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The Wear Resistance of HVOF Sprayed Nickle Chromium and Boron Carbide Coatings.

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ABSTRACT

Pin-on-disk dry sliding wear tests were performed under dry conditions against steel counter material for different loads, speed & sliding distances. Sliding speeds ranging from 1.88 to 5.65 m/s and under loads ranging from 10 to 50 N were conducted for pin specimens of Al6061 alloy MMC pin substrate reinforced with ball milled Nickle Chromium & Boron Carbide particles. This paper describes the dry slide wear behavior of Al6061 alloy composite coatings deposited by HVOF coating technique. It was evident from the experiment that the wear resistance of the coatings produced using Nickle Chromium & Boron Carbide powders is greatly improved compared with the substrate material. The highest wear resistances of the coatings were also determined in the coating. Construction and structure of coatings were studied using electron microscopy (SEM) & EDX analysis. The research results showed that all coatings exhibit comparable increase in the wear resistance property of the pin due to the presence of Nickle Chromium & Boron Carbide particles

Keywords: Wear; Composite; Aluminum 6061 MMC; Nickle Chromium & Boron Carbide particles

1. INTRODUCTION

Superior wear resistance is one of the attractive properties in MMCs. It has been found that particulate-reinforced MMCs show wear resistance on the order of 10 times higher than the un-reinforced materials in some load ranges. Many studies have been performed in order to understand the effects of various factors such as the particle size [3], the fraction of the reinforcing particles the load and the sliding speed on the wear resistance of the particulate-reinforced MMCs with Aluminium matrices.[1]

J. Brezinová et al found that the HVOF coating of WC-Co-Cr showed the highest hardness than the coating Cr3C2-25NiCr. Tungsten carbide and chromium carbide-based coatings are frequently used for many of the applications in gas turbine, steam turbine and aero-engine to improve the resistance to sliding, abrasive and erosive wear. The former is used up to 500°C and the latter up to 800°C. Also, for sliding wear and abrasive wear resistance, the carbide coatings are considered to be a viable alternative to hard chrome plating due to the strict environmental regulations and cost concerns with regard to the electroplating process. These cermet coatings are deposited by plasma spray, high velocity processes and detonation gun spray processes [2]

Maria Oksa et al in his work had reviewed HVOF thermal spray techniques. Different variants of the technology are described and the main differences in spray conditions in terms of particle kinetics and thermal energy are rationalized. Methods and tools for controlling the spray process are presented as well as their use in optimizing the coating process [3].Thermal spray coatings are often applied for better corrosion and wear resistance. Therefore, low porosity and good adhesion are desired properties for the coating. High velocity processes—especially HVOF (High velocity oxy-fuel) spraying—are the preferred methods for producing coating with low porosity and high adhesion. In HVOF spraying, heat is produced by burning mixture of oxygen and fuel such as hydrogen, kerosene, propane, propylene, natural gas, ethylene, or acetylene. Due to the special nozzle design, a jet with supersonic speed is produced. The ability to produce dense coatings with low amount of degradation, oxidation of metallic materials, and phase transformations is the main feature of the HVOF process. This is due to the short dwell time of the particles in a relatively cold flame. It is widely used to produce cermet and metal coatings, but the HVOF process has also been demonstrated to be able to deposit dense ceramic coatings.

Cr3C2-NiCr was plasma sprayed on the substrate 1Cr18Ni9Ti in order to solve the erosion wear at high temperature encountered in the oil-refining industry. The erosion-wear test was carried out at room temperature, 400, and 700°C at impact angles of 30° and 90° at a given gas fluid velocity using a high-temperature erosion-wear tester. Plasma sprayed coatings Cr3C2-NiCr improve the erosion resistance of the substrate effectively. . Coating Cr3C2-NiCr has good erosion resistance due to its high hardness and moderate toughness [5]. The suitable combination of moderate process temperature and high particle velocity made HVOF the standard process for manufacturing highly dense cermets coatings (e.g., WC-based and Cr3C2-NiCr) with excellent adhesion to the substrate and low thermal deterioration The pure carbide based coatings, due to brittleness, do not perform well in impact loading conditions. Low porosity, high hardness, high adhesion strength and compression stress are among the most important properties of HVOF-sprayed Ni-based or WC-based coatings which, in turn, comply with the requirement for high wear resistance [6, 7].

