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A Review onWC based cermet Coatings on Steel Substrate

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Abstract

Cermet is a category of materials that combines elements of ceramic and metals to create materials with the greatest qualities of both, including high hardness, resistance to abrasion and wear, resistance to erosion and corrosion, and resistance to deformation under high temperatures. In recent decades, WC-based cermet powders have been coated on steel using a variety of thermal spray processes, including detonation guns, high velocity oxygen or air fuel, plasma spraying,and other cladding methods like tungsten inert gas arc and laser cladding. In recent years, WC-based Cermet coatings on steel have been more well-liked as a possible method for enhancing metallurgical, mechanical, erosion, corrosion and wear qualities. This review paper summarizes the tungsten carbide-based cermet coatings on various grades of steel substrates.

Keywords:Micro hardness;Corrosion Resistance;WearResistance;*WC based Cermet*Coatings.

1. INTRODUCTION

As engineered composites, Cermets display exceptional hardness and toughness, which are typical properties of metals (binder phase) and ceramics (reinforcement phase). As ceramic phases, titanium, tungsten, molybdenum, tantalum, vanadium and niobium carbides, oxides, nitrides, and carbonitrides are used. As a metallic binder, molybdenum, nickel and cobalt alloys are frequently employed [1,2]. Cermet coatings have many benefits, such as better resistance to oxidation and wear, increased refractoriness, and mechanical properties. As a result, they are frequently used in forming and cutting applications, bearings, abrasive slurry nozzles, and coatings that resist corrosion and erosion. Their ballistic impact resistance has also garnered them a lot of attention [3-6]. Since the introduction of the first cermets (WCCo) in 1927, several metals and ceramics have been used to improve the qualities of cermets. Nowadays, cermets based on TiC, Ti(C,N), and WC-Co with binders like Co, Mo, Fe, Ni, and alloys are used in many different industries for a range of purposes [7,8].Stainless steel has been used for roofs and building facades since the 1920s. One of the earliest examples of its structural application was a reinforcing chain installed in 1925 to reinforce the dome of London's Saint Paul's Cathedral. Nowadays, stainless steel is utilised in many different structural and architectural elements. Because of its remarkable machinability, high strength, weldability, and toughness, steel is widely used in the transportation, power, construction, and automotive industries. Cermet Coatings are a strong choice for applications requiring resistance to wear and corrosion. They can be deposited utilising a number of thermal spray techniques. Chromium and tungsten carbide coatings are typically applied to machine components to improve their resistance to sliding wear, erosive and hot corrosion, and to lower the coefficient of friction of the mating component [9–10].

Tungsten carbide-based coatings are employed in consumer goods, research, and other industries due to their exceptional mechanical and tribological properties. Due to the high volume % of WC particles bound by a powerful Co or Co-Cr alloy binder, WC cermet coatings have remarkable erosive and abrasive wear resistance [11–13]. Wear protection is required for essential machine parts and components in critical industrial applications, including utility boilers, paper machine cylinders, industrial gas turbines, chemical and offshore process elements, such as ball values and aircraft landing gear axles [14,15]. Currently, the primary commercially available WC-based powders compositions are as follows: WC-12Co [16], WC-17Co [17-19], WC-12Ni [20, 21], WC-17Ni [22-24], WC-10Co-4Cr [25, 26] and WC-20CrC-7Ni [27-30] (all compositions in wt. %). Co is the most widely used binder material since it provides the WC phase with sufficient wetting. On the other hand, WC is typically selected because of its exceptional toughness and hardness as a ceramic [31, 32]. Austenitic stainless steels, such as AISI 316L, have an excellent cost-durability ratio and are essential for use in the chemical industry and energy production because of their high temperature tolerance and harsh circumstances [33–35].

2. RESEARCH PROGRESS IN WC-COCR CERMET COATINGS

Wielage et al. [36] studied the tungsten carbide coatings made by HVOF, APS thermal spraying and electroplated hard chromium coating for abrasive wear resistance. For HVOF sprayed coatings, the effect of abrasive wheels mass loss phenomena in the Taber abraser test was investigated. Based on wear resistance, 86WC-10Co-4Cr emerged as the top-performing cermet material out of those under consideration.

In their study, Pulsford et al. [37] used a new, portable High Velocity Oxy-Air Fuel (HVOAF) thermal spray torch for coating internal surfaces on cylindrical pipes with IDs of 70 mm, 90 mm and 110 mm. They used a commercially available WC-10Co-4Cr powder feedstock to coat the pipes. The coatings' microhardness and fracture toughness were assessed and dry sliding wear behaviour was examined under two loads of 96 and 240 N. Due to poor fracture toughness, the coating sprayed at 110 mm (high ID) demonstrated the highest specific wear rates at both high and low conditions. In contrast, the coating sprayed at 90 mm (medium ID) showed the lowest specific wear rates at high and low conditions due to the highest fracture toughness and microhardness.

