Causes of Defects in Laser Cladding and Control Methods

Biao Xue

Xi'an Institute of Transportation Engineering, Xi'an 710300, China.

Abstract: This paper presents a detailed analysis of the causes of crack defects, porosity defects, oxidation burn defects, substrate deformation defects in the process of operation, surface flatness not up to the expected defects and effective solutions to control the method, hoping to provide relevant practitioners with certain references to reduce the incidence of defects of the surface layer of the laser melting and cladding process from the fundamental level to improve the performance of the material, and ultimately to contribute to the development of China's manufacturing industry, and the development of a better, more efficient, and more effective way to reduce defects. In the end, it will make a better and greater contribution to the development of China's manufacturing industry.

Keywords: Laser Cladding Technology; Crack Defects; Porosity Defects; Oxidation Burn Defects; Substrate Deformation Defects

Introduction

In modern industrial production, laser cladding is a new surface modification production technology, also known as laser deposition, laser cladding technology. The principle of this technology is to add a layer of cladding material to the surface of a variety of substrates, and then under the action of a high energy density laser beam, the cladding material and the substrate surface of a thin layer of fusion coagulation, and ultimately the formation of metallurgical bonding filler cladding layer on the surface of the base layer of the material. In general, laser cladding technology really realises the goal of "making the base material and the cladding material become one, with no gap in the middle", which greatly improves the performance of the material and increases the application range of the material. However, in practice, it is found that the laser cladding layer itself may appear a variety of defects, the need to determine the types of defects and the causes of the formation of these defects, to find solutions to control methods to improve production efficiency and quality.

1. Analysis of the causes of defects in the laser cladding layer

1.1 Analysis of crack defects and causes of laser cladding layer

Crack defects are the most common defects in the laser cladding process. Cracks are generally generated at the junction of the material matrix and the cladding layer, and may run through the entire cladding layer. Cracks are characterised by a parallel extension in the direction perpendicular to the laser scan to the area in front of the cladding. This is due to the fact that the coefficients of thermal expansion of the substrate and the cladding are not the same, with the consequence that both the substrate and the material to be clad are heated up very quickly by the laser, but that the temperature drops rapidly when the laser light is stopped. As a result, the thermal and organisational stresses in the cladding layer are different at different stages of the cladding process, resulting in cracks.

1.2 Analysis of porosity defects and causes of laser cladding layer

Porosity defects are also common defects in laser cladding, the causes are as follows: as mentioned above, the formation process of laser cladding needs to use a laser, the heating process corresponds to the melting, the cooling process corresponds to the solidification, which can be completed in a short period of time. The short operating time is of course a great advantage, but the problem is that, in such a short period of time, once the metal powder, which is an important

production material, is damped, resulting in a certain amount of moisture, or enters the oxides in the process of sudden changes in temperature in the redox reaction may lead to the emergence of gases inside. Once these gases can not be discharged in a short period of time all, in the laser melting cladding layer solidification is completed, it will generate pores.

1.3 Laser cladding layer oxidation burn defects and cause analysis

Laser cladding formation process, but also prone to oxidation burns, the causes are mainly concentrated in the following three aspects: first, as raw material metal powder itself is affected by oxidation; second, the formation of air holes in the internal residual amount of air; third, laser cladding operations, sealing control problems, resulting in the infiltration of oxygen in the external environment.

1.4 Analysis of defects and causes of substrate deformation during laser cladding operations

In the process of laser cladding, the base material may be deformed, and this defect is mainly related to thermal stress. Specifically: the material substrate will bend towards the cladding surface after being subjected to thermal stress. If the preheating and post-heat treatment of the substrate are not sufficiently sophisticated, or if the thickness of the cladding layer is large, this will increase the degree of deformation of the material substrate. In addition, there is a difference in the amount of laser light consumed by different types of metal powders during the cladding process - the more laser light there is, the more heat is stored internally, and the more deformation of the material substrate occurs in the end.

1.5 Analysis of surface defects and causes of unevenness of laser cladding layers

The requirement for a laser cladding layer is that the surface must be flat, and any unevenness will result in a significant reduction in the application value of the material. The reason for the uneven surface is that the high temperatures generated by the laser irradiation liquefy the material in a very short period of time. As a result, the tension on the surface of the liquid material rises, causing the melt at the front of the laser beam to expand rapidly [2] and the melt at the back to contract rapidly due to solidification and crystallisation, resulting in an uneven surface.

