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Characterization of PVD Tialn Coatings on Beater Mill Plates

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ABSTRACT: In this work, a magnetron sputtered PVD coating is done on the extracted samples in the form of plate from the Beater mills which is available in Neyveli Lignite Corporation. A TiAlN coating is made on the surface of the substrate as it has high oxidation and wear resistance which is the ultimate goal for our work. The coated samples are then tested for its service. Initially the scratch test is made to determine its adhesiveness, then microhardness is checked to determine its hardness after coating, and pin on disc test is carried out to determine the wear resistance. From the above test results, it clearly revealed the existence of better properties.

KEYWORDS: Scratch test, XRD, Microhardness, Pin on disc, Beater plate, Fuel distributor plate.

I. INTRODUCTION

Pulverizers are mechanical device which are used for grinding different types of materials. For example, they are used to pulverize coal for combustion in the steam-generating furnaces of fossil fuel power plants. Out of various types beater mills are unique which carry out multi-functions such as crushing, drying, shifting and transportation of coal. The pulverized coal from beater mill is used to burn in the combustion chambers of boilers. The beater mill usually consist of fuel distributer plate(F.D.P) and beater plate(B.P) which are used to distribute the fuel uniformly and to powderise the fuel. Due to its functions, there is a need for the replacement of both plates at shorter span. This replacement is due to high wear rate. Basically there are three main reasons in which wear occurs in the beater mills which are oxidation of materials, erosion, combined effect of oxidation and erosion. In Pulverizers the lignite is deposited by drying it with the flue gases coming out from the furnace to reduce moisture present in the lignite. The flue gas from furnace consist of oxides like SO2, CO2, CO, etc which tends to react with the substrate and induce the oxidation process (corrosion).The next reason for wear is abrasion due to particles hitting on the surface of the plate. When the lignite is deposited into the mill it consist of hard sand particles, stones and even some iron particles. When these particles come into contact with the substrate that too in 500 rpm wearing of surface will happen. Due to oxidation process weakening of surface takes place. When the weakened surface comes into contact with the hard solid particles like lignite, stones and iron then wearing of surface takes place because the substrate is soft enough by the oxidation process to be peeled off by the incoming solid particles. Thus through this continuous run of oxidation and erosion more amount of material will be removed from the plates, thus the failure of plates happens which automatically leads to the failure of Pulverizers.

In order to increase the life of the component the surface treatment process or post-processing is carried out by adding a thin layer of coating on top surface of the component. A very important coating process is Sputtering by PVD. Unlike many other vapour phase techniques there is no melting of materials. Initially the Ions are generated in the form of plasma and directed at a target then these ions sputter targets atoms, and the ejected atoms are transported to the substrate and the atoms condenses to form a thin film layer of coating. In PVD processes the high vacuum employed makes it possible to achieve coating properties with higher hardness, good adhesion and wear resistance, and these properties can be tailored for every specific application. More over PVD processes are used for coating the component that operate at relatively low temperatures. The temperatures are chosen to lie at or below the tempering temperature of

