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DRY SLIDING WEAR PERFORMANCE OF THERMAL SPRAYED MICRO-NANO BORON CARBIDE COATING ON 410 GRADE STEEL

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ABSTRACT

Conventional boron carbide powder particles of grain size 105 µm were blended with 1 %, 2 % and 3 % of nano sized (44-55x10^{-9}µm) boron carbide powder particles. The blended powder was 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 value on the surface of coated and un-coated substrates. Worn surface morphologies were observed using scanning electron microscope. The presence of elements of boron and carbide were confirmed in the analysis. Pin-on-disc tribometer was used to study the tribological behavior of these coatings as per ASTM G99 standard. The results indicate that the increase in the amount of nano powder in the blend significantly increases the hardness and wear resistance compared to only micro boron carbide coated and un-coated steel substrates.

Keywords: wear, boron carbide, nano size.

INTRODUCTION

Wear is the successive loss of material at the contacting surface during manufacture or in service which ultimately lead the component to malfunction and finally a failure. Wear can be defined as loss of materials from solid surfaces due to mechanical interactions [1]. Boron carbide (B_4C) is the third hardest material having excellent characteristics like extreme hardness, low density, chemical resistance, good nuclear properties [2]. For various applications, thermally sprayed coatings are extensively used to counter the surface degradation process such as wear, erosion, corrosion, etc. High Velocity Oxy Fuel (HVOF) technology has been used to spray low melting point materials like metals and metal-ceramic composites. Due to well adhering and dense coating, HVOF systems are mainly used in the manufacturing and automobile industries. Due to minimum duration involved in the coating process and lower enthalpy of heat, HVOF process minimizes the splitting of carbide phases [3]. Although, the B_4C properties like lower fracture toughness and poor oxidation resistance may limit its applications, B_4C has been used as wear resistant surface coating [4]. Recently, nano-structured boron carbide particles have shown many advantages over their bulk counterparts [5]. To obtain B_4C of nano structure, several techniques have been developed including the use of CNT Template [6-8]. Chromium carbide being harder material, has exhibited excellent strength, anti corrosion and anti erosion properties [9].

The present research work aims at investigating the wear behavior of thermally sprayed micro B_4C blended with 1 %, 2 % and 3 % of nano B_4C particles under dry sliding conditions at room temperature and at constant load and sliding speeds.

EXPERIMENTAL PROCEDURE

Materials

B_4C powder particles of grain size 105 µm and nano size B_4C particles (44-55x10^{-9}µm) were fused in different proportion and crushed. Micro and nano B_4C powder particles were mechanically prepared using high energy ball milling machine with tungsten carbide balls. The 410 grade steel substrates of size 40 mm diameter and 3 mm thick were grit blasted using alumina to improve the adherence of coating and cleaned using acetone and dried. The chemical composition of 410 grade steel is shown in Table-1. The powder composition is shown in Table-2.

Table-1. Chemical composition of 410 grade steel.

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

Table-2. Powder composition of B_4C [micro- nano].

Coating	Composition	Powder Type
A	Micro B_4C	Pure
B	Micro B_4C and 1 % Nano B_4C	Blend
C	Micro B_4C and 2 % Nano B_4C	Blend
D	Micro B_4C and 3 % Nano B_4C	Blend

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COATING PROCEDURE

In this research work B_4C powder particles were made to deposit on 410 grade steel using HVOF technique. Steel substrates of size 40 mm diameter and 3 mm thick 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 process parameters of HVOF technique are listed in Table-3. Commercially available and blended B_4C particles of various composition are used as feed materials for HVOF technique. This system contains combustion chamber in which fuel (kerosene, Hydrogen) and oxygen are fed into the chamber to obtain continuous ignition and combustion process. Because of combustion, hot gas is 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. The high velocity gas stream finally deposits the molten or semi molten material on the surface of the substrate. On subsequent cooling, the coating bonds with the substrate.

Table-3. Process parameters used in the experiment.

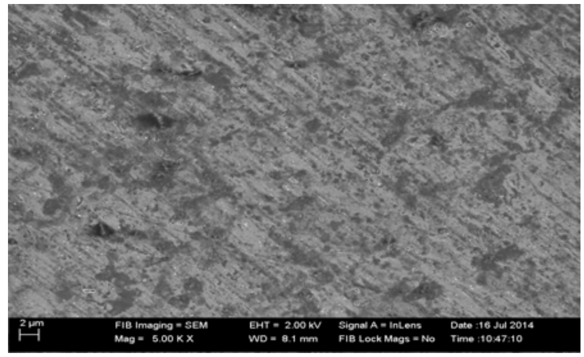
Parameter	Operation Range
Operating Power (Kw)	80-90
Current (Amps)	300-500
Fuel Kerosene (l/Hr)	15
Oxygen flow rate (l/min)	270-280
Powder Feed rate (g/min)	10-12
Nozzle to substrate distance (mm)	95-100

