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INVESTIGATION OF HVOF THERMAL SPRAYED MICRO B_4C, MICRO-1%, 2%, 3% NANO B_4C COATINGS ON DRY SLIDING WEAR PERFORMANCE OF 410 GRADE STEEL

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ABSTRACT

Coating Technology is the material Technology of the 21st century, because, thermal spraying as an important tool for study the Surface Engineering Technology. In the present research work, the conventional Boron carbide (B_4C) powder particles of grain size 105 micrometer, and Micrometer sized Boron Carbide were blends with 1%, 2%, 3% of nano sized (44-55x10^{-9}) boron carbide powder particles were sprayed on commercially available, Grit blasted 410 grade steel using High Velocity oxy Fuel Technique. Vickers micro hardness tester was used to measure the Hardness values on surface of the coated and Un-coated substrates. Worn surface morphologies were observed in SEM. The presence of elements boron and carbide particles are confirmed in EDX spectrum analysis. As per ASTM G99, Pin-On-Disc tribometer was used to study the Tribological behavior of these Coatings. It was confirmed from the results, increasing the blending of % of nano powders, enhance the good hardness and Wear resistance compared to Micro B4C coated and Un-coated Steel substrates.

Keywords: 410 grade steel, wear, boron carbide (B_4C), nano B_4C.

INTRODUCTION

Wear can be defined as loss of materials from solid surfaces due to mechanical interactions [1]. Boron Carbide is the third hardest material, and having excellent characteristics like extreme hardness, low density, chemical resistance, good nuclear properties. [2] For various applications thermally sprayed coatings are extensively used to counterpart the surface degradation process such as Wear, Erosion, and Corrosion. Due to minimum duration involved in coating process and lower enthalpy of heat HVOF Process minimize the splitting of carbide phases [3]. Although, B_4C particles properties like lower fracture toughness and poor oxidation resistance may limit its applications, B_4C utilized as surface coating to conduct wear test. [4]. Recently, Nanostructured Boron carbide particles have many advantages over their bulk corresponding particles [5]. To Obtain B_4C of nano structure, several techniques have been developed including CNT Template-mediated. [6-8]. Cr3C2 being harder material and exhibits excellent strength, anti corrosion, anti erosion properties [9].

In the present research work, our aim is to investigate the wear behavior of the thermally sprayed Micro B_4C and 1%, 2%, 3% of Nano B_4C particles blended with Micrometer size B_4C particles under dry sliding conditions at room temperature for different sliding speed and by keeping load as constant.

EXPERIMENTAL PROCEDURE

Materials

A micrometer sized B_4C powder particles of grain size 105 micrometer and nano size B_4C particles were fused and crushed. Micron sized B_4C with 1%,2%,3% volume of nano B_4C powder particles were mechanically prepared using high energy ball milling machine with WC balls. At the speed of 140-150 rpm with 1:1 ball to weight ratio and the ball milling was carried at for 1 hour. The 410 grade steel substrates of size Ø40x3mm thickness were grit blasted using Alumina to improve the adherence of coating and cleaned using acetone and Dried. The chemical composition of 410 grade steel shown in Table-1.

Table-1. Chemical composition of 410 grade steel.

Element	C	Mn	Si	Cr	P	S	Fe
Weight %	0.15	1.0	0.5	11.5-13.5	0.04	0.03	Balance

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Table-2. The 4 different powder chemical composition of B_4C [micro- Nano].

Coating	Excising composition	Powder type
A	Pure B_4C	
B	Micro-B_4C-1%Nano B_4C	Blend
C	Micro-B_4C-2%Nano B_4C	Blend
D	Micro-B_4C-3%Nano B_4C	Blend

COATING PROCEDURE

HVOF technology was used to spray low melting point materials like metals, metal ceramic composites. Due to well adhering and dense coating, HVOF systems are mainly used in the manufacturing and automobile industries. In this present research work B_4C powder particles were made to deposit on 410 steel using HVOF techniques. Steel substrates of size Ø40x3mm thickness were grit blasted at 3 kg/Cm^2 pressure using alumina grits to improve the coating adherence. Grit blasted substrates were cleaned with acetone in an ultrasonic unit. Coating parameters of HVOF Technique were listed in Table.3. Commercially available and blended B_4C particles are used as feed materials for HVOF Technique. This system contains combustion chamber in which fuel (kerosene, Hydrogen) and oxygen are feed into chamber to obtain continuous ignition and combustion process. Because of combustion, hot gas emitted through a nozzle (DJ2600) at high velocity. Then B_4C powder particles were fed axially into the high velocity hot gas stream. The powder to be deposited is often in molten or semi molten state. Finally hot gas stream and partially melted powder particles were made to deposit on 410 steel. Good bond strength of coating was obtained due to high velocity.

