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Thermal Spray Technology in Automotive Industry Applications

Yajie Zhang

University of Science and Technology Liaoning, Anshan, Liaoning, China.

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***Corresponding author:** Yajie Zhang, University of Science and Technology Liaoning, Anshan, Liaoning, China.

Abstract

As an advanced surface treatment technology, thermal spraying plays an increasingly important role in the automotive industry. This article will introduce in detail the common methods of thermal spraying, such as flame spraying, arc spraying, and plasma spraying. It will also explain their unique technical characteristics, including uniform coating, strong bonding force, wear resistance, and corrosion resistance. Next, the article will focus on the application of thermal spray technology in automobile manufacturing, maintenance, and common coatings. In the automobile manufacturing industry, thermal spray technology is widely used for anti-corrosion and wear-resistant treatment of key components such as engines and chassis. In the field of automobile maintenance, thermal spray technology can be utilized to repair damaged parts and extend their service life. Additionally, thermal spray technology can prepare coatings with special functions, such as heat insulation and conductivity, among other commonly used coatings. Finally, this article will discuss the development trends in thermal spray technology, including research on new materials, process optimization, and intelligent applications, to further enhance the utilization of thermal spray technology in the automotive industry.

Keywords

Thermal spraying, methods, characteristics, applications, development trends

1. Introduction

Thermal spray technology [1] is one of the surface technologies widely used in equipment maintenance and machinery manufacturing. Thermal spraying is a surface processing technology that uses a heat source to heat the spray material to a molten state and blows it through airflow to atomize it and spray it onto the surface of the part at high speed to form a spray coating. The spraying temperature, the impact speed of the melt on the substrate surface, and the properties of the material forming the coating form the core of spraying technology. The entire development of thermal spray technology is basically advancing along these three main lines. Temperature and speed depend on different heat sources and equipment structures. In a sense, the higher the temperature and the greater the speed, the more conducive to the formation of excellent coatings. This highlights the importance of temperature and speed in the overall development of technology. Competition and coordination are essential aspects of the process. The wide range of spray material options is another advantage of thermal spray technology. It is these three elements, as well as many other controllable influencing factors, that make thermal spraying a truly unique technology with superimposed effects. It can design a variety of modified surfaces as needed, and obtain the benefits from general machines. City maintenance, until it is widely used in high-tech fields such as aerospace and bioengineering. As an important application of material protective coating technology, thermal spraying technology has the following characteristics: compared with other coating technologies, it has a fast deposition speed and is easy to automate to achieve mass production. Since the coating is not repairable, its quality must pass the process. The consistency is strictly controlled. The coating preparation has the characteristics of line of sight. It is a single-piece gradual accumulation production method. It is suitable for preparing coatings on the surface of structural parts of different sizes. It can not only prepare coatings on the entire part surface but also on limited parts of the surface, preparation of coatings with good flexibility [2].

2. Thermal spraying method

2.1 Flame spraying

Flame spraying is a method that uses the combustion of flammable gas as a heat source to melt and atomize metal wire or powder and blow it onto the surface of the substrate. The core of this method is to use the high temperature of the flame to bring the spray material to a molten state, and then atomize it through a specific spray device and spray it evenly on the target substrate. Due to the limitation of the combustion gas temperature that flame spraying relies on, the melting point of spraying materials is usually controlled below 2500°C, which makes flame spraying widely used in industry.

In recent years, with the continuous advancement of technology, supersonic flame spray technology has emerged. By optimizing the combustion process, this technology allows the injection speed to be as high as twice the speed of sound, and the speed of molten particles to be as high as 400m/s, which is about 4 times that of ordinary flame spraying and far faster than the speed of plasma spraying. Therefore, the coating prepared using supersonic flame spraying technology is denser and has greater bonding strength.

Supersonic flame spraying technology has a high deposition rate and stable coating performance, which makes it particularly suitable for spraying high-performance coatings such as carbide coatings. For special-purpose vehicles, their key components have extremely high requirements for coatings, which need to have good wear resistance, corrosion resistance and other properties. Therefore, supersonic flame spray technology has important application value in the manufacturing and maintenance of special vehicles.

In general, flame spray technology, especially supersonic flame spray technology, plays an increasingly important role in the automotive industry with its unique advantages. With the continuous development and improvement of technology, it is believed that flame spray technology will bring more innovation and application value to the automotive industry in the future.

2.2 Arc spraying

Arc spraying is an advanced surface treatment technology that uses the arc generated between two continuously fed metal wires as a heat source to melt metal. During this process, the molten metal is atomized by compressed air to form fine metal particles, which are accelerated and sprayed onto the surface of the workpiece to ultimately form a uniform coating.

Due to the low velocity of spray particles in traditional arc spraying technology, the coating is severely oxidized during the formation process, which in turn affects the quality and performance of the coating and limits its application in certain fields. However, with the advancement of science and technology, the emergence of high-speed active arc spraying technology has injected new vitality into the development of arc spraying technology.