WEAR STUDIES

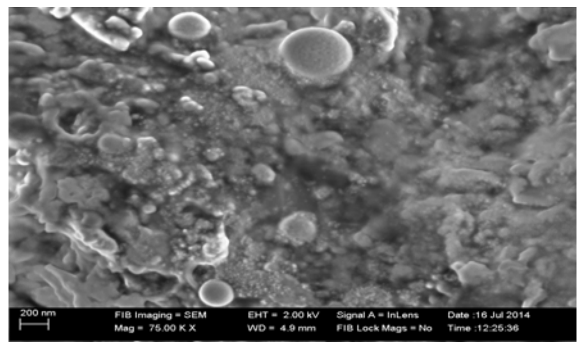
The Wear tests on the uncoated and coated steel substrates were carried out using pin-on-disc tribometer at room temperature and dry sliding conditions as per ASTM G-99 standard. The uncoated and coated steel substrates were pressed against the rotating disc with 120 mm track diameter and hardness of 62 HRC. A normal load of 39.29 N and sliding velocity of 1.69 m/s was used for the experimentation. Acetone was used to clean the worn surface after the test. The weight loss due to wear was used to measure wear rate. Surface morphology and elemental analysis of un-coated and coated steel substrates were carried out using SEM and SEM EDX.

RESULTS AND DISCUSSIONS

The Figure-1 (a)-(e) shows the SEM microphotographs of un-coated and B_4C coated steel substrates. Fairly uniform distribution of particles is achieved by using HVOF technique. The microphotographs reveal the absence of micro cracks and lamellar structures. The factors like low porosity, dense, well adhering and homogeneous coating is observed due to high impact velocity of coated particles. Figure-2 shows the EDX spectrum analysis carried out at the interface of the substrate and coated surface which shows the different elements present.



(a)



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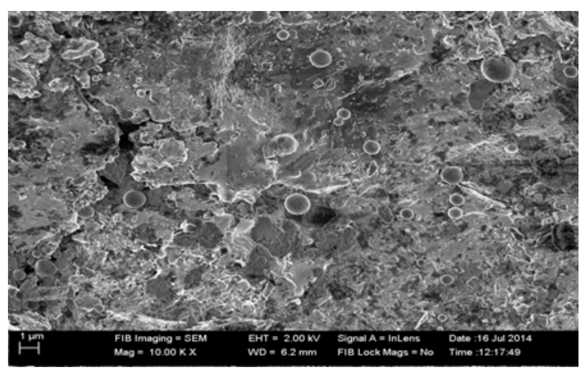

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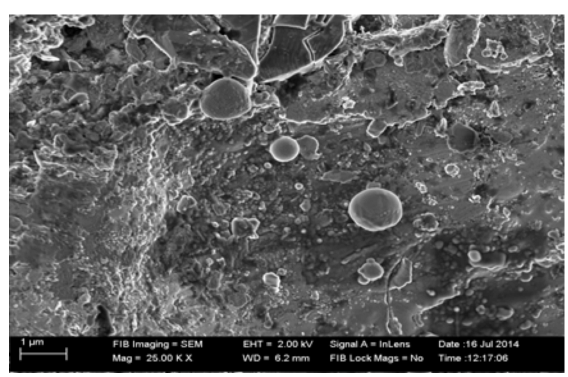

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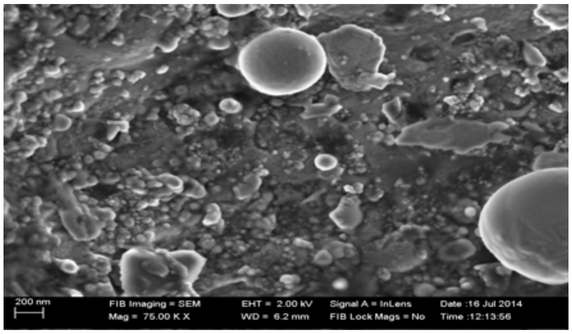


(e)

Figure-1. (a) Base material, (b) micro B_4C coating, (c) 1% of Nano B_4C coating, (d) 2% of Nano B_4C coating, (e) 3% of Nano B_4C coating.

The wicker's micro hardness test was carried out at the surface of base substrate and B_4C coated surfaces. Diamond indenter was used with a load of 100 grams and dwell time of 10 seconds. 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 due to the addition of nano B_4C than only micro B_4C coated steel substrate and un-coated substrates. The arrow marks shows the B_4C particles.

