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ANTI-WEAR BEHAVIOUR OF PLASMASPRAYED ALUMINA & ZIRCONIA COATINGS ON ALUMINIUM 7075T6

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***Abstract*—This paper is done essentially to study results of Alumina (Al_2O_3), Zirconia (ZrO_2) and Alumina-Zirconia (Al_2O_3+40%ZrO_2) ceramic coatings by using plasma spray process, with different coating thickness of 100µm, 150µm and 200µm are deposited on Al-7075T6 substrate. Coating microstructure were characterized by using SEM. The coating Micro hardness, Tribological behaviour and Surface Roughness of the coated specimens were determined for Aluminium (Al-7075T6) and Coated Al-7075T6. NiCrAl is used as a bond coat for providing better coating adhesion. Dry sliding wear test were performed for different sliding distance of 1000m, 2000m, and 3000m at a constant load of 10N by using a Pin-on-Disc. From the above work the results were obtained it showed that, Alumina-Zirconia (Al_2O_3+40%ZrO_2) coated specimens having very good wear resistance property when compared to Alumina (Al_2O_3), Zirconia (ZrO_2) coating materials. These results clearly demonstrate that the significant improvement in coating performance can be achieved by proper thermal spray conditions and proper mixing of coating powder composition.**

***Key Words* — Ceramic coatings, Aluminium 7075, Alumina (Al_2O_3), Zirconia (ZrO_2), Thermal Barrier Coating (TBC), Surface Roughness.**

I. INTRODUCTION

In many applications the mechanical components have to operate under severe working conditions such as high Load, Speed or Temperature and Chemical environment. Thus their surface modification is necessary to protect them from different types of degradation. Aluminium and its alloys are preferred as structural components because of its high strength to weight ratio. They are also easy to shape and relatively inexpensive. However, they have low wear and abrasion resistance which limit their use. Ceramic coatings produced by Thermal Spray Techniques are being developed for a wide variety of applications, example. aerospace, automotive, structural and industrial [1-2]. Thermal spraying is a semi-molten state coating technique. To improve the wear resistance, there are many techniques, such as Metal-Matrix Composites, Plasma Spraying, Thermal Spraying and Hard Anodizing have been explored. Plasma spraying is used to produce coatings; they are mainly used as protective coatings to improve the wear and corrosion resistance of the material and in some cases to improve the optical, electronic/electrical or thermal properties.

Alumina is one of the widely used engineering ceramic materials because of its high elastic modulus, high wear resistance and chemical corrosion resistance, high-temperature stability and the retention of strength at high temperatures. Zinc-based alloys have been found suitable for a number of engineering and tribological applications such as good mechanical strength because of its high toughness, good resistance against crack propagation, good thermal resistance, relatively high thermal expansion coefficient, and low thermal conductivity at high temperature [3–7] .

The proper combination of a material Al_2O_3 with a ZrO_2 looks as a promising way to produce an excellent improvement in the mechanical properties such as hardness, wear resistance, and scratch resistance l[8, 9]. Plasma sprayed Al_2O_3-TiO_2 is used as a wear resistant coating in ship engine values, cast iron pressing mandrels, slide gate plate[10-14]

II. EXPERIMENTAL WORK

A. Materials and coating deposition

The substrate is used as a Aluminium alloy (Al-7075T6). Coating material powders Al_2O_3 and ZrO_2 are used and premixed to form three different compositions shown in Table 1. . The chemical composition of the substrate is shown in Table 2. In the present work NiCrAl bond coat of 10-20µm was deposited to provide the best attainable adhesion between substrate and coating and top coat with different thickness of 100µm, 150µm and 200µm thick deposited by plasma spray process [15] shown in Figure 1. Before coating surface was cleaned with acetone. The plasma spray process parameters are listed in Table 3.