Table-3. Parameters used in the experiment.

Parameter	Operation range
Operating Power(Kw)	80-90
Current(Amps)	300-500
Fuel Kerosene(l/Hr)	15
Oxygen flow rate(l/min)	270-280
Powder Feed rate(g/min)	10-12
Nozzle to substrate distance(mm)	95-100

PIN-ON-DISC TRIBOMETER

Surface morphology and elemental analysis of Un-Coated and Coated steel substrates were carried out using SEM and Equipped with EDX. The Wear behavior of B_4C and blended B_4C powder particles coated 410 steel substrates were carried out using Pin-On-Disc Tribometer at room temperature and dry sliding conditions as per ASTM G-99. The Un-coated and B_4C powder particles coated steel substrates were pressed opposite to rotating disc with 120 mm track diameter and hardness of 62HRC. To study the effect of coating on steel substrates normal load of 39.29 n and sliding velocity 1.69 m/s, 2.26m/s, 2.85m/s. After wear test acetone was used to clean the worn steel substrates. Before and after wear test, the loss of material was measured by means of an accuracy of 0.0001gm using electronic weighing machine. The weight loss was used to measure wear rate.

RESULTS AND DISCUSSIONS

Microstructure, Microhardness

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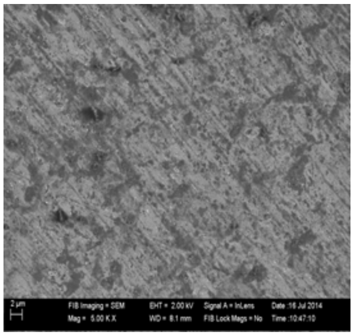

Figure-1(a). Un-CoatedSteel Substrates.

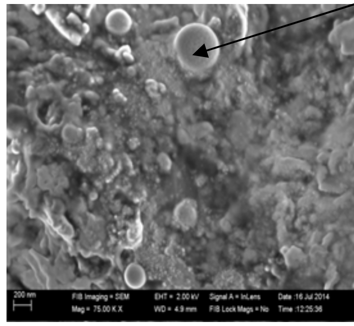

Figure-1(b). Micro B_4C coating.

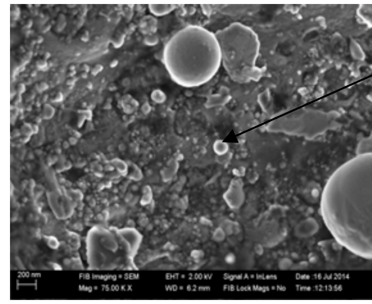

Figure-1(e). 3% of Nano B_4C coating.

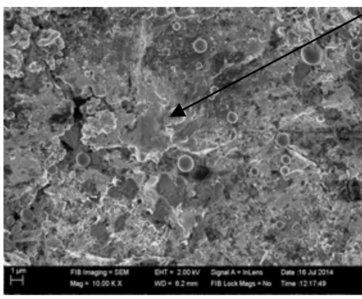

Figure-1(c). 1% of Nano B_4C coating.

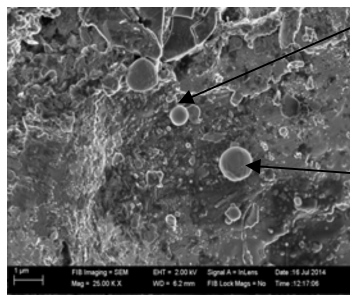

Figure-1(d). 2% of Nano B_4C coating.

The Figure-1(a-d) shows the SEM Microphotographs of Un coated and B_4C Coated Steel Substrates. Fairly uniform distribution of Particles can be achieved by using HVOF technique. It was revealed from SEM microphotographs; no micro cracks and absence of lamellar structures are observed. It was confirmed that, factors like low porosity, dense and well adhering and homogeneous coating are observed due to high impact velocity of coated particles(9). Figure-2 shows the EDX spectrum analysis carried out on the interface of the substrate and coated surface. From the EDX it was confirmed that the presence of boron and carbide particles on coated surface. The wicker's micro hardness test was carried out at the surface of base substrate and B4C coated surfaces. Table-3 shows the parameters consider for micro hardness test. Figure-3 shows the micro hardness values of coated and Un-coated surfaces. From the experimental results it was confirmed that, there is a significant improvement in the hardness of Nano B4C particles coated steel substrates than micro B4C particles coated steel substrates and Un-coated substrates. The arrow marks shows the B4C particles.