A. Aguero et al [9] experimentally studied that WC CoCr coatings were deposited by HVOF thermal spray to be used as candidates to replace electrolytic hard Cr coatings currently employed on landing gear actuators. Powders with different WC particle size and shape as well as flame energies were employed and studied and the resulting coatings exhibited very low porosity as measured by image analysis and higher hardness than electrolytic hard Cr coating

2. EXPERIMENTAL PROCEDURE

2.1 High Velocity Oxy-FuelSpraying (HVOF)

Nickle Chromium-Boron Carbide (Ni80Cr20 & B4C) based coatings were produced by using HVOF spray system. Model- Metallization, Met-PCC (HVOF) Diamond Jet, Plasmatron India, Navi Mumbai-Figure-1. The coatings were applied on Al 6061 MMC (2%Gr+8% Al2O3) substrate. Specimens are initially grit blasted at a pressure of 3 kg/cm2 using Al2O3 having grit size of 60µm for the average roughness of the surface was 6.8µm. The standoff distance in shot blasting was kept between 120-150 mm. The average roughness of the substrates was 6.8µm. The grit blasted specimens were cleaned with acetone in an ultrasonic cleaning unit In the HVOF process; fuel and oxygen are introduced to the combustion chamber together with the spray powder. The combustion of the gases produces a high temperature and high pressure in the chamber (Fig 2), which causes the supersonic flow of the gases through the nozzle. The powder particles melt or partially melt in the combustion chamber and during the flight through the nozzle. The flame temperature varies in the range of 2500 °C–3200 °C, depending on the fuel, the fuel gas/oxygen ratio and the gas pressure. In the HVOF process the particles melt completely or only partially, depending on the flame temperature, particle dwell time, material melting point and thermal conductivity. A few different HVOF spray systems exist with partly different gun designs and capacities.[12,13,14]

This investigation was focused to evaluate the on dry slide wear rate of HVOF coated Ni80Cr20 & B4 C surface with particles with an average particle size of 30 -40 µm with 80 and 20 wt. % ball milled at a laboratory.

Each one has differences in design, but all are based on the same fundamental principles. The combination of high pressure (over 3 bar) and gas flow rates of several hundred litres per minute generate supersonic gas velocities. Spray standoff distance is 200 mm. Chemical analysis of base metal was determined by using vacuum emission spectrometer. Chemical composition of Ni80Cr20-B4C powder was analysed using Energy Dispersive Spectroscopy (EDS).

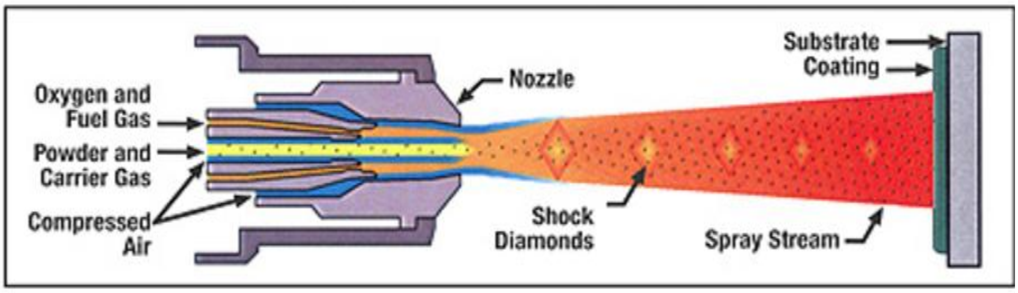

Figure-1: Principle of HVOF process (Courtesy: Eastern Metallizing Co Pvt Ltd, Kolkata)

Microstructures of the surface coated specimens are taken using Scanning Electron Microscope (SEM) connected to Energy Dispersive X-ray analysis equipment's (EDX). SEM images were used for study the distribution of Ni80Cr20 & B4C particles on the substrate. XRD pattern was carried out using X-Ray diffract meter with Cu K radiation using wavelength of 1,790 Å at operating voltage 40.0kV and current 30 mA.

Figure-2: HVOF equipment

2.2Wear Test.

The wear test was carried out using a pin on disc Tribometer (Model: TR-20 LE, DUCOM Bangalore make) as per ASTM G 99. A pin on disc tribometer consists of a stationary pin under an applied load in contact with a rotating disc. The used Pin-on-disc methodology was used [15]. The wear performance of the coating was evaluated at room temperature (25^0C).Samples to be tested were cleaned ultrasonically with isopropanol, dried and weighed before testing. In the present experimental work, 3 types of test were conducted by varying the load; speed and Sliding distance throughout all the coatings are given in the table-1.