Table 1: Coating powders (wt%)

Composition	Al_2O_3	ZrO_2
1	100	-
2	-	100
3	60	40

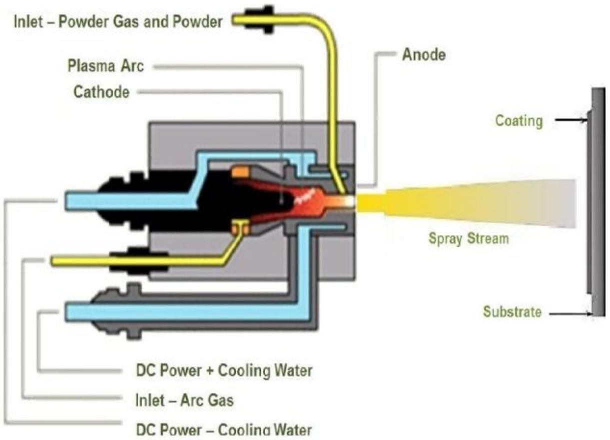

Figure 1: Plasma-Arc Gun Cross section

Table 2: Chemical composition of Al-7075T6 alloy

Constituent	Percentage
Cu	1.392
Mg	2.136
Si	0.022
Fe	0.136
Mn	0.160
Ti	0.062
Zn	5.153
Cr	0.236
Al	Bal

Table 3: Plasma spray process parameters

Coating Parameters	
Gun	METCO 3MB
Primary gas flow rate (Argon, lpm)	80-90
Secondary gas flow rate (Hydrogen, lpm)	15-20
Carrier gas flow rate (Nitrogen, lpm)	37-40
Powder feed (grams/min)	40-45
Spray distance (mm)	100
Current (A)	500
Voltage (V)	60-70

B. Characterisation of coatings

Coating microstructure Al_2O_3, ZrO_2 and Al_2O_3 +40%ZrO_2 coated samples were characterized by using Scanning Electron Microscope (SEM) is used to study the microstructure of the substrate.

C. Micro-hardness

Measurement of hardness is to be done to find out micro-hardness [16] of substrate and coated material. Micro-hardness test was evaluated on a cross section of coatings with a load of 250 g and dwell time period is 10 sec and average value of three reading are reported in Table 5.

D. Surface Roughness Measurements

The surface roughness of the pin specimens were measured by Talysurf before performing the wear tests. Talysurf instrument is as shown in Figure 2.During conducting test 0.8 mm was the cut-off length of that instrument and an average value of five reading is tabulated in Table 4.

Table 4: Surface Roughness Values for uncoated and coated specimens

Coating Material	Coating Thickness	Roughness Value R_a (µm)	
		Before Wear Test	After Wear Test
Uncoated	-	13.71	2.95
Al_2O_3	100 µm	16.58	3.45
	150 µm	14.62	2.98
	200 µm	9.24	1.04
ZrO_2	100 µm	7.84	3.02
	150 µm	7.71	2.34
	200 µm	7.22	1.52
Al_2O_3 + 40%ZrO_2	100 µm	9.29	5.13
	150 µm	7.13	4.25
	200 µm	6.59	3.07

E. Wear Testing

According to ASTM G99-04 standards [17], the dry wear tests carried out on a Pin-on-Disc wear testing set-up as shown in Figure 3.The diameter of cylindrical pin specimens is 8mm and 30mm length coated with Alumina, Zirconia and combination of Al_2O_3 + 40%ZrO_2 oxides of different coating thickness were used as test material. Hardened steel was used as the counter face material. The dry sliding wear tests were conducted at a constant load of 10N for a sliding distance of 1000m, 2000m and 3000m respectively. By using an electronic weighing balance weight losses of the specimens were evaluated. By SEM wear scars was observed in order to find out the microstructural behavior and wear mechanism for both uncoated and coated specimens.

Figure 2: Talysurf (Surface roughness tester Model: SJ-301)

Figure 3: Wear testing machine

III. EXPERIMENTAL RESULTS

A. Characterisation of coatings

Figure 4 and 5 shows the SEM images of coating powder samples at 200x magnification and the SEM images of the coated specimens before wear test on Al-70745T6 substrate are shown in Figure 6,7 and 8 that is Al_2O_3, ZrO_2 and Al_2O_3+40%ZrO_2 with a little porosity present on surface of the samples.

