminum plate. They established a small hole model for laser deep penetration welding in the welding temperature field simulation and built an experimental platform for welding experiments to verify the correctness of the established small hole model.

Martinson et al. [11] compared the welding temperature field and stress-strain field results of laser spot welding and resistance spot welding of 2.0mm thick low-carbon steel plate, and established a welding simulation model for laser spot welding for welding simulation. The results show that the compression area and maximum compression stress obtained by laser spot welding are greater than those of resistance spot welding. The reliability of the laser spot welding simulation model can be verified based on the welding temperature field results.

Krasnoperov et al. [12] conducted laser welding experiments on 0.75mm thick stainless steel sheets and studied four different welding modes of laser welding, including open keyhole complete penetration welding, closed keyhole complete penetration welding, unstable penetration welding, and non penetration welding. They summarized the characteristics and causes of three welding modes.

Liu et al. [13] proposed a new method of synchronous heat dissipation and ultrasonic hybrid laser welding (SHS+UHLW). We established simulation models for synchronous heat sink assisted laser welding (SHSLW), ultrasonic assisted laser welding (UALW), and SHS+UHLW for comparison, and studied the distribution of stress and deformation under different welding processes. The results showed that compared with conventional laser welding, SHSLW, UALW, and SHS+UHLW all reduced the residual stress and post weld deformation of the weld seam. Among them, SHS+UHLW has a more significant reduction effect, with stress and deformation reduced by 8% and 40% respectively. In the SHS+UHLW process, the ultrasonic cavitation effect and cooling are used to refine the grain size of the weld seam to the maximum extent, thereby improving the mechanical properties of the weld seam. Compared with LW, the hardness and tensile mechanical properties of SHS+UHLW joint have increased by 11.8% and 13.62%, respectively. Therefore, this method not only reduces the deformation of thin plates, but also improves the mechanical properties of welds, achieving coordinated control of welding deformation and weld performance.

Deng et al. [14] optimized the welding deformation of stainless steel plates by changing the welding process parameters. The results indicate that different heat inputs have a significant impact on both lateral and longitudinal deformation, and bending deformation increases with increasing heat input.

Adak [15] placed a cooling system (water circulation) under the welding plate to regulate the temperature of the welded thin plate.

Experimental results showed that placing a cooling system under the lower plate can significantly reduce welding deformation by about 41%. However, the cooling system accelerates the cooling rate of the molten pool, greatly reducing the forming quality of the weld and thus lowering the performance of the weld.

Zhan [16] placed the specimen at a certain angle in the opposite direction of deformation before welding, which is called the reverse deformation method. The key to implementing this method is to design specific fixtures. The influence of welding sequence on deformation was analyzed using ANSYS, and a new welding sequence was proposed to reduce welding deformation.

Guirao [17] studied the effect of heat input on the deformation and stress of a thin plate with a thickness of 0.5 mm during micro arc welding. In the experiment, copper fixtures were used to constrain the sample, resulting in faster cooling in the thickness direction, smaller temperature gradients, and reduced angular deformation.

Rong et al. [18] studied hybrid laser magnetic welding of 316L stainless steel. A new simplified heat source model was developed to simulate temperature distribution, taking into account the influence of magnetic field on the geometry of magnetic beads. Combining steady-state magnetic field with laser welding reduced angular deformation by 26.56%, longitudinal residual stress decreased, and transverse tensile stress decreased from 199.1 MPa to 167.3 MPa. Laser magnetic welding helps to improve the quality of the weld bead, reduce angular deformation, residual stress, and plastic strain.

Wu et al. [19] established a three-dimensional conical heat source model and conducted thermal and static analysis on 304 stainless steel using ANSYS. The welding process, molten pool morphology, and post weld deformation were observed and verified through experiments. The final experiment showed that the simulation results matched well with the experimental results.

Yang Yibin [20] established a finite element model for welding thin plates and studied the local and global instability deformation during the welding process, as well as the transverse shrinkage deformation law of bipolar plates. The welding deformation was measured through experiments, and the results showed that the established finite element model was reliable.