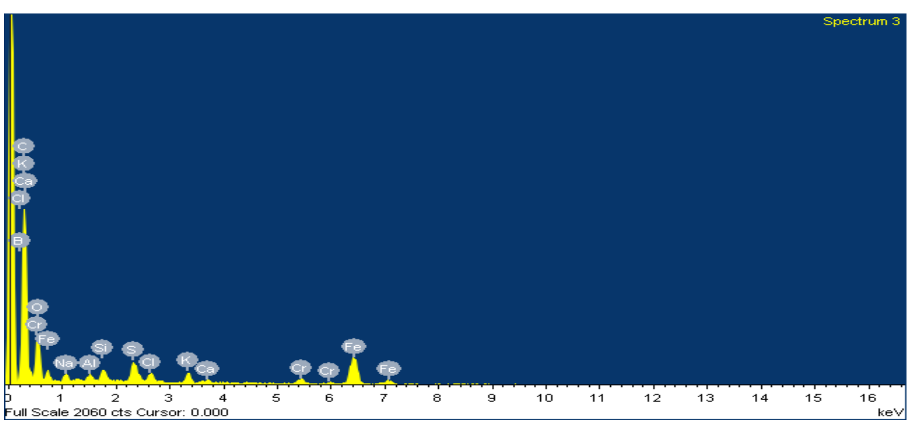

Figure-2. EDX spectrum at the cross section of base metal and B_4C coating.

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Table-4. Parameters considered for micro hardness test.

Testing parameters considered	
Load	100 (gms)
Dwell time	10 (seconds)
Number of Indentation	3(average)
Type of Indentor	Diamond
H.V 0.1 (Hardness in Vickers)	Hardness in Vickers for 100 (gms)

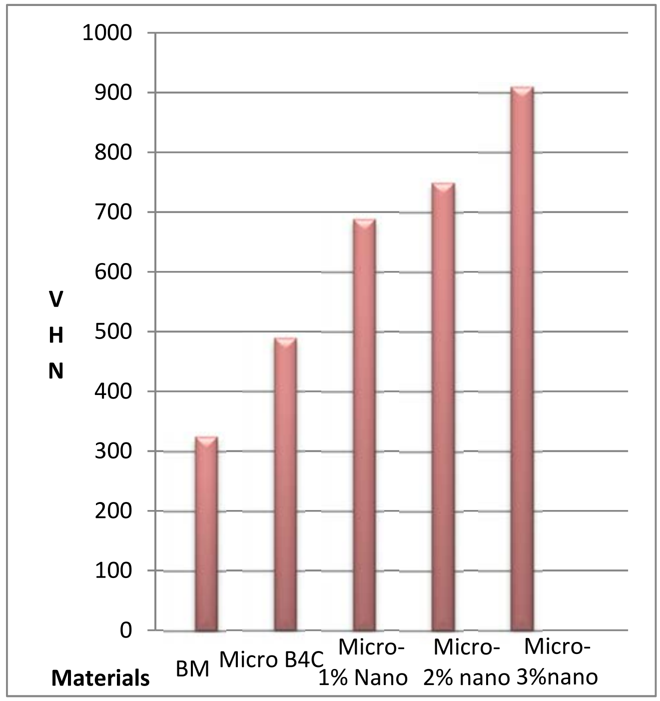

Figure-3. Micro hardness values for and Un-coated steel substrates and B_4C coated substrate.

TRIBOLOGICAL PERFORMANCE

Figure-4(a-l) shows SEM Microphotographs of worn surfaces of the Un-Coated, Micro B_4C coated and Blended Micro-Nano sized B_4C at different sliding velocities for constant load of 39.29N. From Figure-4(a) (b) (c) it was clear that, while increasing the Sliding velocity, Base material substrates Illustrates the chipped morphology, brittle erosion, cracking on the surface. Formation of grooves on the un-coated steel substrate was more than the coated steel substrates because B4C particles resist the formation of grooves. Figure-4(d) (e) (f) shows the worn surfaces of the Micro B4C coated steel substrates which are subjected for different sliding velocity; Figure-4(g-o) shows the worn surfaces of the micro-1%, 2%, 3% of blended nano B4C particles coated steel substrates. From the SEM microphotographs it was clear that, by increasing the sliding velocity keeping load as constant the material removal rate will increases, but from weight loss method it was confirms that by increasing the percentage of Nano B4C particles, resistance to the wear will also increases. As the sliding velocity increases the temperature between the coated surface and the counter rotating disc was increases which in turn in increasing the wear rate. [10]. Figure-5 shows the graphical representation for comparing the wear rate of Un-coated steel and Micro B4C coated and 1%, 2%, 3% Blended nano B4C coated steel substrates.