Steels in order to avoid the alteration of fundamental material properties. PVD coatings are thin and hence the components with close tolerances retain its form, fit and dimensions after coating, without the need of refinishing operations. The first generation of hard PVD coatings was single metal nitrides such as TiN, CrN and ZrN. They have been commercially exploited since the middle of the 1980s in cutting applications (because of their higher hardness compared to high speed steel and cemented carbide) and for decorative purposes because of their attractive appearance: TiN has a distinctive yellow gold color, CrN looks like silver, ZrN has a white gold color. Alloyed coatings improve hardness, wear resistance, toughness and oxidation resistance by introducing other elements such as C, Al and Cr into the TiN lattice. The three basic coatings - TiN, TiCN and TiAlN - currently make up more than 70% of the world's coating market. Simon Montgomery et al [1] wear as a form of energy and productivity loss is major concern for many industries. So industrial people are seeking for the economical replacement for this problem because production of whole part by the costly material is not possible and cost effective. So the engineers adopted the surface treatment technique, in that the optimal method is PVD and CVD because it shows the versatile solution to the problem. So based on the analysis of different characteristic of PVD and CVD coating it is said to be the prominent and promising coating process. A.Schreyet al [2] states that today there exists only a little information about hard coatings obtained by physical vapour deposition (PVD) on ceramic substrates. The aim of the PVD coating on ceramic substrates is a further improvement of the material properties, *e.g.* wear resistance. Coatings have been deposited by reactive magnetron sputtering on silicon nitride (Si_3N_4), aluminium oxide (Al_2O_3) and Al_2O_3 + TiC ceramic. As a reference, coated high speed steel and cemented-carbide substrates have been used. Mechanical characterization of the coatings has been made by determination of hardness, critical load and impact load (coating impact test). Scanning electron microscopy investigation of the rupture structure and X-ray diffraction allowed the determination of the coating-substrate microstructure. Model wear tests gave information on the wear resistance of the coated ceramics, and annealing tests verified thermal stability. Youqiang Xing et al [3] four nitride coatings (CrN, ZrN, CrAlN, and TiAlN) were deposited on YT15 cemented carbide by cathode arc-evaporation technique. Erosion wear tests were carried out, the erosion wear of these nitride coatings caused by abrasive particle impact was compared by determining the wear depth and the erosion rates of the coatings. Results showed that the coatings with Al (CrAlN and TiAlN) exhibited higher erosion wear resistance over those without Al (CrN and TiN). Analysis of eroded surface of the coatings demonstrated that the TiN and CrN coatings exhibited a typical brittle fracture induced removal process, while AlTiN and CrAlN coatings showed mainly micro cutting and cycle fatigue fracture of material removal mode. X.Z.Ding et al [4] By analysing the properties of TiN, CrN, TiAlN, CrAlN coating by vacuum arc method on the substrate they reported that TiAlN and CrAlN has shown the good oxidation resistance, hot hardness and hardness. The CrN and TiN oxidized at 500°c to 800°c and it also delaminated at that temperature but the TiAlN and CrAlN shows the good oxidation resistance 900°c. L.A.Dobrzański et al [5] Metal working industries has shown interest in improving tools used in hot working process. So for that the metal have to possess good resistance to friction, wear and it has to possess good mechanical properties. To get more efficient output duplex layer coating is done that is the thermo chemical process is followed by PVD. In these type of coating of material like tin, TiAlN on the substrate showed good result (i.e.) high adhesive strength, hot hardness, thermal conductivity, wear resistance and oxidation resistance.

II. MATERIALS AND METHODS

The optical emission spectroscopy is carried out to detect the composition of the materials which is obtained from the beater mills present in the Neyveli Lignite Corporation. From the test results it showed that the beater plate is made of 90Mn Cr V8 cast steel and the fuel distributor plate is made of IS2062 mild steel and the compositions are listed in Table 1a & 1b.

C	P	Si	S	Mn	Cr	V	comp
0.85-0.95	<0.03	0.15-0.3	0.03	1.90-2.10	0.2-0.5	0.05-0.15	%

C	Mn	S	P	Si	comp
0.23	1.50	0.050	0.050	0.40	%

Table 1a & 1b shows the chemical compositions of Beater plate and Fuel distributor plate.

A Magnetron-sputtered deposition method is carried out under the Working temperature ranging from 200-300°c and a Working pressure of 0.5-1pa at a Deposition speed of 0.1µm/min. Titanium aluminium nitride is selected as the coating material because of its very good resistance to oxidation and wear which is shown in Fig 1a & 1b. In order to characterize the coating and its effects, further methodology investigations like presence of coating is identified using X- ray diffraction method (XRD), the evaluation of adhesion of coating over the substrate is made using the scratch tester, and microhardness is tested using the Vickers hardness tester, Wear resistance test is carried out on pin-on-disc machine. Finally the characterization values of the coated and uncoated materials is compared and correlated to find out whether the surface property of the material has improved or not.

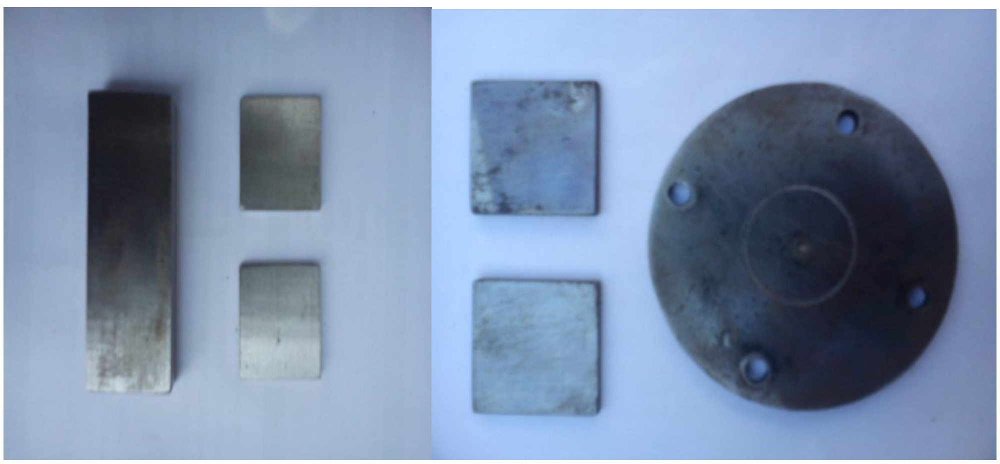

Fig 1a &1b Sample Substrate Material before and after coating.