For the laser cladding welding of 0.6mm thick 304 stainless steel sheet, Xie Moyu [21] studied three aspects. Firstly, the influence of laser cladding welding process parameters on the weld morphology, microstructure, and mechanical properties of stainless steel sheet was studied, and the process parameters were optimized using variance analysis. Then, the microstructure and mechanical properties at different positions of the welded plate were studied. Finally, the causes, characteristics, influencing factors, and control methods of welding humps were investigated.

He Xiaodong et al. [22] studied the effects of laser welding line energy on residual stress, deformation, and weld morphology of 4mm thick TC4 titanium alloy plate after welding using a combination of experimental and simulation methods. The results show that both longitudinal residual stress and welding angle deformation are negatively correlated with the magnitude of welding line energy, and as the welding line energy increases, the weld section changes from a "nail" shape to an "H" shape.

Zhang Xuanjun et al. [23] studied the effect of welding speed on the surface flatness of the weld seam when using a continuous laser for right angle welding of 1mm thick 304 stainless steel sheet. The results show that the higher the welding speed, the worse the welding flatness. When the welding speed is 0.9m/min, the surface of the weld is relatively smooth and the welding effect is better.

Lei Ran [24] conducted extensive laser welding experiments on 0.6mm thick stainless steel sheets, studied the effects of conventional welding process parameters on post weld deformation of the sheets, and measured the mechanical properties and molten pool morphology of the welds. The results show that there is a negative correlation between post weld deformation and welding power. With the increase of welding speed and protective gas flow rate, post weld deformation shows a trend of first decreasing and then increasing; Whether fusion occurs will affect the hardness of the material. The tensile strength of the joint is lower than that of the base metal when it is not fully welded, and the strength of the joint is greater than that of the base metal when it is fully welded; The larger the welding power, the longer the molten pool. As the welding speed increases, the molten pool length first decreases and then increases.

Zhang [25] proposed a multi beam preheating method to reduce distortion. Yi et al. successfully utilized transient thermal tension technology to reduce buckling deformation during thin plate welding. There are also some control techniques based on mechanical methods, such as the prestressing method.

Casalino et al. [26] used laser offset welding to connect AZ31B magnesium alloy and 316 stainless steel into a butt joint structure. The results indicate that the use of adhesive welding method can effectively avoid many drawbacks of laser welding between magnesium and stainless steel. It can produce good metal welds, with good tensile strength and effective connections.

Tao et al. [27] enhanced the performance of laser welded joints between AZ31B magnesium alloy and DP590 duplex steel using pre fabricated groove structures with external and added Sn powder. The results indicate that plasma has a shielding effect on laser energy, thereby improving the absorption rate of laser energy. This promotes the "bidirectional" metallurgical bonding of the magnesium/steel interface, thereby improving the mechanical properties of the magnesium/steel joint.

Suman et al. [28] performed nanosecond laser welding on Al Cu and Cu Al joints. The results showed that by changing the laser power, Al Cu welds exhibited better microstructure, with fewer voids and cracks compared to Cu Al welds.

Shu et al. [29] conducted welding experiments on 316L stainless steel and 6063 alloy thin plates with different wire distances. The results indicate that when the line spacing is 0.02 mm, an oxide free joint is obtained, and thermal conductivity decreases with increasing line spacing.

Abderrazak et al. [30] established a three-dimensional transient heat source model using the Goldak volume method and studied the thermal fluid flow in laser welding of magnesium alloys. This study reveals the influence of surface tension temperature coefficient and Marangoni convection on the formation of molten pools.

Artinov et al. [31] established an equivalent volume heat source model for predicting the temperature and weld bead profile of alloy steel laser welding, and the numerical results showed good correlation with experimental results. In one of the studies, the authors demonstrated that by changing or modifying the heat source parameters, the heat source model used for numerical simulation of laser welding can be adjusted to produce better results similar to experiments.

Aghaee Attar et al. [32] studied six different thermal distribution models for thermal and mechanical analysis of 304 stainless steel and copper dissimilar laser welding. Rahman Chukkan et al.[33] compared the prediction of temperature, residual stress, and deformation in laser welding of 316L stainless steel using different heat source models, including 3D cone, 3D cone and double ellipsoid composite heat sources, and combined 3D cone and cylindrical composite heat sources. The numerical results indicate that the 3D conical and cylindrical composite heat source can accurately predict the residual stress and deformation of thin plates after welding.