Parameters used in Wear test- Table- 1

SL	Parameters	Load,N	Discrotating speed, rpm	Sliding Distance, m
1	Varying the loads	10,30 & 50	600	2000
2	Varying the Speed	30	300,600 & 900	2000
3	Varying the Sliding Distance	30	600	1000, 2000 & 3000

The dry sliding wear test has been repetitively conducted for all the coatings and the average of all the reading was recorded. The wear rate of each sample was calculated from the weight loss, the amount of wear is determined by weighing the specimen before and after the test using precession electronic weighing machine. Since the mass loss is measured it is converted to volume loss using the density of the specimen. In order to study tribological behavior of coatings in severe conditions, the tests were carried out without any lubrication. The worn-out surfaces of the pins were subsequently examined under a SEM to identify the possible wear mechanisms. The wear debris was collected during wear tests and was subjected to morphological characterization under SEM

Gobind et al [4] have reviewed that the HVOF sprayed coatings can play important role in protecting materials and alloys from wear and corrosion phenomena and There has been considerable progress has been made in the HVOF sprayed process by optimizing the process parameters like Fuel Ratio, flow rate, and spray distance over the last few years.

3. RESULTS AND DISCUSSION.

Figure-3, illustrate the surface SEM micrograph of HVOF method showing the uniform distribution of Boron carbide particles in the matrix of Nickle chromium which is ball milled for 12-15 hrs. All the coating revealed that there is a good bonding existing between the metal matrix and reinforcement's .From the microstructure it was found that Nickle Chromium & Boron Carbide uniformly coated with thickness about 180 to 200µm on the surface of Al 60601 MMC.

Fig-4 Illustrate the XRD pattern of the Ni80Cr20 & B4C coating on the Aluminium Composite surface. It is observed that the Ni80Cr20 & B4C coating using HVOF consists of Boron Carbide and Nickle Chromium is dominating phase. During HVOF spraying the different phase transformations are taking place, notable quantity of binder phase is present in the coating. TaharSahraoui et al [8] has mentioned that the nature of the microstructure phases and their percentage in HVOF coatings depend mostly on the heat and mass transfer between the gas jet and the in-flight particles prior coating formation The nature and the stoichiometry of the fuel and the corresponding combustion gases are crucial operating conditions that tune the microstructure and thus the coating properties.

The wear test is conducted under three different loads of 10N, 30 N and 50 N and it is obtained from the test such that the weight loss during the wear test is highest for the load of 50 N and is lowest for the load of 10 N. so it is concluded from the test, as the load increases the wear rate is also increases as illustrated in figure-5. In

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the similar way the wear test for three different speeds of 300,600 & 900 rpm and it is obtained from the test such that the weight loss during the wear test is highest for the speed of 900 rpm and is lowest for the load of 300rpm (Figure-6).So it is concluded from the test, as the speed increases the wear rate is also increases. But in case of sliding distance test, wear reduces as sliding distance increases(Figure-7)

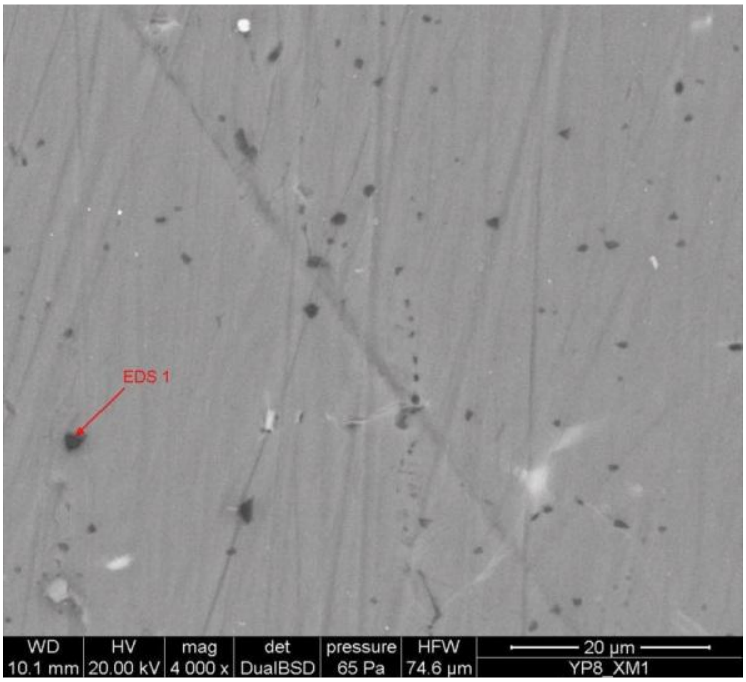


Figure-3: Uniform reinforcement of B4C & Ni80Cr20 particles in coating.