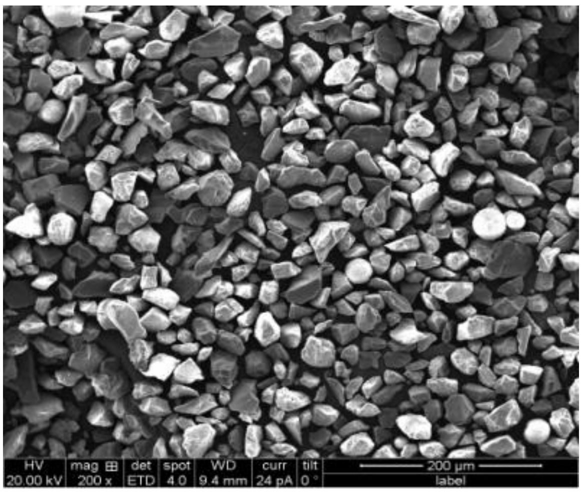

Figure 4: SEM image of Al_2O_3

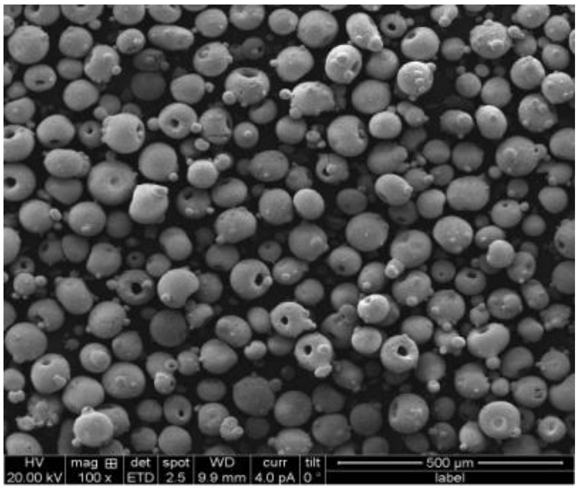

Figure 5: SEM image of ZrO_2 powders at 200x magnification.

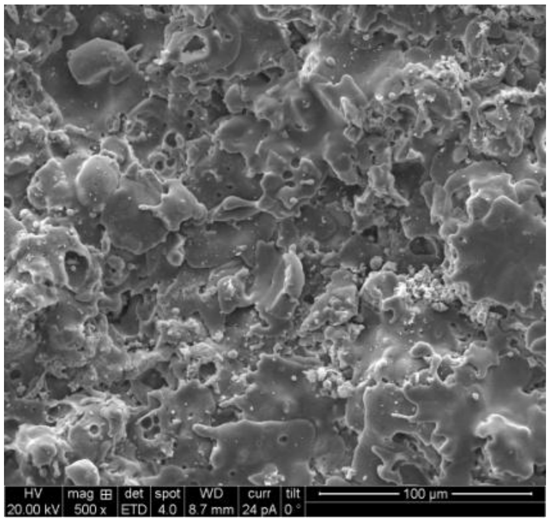

Figure 6: SEM image of Al_2O_3 coated specimen.