Ahmad et al. [34] successfully welded the super alloy Inconel 625 and duplex stainless steel 2205 (DSS 2205) using a fiber laser with different heat inputs. As the energy input decreases, the width of the weld seam narrows and the mechanical properties of the joint improve. Characterization of welded joints using scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), X-ray diffraction (XRD), and microhardness testing. No solidification cracks or porosity were observed in the microstructure of the weld metal (WM). Honeycomb shaped dendritic and columnar dendritic grains are the main grain types observed in welded metals. At a heat input of 43 J/mm, compared to the sample welded at a heat input of 21.5 J/mm, more molybdenum and niobium segregation appeared in the interdendritic arms of the weld metal. Research on tensile strength shows that when the provided heat is low (i.e. 21.5 J/mm), the maximum strength is 890 MPa. This strength value is greater than the strength value of the base material (DSS 2205).

MIS Ismail et al. [35] established a three-dimensional finite element model to simulate the temperature, stress, and deformation fields in continuous wave (CW) laser micro welding of stainless steel thin plates. Welding deformation was evaluated experimentally using a single-mode fiber laser with a high-speed scanning system. The application of the developed thermal model shows that laser parameters (such as laser power, scanning speed, and spot diameter) have a significant impact on the temperature field and weld pool. Numerical simulations were conducted using a non coupled thermodynamic model in the case of welding deformation. During heating and cooling, plastic deformation can generate welding stress and deformation. It can be confirmed that residual stress is higher than the yield strength and has the greatest impact on welding deformation. The numerical simulation results demonstrate that the developed finite element model can effectively predict the thermal cycling, thermal stress, and welding deformation of thin materials.

Pankaj et al. [36] conducted experiments and numerical analysis on CO2 laser welding of AISI 304 stainless steel plate with a thickness of 1 mm. Predicting transient thermal history is crucial when designing welded joints. A 3D finite element model was developed using ANSYS to determine the influence of welding process parameters (i.e. laser power and welding speed) on the thermal history of laser welded joints. The influence of weld geometry obtained from experiments was considered in this 3D finite element model to simulate a moving volumetric heat source. The element birth and death technique is used in finite element thermal analysis to simulate the progress of laser welding zones. It is observed that the cooling rate is greatly affected by changes in laser power and welding speed. It was also observed that increasing laser power and decreasing welding speed would lead to an increase in the size of the fusion zone and heat affected zone. The transient thermal analysis results obtained from the finite element model and experimental results have been well validated, with a maximum percentage error of 6.47% for peak temperature.

Kim et al. [37] studied a hybrid welding process that combines TIG arc welding with YAG laser. Especially, the welding conditions suitable for thin steel plate welding were studied, and welding results with beautiful surface and back weld beads but no welding defects were obtained. During the research process, it was confirmed that the emission position of the laser beam is crucial for achieving good welding in hybrid welding. Therefore, a new intelligent system using visual sensors to monitor the welding area has been constructed. In addition, a control system was constructed to emit the laser beam to a selected position in the molten pool, which is formed by TIG arc. The results of welding experiments using these systems indicate that the hybrid welding process and control system are effective for stable welding of thin stainless steel plates.

Farid [38] studied the precise seam welding ability of a photolytic iodine laser (PIL) on a 0.1 mm thick AISI 316 stainless steel sheet in a lap structure. The welding performance data of PIL laser was compared with Nd: YAG and CO2 lasers. The advantages of PIL welds include narrow seams, extremely fine solidification unit structure, complete austenitic structure, and smaller heat affected zone (HAZ). In contrast, the welds produced by Nd: YAG and CO2 lasers exhibit wider seams, coarser solidification structures, dual phase microstructures of austenite and ferrite, and larger heat affected zones due to slow cooling and transverse thermal diffusion of the melt.

Zain Ul Abdein et al. [39] studied the thermo mechanical response of thin plates made of aluminum alloy 6056T4 used for manufacturing fuselage panels under complex industrial boundary and load conditions to laser beam welding. Single pass fusion welding with laser beam was performed on several test boards. Use thermocouples to record temperature history. By macroscopic inspection of the geometric shape of the weld seam and observation of the displacement field through 3D image correlation technology. Then use Abaqus for decoupling thermodynamic analysis and compare the simulation results with experimental results. Good consistency was found between the simulation results and experimental results.

