Research on Influencing Factors of Automotive Body-in-White Laser Welding Quality

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Abstract: Laser welding technology is fast, advanced, and flexible. It is the key technology to ensure the development of new automotive products. It is also a technology to improve product quality and reduce costs. However, the application of laser technology in automobile manufacturing still has a certain distance compared with foreign countries. In order to improve the competitiveness of the automotive industry, it is necessary to strengthen the research on the application of laser welding technology in automobile body-in-white. This article will start with the factors that affect the quality of laser welding of automobile body-in-white, and based on the analysis of laser welding mechanism and related characteristics, talk about the influence of laser welding power and give relevant solutions welding speed on the quality of laser welding of automobile body-in-white.

1. Automotive Body-in-White Laser Welding Overview

1.1 Car Body-in-White Overview

The body is an important part of the vehicle, which will have an important impact on the overall safety, power and economic comfort of the car. At the same time, whether a car has a personality and can attract consumers' favor. It is also closely related to the car body design and quality. The car body includes two parts: body-in-white and its accessories. The body-in-white refers to the white leather body that has been welded but not painted. It is a comprehensive welding of the body structure and cover parts which excludes body attachments and trim. The body-in-white can be divided into three types: non-loaded, semi-loaded and load-bearing. The characteristics of the non-loaded body-in-white are that the body is flexible connected by rubber cushions or springs and frames. The body only bears the weight and inertia of the carrying personnel and the cargo itself, and the frame supports the entire vehicle foundation, but the frame’s design does not need to consider the auxiliary role of the body in carrying the frame. The characteristic of the load-bearing body is that the car does not have a frame, and the body can bear all the gravity of the car. The body has the bearing capacity of the frame and the body. Because the frame is removed, the mass of the overall vehicle is reduced, and the height is reduced, thereby achieving lighter weight and higher speed of the vehicle body. The body is the bearing foundation, so the performance of the body material can be fully utilized to make the body structure more reasonable. However, the load-bearing body will also increase the bearing capacity of the body due to the cancellation of the frame, which will affect the ride comfort and even reduce the service life of the body. It will be more difficult to modify it later. The structural feature of the semi-loaded body is that the body is rigidly connected to the frame by welding and other methods. The frame bears the load of the main components, and the role of the body is to strengthen the frame and share the advantages of the part of the load of the frame and non-load-carrying body [1].
1.2 Overview of Automotive Body-in-White Laser Welding Technology

Automotive body-in-white welding is an important part of automobile production. The quality of body welding will directly affect the appearance of the body, the carrying capacity and service life of the body. Adopting scientific and reasonable welding process can improve production efficiency and ensure the quality of body structure. There are many methods of automobile welding, including electric welding, carbon dioxide gas shielded welding, laser welding and so on. The laser welding technology uses a laser mirror to reflect the light beam generated by the laser, so that it is concentrated in the focusing device to generate a beam of huge energy. Once the focus is near the workpiece, it will immediately melt and evaporate. The application of laser welding technology has played a significant role in all aspects of welding schedule, efficiency, reliability and automation. In recent years, because of the research and application of high-performance and high-power laser welding equipment, laser welding technology has become one of the most promising manufacturing welding technologies and has been widely used in welding smelting in various fields. The main application features of laser welding are: firstly, it can reduce heat to a minimum, reduce the range of thermal influence, and minimize deformation problems due to heat conduction. Second, laser welding can reduce the time and materials required for thick plate welding, which has obvious economic advantages. The third laser welding eliminates the need for electrodes and reduces pollution caused by the electrodes. In the fourth laser welding, the laser beam is easy to focus and align, and is also guided by optical instruments. These are characteristics that other welding processes do not have. Generally speaking, the welding technology of the machine is also affected by the welding position, which requires that the laser beam must be in the focus range. In addition, highly reflective and highly thermally conductive materials can be affected by laser welding to cause performance changes, and laser welding equipment is generally expensive.

2. Factors Affecting Automotive Body-in-White Laser Welding Quality

2.1 Effect of Laser Power on Welding Quality

After laser welding of steel and aluminum materials, their quality is mainly affected by factors such as pre-welding processing clamps, welding process parameters, and the physical characteristics of the material being welded. Among them, the welding process parameters have the greatest impact on the quality of laser welding, including laser power, welding speed, high focus, protective gas type and flow, etc. [2]. First of all, for continuous laser welding, the laser power refers to the output power of the laser. Low-power lasers that work continuously generate ordinary and limited heat transfer welds on the sheet at a lower speed. High-power lasers High speeds produce narrower welds, or lower depths produce thicker welds on thick plates. The laser power controls the penetration depth and the welding speed. The laser welding penetration is related to the beam power. When other conditions are unchanged, the penetration depth will increase with the increase of laser power.

