DOI: 10.23977/jmpd.2022.060104
ISSN 2516-0923 Vol. 6 Num. 1

Research Progress of HEA Wear-Resistant Coatings for Strengthening Mechanism

Ma Mingxing, Li Shangzhi, Dong Chen, Wang Zhixin*, Zhang Zhixin, Li Xin, Yu Yiheng, Liu Wendong

School of Materials and Chemical Engineering, Zhongyuan University of Technology, Zhengzhou 450007, China

**Corresponding Author*

Keywords: High entropy alloy, Wear-resistant, Strengthening mechanism, Research progress

Abstract: This paper discusses and analyses the preparation methods, performance characterization and analysis methods, influencing factors, and strengthening mechanism of high-entropy alloy wear-resistant coatings, and then perfects and enriches the relevant theories of high-entropy alloys.

1. Introduction

With the continuous improvement of the level of science and technology and material performance requirements, traditional metal materials are difficult to meet the requirements of performance under various extreme conditions as industrial applications continue to expand. Traditional alloys often use small or trace amounts of a variety of metal or nonmetal elements to adjust their performance. If the content of alloying elements is high, complex intermetallic compounds that are hard and brittle will be formed, which will reduce the toughness and performance of the alloy. This is the main reason that hinders the development of the alloy in the multi-directional direction. At the beginning of this century, the research groups of Ye[1] and Cantor[2] independently published multi-principal HEAs formed by five or more main alloying elements. Different from the traditional alloy design concept, high-entropy alloys have high hardness, high wear resistance, thermal stability and corrosion resistance and other excellent properties concern, is considered to be a new direction of the metallic material[3].The high entropy alloy coating can greatly improve the surface property of the material without changing the matrix property or a little, which can not only save the cost, but also solve the adaptability problems caused by technological innovation, so that its application scope and service can be greatly expanded. This article analyses and discusses the common preparation methods, performance characterization methods, influencing factors and strengthening mechanism of high entropy alloy wear-resistant coatings, and provides references for researchers engaged in high entropy alloy wear-resistant coatings.

2. Preparation Methods High Entropy Alloy Wear Resistant Coating

The thermal spraying method is a method of mechanically combining the spraying material with the substrate. The process of 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. Thermal spraying is not limited by the base material. The spraying materials are very wide, the base material is less damaged, the operation process is flexible and convenient, the coating thickness range is large, and the economic benefits are good. However, because the coating prepared by thermal spraying is a structure formed by the accumulation of particles, the bonding between the particles is not sufficient, and there are areas where there is no bonding, so defects will be formed in the coating. Moreover, 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. Wu[4] prepared FeCoNiCr high entropy alloy coatings by plasma spraying, and studied the effects of different elements on the structure and properties of the alloy coatings. The addition of element Al reduces the wear of the high-entropy alloy coating, the alloy coating with Mo has the best corrosion resistance, and the alloy coating with Mn has the best wear resistance. Magnetron sputtering is a method that uses a magnetic field to prepare coatings. The process flow of the magnetron sputtering method is that the target material is bombarded by plasma under the action of a magnetic field, and the atoms sputtered from the surface of the target material form a coating on the surface of the substrate. Its advantage lies in the small damage to the substrate during the preparation process, fast sputtering deposition rate, and easy control of film thickness. However, a large number of studies have shown that the thickness of the film prepared by magnetron sputtering is limited, and the bonding force between the film and the substrate is poor. Laser cladding is a method of preparing metal coatings and a new type of surface modification technology. The laser cladding process is that under the action of the laser beam as the heat source, the cladding material on the substrate melts rapidly with the thin layer of the substrate, and the cladding layer is solidified when the beam leaves. Laser cladding has the advantages of fast heating speed, low coating dilution rate and fast cooling speed. The bonding force between the cladding material and the substrate is strong and the influence on the substrate is small. The cladding of materials with excellent performance on the base material not only enables the surface of the base body to obtain excellent performance, but also saves materials and reduces costs. However, laser cladding still has some shortcomings, such as segregation caused by uneven composition and organization during rapid solidification and increased cost due to expensive laser equipment.

3. Performance Characterization

Wear resistance refers to the ability of a material to resist surface damage caused by friction and wear between objects in contact with each other. Wear rate is usually used to indicate wear resistance. Test on the friction and wear testing machine to obtain the friction factor, wear and other wear resistance performance indicators. Under normal circumstances, the smaller the friction coefficient under the same conditions, the better the wear resistance. The wear mass can be calculated from the loss of material mass and volume before and after the friction and wear experiment. The wear mechanisms of solid friction pairs mainly include abrasive wear, adhesive wear, oxidation wear, surface fatigue wear, etc. The actual wear process is often the result of the combined effects of the above-mentioned multiple wear. Jiang [5]used laser surface alloying technology to prepare a high-entropy alloy coating on Q235 steel. The coating wear mechanism is abrasive wear and oxidative wear. The main influencing factors of high entropy alloy wear-resistant coating are: (1) Alloy elements. The hardness of the material is one of the indexes of the wear resistance of the material. According to the Archard relation, the wear resistance of the material increases with the increase of the hardness. (2) Processing method. After the material is properly heat-treated, its structure will change, defects such as vacancies will be eliminated, and the performance of the material can be improved. (3) Other factors. Generally, the workpiece will be served in a special environment (acid or alkaline). It is also a research direction to improve the comprehensive wear performance of the material to extend the service life of the workpiece.