Nikhil Kumar et al. [40] used an empirical model developed by RSM to investigate the effects of laser power, scanning speed, and pulse width on ultimate tensile strength and welding width. The results of the analysis of variance indicate that the developed model can fully predict the response within the range of input parameters. In addition, microstructure analysis and hardness and tensile performance tests were conducted on the welds of 304 stainless steel and 316 stainless steel. The results indicate that compared to high heat input, low heat input typically results in fine grain structure and improved mechanical properties, regardless of the substrate composition. Compared with 316 stainless steel, 304 stainless steel has better microstructure and mechanical properties.

Suman Chatterjee et al. [41] conducted experimental research on laser butt welding using pulsed Nd: YAG laser. The influence of laser parameters such as laser current, pulse width, and welding speed on the welding quality of 0.45mm thin plates was studied. Research has shown that laser current is the most important parameter in thin plate welding, as it helps to achieve good mechanical and metallurgical quality of the welded joint. The welding strength increases to a certain level with the increase of scanning speed, and then decreases. Overlapping solder joints can seriously affect the surface integrity (surface roughness) and welding strength of the welded joint. The microhardness of the melt zone (FZ) is higher than that of the heat affected zone (HAZ), due to differences in grain structure (coarseness) caused by cooling rate. Laser pulse energy has a significant impact on the generation of residual stresses in welded joints.

Yu Jie [42] studied the influence of channel structure parameters on the stiffness of metal bipolar plates through Abaqus modeling. Channel structure parameters include channel wall thickness, ridge width, and channel height. The simulation results show that the wall thickness of the flow channel has the greatest impact on the stiffness and stability of the metal bipolar plate, while the gas pressure has the smallest impact. Simultaneously reducing the wall thickness of the flow channel, increasing the ridge width, and increasing the height of the flow channel will lead to a decrease in the stability of the metal bipolar plate structure.

Xiao Chaoyang [43] studied the stacking welding of metal bipolar plates, explored the main forms of deformation after bipolar plate welding, and designed a set of fixtures and welding processes based on this to determine the degree of influence of welding joints. The results showed that the main deformation after metal bipolar plate welding was angular deformation, with a minimum deformation of 0.36 mm and a maximum deformation of 0.54 mm. The maximum deformation at the weld seam is about 1.65 mm. Using fixtures during laser welding can effectively reduce its deformation. Through finite element analysis, the maximum deformation does not exceed 0.2 mm. The degree of influence of welding process parameters on welding joints varies from high to low, including welding power, welding speed, defocus amount, and pulse width.

In his thesis, Li Jianqiang [44] studied the effects of process parameters such as welding power, welding speed, and defocus on weld width, weld depth, waist width, and waist height using a quadratic regression universal rotation combination design method. The corresponding regression equations were obtained and significance tests were conducted on the regression equations, regression coefficients, and regression equation fit; We conducted single factor impact study, two factor impact study, and three factor optimal result study using the obtained regression equation, and determined the optimal results under different conditions. Finally, the laser welding process was simulated using ANSYS software.

Bai Qinghua et al. [45] used ANSYS software to establish a flat plate with a material of 60CrMnMo and a size of 120 mm × 120 mm × 8 mm. They studied the simulation of multi pass welding with welding hammer impact, and obtained the starting time of hammer impact by analyzing the stress field values and distribution. The simulated temperature field results were consistent with the actual welding temperature distribution law.

Li Shuailun [46] designed fixtures for the welding hammer striking equipment, allowing it to move in three degrees of freedom, reducing stress at and around the weld seam, and increasing the strength of the weld seam.

Han Yuzhen [47] established a thermal elastoplastic finite element simulation model using Abaqus to study the effect of laser arc composite welding on welding materials. The results showed that compared with laser welding and arc welding, laser arc welding combines the advantages of both, avoids their disadvantages, and reduces the deformation of the plate after welding.