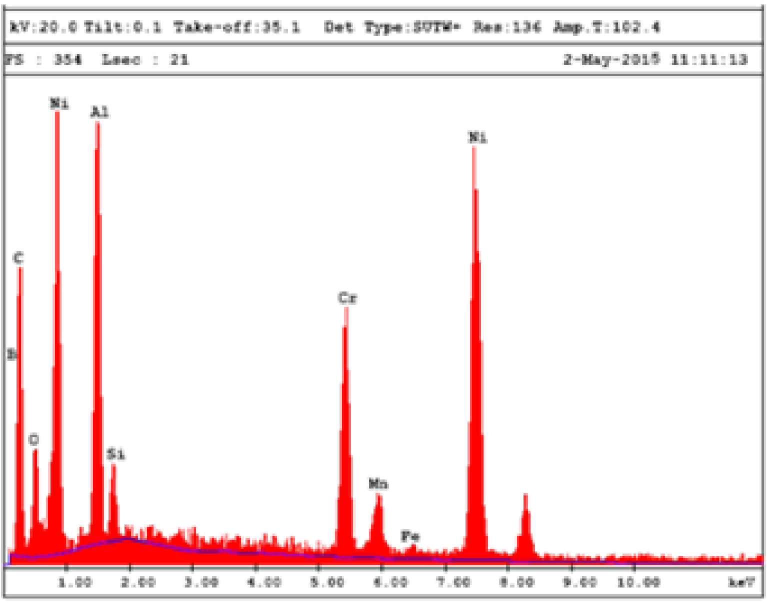


Figure-4: XRD patterns of Nickle Chromium-Boron Carbide coatings

Similar results were found by M. Mruthunjaya et al [15] WC-Co coating is developed on the stainless steel AISI 304 by High Velocity Oxy-Fuel spray technique. L .Parthasarathi et al [10] investigated that plasma sprayed NiCrBSiCFe coating exhibited up to 4.5 times increase in wear resistance compared to the uncoated AISI 316 ASS substrates.

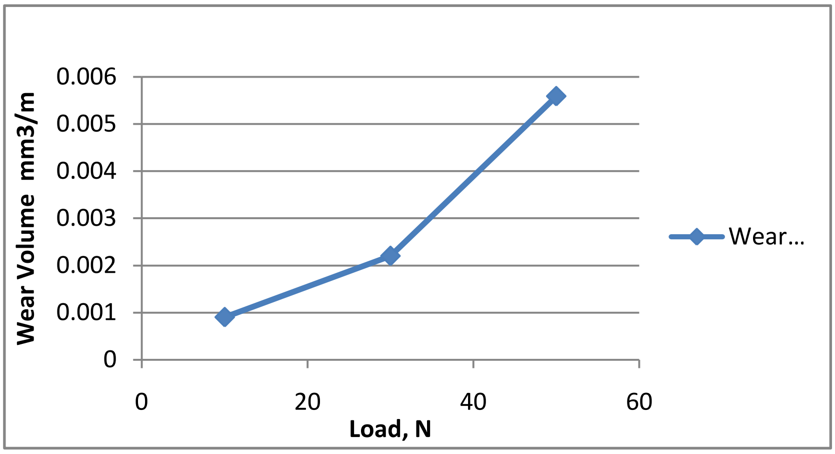


Figure- 5: Wear volume increasing with increasing load

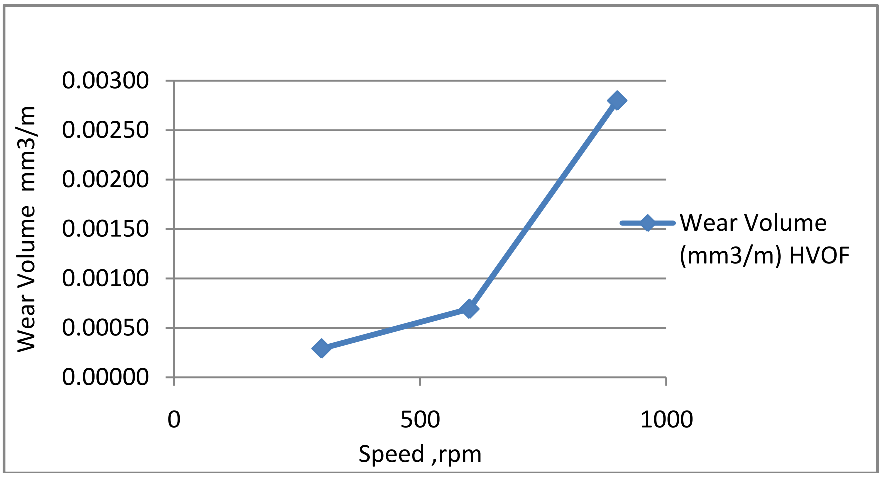


Figure-6: Wear volume increasing with increasing Speed.