III. RESULTS AND DISCUSSIONS

In order to have the confirmation of coating over the substrate the X- ray diffraction is used. A beam of X-rays strikes a single crystal, producing a scattered beams. When they land on a piece of film or other detector, these beams make a diffraction pattern which is shown in Fig 2a & 2b for the beater and fuel distributor plate. From the Fig 2a & 2b it clearly shows the peak value of (45.64) which conforms the presence of TiAlN coating over both of the plates as TiAlN has specific peak value of the same.

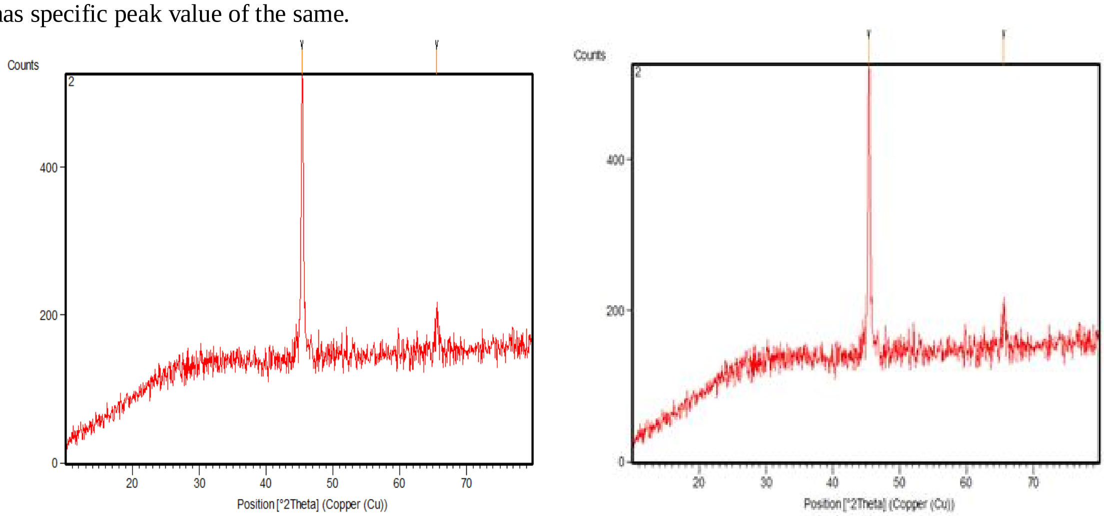

Fig 2a & 2b shows the XRD Result of Beater & Fuel distributor Plates.

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After the validation of coating existence, the scratch test is made on the sample with a sphero-conical which is drawn at a constant speed across the sample, under a constant load. During constant loading there exist a critical load at which there will be a recognizable failures. In the case of a constant load test, the critical load corresponds to the load at which a regular occurrence of such failure along the track is observed. The recognition is felt by the detector called Acoustic emission detector. It does the detection of elastic waves generated as a result of the formation and propagation of micro cracks. The results that are obtained during the scratch test is shown in Table.2

CRITICAL FORCES (N)	BEATER PLATE	FUEL DISTRIBUTOR PLATE
TOTAL DELAMINATION	86	66

Table.2 shows the scratch result for Beater and Fuel distributor plates.

From the above result it is clearly noted that the bonding strength of TiAlN coated over the beater and fuel distributor plate is high as the acoustic emission itself started only at 56 N and the complete delamination occurred at 110N. In this case the bonding is perfect and there is no chance of peel off of the coating material is possible. By this we can definitely say that the property of the substrate is improved. From the above result we can suggest the physical vapour deposition (magnetron sputtering) coating process for the coating of TiAlN over the Pulverizers plates is effective.
A Vickers microhardness test is carried out to find out the hardness of the substrate. These test are done in both coated and uncoated surfaces to find out the difference in hardness between them. In order to test the microhardness a load of 50g and a dwell period of 15sec is given to take the readings and the average values are taken. The tested Microhardness value of Beater plate (B.P) without any coating is 612 HV, while the Microhardness value of Beater plate (B.P) after coating is 2927 HV. Similarly the Microhardness value of fuel distributor plate (F.D.P) before coating is 354 HV, while the Microhardness value of fuel distributor plate (F.D.P) after coating is 2443 HV. From the above hardness value it is clearly seen that the coating has improved the hardness of the substrate to a great extent, this clearly ensure that the coating has improved the characteristic of the substrate.