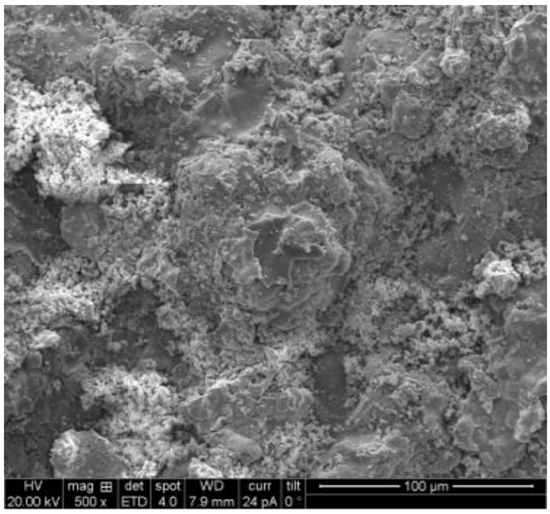

Figure 7: SEM image of ZrO_2 coated specimen

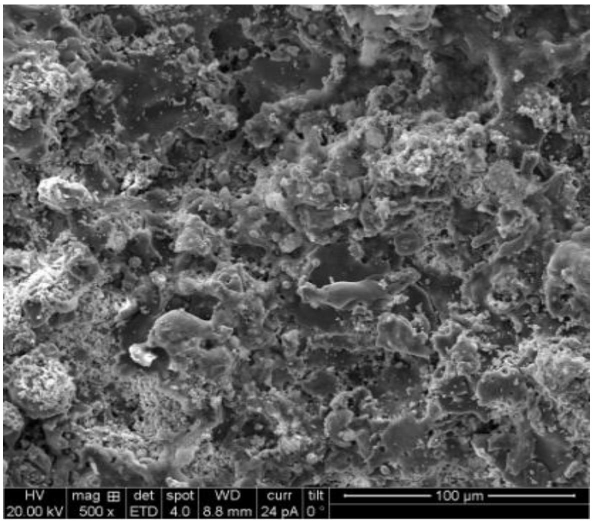

Figure 8: SEM image of Al_2O_3+40%ZrO_2 coated specimens

B. Surface Roughness Measurement

Figure 9 shows the recorded values of both coated and uncoated specimens before wear test indicating higher R_a values in comparison with the specimen surface after wear test. . Al_2O_3+40%ZrO_2 coated material having a coating thickness of 200µm is showing a lesser R_a value of before wear test was, recorded in comparison with other values of coated and uncoated specimens. Coated specimens show that coating material particles along with the bond surface have created a rough surface area. After the performing of wear test, the coating layer either abraded to create a surface wherein which less R_a has been recorded.

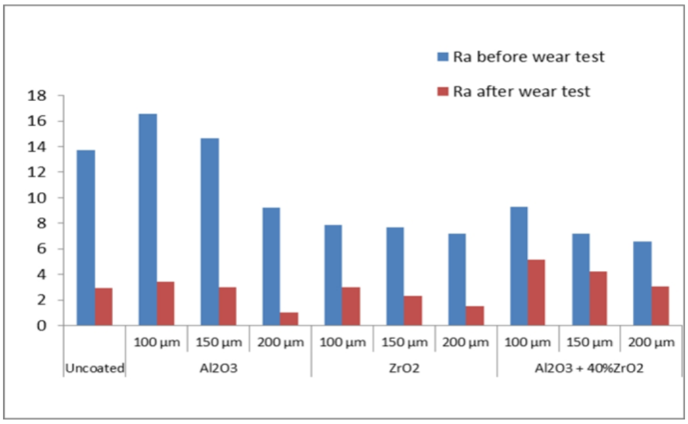

Figure 9: Surface Roughness of uncoated and coated specimens

C. Micro-hardness Measurements

The values of micro-hardness for different coating powders are recorded in Table 5. From the table it is clear that Al_2O_3+40% ZrO_2 Coated is having the highest hardness value compared to other coated and uncoated specimens. Figure 10 shows the Micro-hardness of coated and uncoated specimens.

Table 5: Hardness values of specimens

Specimens	Vickers hardness number (HV)
Al-7075T6	177
ZrO_2 Coated	273
Al_2O_3 Coated	340
Al_2O_3 + 40% ZrO_2 Coated	429

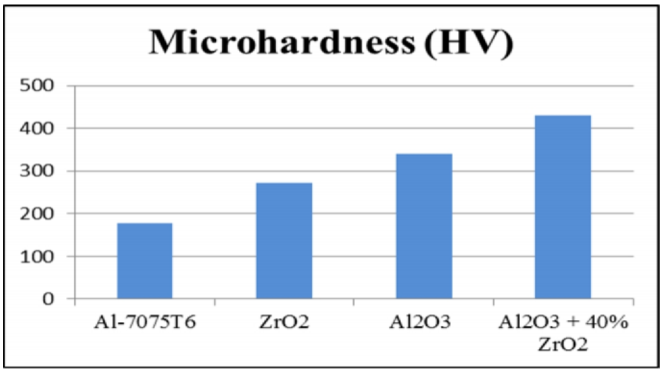

Figure 10; Micro-hardness of uncoated and coated specimen

D. Wear Analysis

According to ASTM G99-04 standards wear test was conducted by a Pin-on-Disc to simulate dry sliding wear of the coatings. Figures 11, 12, and 13 shows effect of sliding distance on wear loss of uncoated and coated specimens at constant load for different powders. . Figures 14, 15, and 16 shows the effect of sliding distances on wear loss for different coating thicknesses compared to bare Aluminium (Al-7075T6). . After initial wear there is a decrease of wear loss at a sliding distance of 3000m which is due to the strain hardening in the disc material and coated specimens, thereby reducing the weight loss with the increase in sliding distance.