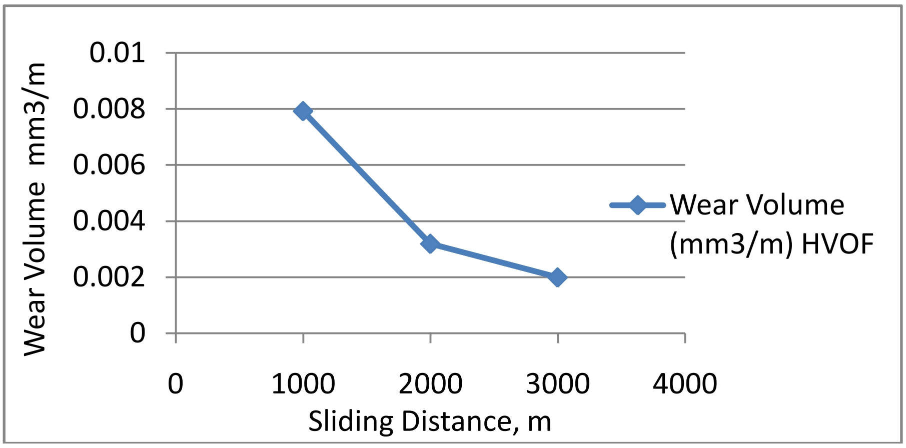
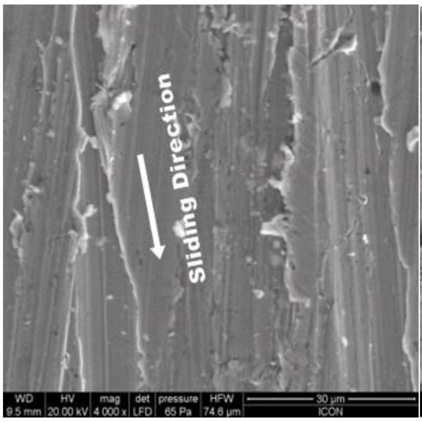


Figure- 7: Wear volume decrease with increasing sliding distance.

The worn surface topographies indicate that the dominant Nickle chromium Phase which retains B4C particles are well anchored into the matrix, they prevent the removal of the soft matrix by micro-cutting mechanisms, as observed in other composite materials It is thus evident that the Ni80C20r-B4C particles effectively protect the coated surface and limit the material removal by the counterpart and we can able to observe in Figure 8 & 9, some of porosity in the coated surface



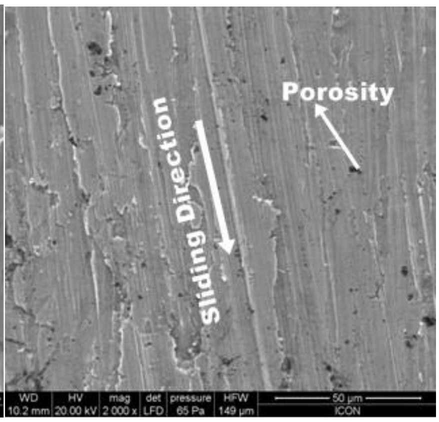


Figure- 8:Worn surface & sliding direction of wear with increase in load.

Figure- 9:Worn surface & sliding direction of wear with increase in speed

4. Conclusion:

The result of the present study Nickle Chromium & Boron Carbide HVOF coatings can be summarized as follows

1. HVOF coating surface SEM shows the fine mesh size coating having fine structure and the homogenous distribution of Boron carbide &Nickle chromium hard face particles.
2. During the coating process the particles remained intact and the composition of the powder particles remained unchanged despite the high velocity application
3. Nickle Chromium and Boron Carbide mixed powders have been successfully deposited by HVOF process to develop coatings of average 200μm thick on Al 6061 MMC composite substrates.
4. The HVOF coatings exhibits better wear resistance by considering different loads and speeds

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