2.2 Effect of Laser Welding Speed on Welding Quality

In the case of constant laser power, increasing the welding speed will reduce the heat input and the weld penetration depth. Therefore, appropriately reducing the welding speed can increase the penetration depth. But when the speed is too low, the penetration depth will no longer be increased, the material will be over-melted due to the increase of the melting width, and the weldment will be welded through. This is because during laser welding, small holes are generated and metal gas is in the small holes. When the welding speed is too small, the heat input increases, more and more metals are melted, and the recoil pressure generated by metal vaporization cannot maintain the existence of small holes. The depth of the pinhole no longer deepens, but will deform under the effect of heat conduction. In addition, with the increase of metal vaporization, the temperature in the small holes increases, and the increase of the plasma concentration increases the absorption capacity of the laser, which cannot play the role of laser welding.
2.3 Effect of Spot Diameter on Welding Quality
The effect of the size of the spot irradiated on the welding surface on the quality of welding is that when deep welding is performed, the power density at the laser focus must be high during welding. However, the first method to increase the power density is to increase the laser power, and the second is to reduce the spot diameter. When the spot diameter is reduced, the welding power density is increased. Therefore, we can use a short focal length lens and reduce the transverse mode order of the laser beam to reduce the spot diameter. After the low-order mode is focused, a smaller spot can be obtained [3].

2.4 Influence of Defocus Amount on Welding Quality
Defocus amount refers to the distance from the surface of the weldment to the focal point of the laser. The amount of defocus not only affects the laser spot size on the welding surface, but also affects the incident direction of the laser beam. Therefore, the depth of laser welding, the width of the welding, and the welding The shape of the cross section of the seam will have an effect. When the amount of defocus is large, the penetration depth will be small, but when the amount of defocus is very small, the penetration depth will increase, and a large number of small holes will be generated, making the welding very unstable, which will cause large and small welds, while the seam forming quality is poor. The amount of defocus also affects the radius of the melting spots on the surface of the material and the diameter-depth ratio of the molten pool, which affects the quality of the welding process. When the defocus amount is changed, the size of the laser heating spot and the incident light beam can be changed. When the welding plate is thicker, a reasonable defocus amount can be used to obtain a larger molten pool. However, if the defocus amount is too large, the diameter of the light spot will be increased, which will reduce the power density on the light spot and reduce the penetration depth.

2.5 Influence of Shielding Gas on Welding Quality
The protective gas for laser welding can protect the welding metal from the harmful gases from the outside, avoid the oxidation pollution, and improve the quality of the welded joint. Second, it affects the plasma in welding. During deep-fusion welding, the high-power laser beam heats and vaporizes the metal, forms a metal gas above the molten pool, and dissociates under the action of the electromagnetic field to generate a plasma. It has a certain hindrance to the laser beam. The laser beam is affected and absorbed by the welding. Plasma clouds can be suppressed by blowing a protective gas in laser welding. The specific mechanism is to increase the collision of electrons with ions and neutral atoms by increasing the protective gas, thereby increasing the recombination rate of electrons and reducing the electron density in the plasma. Second, the use of a flowing protective gas to blow out the generated metal gas and ions will also have a certain effect on the gas flow and penetration. When the gas flow rate is too small, the plasma cloud above the molten pool cannot be removed, and the removal effect will increase with the increase of the gas flow rate. However, when the gas flow rate is too large, the problem of collapse under the molten pool will also occur.

2.6 Effect of Pulse Energy and Pulse Width on Welding Quality
In pulse welding, the energy of the pulse will directly affect the heating energy and the amount of metal melting. The width of the pulse determines the heating time during welding and affects the penetration and the size of the heat affected zone. When the pulse energy is constant, different materials have the best pulse width. At this time, the welding penetration depth is the largest. For metals with good thermal conductivity and lower melting point, greater penetration depth will be obtained. There is a certain relationship between the pulse energy and the pulse width during welding. There is a certain change with the thickness and properties of the material. During welding, in order to keep the power constant, as the pulse energy increases, the pulse width must also increase accordingly, so as to ensure the quality of welding.
2.7 Influence of Power Density on Welding Quality
In pulse laser pulse welding, when the power density is small, the welding is performed by heat transfer welding, and the heat conduction directly affects the diameter of the solder joint and the depth of penetration. When the laser spot power density is constant, a pinhole effect will occur during welding, and deep-melt solder joints will be generated. A small amount of metal will evaporate, which will not affect the formation of solder joints. However, when the power density is too large, the metal reacts strongly and the metal gas generated by metal vaporization increases, which will form small holes filled with metal gas in the solder joints, which cannot form strong solder joints, which will affect the quality of the solder.

