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Research Progress of High Entropy Alloy Coating Prepared by Laser Cladding

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Abstract: High entropy alloy is a new type of alloy with good comprehensive properties. This paper reviews the common preparation methods of high entropy alloy coating, and the research status of high entropy alloy coating prepared by laser cladding in terms of hardness, wear, corrosion and oxidation resistance, high temperature softening resistance, etc., and points out the existing problems and development prospects for high entropy alloy coating prepared by laser cladding.

1. Introduction

With the rapid development of social economy and science and technology, metal materials have been playing an important role in human civilization since the bronze age. Because of its excellent properties, the application of alloy materials has been greatly expanded. Traditional alloys usually consist of no more than three metal elements, and several kinds of metal or non-metallic elements are added to a metal to control its properties, in 2004, Ye [1] and the team of Cantor [2] independently reported a new alloy, high entropy alloy (also known as multi principal component alloy), which is different from the traditional alloy. With the deepening of the research on high entropy alloys, the connotation and extension of the concept has been greatly developed. For example, the alloy principal components have been expanded from more than five to more than four, and the phase structure of alloys has extended from FCC, BCC, HCP single-phase structure to two-phase or multi-phase structure [3]. At the same time, the existing form of high entropy alloy has also rapidly expanded from bulk to powder and film. As a common application method of film-like morphology, coatings can prepare films with certain functions on the surface layer of the original workpiece or substrate as far as possible, so that the performance and application range of the substrate are greatly improved. As a common preparation method of traditional alloy coating, laser cladding is widely used in the research of high entropy alloy coating because of its high production efficiency and low cost.

2. Common Preparation Methods of High Entropy Alloy Coating

Magnetron sputtering is a method that uses a magnetic field to prepare coatings. The process flow of the magnetron sputtering method is that under the action of a magnetic field, plasma hits the target material, causing atoms to be emitted from its surface, thereby forming a coating on the surface of the substrate. The advantage of magnetron sputtering method is that the damage to the substrate is small during the preparation process, the sputtering deposition rate is fast, and the film thickness is easy to control. However, a large number of studies have shown that the thickness of the film prepared by the magnetron sputtering method is limited, and the bonding force between the film and the substrate is poor. The thermal spraying method is a method of mechanically combining the spraying material with the substrate. The process of the thermal spraying method is to heat the coating material to a molten state, and then spray it on the surface of the substrate at a certain speed to form a coating. The advantage of thermal spraying is that the substrate material is not limited, the spraying materials are very wide, the damage to the substrate material is small, the operation process is flexible and convenient, and the coating thickness range is large. How-ever, because the structure of the coating is the combination of particles, the combination of particles Insufficient, there are areas where there is no bonding, Therefore, defects will form inside the coating. And the spraying process is in an atmospheric environment rather than a vacuum condition. The molten particles easily react with the gas to oxidize the particles, causing inclusions and reducing strength. Electrochemical deposition [4] is a method in which positive and negative ions are moved by an electric field, resulting in the formation of a coating on the surface of the substrate. Although the coating prepared by electrochemical deposition method can be electrodeposited on large-area complex workpieces, there is a large stress between different layers in the coating, which leads to warping and cracking of the coating [5].The plasma cladding heat source is a high-energy plasma beam, which melts the powder on the surface of the substrate and the surface of the shallow layer, and rapidly solidifies, thereby forming an alloy coating on the surface of the substrate. The coating prepared by plasma cladding has the advantages of uniform heat out-put, low cost, not easy to produce cracks, pore defects, etc., but due to the high energy of the plasma heat source, it is easy to cause large stress and large deformation inside the substrate [6].Laser cladding technology [7] refers to placing the material that needs to be coated on the surface of the substrate, and under the action of high-energy laser beam radiation, it melts with the surface of the substrate and solidifies quickly to form a coating. Laser cladding is a processing technology that combines various advantages such as wear resistance, high hardness, and strong corrosion resistance. It has strong bonding force and few internal defects in the coating, which makes up for the shortcomings of magnetic sputtering and thermal spraying. After processing by this technology, the mechanical properties of the material can be improved to a large extent, so that it has special and excellent properties that the substrate does not have [8]. Especially in the modification of material surface, laser cladding technology plays an important role in repairing parts. Compared with the preparation of traditional surface coatings, the main advantages of laser cladding technology are [7]: (1) Laser cladding technology can be performed on relatively cheap substrate materials, saving costs;(2) The thickness of the coating can be controlled to meet actual needs; (3) The cladding layer formed by the substrate and the coating material is relatively strong and has good mechanical proper-ties; (4) The damage to the substrate material is small; (5) The laser cladding process is fully automatic Machine, save manpower; (6) The substrate surface has little effect on the cladding layer.

3. Performance Characterization of Laser Cladding High-Entropy Alloy Coating

High-entropy alloys have more types of alloying elements, the difference in atomic radius and the greater difference in mixing enthalpy between the elements. In the pro-cess of nucleation and growth of crystal grains, it is easy to produce more serious solute redistribution, which reduces the diffusion rate of alloy melt and increases the diffusion distance. It is easy to reduce the production rate of solid crystal nuclei and cause larger internal production. Furthermore, the hardness and wear resistance of the alloy coating can be improved due to solid solution strengthening and fine grain strengthening. The corrosion resistance of high-entropy alloy is mainly affected by factors such as preparation methods, types of alloying elements, and solidification processes. The oxidation resistance of metal materials is mainly the oxidation corrosion phenomenon that occurs in high temperature environments. Traditional metal materials are prone to performance degradation, especially hardness reduction, at higher temperatures. Due to the variety of elements in high-entropy alloys, the decrease in Gibbs free energy of the system at high temperatures tends to keep the alloy phase structure stable, thereby improving the resistance to high-temperature softening[9]. Compared with traditional alloys, laser cladding technology to prepare high-entropy alloy coatings has a variety of excellent properties, and has multiple uses in industrial production and life:(1) It can improve the surface mechanical properties of parts, and can also be processed on parts with complex shapes and special functions [10];(2) It can be used for cutting tools and mold materials. For cutting tools, laser cladding on the surface can make the tools have better cutting performance. For mold materials, the inner layer of the mold Coating can enhance wear resistance [11];(3) It can improve the binding force of the two materials and facilitate processing and assembly;(4) The high-entropy alloy coating still has high hardness at high temperature and can be used in aerospace materials to make it work in high-temperature environments;(5)Laser cladding has a faster cooling rate and solidification rate, and the cladding process is automated and has low pollution. It is widely used in material design research and development [10].

4. Conclusion

Laser cladding has the advantages of fast heating and cooling, low dilution rate, low substrate damage, and less film material re-striction. By preparing a high-entropy alloy coating on the substrate, it can not only have a surface coating with excellent performance, but also retain the performance of the substrate to the utmost extent and save costs, which has a very broad application space and market prospects. HEAs related theories and applications will surely be gradually enriched and perfected, greatly expanding the connotation and extension of metal materials.

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