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Wear and Friction Study of Ferroelectric Composite Nanomaterial on Pin on Disc Machine

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Abstract: *Ferroelectric perovskites have been the subject of extensive studies due to their promising electrical characteristics, which has a potential usefulness in fundamental research and technological applications. Friction is one of most important aspect of material science for which the atomic nature and the chemical interaction at the material surface, plays crucial role. Hence, to understand the mechanisms of friction at the atomic level, with desired material is an essential step in the design of new materials with specific frictional properties. In present research perovskite composite nanomaterial $BaNi_{0.5}Nb_{0.5}O_3$ (BNN) was synthesized by conventional solid state method and palletized. With the Pin on Disc machine, the coefficient of friction and wear of the material against copper was found at various constant speed of 500 rpm, 750rpm and 1000 rpm of the disc.*

Keyword: *coefficient of friction, wear, composite nanomaterial, perovskite, etc.*

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I. Introduction

General Engineering materials have limitations in achieving optimum levels of strength, stiffness, density, toughness and wear resistance. To overcome these shortcomings, discontinuously reinforced aluminium metal matrix composites (DRAMMCs) are gaining importance due to their high specific strength, high stiffness, low density and good wear resistance and they have the potential to replace their monolithic counterparts primarily in automotive, aerospace and energy applications [1]. Fabrication of MMCs has several challenges like porosity formation, poor wettability and improper distribution of reinforcement. Achieving uniform distribution of reinforcement is the foremost important work. A new technique of fabricating cast Aluminium matrix composite has been proposed to improve the wettability between alloy and reinforcement. In this, all the materials are placed in graphite crucible and heated in an inert atmosphere until the matrix alloy is melted and followed by two step stirring action to obtain uniform distribution of reinforcement. The fabrication techniques of MMCs play a major role in the improvement of mechanical and tribological properties. [2][5]

The performance characteristics of Al alloy reinforced with 5% volume fraction of SiC fabricated through stir casting and found that the stir casting specimen have higher strength compared to powder metallurgy specimen. The size and type of reinforcement also has a significant role in determining the mechanical and tribological properties of the composites. The effect of type of reinforcements such as SiC whisker, alumina fiber and SiC particle fabricated by Powder Metallurgy on the properties of MMCs has been investigated. It was found that there existed a strong dependence on the kind of reinforcement and its volume fraction. The results revealed that particulate reinforcement is most beneficial for improving the wear resistance of MMCs. [2] Wear is an important property in the selection of DRAMMCs. Wear is not an intrinsic material property but characteristics of the engineering system which depend on load, speed, temperature, hardness, and the environmental conditions. Wear performances of particulate reinforced aluminium matrix composites reinforced with various reinforcements ranging from very hard ceramic particulates such as SiC and Al2O3 have been reported to be superior when compared with unreinforced alloys. The principal tribological parameters that control the friction and wear performance of DRAMMCs like load, sliding velocity, sliding distance, reinforcement size and reinforcement volume fraction. There has been an increasing interest in composites containing low density and low cost reinforcements [3]

Friction and wear are responses of a tribo-system, Coefficients of friction and wear are parameters describing the state of contact of bodies in a tribo-system, and they are not material constants of the bodies. The wear and friction may be treated as material properties for technical conveniences with an engineering sense only in some special states of contact. Friction and wear, as two kinds of responses from one tribo-system, must be exactly related with each other in each state of contact in the system, although a comprehensive simple relationship should not be expected. Technical senses of past tribologists, on the other hand, have already introduced successful methods of controlling wear without asking details of wear mechanisms. They are soft or hard film coating, multi-phase alloying and composite structuring in addition to traditional method of lubrication. It would be helpful for the understanding of wear mechanisms to confirm the tribo-characters of materials by those methods, in the viewpoints of wear and friction, by describing the tribo-phenomena with the representative terms of ''roughness, hardness, ductility, oxide film, reaction layer and adhesive transfer''[6][7][11] [12].