2. Effective control of laser cladding layer defects in brief

2.1 Effective control methods for laser cladding layer crack defects

Effective control methods for laser cladding layer crack defects are as follows: First, in the process of cladding layer formation, pay attention to adjusting the stress state, so that the tensile stress is reduced as much as possible. The method can be used to reduce the linear expansion coefficient of the cladding layer, so that it is as close as possible to the linear expansion coefficient of the material matrix. The purpose of doing so is to greatly reduce the internal residual tensile stress that needs to be dealt with in the formation of the cladding layer in the middle and later stages, and ultimately achieve the purpose of preventing or reducing the generation of cracks. Second, optimise the laser cladding process method, adjust the relevant parameters. For example, adjusting the scanning and powder feeding speed and changing the power density can effectively improve the quality of the cladding layer. Third, some alloying elements can be added to the material, with the purpose of increasing the toughness of the cladding layer, and ultimately achieving the purpose of controlling cracks. Practice shows that if the main component of the material base layer is iron, add nickel, cobalt and other elements [1], can effectively change the organisational state, crack control effect is very obvious.

2.2 Effective control methods for laser melting cladding layer porosity defects

Effective methods to solve the porosity defects are as follows: First, before using the metal powder, it is necessary to choose a more stable performance of metal materials, that is, metal materials that are not prone to redox reactions. Second, the metal powder should be baked before use to ensure that the internal moisture is drained. Third, try to reduce the thickness of the laser cladding layer, so that the internal gas is easier to escape, to avoid being "sealed" in the cladding layer.

2.3 Effective control methods for oxidation burnout defects of laser cladding layer

Effective methods to control the defect are: first, before carrying out the relevant operations, technicians need to check the metal powder, once found that the metal powder has been oxidised, it should not be used. Secondly, the inert protective gas should be directed to the molten pool to avoid the oxygen in the environment to enter into it. Thirdly, a small amount of silicon and aluminium elemental powder can be added to the metal powder in advance. The purpose of doing so is to enable the cladding layer to form a layer of high density oxide protective layer, which can effectively block the penetration of oxygen, and ultimately achieve the purpose of preventing the oxidation of the cladding layer.

2.4 Effective control methods for deformation defects of the substrate in the process of laser cladding operation

The following methods can be used: first, before the cladding operation, the material substrate is preheated. The purpose is to increase the temperature of the material, so that when receiving laser irradiation, it is possible to start cladding without too much laser light, and the heat stored in the interior is low, so it is difficult to appear deformation. Second, the thickness of the cladding layer is reduced as much as possible. Thirdly, after the cladding operation is completed, it is necessary to carry out post-heat treatment on the parts in order to eliminate the residual stresses in the cladding process.

2.5 Effective control methods for laser cladding layer surface unevenness defects

The method of controlling the defect is: first, you can add some rare earth elements in a small amount in the metal powder, and ultimately achieve the purpose of reducing the melt tension and improving the wettability, which can significantly improve the quality of the cladding layer. Second, improve the laser diffusion beam power at the same time, at the same time should also reduce the laser scanning speed, can effectively reduce the unevenness of the laser cladding layer. Third, for the already completed cladding operations for the inspection of the cladding layer, found that the flatness is not enough, you can carry out the second cladding operations, can effectively adjust the surface flatness.

3. Conclusion

The application principle of laser cladding technology is to add external materials to the molten pool formed by laser irradiation of the substrate through synchronous or pre-positioned materials, and to make them solidify together to form a cladding layer. During the operation process, affected by the different thermal expansion coefficients of the cladding layer and the base material, the generation of gas and can not be discharged in a timely manner and other factors, the laser cladding layer will appear cracks, pores, oxidation burns, deformation of the base material, surface inequality and other defects. In general, the operator should clarify the formation of these defects and control them in the production process, and ultimately produce materials that meet the standards.

References

[1] Lv XR, Ma XW, Dong LH, et al. Research progress on formation mechanism and inhibition method of pore and crack defects in laser cladding[J]. Functional Materials, 2020, 51(06): 6034-6043.

[2] Lin YH, Lin ZH, Chen QT, et al. Analysis and control of defects in TiB/Ti laser cladding layers[J]. Advances in Laser and Optoelectronics: 1-14.

Author Introduction: Xue Biao, (October 1994-), male, Han, Shaanxi Province, Xi'an Institute of Transportation Engineering, teaching assistant, master's student, mainly engaged in research on lasers and their applications.