From the results it was clear that by increasing the Percentage of nano particles leads to the resistance to wear.

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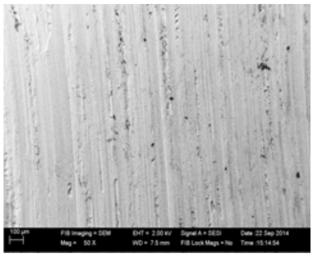

Figure-4(a). BM 300 Rpm.

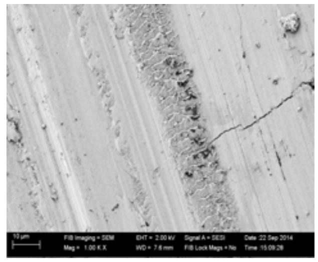

Figure-4(b). BM 400 Rpm.

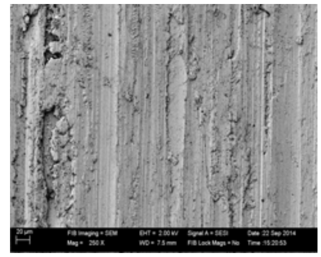

Figure-4(c). BM 500 Rpm.

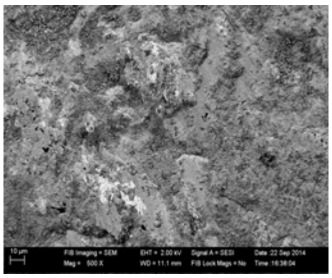

Figure-4(d). Micro B_4C 300 Rpm.

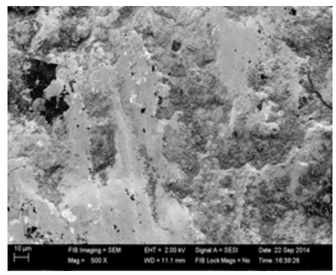

Figure-4(e). Micro B_4C 400 Rpm.

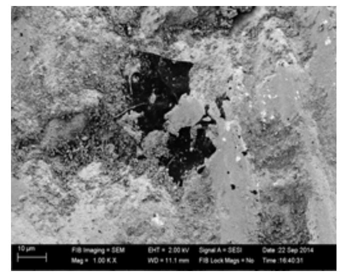

Figure-4(f). Micro B_4C 500 Rpm.

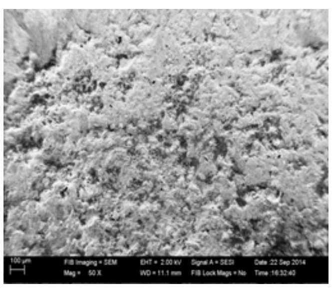

Figure-4(g). MicroB_4C-1%nano B_4C 300 Rpm.

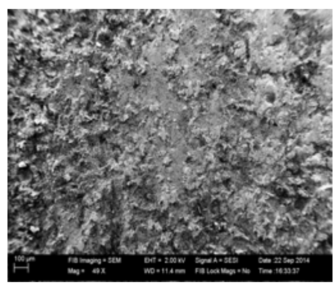

Figure-4(h). MicroB_4C-1%nano B_4C 400 Rpm.

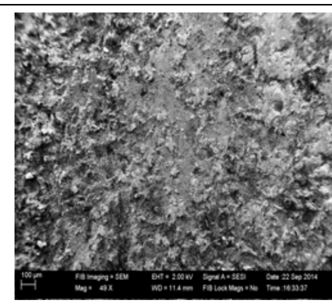

Figure-4(i). MicroB_4C-1%nano B_4C 500 Rpm.

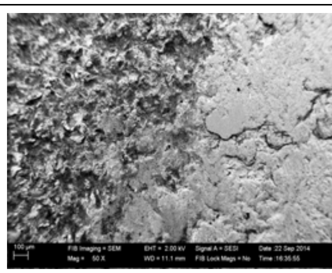

Figure-4(j). MicroB_4C-2%nano B_4C 300 Rpm.

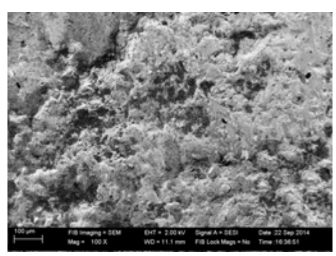

Figure-4(k). MicroB_4C-2%nano B_4C 400 Rpm.

