

A Critical Analysis of Cold Spray Coatings and its Tribological Performances

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Abstract

Coatings are utilized for temperature barrier, protection against corrosion and wear etc. Cold spray is a solid-state processing method that is unique among thermal deposition procedures since it deposits particles at temperatures below their melting point. This technology does not involve particle melting, hence retaining the original properties of the materials. Increased coating strength is achieved by retaining of feedstock powder microstructures and characteristics, which prevents oxide formation and other undesirable structural changes. Cold spray is still an emerging, but very promising, technology. In some applications, it offers a way to overcome important limitations of traditional thermal spray technologies, such as high levels of porosity and oxide in the sprayed material. It is well suited for the deposition of oxygen or temperature-sensitive compounds. This process offers a range of technical advantages compared to the thermal spraying method, as it relies on kinetic energy rather than thermal energy. Currently, this process is widely utilized in different sectors to enhance the worth of an item, as it effectively enhances the usability and efficiency of numerous industrial products. When compared to conventional thermal spray processes, cold spray technology is superior at decreasing porosity, increasing hardness, adhesive strength, and retaining characteristics of feedstock powders. This review paper summarizes the cold spray coating technique, focusing on its salient characteristics and practical uses.

Keywords: Cold Spray Coatings, Thermal deposition, Kinetic energy, Hardness, Porosity

INTRODUCTION

Surface modification can be achieved through the application of several methods. Coatings can experience mechanical, tribological, corrosion and erosion changes as a result of this, as well as other undesirable effects such as increased stress residue, propagation of cracks, material oxidation, and phase transition. Due to its many advantages over other thermal spraying methods, the use of cold spraying has been increasingly prevalent in recent years [1]. The cold spray method eliminates the requirement for using fossil fuels by applying coatings via the low-temperature heating of powder impacting at high speeds on the base material.

The HVOF coating process is very harmful to the environment because it requires a plenty of energy

and produce a great amount of harmful gases like carbon monoxide and carbon dioxide when fossil fuels like kerosene, LPG etc. are burned with oxygen in the combustion chamber. An environmentally friendly technique known as the cold spray coating process can be considered as a potential alternative to the HVOF process in order to solve this issue. CS is a technique that has been found to be effective in depositing coatings that are tightly packed, with particles that are interlocked, resulting in reduced porosity. These coatings also tend to have higher micro hardness and are purer, with very low

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The use of high-pressure gases like helium or nitrogen are utilized in the cold spray technique. Feed stock powder is heated lower than the point of melting. The heated powder is then accelerated via a de Laval nozzle at high speed before crashing onto the substrate. More material is left behind when the flow is stopped for a longer time. What makes cold spray work is the idea that energy should be kept in the same form. It has kinetic energy, which is changed into heat and deformation energies when the feedstock material hits something. This causes serious plastic deformation in one area. It then moves to the substrate's surface, where it heats up a little, but not enough to change the phase. Figure 1 is a picture that shows how cold spraying works. When the coating is made in a plastically distorted state, it has few holes and a high level of adhesion and cohesion strength. This makes the coatings less hard, less likely to rust, and less likely to wear down.

APPLICATION OF COLD SPRAY COATING

Increasing the value of a product by making it more useful and efficient is a common practice in many businesses today. Many complicated elements are lasting longer and needing less replacement as a result of cold spray methods [14]. Due to several properties of CS, it is widely used in different sectors as depicted in Figure 2. Many different sectors utilize cold spray to prevent corrosion, including automotive, aerospace, glass production, metal processing, chemical and printing [15]. The cold spray technique may be used to cover a wide range of metallic and composites. The cold spraying procedure is commonly used to generate aluminum (Al) and its alloy coatings, which find widespread use in the aerospace industry. These coatings are ideal for protecting against corrosion since they are very resistant to oxidation [16]. Copper based cold sprayed protective coatings have proven to be highly effective in combating corrosion, making them a popular choice in various applications such as thermal exchangers, electronics sectors, and conducting systems. Cold spray is utilized in electronic industries to improve the electrical properties of materials due to its superior thermal and electrical conductivity by the resulting coating. The utilization of cold gas dynamic in power electronics is mostly attributed to the prevalent usage of ceramics as insulating substrates. Cold spraying methods are also used to create copper matrix composite coatings for potential use in electrical applications [17].