Recently, the perovskite material silver tantalate (AgTaO3) has been identified as a promising new solid lubricant for hightemperature applicationsSilver tantalate (AgTaO3) coatings have been found to exhibit outstanding tribological properties at elevated temperatures. To understand the mechanisms involved in the tribological behavior of the Ag-Ta-O system, tantalum oxide coatings with a small content of silver were produced to investigate the metastable nature of this self-lubricating material. The coatings were produced by unbalanced magnetron sputtering, ball-on-disk wear tested at 750 ^{0}C, and subsequently characterized by X-ray diffraction, Scanning Auger Nanoprobe, cross-sectional Scanning Electron Microscopy, and Transmission Electron Microscopy. Complementary molecular dynamic simulations were carried out to investigate changes in the chemical and structural properties at the interface due to sliding for films with varying silver content. Both the experimental characterization and the theoretical modeling showed that silver content affects friction and wear, through the role of silver in film reconstruction during sliding. The results suggest that the relative amount of silver may be used to tune film performance for a given application. [4] [8][9][10]

II. Experimental Setup

The Pin-On-Disc Tester is used to test the friction and wear characteristics of dry or lubricated sliding contact of a wide variety of materials including metals, polymers, composites, ceramics, lubricants, cutting fluids, abrasive slurries, coatings, and heat-treated samples. The test is performed by rotating a counter-face test disc against a stationary test specimen pin. Wear, friction force, and interface temperature can be monitored using Tribo DATA, the supplied Windows-based Data Acquisition Software. The normal load, rotational speed, and wear track diameter can be adjusted in accordance with ASTM G99 test standard. Fig.1 shows the schematic diagram of pin on disc testing machine. Specifications of machine are described in Table 1.

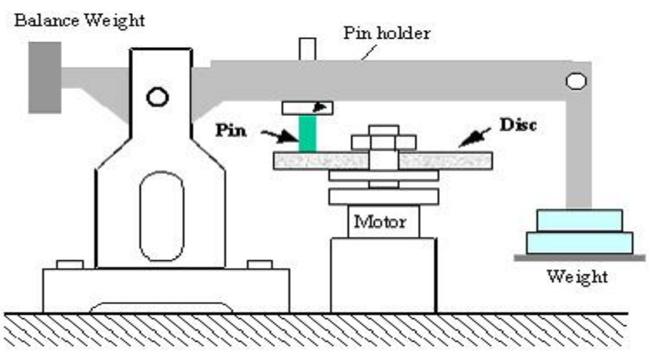

Fig.1. Wear and friction test rig (pin on disc testing machine)

Machine Specifications

Power:	500 VA
Sliding Speed Range:	0.26 m/sec to 10 m/sec
Disc Rotation Speed Range:	100 - 2000 rpm
Normal Load:	200 N Maximum
Friction Force:	0 - 200 N
Wear Measurement Range:	up to 4mm
Pin Size:	3mm to 12mm diagonal /diameter
Disc Size:	160mm diameter x 8mm thick
Mean Wear Track Diameter:	10mm to 140mm
Pin on Disc Tester with Environmental Control chamber Temperature :	60°C maximum

III. Experimentation

Experimentation was carried out in three steps. i. e. synthesis of perovskite nanomaterial, formation of its pallet and testing for tribological properties on pin on disc machine, by varying the speed of rotation of disc.

III.1 Synthesis of Perovskite composite nanomaterial:

Perovskite Composite nanomaterial was synthesized by conventional solid state reaction method. The mixture of barium oxide, nickel oxide and niobium oxide (99% AR grade) were taken in the stoichiometric proportion for sample then it was crushed for 4 hours. This sample was then heated in air in the muffle furnace in the silica crucible at 950 degree Celsius for 12 hours, and then cooled slowly. Again the material is crushed for four hours and then annealed at 450^0 C for two hours.

XRD of the BNN material was carried out which showed sharp single peaks, which indicates the single phase nature of the sample with cubic perovskite structure [13][14].

III.2 Pallet preparation:

The perovskite ceramic powder is palletized of thickness 3mm and diameter 10.114mm,by applying a force of 40 KN on CTM. The pallet is then sintered in air at 600^0 C for one hour, so that binder gets evaporated.