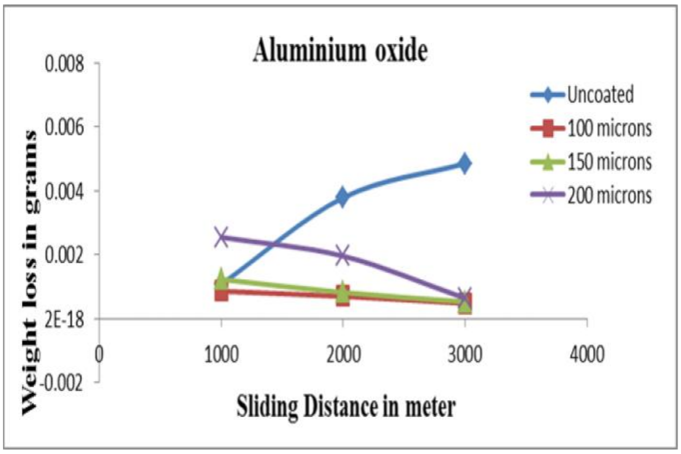

Figure 11: Effect of sliding distance on wear loss for Al_2O_3

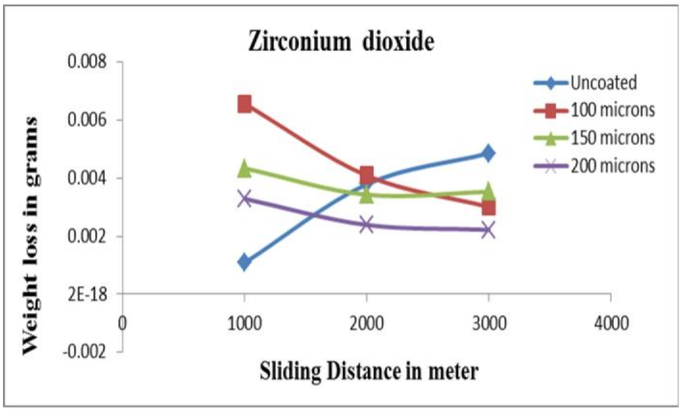

Figure 12: Effect of sliding distance on wear loss for ZrO_2

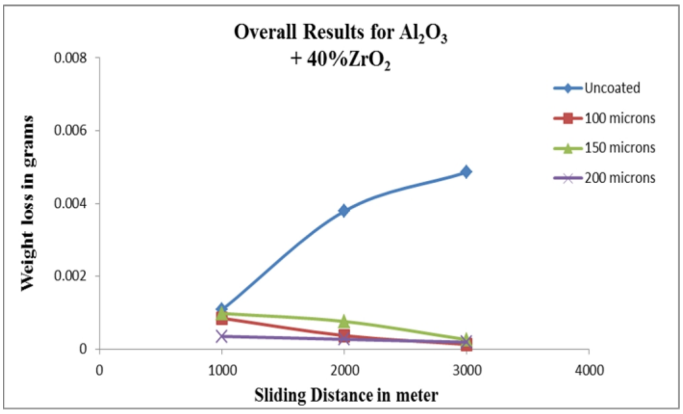

Figure 13: Effect of sliding distance on wear loss for Al_2O_3+40% ZrO_2

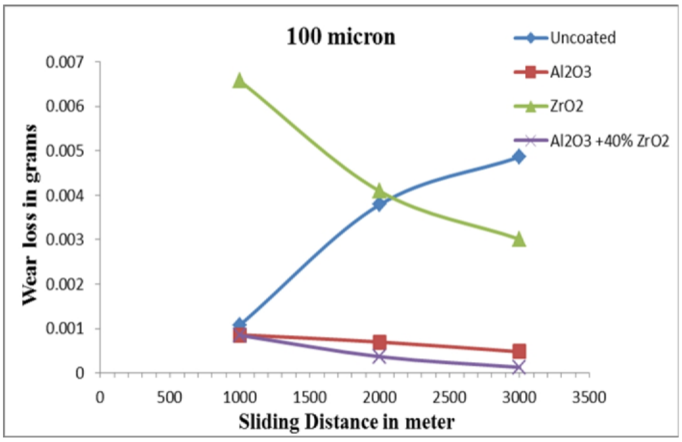

Figure 14: Effect of sliding distance on wear loss for a 100 µm

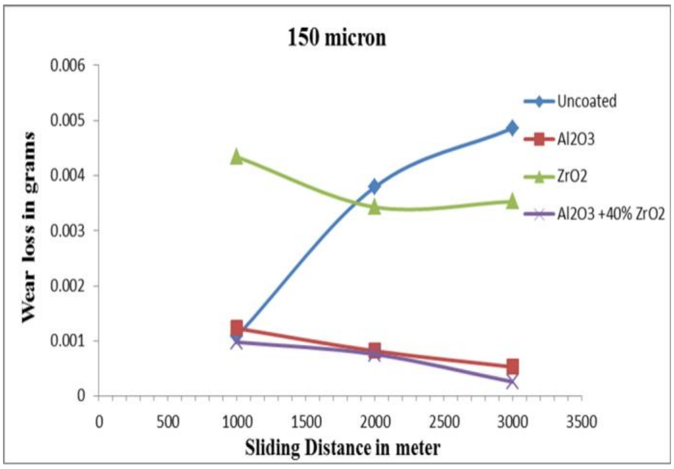

Figure 15: Effect of sliding distance on wear loss for 150 µm

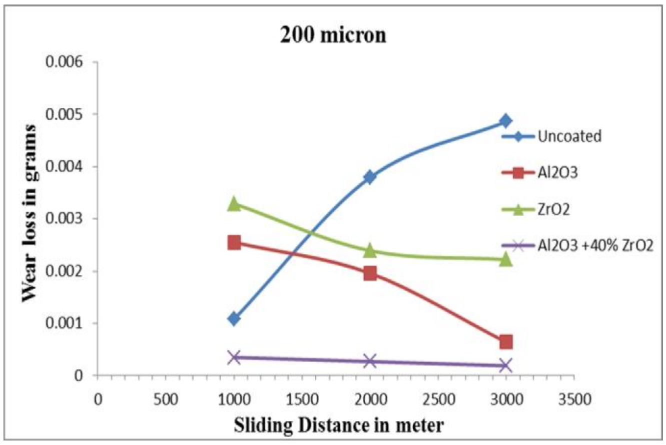

Figure 16: Effect of sliding distance on wear loss for 200 µm