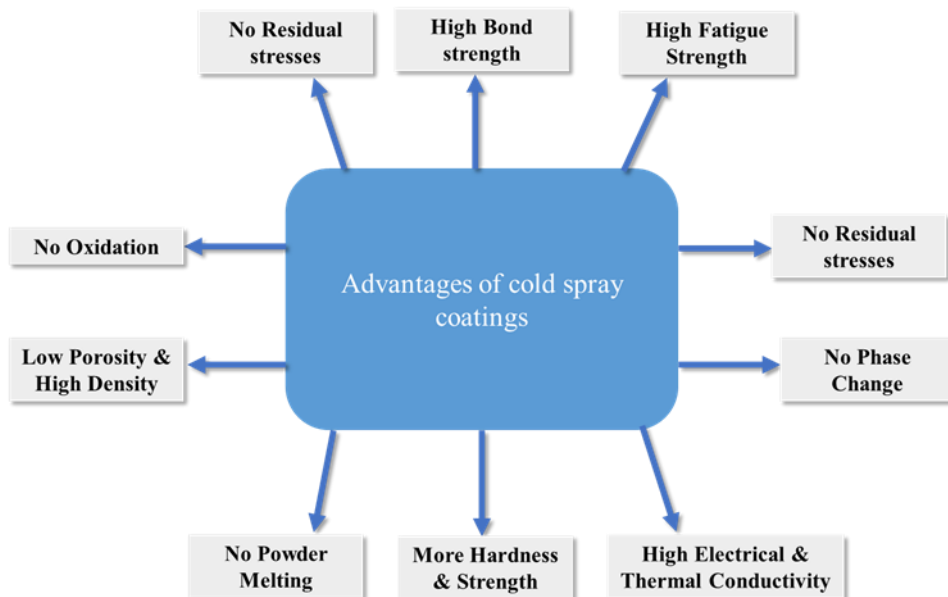


Figure 2. Advantages of cold spray

Several studies into the effectiveness of the cold spray approach in protecting coal fueled boiler tubes against high temperature corrosion have been carried out by many researchers [18]. These researches show that cold spray coating is an effective method for reducing erosion corrosion in boiler tubes. This type of coating is commonly used for fixing and maintaining things[19].Zinc and its alloys have been