3. Suggestions on Quality Control Measures for Laser Welding of Automobile Body-in-White

3.1 Laser Welding Equipment Maintenance
Automotive body-in-white laser welding quality defects are most common in voids, fusion-type welds, poor solder connections, single-sided solder joints, rough weld surfaces, and insufficient or excessive weld fill at the beginning and end of the weld. Analyzing the factors that cause these quality defects shows that many quality problems are caused by equipment failures, so it is very important to do daily equipment maintenance and repair. For the maintenance of laser equipment, in addition to daily inspection of glass lenses, the residue generated during welding should be cleaned in time, the bolts on the fixture should be tightened to prevent it from falling off during welding. Besides, the arc lamp in the laser should be checked regularly. We also need to replace aging arc lamps, and robots daily maintenance of auxiliary equipment also needs to be strengthened.

3.2 Dimensional Accuracy Requirements for Laser Welding Workpieces
The main factors affecting the quality of laser welding are process parameters. In order to ensure the accuracy and quality of laser welding, accurate beam positioning and precise clamping technology are required. In addition, controlling the laser power and welding speed, and controlling the gap between the parts to be welded. Generally, the gap between the parts to be welded in the body-in-white laser welding is 0.2mm.

4. Laser Welding Process and its Application Development in Automotive Body-in-White Welding

4.1 Composite Welding
While applying laser welding technology, we are also strengthening research on this technology. In order to solve the disadvantages of laser welding in application, for example, for the base material is easy to be melted and vaporized by heat, creating deep-melted pores, we need to fill the pores with metal gas. These gases will form a plasma cloud under absorption and reflection under the action of laser. After that, the absorption rate of the laser light by the metal material is reduced, thereby reducing the problem of the laser energy utilization rate. In this way, we can use the heating properties of other heat sources to improve the heating of the workpiece by the laser, and combine the laser with other heat sources to achieve composite heat source welding, such as combining laser and electric arc, combining laser and plasma arc, laser and induction heat sources are combined for welding [4]. This composite welding process combines the advantages of multiple welding technologies, which can increase the penetration depth of welding, improve the welding speed and production efficiency, while reducing the cost of equipment and improving the coupling characteristics of laser energy.

4.2 Laser Welding Laser Generator and its Technological Development Trend
The lasers currently used in laser welding technology are generally high-power carbon dioxide lasers and pulsed lasers. The problem we need to solve is how to develop a large-capacity and high-panel light source to improve conversion efficiency and reduce losses, while ensuring the quality of the laser
beam and high-efficiency and high-reliability propagation, while reducing costs. In the future, the output power of single-fiber and single-mode fiber will exceed kW [5], people can use direct diode array laser output wavelength in the near-infrared region to increase the average laser power significantly, and the photoelectric conversion efficiency continues to improve. The application of these devices and technologies in the field of automotive body-in-white welding can improve the quality and efficiency of welding through the improvement of welding processes and materials.

4.3 Development of Automotive Body-in-White Welder Technology

With the mass production of automobiles, the product quality and efficiency have been further improved, so that robot laser welding technology has been widely used in automotive welding. The use of more flexible, highly automated and highly flexible welding equipment can ensure the welding production efficiency while ensuring the high precision and quality of the welding. Automated flexible production system is the main development trend of automotive welding. In welding, the application of robotic laser welding technology and the use of combined lightweight intelligent automatic welding equipment can not only improve product quality, but also improve production efficiency and control the material consumption.

5. Conclusion

Laser welding technology has been widely used in modern automobile manufacturing industry because of its high production efficiency and high welding process accuracy. With the continuous development of the automotive industry, the automotive body-in-white welding technology will develop in the direction of automation and informatization. However, the premise of the application of automation technology is that the welding process must be improved. Therefore, continuous research and improvement of laser welding should be conducted. The factors of welding quality are eliminated one by one, making full use of the role of laser welding technology.

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