Geng et al. [38] investigated the tribological characteristics of low-pressure plasma sprayed (LPPS) WC-Co coatings at high temperatures. They concluded that a higher cobalt concentration is advantageous for the coating because it can retain many bigger WC particles with fewer brittle phases and build a denser microstructure for a higher hardness that may resist wear. The cobalt can slow oxidation and the loss of hard WC phases while preserving the coating's ability to support loads. Additionally, cobalt can encourage the creation of $CoWO_4$ at high temperatures, which might lower friction and preserve wear resistance. As a result, at various temperatures, the LPPS WC-17Co coating exhibits better tribological characteristics than the LPPS WC-12Co coating.

Goyal et al. [39] used SEM, XRD, roughness tester, microhardness tester and optical image analyzer to characterize the HVOF sprayed CoNiCrAlY and WC-Co-Cr coatings on CA6NM turbine steel. A high-speed erosion test equipment was also used to evaluate these coatings under accelerated slurry erosion conditions. In all slurry erosion circumstances, the study found that CoNiCrAlY coating had worse erosion resistance than WC-Co-Cr coating when HVOF was used to spray the coating. The increased hardness of the WC-10Co-4Cr coating applied using HVOF compared to CoNiCrAlY coating may cause this behaviour.

The corrosion resistance and tribological performance of WC-Co coatings are examined by Ghosh et al. [40] regarding surface roughness and residual stress. These are the main findings of this investigation:

1. The wear debris (mostly WC particles) becomes stuck between the rubbing surfaces during the tribotest of the coating as it has been applied. This encourages a robust three-body abrasion action. Therefore, wear occurs due to binder loss and WC particle displacement.
2. As the actual surface area rises, coating corrosion rates also rise. The corrosion of as-sprayed and ground coatings occurs by removing significant numbers of WC particles or pulverized/ fragmented WC particles. Regarding nano-finished coatings, an oxide layer or pseudo-passive film protects against further coating deterioration.

On the 35CrMo steel substrate, Liu et al. [41] used HVOF to deposit standard WC-10Co-4Cr composite coatings and coatings with bimodal structures, respectively. The findings demonstrate that the bimodal coating has improved mechanical qualities, highly dense microstructure, reduced porosity and more excellent slurry erosion resistance compared to the traditional coating. The two types of coatings' erosion-corrosion mechanism, known as spalling, are brought on by the beginning and spread of cracks under fatigue stress.

Zhang et al. [42] used SEM, potentiodynamic polarisation, electrochemical impedance spectroscopy (EIS) and open circuit potential (OCP) to examine the corrosion behaviour of sealed and unsealed nanostructured WC-CoCr coatings by HVOF spraying under various corrosive environments. SEM micrographs showed that the aluminium phosphate sealant was efficiently applied to most pores to decrease the exposed area of the coating. In both 1 mol/L HCl solutions and 3.5 wt% NaCl, electrochemical analysis showed that the sealant may shift the corrosion potential using ultrasonic energy in a more noble direction, increase the resistance of charge transfer, reduce the corrosion current density and significantly improve the corrosion resistance of the coating.

To strengthen cold work die steel wear resistance at high temperatures, Hong et al. [43] developed an effective WC CoCr coatings by HVOF. At each test temperature, the coating outperformed the die steel's wear rate and resistance to sliding wear. However, there were no appreciable differences in the coatings' and die steel's inclinations for friction coefficients to vary significantly with temperature. The coating's nanocrystalline grains and fcc-Co phase can be blamed for these results.

In this investigation, Liu et al. [44] produced WC-10Co4Cr coatings on 35CrMo steel substrates with two different architectures (conventional and bimodal). The outcomes are as follows:

1. The bimodal coating deposited by HVOF offers better mechanical qualities and attributes than the standard coating because of its denser structure, smaller porosity and higher hardness.
2. The primary cavitation erosion failure mechanism is spalling of coating, due to fracture propagation and connection bubble collapse. Additionally, when the bubble bursts, the unmelted WC particles on the surface of traditional coatings peel off to create craters.

Ludwig et al. [45] employed HVOF to deposit WC-10Co4Cr on AISI 410 stainless steel to increase this material's erosion resistance under the circumstances resembling those seen in hydraulic turbines. The following were the key findings from the tests:

1. The amount of oxygen in the gas mixture decreases, increasing the temperature of the particles throughout the deposition process. This, together with the particles' greater velocities at low standoff distances, causes the porosity to drop.
2. The WC-10Co-4Cr coatings created by the HVOF method significantly improve the wear performance caused by slurry erosion compared to the uncoated AISI 410 steel substrate. Within the examined range, the porosity did not affect how well the coatings performed in the erosion test.