4. Strengthening Mechanism of Wear-Resistant Coating

Factors such as different alloying elements and process parameters will change the wear resistance of the coating. The following are several reasons to improve the hardness and wear resistance of high-entropy alloy coatings:(1) Laser cladding has a higher melting rate and solidification rate, and the movement of atoms and grain growth are restricted, thus promoting grain refinement and improving segregation. Solid solution strengthening and fine grain strengthening increase the hardness of the coating. Gu[6]prepared AlxMo0.5NbFeTiMn2 high-entropy alloy coating by laser cladding. The coating was processed by laser cladding, and the metal was rapidly solidified to promote fine crystal nucleation. After adding Al, it also produced solid solution strengthening, hardness and wear resistance. Sexual improvement. (2) The lattice distortion usually causes the internal energy of the material to increase, the microscopic stress increases, and the dislocation slip deformation is hindered, which increases the strength and hardness of the material. The high-entropy alloy composed of multiple elements produces obvious lattice distortion, and the strength and hardness are also significantly improved. (3) The formation of protective film on the coating surface can increase hardness and wear resistance at the same time. (4) Generally, the hardness of the BCC phase is higher than that of the FCC phase, and the hard Laves phase has a second phase strengthening effect, both of which can greatly increase the hardness of the coating. Li[7]prepared AlCoCrFeNiNb0.75+WC high-entropy alloy coating on 304 stainless steel by laser cladding technology, and studied the effect of WC content on the structure, hardness and friction and wear properties of the coating. (5) Adding a certain alloy element can improve the hardness and wear resistance of the high-entropy alloy coating. Zhan[8] prepared AlCoCrFeNiSix high-entropy alloy coating on the surface of AISI304 stainless steel. The addition of Si element enhanced the solid solution strengthening, dislocation strengthening and fine-grain strengthening of the coating, and improved the hardness of the coating.

5. Conclusion

HEA coating can improve the surface properties of the material under the premise of maximizing the retention of the performance of the substrate, which can save costs and solve the adaptability problems caused by technological innovation. It has important development space and market prospects. Factors and strengthening mechanisms are discussed and analysed, and the research status of high-entropy alloy wear-resistant coatings are discussed and analysed, so as to improve and enrich the relevant theories of high-entropy alloys.

Acknowledgements

Supported by Key Scientific Research Projects of Henan Province, China (20B430022), Science and Technology Guidance Project of China National Textile and Apparel Council (2020029), Henan Undergraduate Training Program for Innovation and Entrepreneurship (S202010465030).

References

[1] Yeh J W (2006). Recent progress in high-entropy alloys. European Journal of Control, vol.31, no.6, pp:633-648

[2] Ma Mingxing, Wang Zhixin, LU Jinbin (2019). Effect of CeO2 doping on microstructure and wear resistance of CoCrCuFeMn high-entropy alloy. Transactions of Materials and Heat Treatment, vol.40, no.9, pp:50-56

[3] Zhu Shuaishuai, Yu yaqiu, Zhang Baosen (2020). Microstructure and wear behaviour of in-situ TiN-Al2O3 reinforced CoCrFeNiMn high-entropy alloys composite coatings fabricated by plasma cladding - sciencedirect. Materials Letters, vol.272,127870

[4] Wu Yuqing (2020). Investigation on Preparation and Tribological Properties of Plasma Sprayed High-entropy Alloy Coatings. Yangzhou University

[5] P.F.Jiang, C.H.Zhang,S.Zhang (2020). Fabrication and wear behavior of TiC reinforced FeCoCrAlCu-based high entropy alloy coatings by laser surface alloying. Materials Chemistry and Physics, vol.255,123571

[6] Gu Zhen, Xi Shengqi, Mao Pu (2020). Microstructure and wear behavior of mechanically alloyed powder AlxMo0.5NbFeTiMn2 high entropy alloy coating formed by laser cladding. Surface and Coatings Technology, vol.401,126244

[7] Li Dayan, Jiang Hui, Zou Longjiang (2019). Effects of WC Content on Microstructure and Properties of Laser Cladding AlCoCrFeNiNb0.75 High-entropy Alloy Coating. Hot Working Technology, vol.48, no.10, pp:117-121+126

[8] Zhang Guozhong (2020). Research on Microstructure and Properties of A1CoCrFeNiSix High Entropy Alloy and its Texture Coating Fabricated by Laser Cladding. China University of Mining and Technology