Huang Shuangyue [48] used simufact-wolding to establish large-sized aluminum alloy components and conducted welding simulations. The temperature field and stress-strain field were analyzed, and the effects of heat input and stress on component deformation were summarized. The deformation and residual stress of the components were reduced by optimizing the welding sequence, welding process parameters, and designing fixtures.

Zhang Weizhe [49] studied the laser welding of 0.3 mm thick 304 stainless steel. The influence of process parameters such as laser power, laser pulse width, laser speed, and defocus on the welding quality was studied using a single factor experimental method. The microstructure, tensile strength, and hardness of the welded joint were measured. Finally, the distribution law of the welding temperature field was explored using simulation methods.

Zhang Jingzhen et al. [50] conducted a study on the unstable deformation of a 0.07 mm thick 316L stainless steel sheet. Firstly, the inherent strain of laser welding of the 316L stainless steel sheet was obtained using simulation methods. Then, the characteristic value buckling analysis of the unstable deformation of the sheet was carried out using the obtained inherent strain. Finally, a nonlinear buckling analysis was conducted on the unstable deformation of the sheet. The analysis results showed that the critical buckling load of the sheet was negatively correlated with the area of the sheet, but positively correlated with the thickness of the sheet.

Li Qibo et al. [51] studied the process method of pulsed laser butt welding of 0.2mm thick 1Cr18Ni9Ti. The process parameters affecting welding quality, including welding current, pulse width, and pulse frequency, were optimized and analyzed using a three factor three-level orthogonal experimental method. The evaluation index of the experiment was the tensile strength of the welded joint. The optimization results indicate that a welding current of 82 A, a pulse width of 2.0 ms, and a pulse frequency of 22 Hz can achieve the maximum tensile strength.

Liu Feng et al. [52] optimized the welding sequence of metal bipolar plates and proposed an internal external bonding welding method, dividing the bipolar plates into four parts. The approximate welding sequence is to weld the inner part first, then the outer part, then the inner part, and finally the outermost part. The final experimental results indicate that using this welding sequence can maintain the warpage of the metal bipolar plate at 1 mm to 2 mm.

3. PROBLEMS AND DEVELOPMENT PROSPECTS OF LASER WELDING TECHNOLOGY FOR METAL THIN PLATES

There are still some problems with laser welding technology for metal sheets today, such as heat affected zone (HAZ) issues, welding deformation and stress, porosity and cracking issues, complex process parameter control, material adaptability issues, high welding equipment costs, high surface quality requirements, and difficulty in detecting weld quality. However, the development prospects of metal sheet laser welding technology are very broad, and it will have significant application potential in the following fields in the future:

Automotive industry: With the increasing demand for lightweight and high-strength, laser welding can achieve high-precision welding of complex structural components, reduce vehicle weight, and improve fuel efficiency. Meanwhile, laser technology is widely used for packaging and welding of battery modules in electric vehicles.

Aerospace field: Laser welding technology can effectively weld high-strength alloy thin plates in aerospace, reduce aircraft weight, improve fuel efficiency and flight performance. Meanwhile, laser welding has high precision and is suitable for manufacturing complex geometric components, ensuring structural strength and safety.

Electronics and microfabrication: Laser welding technology is used in the electronics industry to weld precision components such as mobile phone casings, semiconductor chip packaging, etc. It has the characteristics of high precision and low heat affected zone, ensuring welding quality and product reliability.

In the field of new energy: With the rapid development of the new energy industry, laser welding has been widely used in the packaging and manufacturing of electric vehicle batteries and solar thin-film cells. Efficient and pollution-free laser welding technology helps to improve production efficiency and product quality, promoting the development of green manufacturing.

Medical device manufacturing: Laser welding technology is widely used in the welding of biocompatible materials such as stainless steel and titanium alloys, and is used to manufacture precision medical devices and implants, with the advantages of high strength and low deformation.

4. CONCLUSION

Thin plate connection technology is of great significance to the development of industry, and has a significant impact on improving production efficiency and reducing costs. This article analyzes the current research status of thin plate welding technology, discusses the existing problems in thin plate welding technology, and points out the development trend of thin plate welding technology. This provides theoretical reference for the future development of thin plate connection and laser welding industry. In the future, laser welding technology for thin plates will become the core process for more high-end manufacturing industries, promoting the development of lightweight, high-efficiency, and green manufacturing.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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