Wang et al. [46] suggested an alumina-assisted HVOF treatment process. It has been demonstrated to be a practical method for creating completely densified and spherical WC-Co particles without resulting in phase transitions or interparticle bonding. The WC-Co coating produced by HVOF spraying this powder as feedstock material lacks any observable decarburized phase. The microstructure of the coating, in particular, demonstrates the coexistence of amorphous and nanocrystalline Co. Compared to coatings made with a traditional porous powder, this results in a much-improved Co binder and WC/Co interfacial bonding. The newly created WC-Co coating has a four times greater wear resistance than the traditional coating. The findings further demonstrate that the wear rate of cermet coatings induced by localized brittle fracture and oxidation is significantly lower than that produced by plastic deformation, fracture at interface and micro cutting.

Liu et al. [47] examined three HVOF sprayed cermet coatings and stainless steel 1Cr18Ni9Ti for cavitation erosion mechanism and the effect of the corrosive salt solution on cavitation erosion behaviour. The result showed that coatings resistance to cavitation erosion was affected in various ways by the 3.5-weight percent NaCl solution's corrosive activity. The corrosive solution disintegrated the cobalt matrix of the WC-12Co coating, which facilitated cavitation erosion damage. In contrast, the WC-10Co-4Cr and Cr_3C_2-NiCr coatings' surfaces produced oxidation scales in the NaCl solution that could close surface pores, prevent carbide particles from penetrating them and save against cavitation erosion damage. The WC based coating mainly had the application potential against cavitation erosion characteristic in both corrosive and deionized water.

Using a TIG welding heat source, Singh et al. [48] deposited a strong and wear-resistant WC-10Co-4Cr coating on the stainless-steel specimen. The study's findings may be used to derive They conclude that a higher heat input value slows cooling and lengthens the time needed for cladding to solidify. The longer solidification times allow the WC grains to expand, resulting in a dendritic and coarse WC structure. Additionally, slower cooling rates give WC grains more time to fall to the bottom, increasing WC grain disintegration.

To study the cavitation behaviour in a 3.5-weight percent NaCl solution, Ding et al. [49] constructed multimodal WC-10Co4Cr coatings. The key conclusion of the study is that compared to HVOGF (high-velocity oxygen gas fuel), the multimodal WC-10Co-4Cr particles sprayed using the HVOLF (high-velocity oxygen liquid fuel) system achieved lower particle temperatures and significantly higher particle velocities, leading to the formation of a multimodal coating and disk-shaped splats with lower porosity, superior hardness, less decarburization, corrosion resistance and fracture toughness.

Pishva et al. [50] determined how the depth of cut during grinding affected the corrosion behaviour and surface characteristic of WC-10Co-4Cr cermet coatings. As a result, a WC-10Co-4Cr coating with a 400 µm thickness was applied to the carbon steel substrate utilizing the HVOF procedure. According to the result, grinding of the surface enhanced the coatings' porosity and microhardness while reducing their surface roughness. Additionally, the coating porosity and microcracks increased as the cut depth rose. Consequently, the coating's corrosion resistance was reduced.

In the research of Varis et al. [51], the residual stress states of high kinetic, thermal spray processes like high pressure HVAF and HVOF were compared to those of traditional thermal spray processes. They conclude that thermally sprayed WC-10Co4Cr coatings can significantly increase cavitation erosion resistance when applied using high-pressure HVOF and HVAF techniques. Compared to traditional gas-fueled HVOF procedures, The cavitation erosion resistance of the coatings applied with HVAF was 7.1 times higher and 4.5 times higher when using high-pressure HVOF.

Tillmann et al.'s [52] study found that 316L substrates treated by SLM (selective laser melting) were exposed to several pre-treatment processes before a subsequent WC-Co coating deposition via HVOF spraying. Overall, the results showed that the variously pre-treated 316L substrates subjected to SLM processing adhered well to the HVOF-sprayed WC-Co coatings.

In their study, Singh et al. [53] used TIG welding to deposit a nano-structured WC-CoCr cladding on an AISI-304 stainless steel substrate. The findings showed that the welding current exerts the most significant influence on claddings' wear resistance and hardness followed by standoff distance and welding speed. A microstructural analysis showed that material removal had taken place because the SiC abrasive particles during the sliding motion had pulled out the WC grains and caused the soft CoCr matrix to erupt.

4. SUMMARY AND OUTLOOK

WC based Cermets use a combination of ceramic and metallic phases to create materials with the greatest potential results. Cermet Coatings, which may be deposited utilising a number of sprayed thermally techniques, which provides functional alternative for resistance to corrosion and wear. Coatings of WC-Co and WC-CoCr are frequently used to enhance resistance to sliding wear, erosive and hot corrosion as well as to lower the coefficient of friction in mating components. Despite the high technical potential of nanostructured cermet coatings, Due of the high cost of manufacturing nano powders, their usage is restricted (resistance to wear: erosion, sliding, abrasion). To fully harness the potential of such nanostructured cermet coatings, certain significant enhancements are necessary. End-users may benefit from nano-phased thermal spray cermet coatings because they can deliver new, more effective reduced friction solutions while saving money.

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