found to offer exceptional resistance to corrosion in cold spraying coatings[20].Metals (Co-based, Fe-based and Ti-based alloys), polymers, and some ceramics that are biocompatible have been successfully deposited using cold spray processing for use in tissue engineering and antimicrobial applications. Cold-sprayed stainless steel and Ti alloys coatings enhance biomedical implants more [21-23].Bio-ceramic deposit (HAP and Ti) was studied to enhance bone amalgamation in medical and dental implants for a variety of applications [24].High-temperature corrosion resistance is a major selling point for nickel and nickel alloy cold spray coatings in the power generating industry [25].Good corrosion resistance may be achieved with Al-5Fe-V-Si metal cold spray coatings, making them a popular choice for use in internal combustion engines and other automotive applications [26]. Several studies have examined on Al matrix composite coatings on surfaces to improve toughness, resilience to wear, and resistance to corrosion. The TiAl3-Al cold spraying coatings have proven to be highly effective in maintaining their anti-corrosion properties and durability even in high temperature environments. Numerous power and aviation companies employ this coating for repair and maintenance work because of its many benefits [27].A significant proportion of the wetted surfaces in nuclear power plants are comprised of austenitic iron and nickel alloys, which are known to be susceptible to stress corrosion cracking. The utilization of a CS approach has been found to be highly efficient in the restoration of alloys composed of nickel and iron due to the absence of a heat affected zone (HAZ) and the little requirement for surface preparation. For carbon steel that a coating of cold-sprayed Ni provided superior protection against corrosion in an alkaline environment [28]. The findings of the study indicate that the implementation of the proposed method effectively mitigated flow accelerated corrosion, leading to a notable extension in the operational lifespan of the various components within the nuclear power plant. Cobalt-nickel (Co+Ni) alloys are commonly utilized in the repair and maintenance of vital components in nuclear power plant systems [29].The commonly used nuclear plant material Inconel was coated with a cold sprayed Ni coating. Ni coating was found to produce a deposit that was clean, uniform, had few pores, and had an excellent adhesion ability [30]. Coatings made from WC+AISI316 are commonly utilized in the aviation sectors due to their notable resistance to corrosion [31-32]. Additionally, they also observed that cold sprayed coatings of Cu-Al₂O₃ and Cr₃C₂-NiCrCr₃C₂-Ni have demonstrated favorable resistance to wear and corrosion. Both Al+SiC and Al+Al₂O₃ cold sprayed coatings exhibit excellent corrosion resistance and find widespread use in the electronic industry [33].Cold sprayed WC-Co and WC-10Co-4Cr coatings are popular in the turbine and power generation industries due to their high corrosion and wear resistance [34,35]There are many potential uses for Ti/hydroxyapatite coatings, which are applied using a cold spray technique[36].The use of heat sinks in electronic industries is a common practice, often incorporating a cold spraying coating consisting of a mixture of carbon nanotubes and copper.[37].This coating is employed primarily for its corrosion-resistant properties. The SiC coatings deposited through cold spraying exhibit exceptional resistance to corrosion under elevated temperatures. The utilization of these coatings is prevalent in various sectors such as power generating, petrochemical, and mining sectors [38,39].The primary utilization of WO₃ cold spraying coatings is observed in industries associated with photo electrodes [14].The utilization of TiN cold spraying coatings has been found to effectively enhance both wear and corrosion resistance [26].The utilization of MCrAlY Nano crystalline materials as coatings for thermal barriers has led to their extensive application in industries associated with turbines. The utilization of nano crystallized cold spraying coatings of Al/Fe has improved anti- corrosion resistance characteristics when exposed to elevated temperatures [40].Additionally cold spraying coating consisting of CuNiFe are employed as inert anodes in the manufacturing of aluminum[26].Polyamides and polyethylene cold sprayed coatings have demonstrated exceptional efficacy in safeguarding against corrosion, rendering them extensively employed inside chemical industries [41].The cold spray approach to repair corrosion-induced damage on the aluminum 1163RDTV aircraft alloy have been employed by some researchers[42].Cold spraying method is applied to analyze the effects of pure aluminum powder, both uncoated and coated, on AZ31B magnesium alloy for resistant to corrosion and corrosive fatigue life[43].The erosive wear properties of cold spraying composites Ni-WC coating on mild steel substrates was examined by investigators[44]. Additionally, the researchers performed a comparison analysis between these coatings and a Ni coating. It has been observed that the erosion rate can be increased by decreasing the

water content in the coating. A comparative analysis of the outcomes resulting from the application of Stellite 21 coating on low carbon steel using two different techniques: cold spraying process and High Velocity Oxy Fuel was conducted by the researchers [45]. The main aim of their study was to evaluate the oxidative and tribo-mechanical attributes related to each method of coating application. The wear and oxidation behavior of samples coated with CS demonstrate superior characterization in comparison to specimens coated with HVOF.

CONCLUSION

Cold spray technology has developed as a potential solution for a variety of tribological applications, with specific advantages over traditional methods. The following are the highlights of this technology:

- The cold spray technique offers great potential in tribological applications due to its low heat input, minimum substrate deformation, and ability to deposit a variety of materials without oxidation or degradation.
- These attributes make it especially well-suited for improving surface qualities associated with friction, wear, and lubrication in several industrial sectors, including aerospace, automotive, marine, and manufacturing.
- Cold spray has the capability to quickly apply thick coatings, especially on surfaces that are uneven or sensitive to heat. This allows for the development of durable protective layers that can endure challenging operational circumstances.
- The solid-state process also stops the substrate from breaking down when heated and lets materials with specific microstructures and properties be deposited, which improves the performance of the part in certain tribological conditions.
- Cold spray coatings improve wear resistance, friction, lubricant retention, and distribution on functioning surfaces. This allows sophisticated tribological systems with optimized friction and wear characteristics to lengthen component lives, enhance energy efficiency, and minimize maintenance.
- Cold spray technology has shown tremendous potential in the field of friction and wear applications, but investigators are still optimizing process parameters, exploring new materials and alloy compositions, and improving coating adhesion and microstructural control.
- These endeavors will aim to expand the range of cold spray technology in tribology and accelerate its use in a more extensive array of industrial applications, consequently enhancing performance, durability, and sustainability across diverse engineering fields.

DECLARATION OF INTEREST

The author declare that there is no conflict of interest regarding the publication of this manuscript.

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