III.3 Wear Testing on Pin on disc Machine:

Wear and friction of BNN pallet is tested against copper plate on pin on disc testing machine without lubrication at a load of 500g. After fixing the pallet above the copper disk of thickness 10mm and allowed to slide over it. The wear and friction parameters are recorded periodically. The testing of experimental parameter is recorded at disc speed of 500rpm, 750 rpm, 1000rpm .

IV. Results And Discussion

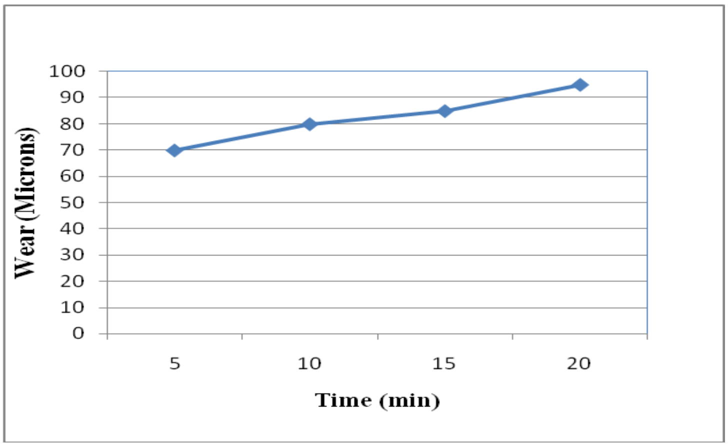

Fig.2. Graph of wear vs. time (500 rpm)

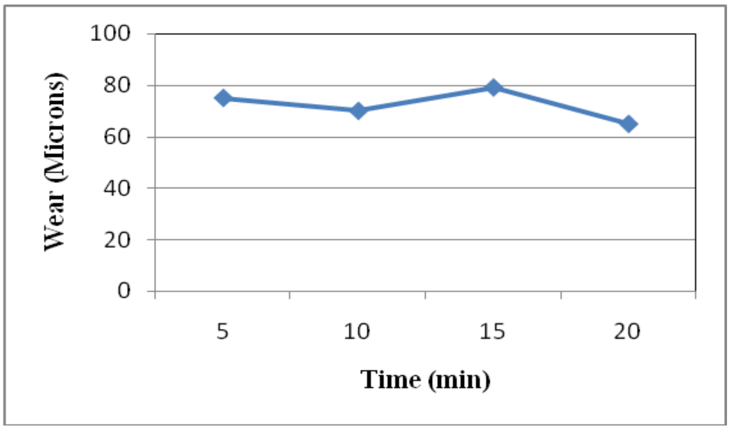

Fig.3. Graph of wear vs. time (750 rpm)

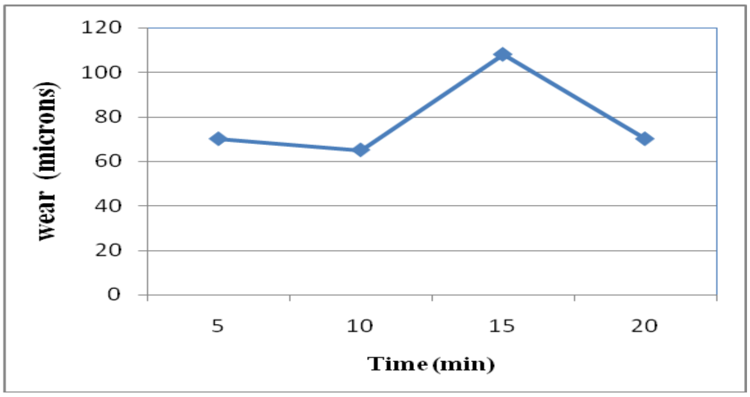

Fig..4. Graph of wear vs. time (1000 rpm)

The Fig. 2, 3, and 4 indicates graph of wear verses time. It shows that initially there is increase in wear still 15 minutes time later on wear decreases. The decreasing trend of the wear rate when time of sliding increases is due to the formation of protective mechanically mixed layer between pin and capture force.