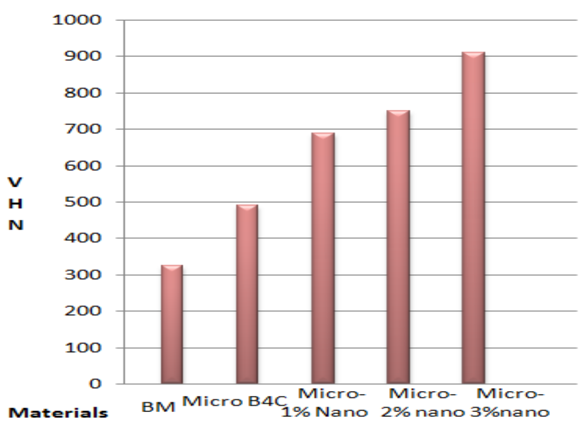
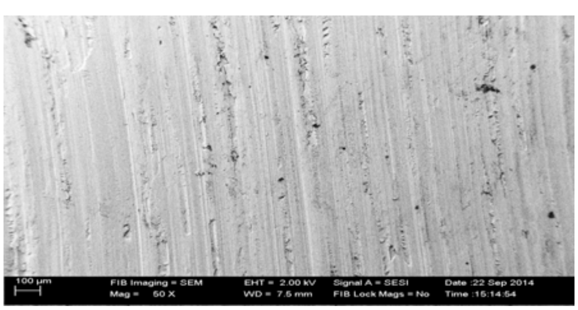
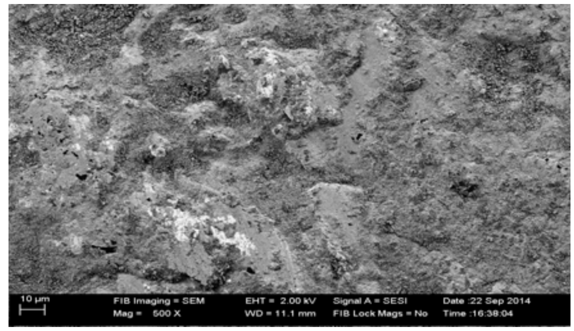


Figure-2. Micro hardness values of un-coated and B_4C coated substrate.

TRIBOLOGICAL PERFORMANCE



(a)



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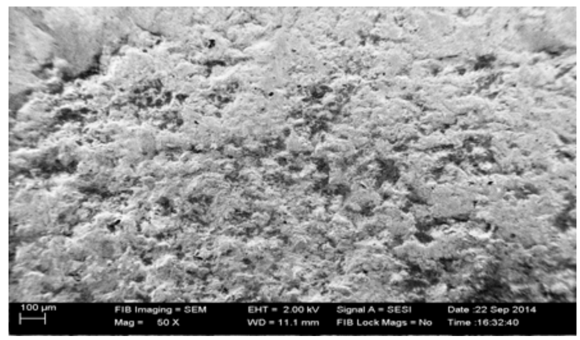

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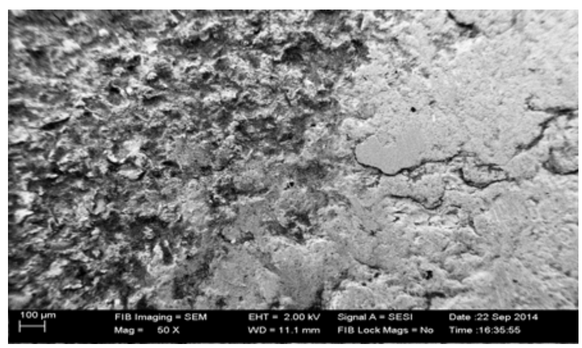

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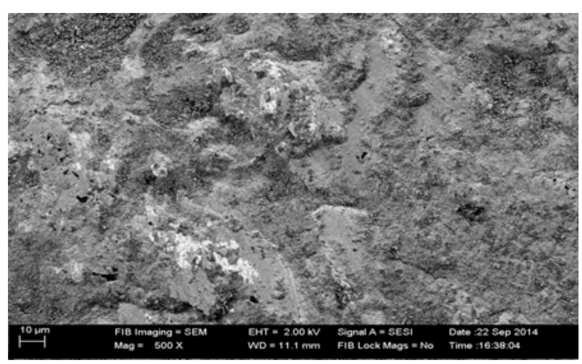

(e)

Figure-3. (a) BM (b) Micro B_4C (c) Micro B_4C-1% nano B_4C (d) Micro B_4C-2% nano B_4C (e) Micro B_4C-3% nano B_4C.

