Wear Behaviour of Cermet Coatings Deposited by Different Thermal Spray Techniques: A Review

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***Abstract*—Wear and erosion are recognized as a serious problems in coal based power plants, hydro power plants, turbine blades, aircrafts, piston-cylinder mechanism, penstocks and in various industry components. This results the premature failure of the working component or these component does not perform its function properly so there are essential requirement to alter or repair it and one of best option to overcome this problem is the use of protective coatings either nanostructured or conventional coatings. Different composition of WC/Cr_3C_2NiCr coatings are used to enhance the erosion and wear resistance of component in industries. The Nano coatings have good hardness, highly dense, very low porosity and excellent wear resistance so it has great competence to resists the spallation, wear and erosion. In this review paper analysis of previous literatures and summarised the effect of wear and erosion, erodent size and shape, different coating material compositions and thermal spray process and the properties of erosion and wear on the substrate.**

Keywords— Erosion; wear; erodent; WC/Cr_3C_2NiCr coating; wear resistance.

I. INTRODUCTION

Component in working mode operated under extreme conditions in industries. Degradation of materials is becomes a severe problem due to sliding wear and the presence of erodent in working environment [1]. Hydro power plant, boiler power plant, gas turbine, steam turbine, aircrafts, piston-cylinder arrangement, mining are some instances, where wear and erosion limits their use and therefore reduce their durability and reliability. The erosive particles or the erodent are presents in the environment of actual working condition in the industries that can impact at the external or internal surface of the component and resulting in damage due to wear and erosion. Erosion is due to the impact of hard solid particles, presents in the water is a common phenomenon that occurs in hydro power plants especially in hydro turbines and spear and many other industries. Coating protect the substrate from the impact of erodent particles.

The coatings behave like a barrier between the substrate and the erodent or the aggressive environment and protect the component from the erosion. The rate of erosion is depends upon the various factors that is the kinetic energy of the impacting particle, size and shape of erodent, shape factor, density and the shallow impact angle[1].

Nanostructured as well as conventional coatings of tungsten carbide and chromium carbide are broadly use in applications for the wear and erosion resistance for example in steam turbine, gas turbine, and aero-engine and it improve the sliding and erosive wear resistance and hence service life of the component is also extend[2]. Tungsten or chromium carbide thermally sprayed coatings are mainly use to improve the erosion and wear resistance [3-4]. The performance of coating is dependent on the microstructure of the coating, coating powder characteristic and thermal spray process parameters. With various compositions of powder WC and Cr_3C_2 coating i.e. WC-Co, WC-Co-Cr, WC-Ni-Cr and Cr_3C_2-NiCr etc. are use in the industries applications for the erosion and wear resistance. As compared to the conventional coatings nanostructured coating shows better erosion and wear resistance and good surface characteristic because of their low porosity, high hardness and excellent wear resistance [5]. In coal power plant stations large amount of ash are present, it contains many abrasive species like quartz which act as erodent and increase erosion rate in the industry.

II. EFFECT OF ERODENT PROPERTIES AND IMPACT ANGLE ON EROSIVE WEAR

The coating composition, hardness, and microstructure play major determinant role in erosive wear [12]. Desale et al [1] has studied the effects erodent's properties on erosion rate. The erosion rate is highest for Alumina but it has lower hardness as compared to SiC because when the hardness of erodent is higher than the silica (i.e. 700 kgf/cm^2) then the erosive wear is not depend on hardness for same velocity various other factors that is shape factor, impact energy are responsible for erosion. Wear rate is higher for lower shape factor because it shows high angularity and for same particle size and velocity erosion rate is greatly affected by the impact energy i.e. directly proportional to the mass density. So erosion rate depends on hardness as well as shape factor and impact energy. As shown in Table 1. The maximum wear angle is 15° for AA6063 and 22.5° for AISI 304L steel and impact angle is same for all three erodent. So the angle of maximum wear is not dependent on the erodent properties but it depend on the material's properties.

Mishra et al [6] investigated that erosion rate is affected by the erodent use and the impact angle. In investigation SiC and Silica is use as erodent and the erosion is higher due to SiC than the Silica. Due to its hardness and shape (Silica has spherical and SiC has angular shape). The erosion is higher for acute angle due to cutting mechanism (chipping or ploughing) for SiC and 90˚ for Silica due to its spherical shape (deformation).

Liebhard et al [7] found that the feed rate is also play an important role on erosion rate or mass loss. The mass loss is inversely dependent on feed rate as for minimum feed rate the mass loss is higher. The peak value of particle size is must be 300 µm for occurring mass loss, because below this size there is no effective removing of material due to the kinetic energy of particles is too low.