High-speed active arc spray technology uses high-pressure airflow or high-speed jets generated by fuel combustion to atomize droplets of spray material. This technology can not only improve the stability of the arc and enable spray particles to achieve higher speeds but also significantly reduce the contact time between particles and air, thereby reducing coating oxidation. Through this method, the quality of the coating is significantly improved and the bond between the coating and the substrate is stronger.

The application of high-speed active arc spraying technology not only broadens the application scope of arc spraying technology in automobiles, aviation, machinery, and other fields but also improves product quality and performance, bringing significant economic benefits to enterprises. With the continuous development and improvement of technology, it is believed that arc spraying technology will play a greater role in the future and bring more innovation and value to industrial production.

2.3 Explosive spraying

Explosive spraying uses the high energy generated by the gas explosion to heat and accelerate the spray powder so that the powder particles bombard the surface of the workpiece at a higher temperature and speed to form a coating. It is a high-energy spraying method. Compared with general flame spraying, a sufficiently high gas pressure must be provided to produce a flame flow up to 5 times the speed of sound (1830m/S). The consumption of gas is also very large. In terms of oxygen, it is usually 10 times higher than that of general flame spraying [4]. When spraying, a specific pressure ratio of oxygen and acetylene is initially introduced into the inner cavity of the water-cooled spray gun through the air inlet. Subsequently, the powder is fed into the powder supply port, followed by igniting the spark sleeve. The mixture of fluorine and acetylene burns and explodes, producing high-temperature and high-speed airflow. The powder is heated and hits the surface of the substrate at high speed (about 3 times more than the speed of sound) to form a coating, and then purge the barrel with nitrogen to prepare for the next spraying. Repeat this. The bonding strength between the explosive spray coating and the substrate can reach over 100 MPa, and the dense porosity of the coating is less than 1% with minimal thermal damage to the workpiece. The coating thickness is uniform and easy to control. The coating has high hardness and good wear resistance. Explosive spraying can be controlled by a microcomputer and is easy to realize automation.

2.4 Plasma spraying

Plasma spraying is an advanced thermal spraying method that uses a non-transfer plasma arc as the heat source and spray materials in powder form as the coating source. The core of this method is to use a high-temperature plasma arc to melt the spray material and spray it evenly on the surface of the substrate through a specific spray device, thereby forming a strong, wear-resistant, and corrosion-resistant coating.

In the plasma spraying process, the choice of working gas is crucial. Commonly used working gases include argon (Ar) or nitrogen (N2). In order to improve the stability and activity of the plasma, 5% to 10% hydrogen (H2) is also added. After these gases enter the arc-shaped area of the electrode cavity, they are heated and dissociated by the high temperature of the arc, forming high-temperature, high-energy plasma. The temperature of the plasma is extremely high, reaching more than 15,000°C, which is enough to quickly melt the spray material.

Plasma spray technology has many advantages. First of all, due to the high-temperature characteristics of plasma, high-melting point, refractory spray materials can be melted to prepare coatings with special properties. Secondly, the coating quality of plasma spraying is high, and the bonding force between the coating and the substrate is strong, which can effectively improve the wear resistance and corrosion resistance of the substrate. In addition, plasma spraying technology also has the advantages of high spraying efficiency and good coating uniformity, making it widely used in aerospace, automobile manufacturing, mechanical processing, and other fields.

With the continuous development of science and technology, plasma spraying technology is also constantly innovating and improving. In the future, we can expect plasma spraying technology to play an important role in more fields and bring more innovation and value to industrial production.

3. Characteristics of thermal spraying

3.1 Characteristics of flame spraying

Flame spraying has a high deposition rate and stable coating performance. It is especially suitable for spraying carbide coatings and is very suitable for application in special vehicles.

3.2 Characteristics of arc spraying

High bonding strength; high production efficiency, low cost; good safety, stable spray quality, and high energy utilization. The anti-corrosion principle of arc spraying long-term anti-corrosion composite coating on the steel matrix is the combined effect of physical shielding and cathodic protection. The main function of the sealing coating is to physically isolate the erosion of various corrosive media on the metal spray coating and the steel matrix. Arc spraying metal coating provides cathodic protection to the steel matrix by sacrificing itself to protect the steel. The corrosion resistance of the composite coating formed by spraying zinc or aluminum and then sealing is 50 to 130% higher than the sum of the corrosion resistance life values of the zinc or aluminum coating and the sealing coating.

3.3 Explosive spraying

The workpiece has little thermal damage, the coating is even and the thickness is easy to control. The coating has high hardness and good wear resistance. Explosive coating can be controlled by a microcomputer and is easy to realize automation. The explosive spraying process can spray a wide range of materials, from aluminum alloys with low melting points to ceramic materials with high melting points. Explosive spraying can be used. The bonding strength between the coating and the substrate is high, which is the highest among currently known thermal spraying processes. Explosive spraying: The density of the layer is high, and the porosity is the lowest among known spraying processes [5].

3.4 Plasma spraying

Plasma spraying has a high temperature and controllable gas break and can be used to coat metals, oxides, and various other traditional materials with high-density coatings. Plasma spraying technology has developed rapidly in recent decades. Vacuum plasma spraying, controlled air emulsion plasma spraying, solution, and other meat spraying, and supersonic plasma spraying have been developed recently.