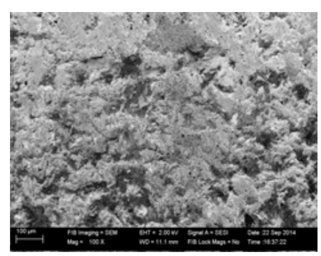

Figure-4(l). MicroB_4C-2%nano B_4C 500 Rpm.

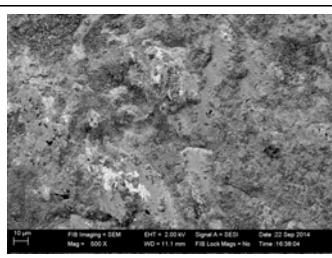

Figure-4(m). MicroB_4C-3%nano B_4C 300 Rpm.

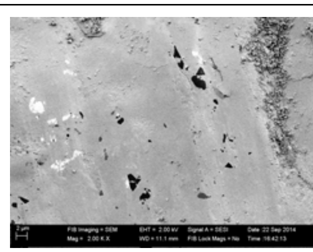

Figure-4(n). MicroB_4C-3%nano B_4C 400 Rpm.

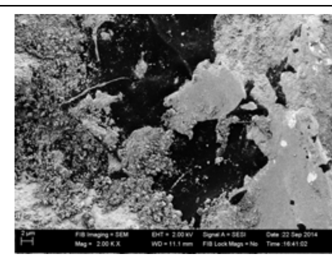

Figure-4(o). MicroB_4C-3%nano B_4C 500 Rpm.

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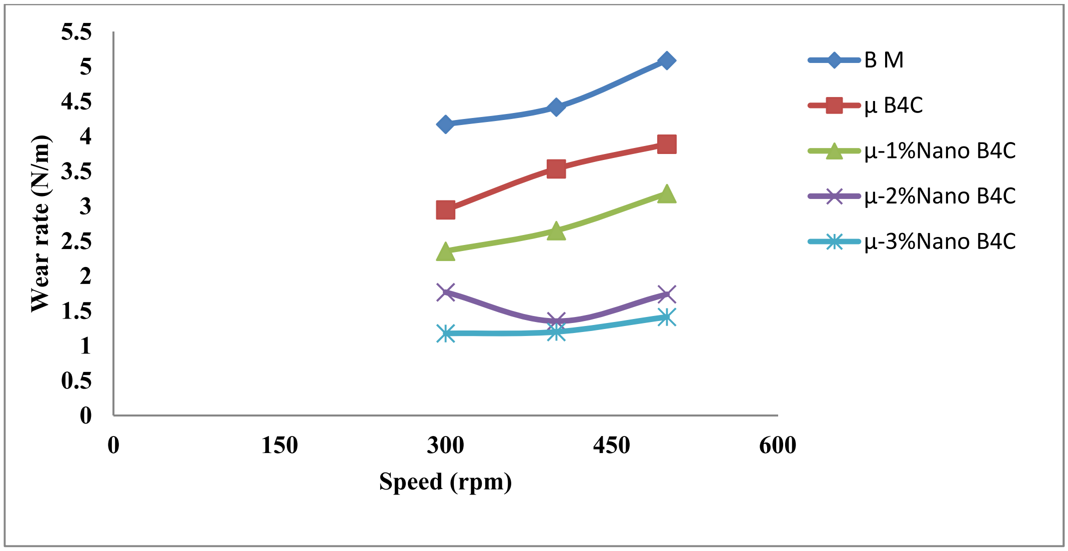

Figure-5. Wear rate of B_4C coated and un-coated surface at different sliding speed.

CONCLUSIONS

In the present investigation, well adhere and dense coating of Nano B4C powder particles obtained using HVOF Technique. Tribological performance of Coated and Un-Coated steel substrates were examined at room temperature at sliding speed of 300, 400, 500 rpm at constant load of 30.29N, from the results we concluded that

- Nano B4C blended with micro B_4C powder particles were successfully deposited by HVOF system on 410 grade steel.
- Increase the percentage of Nano B_4C particles enhances the coating hardness.
- SEM microphotographs show the uniform distribution of Boron carbide particles and EDX spectrum confirms the presence of boron and carbide particles on coating.

Nano B_4C coated surface of 410 grade steel exhibits remarkable wear resistance and hardness compared to micro B_4C and uncoated 410 grade steel

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