Table 1: Erosion affecting properties

Sr. No.	Erodent	Shape	Density(kgm−3)	Modified shape factor	Hardness(HV)	Wear type	Wear	Ref.
1.	Quartz	Blocky	2650	0.7007	1100	Deformation	lower	1.
2.	Alumina	Angular	3940	0.3425	1800	Cutting	Highest	
3.	silicon carbide	Angular	3220	0.4425	2500	Cutting	High	

Table 2: various properties of different coatings deposited by different thermal spray processes

Sr. No.	Coating composition	Coating method	Porosity (%)	Micro hardness (HV0.3)	Volume loss	Wear resistance	Ref.
1.	WC-10Co-4Cr	HVOF	2.1±1.1	836±30	Lower	Better	8
		D-Gun	1.38±0.3	1096±50			
2.	Cr_3C_2-20(NiCr)	D-Gun	0.65±0.3	894±35	Comparative high	Good	8
		HVOF	1.3±0.6	880±30			
3.	WC–4Cr3C2–12Ni	HVOF	0.7–1.8	1012±90	—	—	10
4.	Cr_3C_2-25(NiCr)	HVOF	1.47	854 ± 93	—	low	9
5.	WC–12Ni	HVOF	1.9–2.8	843±123	—	—	10
6.	WC-12Co	HVOF	0.38	1253 ± 176	—	Better	9

III. EROSIVE WEAR PERFORMANCE OF DIFFERENT COMPOSITIONS OF WC/Cr_3C_2-NiCr COATINGS

Murthy et al [8] studied two kinds of coatings WC-10Co-4Cr and Cr_3C_2-20(NiCr) by HVOF and Detonation gun (D-Gun) thermal spray processes. The wear resistant performance of these coatings is evaluated by high velocity oxy fuel and detonation gun thermal spray techniques. The wear resistance is highest for D-Gun thermal spray coating due to its lower porosity, highly dense, good bonding to subtract and higher hardness and both coatings have higher wear resistance as compared to Chrome coating. As shown in Table 2.

Sahraoui et al [9] investigated that the two types of coatings Cr_3C_2-25(NiCr) and WC-12Co deposited by same thermal sprayed method HVOF. The wear resistance is dependent on hardness and porosity so the wear resistance is superior for WC-12Co than the Cr_3C_2-25(NiCr). The performance of Tungsten carbide coating is largely dependent on carbide size and shape. Cobalt and carbon is present in Tungsten carbide coating and due to presence of high hardness and very low porosity it show better wear resistance, Table 2.Berger et al [10] investigated that WC–4Cr3C2–12Ni and WC–12Ni coatings deposited by HVOF process. The hardness is greater for WC–4Cr3C2–12Ni coating. Tungsten carbide coating with cobalt binder has higher wear resistance as compare to Nickle. WC–3.5%Cr3C2–0.8%VC–12%Ni coating shows higher wear and its Young's modulus is lowest. (see Table 2) Karimi et al [18] investigated the erosive wear performance of WC-M (Co, CoCr and Ni) coating deposited by HVOF process at sand erosion test with mean particle size 120 pm, flow velocity 90 m s^{-1} and 0.3 wt. % abrasive concentration. It is found that the cermet with Co matrix have greater wear resistant properties than the Ni matrix. Addition of Cr is also increase the wear resistance of WC-Co by a factor of 4 to 6 by improving binding of carbide. For common metal composition in cermet the coarse carbide shows higher wear resistance than fine carbide.

IV. THERMAL SPRAY PROCESS

Thermal spray process is the foremost method for offering excellent wear resistance. In thermal spray process combustion and energy (like plasma energy) is use to heat and speeded up the particles which adhere the target subtract and develop uniform protecting solid layer [14]. By different composition and different deposition method desired property like erosion, corrosion resistance, thermal or electric insulation can achieved [13]. Detonation gun spray technique is offer highly dense, good bonding strength due to its higher velocity (about 3500 m/sec) [15]. HVOF and D-Gun spray coatings have viable solution to get desired property like wear resistance, hard and highly dense [16]. Selection of spraying process is dependent on functional requirement, adhesion level (shape and size), availability and cost of equipment [17].

V. CONCLUSIONS

All thermal spraying coatings have good properties and some other factor are also affected the wear resistance and coating performance.

- The shape factor for erodent inversely affected the wear resistance and angular shape erodent are responsible for greater wear than round or blocky.
- Use of Co matrix as binder in cermet improve the wear resistance than the Ni matrix.
- Addition of Cr in coating composition, it enhance the wear resistance of coating by improving binding of carbide.
- The angle for maximum wear depend on material's property not on erodent.
- Loss of mass is inversely depend on feed rate.
- Coating of tungsten carbide has greater wear resistance than the Cr_3C_2-NiCr coating.
- All thermal spraying process have good wear resistance but DG spray has higher wear resistance than HVOF.

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