Figure 17 shows the SEM image of the Al-7075T6 substrate after wear test and Figure 18, 19 & 20 shows the SEM images of coated samples of Al_2O_3, ZrO_2 and Al_2O_3 + *40%* ZrO_2 after wear test under a load of 10N at a sliding distance of 3000m. Figure 17 shows that the aluminium substrate has undergone severe wear condition characterised by shearing and plastic deformation and also observed that the substrate surface is weared it causes roughening and the formations of grain (debris). But in Zirconia coated specimen wear track of the substrate observed that scratches and the parallel grooves [18].

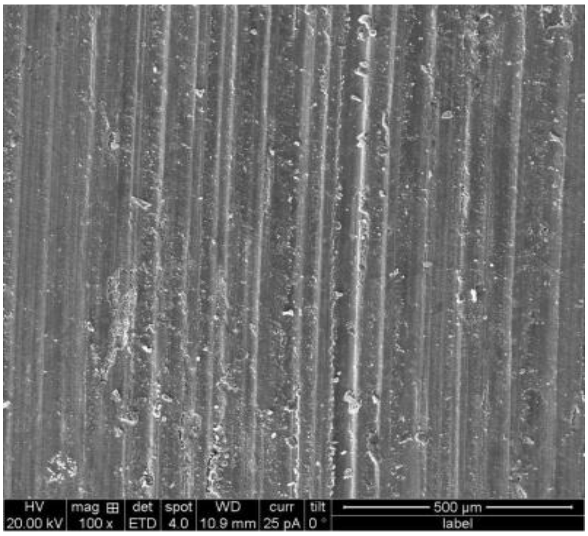

Figure 17: SEM of Al-7075T6 specimens after wear test.