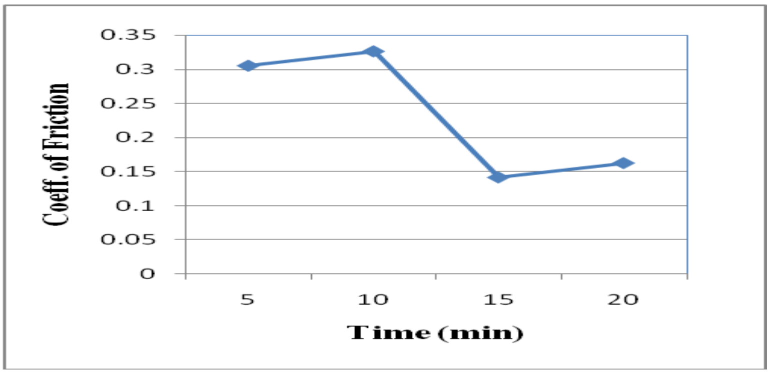

Fig.5. Coefficient of Friction vs. time (500 rpm)

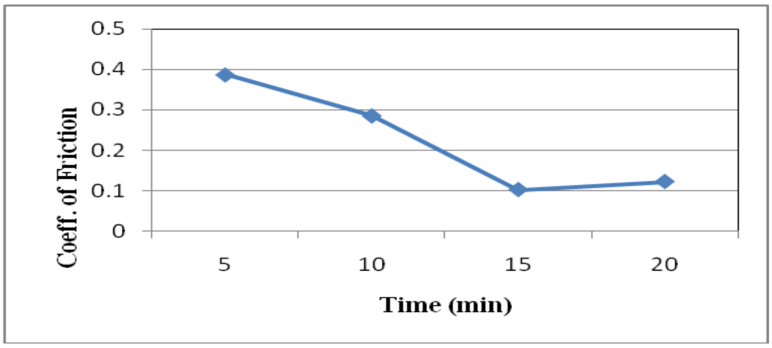

Fig.6. Coefficient of Friction vs. time (750 rpm)

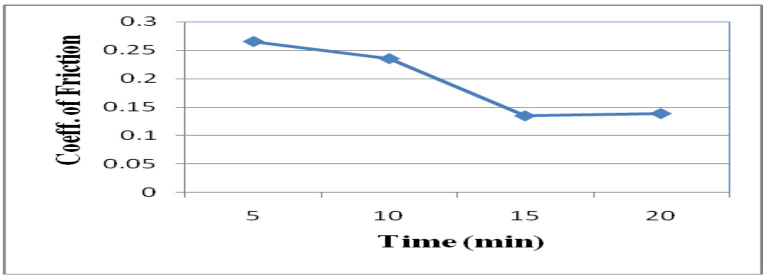

Fig.7. Coefficient of Friction vs. time (1000 rpm)

The graph of COF Vs time is shown in Fig, 5, 6 and 7. It predicts that COF decreases initially from 5min. to 15min. and later on it increases. The COF is observed high for less time and reduced for more time of sliding. This is because at initial the transfer film is found to be stable for more time and temperature rise is also low. Whereas at more time the transfer film is destroyed at faster rate and temperature is also high.

V. Conclusion

For the technical development of wear control in the near future, the characteristics of wear of coatings, composites, metallic alloys and ceramics were reviewed in relation to their frictional characteristics. Also and attempt to study wear and friction of perovskite BNN material against copper is made and COF of BNN is found out. It is concluded that wear of Perovskite material is lower than the conventional material. The Perovskite material has more resistance and less coefficient of friction at more sliding time. While optimum results for wear and COF are obtained at 750 rpm. Hence Perovskite BNN material can be better candidate for various electronic devices.

VI. Abbreviations

BNN- Barium Nickel Niobate
CTM-Compression Testing Machine
COF- Coefficient of Friction
Rpm- Rotation Per Minute
SiC-Silicon Carbide
XRD- Xray Diffraction

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