After the measurement of hardness, the substrates are subjected to a wear test. A pin on disc tester is used to find out the wear resistance of the material. This test is carried out in both coated and uncoated surfaces so that the efficiency of the wear resistance of the coated material over the uncoated material can be determined. Usually, Wear resistance of the material depends highly on the coefficient of friction. By the pin on disc test we can easily find out the coefficient of friction, wear volume and wear rate of the material which is shown in the Fig.3.

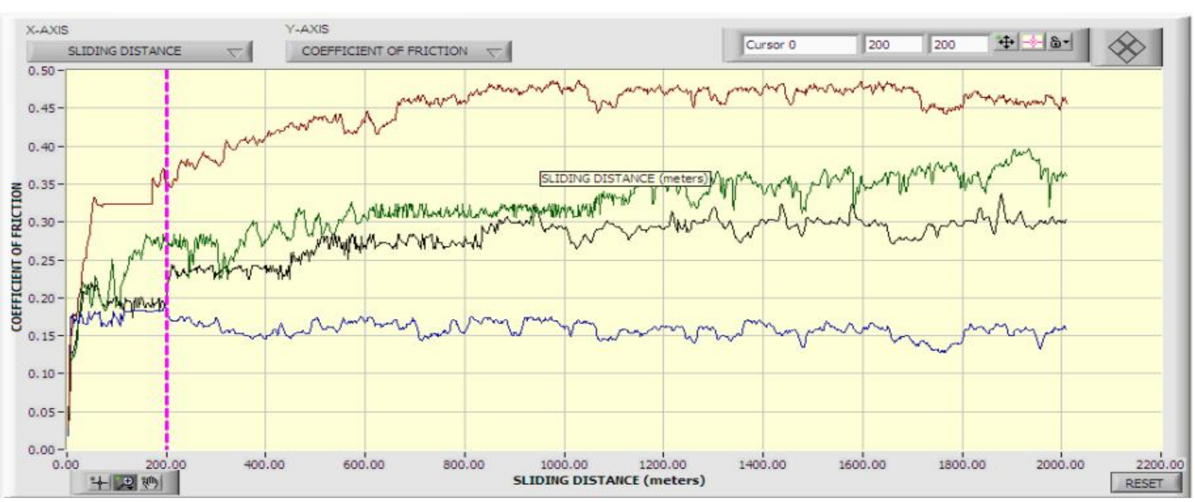

Fig.3. Result of Pin on Disc

The sliding wear test was carried out up to a sliding distance of 2000m. The Coefficient of friction of uncoated Beater Plate is 0.33, while the Coefficient of friction for coated Beater Plate is 0.15. Similarly the Coefficient of friction of uncoated fuel distributor plate is 0.47, while the Coefficient of friction for coated fuel distributor plate is 0.27. All these values can be seen in graph which are shown in different color as in Fig.3. Volume of material removed during the tribological wear for 2000 meters sliding distance at room temperature with 10N load are shown as follows, the volume of material removed in uncoated Beater Plate is 0.8266mm^3, while the volume of material removed in coated Beater Plate is 0.244mm^3 similarly, the volume of material removed in uncoated Fuel Distributor Plate is 1.9593mm^3 and the volume of material removed in coated Fuel Distributor Plate is 0.3889mm^3. So from the test results it is clear that the coating has improved the characteristic of the plate to a great extent because the coefficient of friction is reduced by three times and the wear volume is also reduced more.

IV. CONCLUSION

From the above discussion it is clearly proved that the TiAlN coating over the Beater Plate (BP) and Fuel distributor plate (FDP) has improved the properties of the substrate. In the scratch test the coating last till 86N for BP and 66N for FDP. From this value it is clearly proved that the coating has high bonding strength and also adhesiveness of the coating over the substrate is high, therefore no peel off of the coating is possible. In the hardness test the coating increased the hardness from 612HV to 2912HV for BP and 354HV to2443hv for FDP. Hence it is very well proved that there will be no erosion of coating. Already the TiAlN is known for its high oxidation resistance now by this hardness value it is clearly proved that there is no chance for corrosion or erosion on the plate material. To show a clear view about the wear resistance of the coating, wear test is done. From the result it is seen that coefficient of friction of the coated material is very low as it shows only 0.15 coefficient of friction but in the uncoated material the coefficient of friction is 0.47. Thus the value is reduced by three times. As for this it is predicted that both the frequency of reconditioning and cost involved in reconditioning will be reduced by three times when compared to the present situation.

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