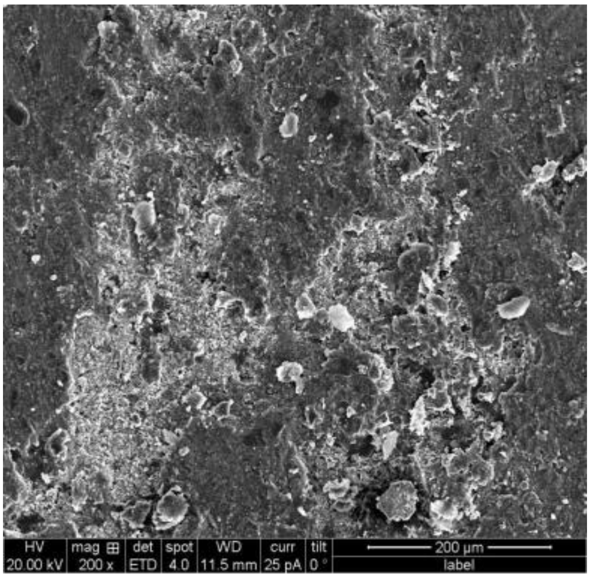

Figure 18: SEM of Al_2O_3 coated specimens after wear test.

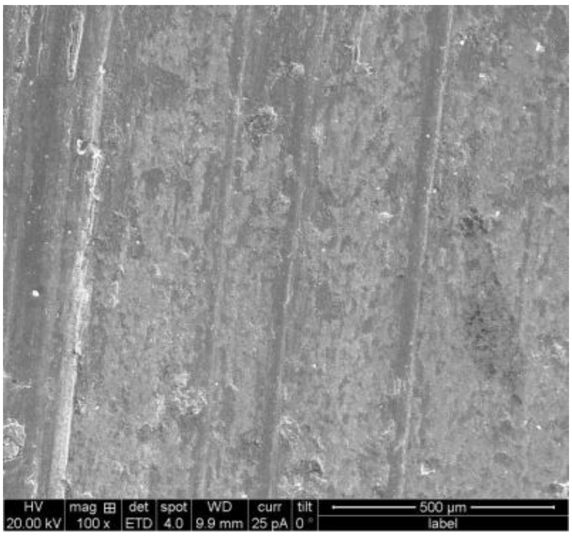

Figure 19: SEM of ZrO_2 coated specimens after wear test.

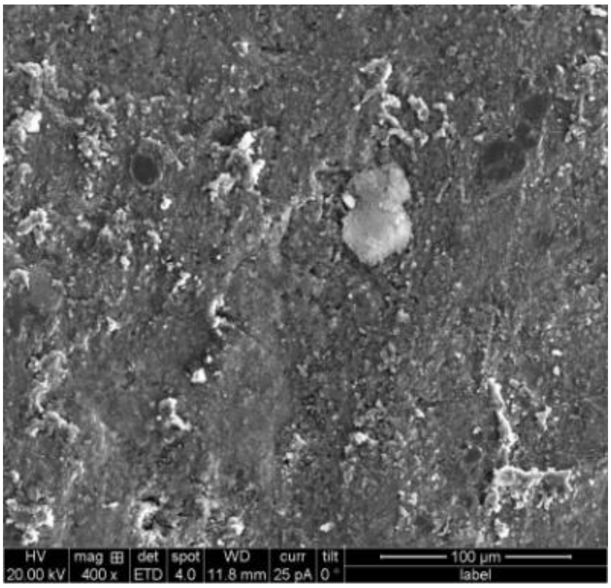

Figure 20: SEM of Al_2O_3 + 40% ZrO_2 coated specimens after wear test.

IV. CONCLUSION

- Alumina, Zirconia and Alumina-Zirconia coatings are deposited on metal substrates with an intermediate bond coat of NiCrAl by plasma spraying process.
- The Alumina-Zirconia coated specimens showed excellent wear property when compared to other coating materials.
- Ceramic Coating result shows the significant improvement in coating performance is achieved for a wear test.
- The SEM of the worn surfaces of coated specimen shows that these surfaces are much rougher than that of bare aluminium which can withstand maximum wear than that of the actual Al-7075T6.
- As we know Zirconia can be found I three crystalline structure Monolithic, Teragonal & Cubic, also Zirconia is stronger than that of Alumina but in Ceramic coating of Zirconia on the substrate is decreased because of the Tetragonal structure is stable up to 2379ºC and above this temperature, the structure turns to cubic structure.
- Usually Cracks and Fractures are observed during changing phases because of 8% volume difference while transition to tetragonal structure from monolithic structure.

- The changing phases might have leads to Brittle wear on the coated substrate. There by increases in wear and lesser in Hardness
- Lastly we can conclude that there is No direct relationship between hardness and tribological characteristics of the coatings has been established.

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