VOL. 11, NO. 6, MARCH 2016 ISSN 1819-6608
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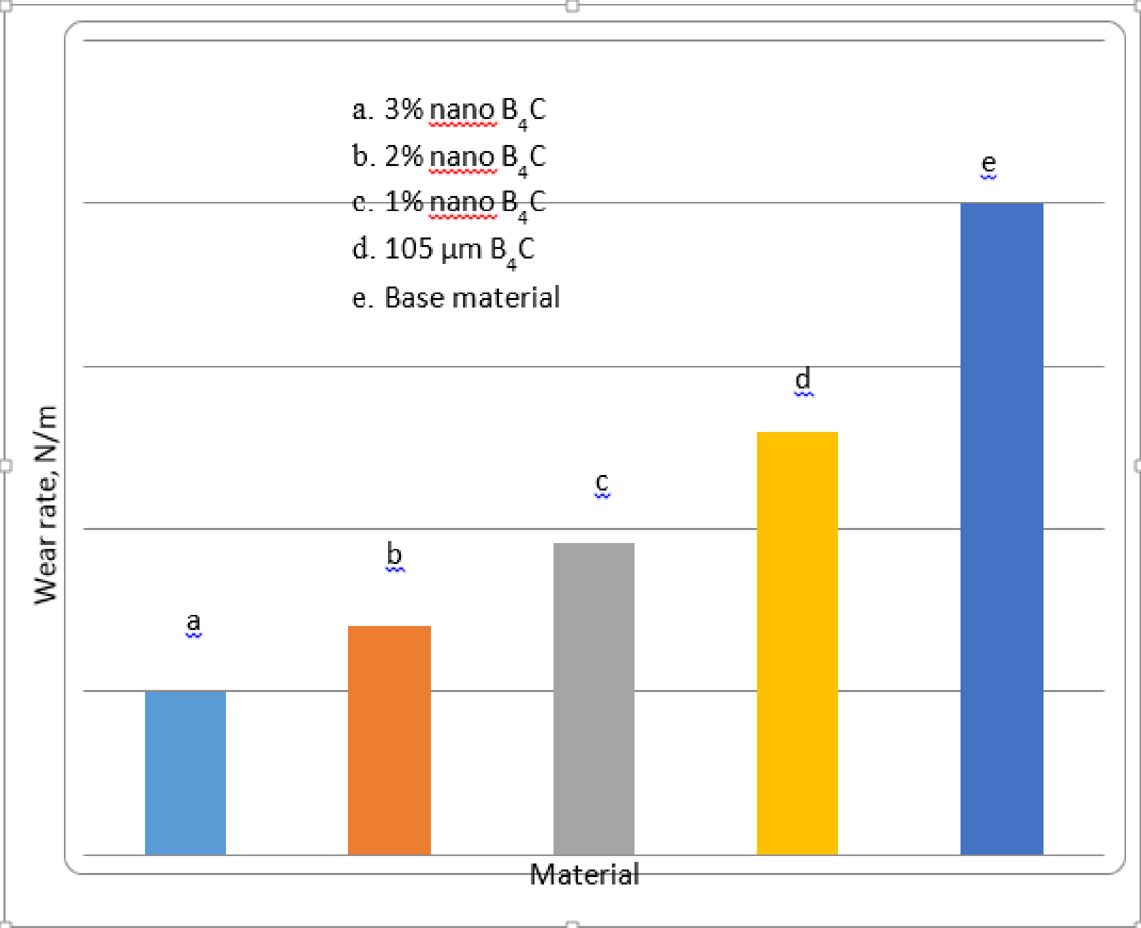

Figure-4. Wear rate of B_4C coated and un-coated surface.

Figure-3 (a-e) shows SEM Microphotographs of worn surfaces of the un-coated, micro B_4C coated and blended micro-nano sized B_4C coating at a sliding speed of 300 rpm for constant load of 39.29 N. From Figure-4 (a) it is clear that the base material illustrates the chipped morphology, brittle erosion and cracking on the surface. Formation of grooves on the un-coated steel substrate was more than the coated steel substrates because B_4C particles resist the formation of grooves. Figure-3 (b)-(d) shows the worn surfaces of the micro B_4C coated and micro-nano blended steel substrates. The weight loss method of wear analysis confirms that by increasing the percentage of nano B_4C particles, the resistance to wear will also increase. Figure-4 shows the graphical representation for comparing the wear rate of un-coated, micro B_4C coated and 1 %, 2 %, 3 % nano B_4C blended coating which clearly indicate the increase in wear resistance of the surface with the increase in the amount of nano B_4C.

CONCLUSIONS

In the present investigation, well adhering and dense coating of nano B_4C powder particles were obtained using HVOF technique. Tribological performances of coated and un-coated steel substrates were examined. From the results obtained, we concluded that -

- Nano B_4C blended with micro B_4C powder particles were successfully deposited by HVOF system on 410 grade steel.
- Increase in the percentage of nano B_4C particles in the blend enhances the coating hardness and wear resistance.
- 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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