4. The application of thermal spraying in the automotive industry

4.1 Application in automobile manufacturing industry

4.1.1 On car engines

Piston rings have to withstand the effects of high-temperature and high-pressure gas in the cylinder. They have a short service life due to wear at high speeds and under difficult lubrication conditions. Therefore, in addition to high strength and impact toughness, the piston ring material must also be heat-resistant and wear-resistant. The HVOF process is used for the alloy steel, cast iron, and stainless steel base of the piston ring, and the CsC-NiCr coating is sprayed to improve the wear resistance of the piston ring;

4.1.2 On automobile gearbox

If the gear shift synchronization is broken, synchronization is achieved by friction. After spraying a layer of aluminum-molybdenum alloy, the gear can have a self-locking function during operation, ensuring safe and stable shifting control performance of the shift fork and transmission box, reliability and life span have a great impact. Therefore, in product design, Cu-A1 and Ni-A1 thermal spraying treatment on the working surface of the shift fork can improve the wear resistance, lubricity, and fatigue strength of the shift fork; In automobile braking systems, spraying oxidized knots on the steel substrate can be used as a disc material to improve the wear resistance of the brake disc. During the body molding process, a sunken area will be formed at the weld between the roof and the front panel. The previous method to compensate for this defect was to grind away the excess solder, thus reducing the strength of the weld. Nowadays, arc-sprayed silicon bronze has been used to fill the seam area, which not only softens the appearance of the car body but also enhances the strength of the weld;

4.1.3 In automotive electrical appliances and control devices

The hydrogen sensor is used to detect the oxygen content in the exhaust gas. The sensor probe needs to withstand high temperatures and be corrosion-resistant. The platinum and zirconium oxide substrates are plasma sprayed with a ceramic coating containing Al203-MgO to protect the sensor probe and improve fuel injection. Precise closed-loop control helps reduce fuel consumption and vehicle emissions. In the ignition system, the steel base of the distributor rotor is coated with A1203-Ti02-ceramic coating by plasma spraying, which can reduce the distributor's noise. It is sprayed on the aluminum alloy base Fe304 coating is used as a magnetic sensing material on the short sensor.

4.2 Application of thermal spraying in automobile repair

Parts that fail due to wear and tear during the driving of the car can be restored to their original dimensions using thermal spraying technology and processed, thus reducing maintenance costs without reducing performance.

Thermal spraying can be used to repair failures caused by wear of moving parts such as cylinders, pistons, and crankshafts. For example, for automobile wheel axles that have failed due to wear and tear, C314 iron-based alloy powder is purchased as a spray material for plasma spraying. After repair, the original quality requirements can be fully met, the service life is extended, and it has obvious economic benefits.

5. Trends and Characteristics of Thermal Spraying Development

5.1 Large-area long-term protection technology has been widely used

For steel structural parts exposed to the outdoor atmosphere for a long time, spraying aluminum, zinc, and their alloy coatings is used instead of the traditional painting method, and cathodic protection is implemented for long-term atmospheric anti-corrosion. For example, television towers, bridges, highway facilities, water gates, and large-scale projects all use spraying aluminum, zinc, and their alloys for anti-corrosion.

5.2 Repair and strengthen the localization of large equipment and imported parts Repair and strengthen the localization of large equipment and imported parts

In recent years, there have been many successful application examples in this area, such as a 1.7-meter rolling mill, high-speed fan rotor, large extruder plunger, etc. The implementation of these tasks has, firstly, solved the urgent need for production; secondly, it has saved a lot of foreign exchange.

5.3 Gas deflagration spraying technology is further applied

Since the particle flight speed of this spraying technology can reach more than 800m/s, the bonding strength between the coating and the substrate can reach more than 100MPa, and the porosity is <1%, it is better than other spraying methods in certain fields. At present, more than 10 units have been installed in China.

5.4 Thermal spray technology is applied in chemical anti-corrosion engineering:

Corrosion is one of the main reasons why mechanical components fail due to the chemical or electrochemical effects of the surrounding medium. It not only causes the loss of a large amount of metal materials but also makes the loss of production shutdown more difficult to estimate, so people pay special attention to chemical anti-corrosion work.

5.5 Laser remelting technology begins to be applied

In recent years, high-frequency induction remelting and vacuum induction remelting have only been used within a certain range. Laser remelting technology has been tested on a small area in the past few years and has not been widely used. Recently, Tsinghua University has used laser remelting technology in valve production, and Shanghai Second Textile Machinery Factory has applied laser remelting technology in textile machinery.

5.6 Has also been used in construction, decoration, medical, and health care

Thermal spray technology has also been applied in architectural decoration, medical, and health care. For example, the large-scale peacock spreading mural in Shenyang International Mall uses thermal spray technology. This technology has penetrated into other fields. For example, in the biological field, thermal spraying is used to manufacture artificial bones. There are currently more than 200 clinical cases in China. In addition, artificial teeth manufactured using thermal spraying have also been initially used.

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