WEAR TESTING AND CHARACTERISATION OF NANO COMPOSITES

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Abstract

Ceramic tools are made by powder metallurgy techniques, through compacting and sintering. For Tribological applications wear rate and coefficient of friction is important for ceramic tools. The wear rate is less for alumina and its composites. Ceramic is used for ceramic liners, bearings and drawing dies Since Nano alumina and composites are having better strength properties they are well suited for the wear resistance applications. In order to test their performance, wear testing has to be carried out. For wear testing a Pin-on-Disc wear testing machine has been designed and fabricated. Upon investigation there is transfer of the metal to the ceramic pin during wear testing due to the strong adhesion between Alumina and the metal. But the transfer of the metal is decreased in the case of Alumina - Zirconia composite. It is observed that the wear rate of the steel disc is higher when the pure alumina pin is used as counter surface than the Alumina - Zirconia composite. Also the coefficient of friction for the Alumina - Zirconia composite is more than the pure Alumina.

Key words: Nano Alumina–Zirconia, Sintering, wear testing, ceramic composite, Characterization

I. INTRODUCTION

Ceramics are nonmetallic inorganic compounds like silicates, oxides, carbides etc. They have high boiling point, high hardness, high temperature resistance, and high wear resistance. They have wide applications like cutting tools, ceramic liners, bearings, fuel cells etc. Ceramics are used for high speed of machining cast iron and steel. The ceramic tools have high hardness at high temperature. Due to its high hardness the wear resistance is high for ceramics and hence it is used in high speed machining and hard materials. The application range of ceramics is shown in fig. 1.

II. WEAR TESTING OF THE CERAMICS AND COMPOSITES

A. Alumina Zirconia Composite

The introduction of Zirconia into alumina as a sintering aid has long been practiced for densification of alumina engineering ceramics. Zirconia exhibits three phases, the cubic phase, the tetragonal phase, the monoclinic phase. Cubic phase exist at high temp 2680 -3700 DC, the tetragonal phase exists at 2370 -1170 DC, the monoclinic phase exist below 1170°C. The property of phase transformation of Zirconia has been used to obtain superior properties.

Wear of the toughened Alumina Zirconias shows more sensitivity to sliding speed than the toughened Alumina's. Zirconia- Yttria had the lowest wear. Coefficient of friction is found to be 0.163 - 0.63. [1]

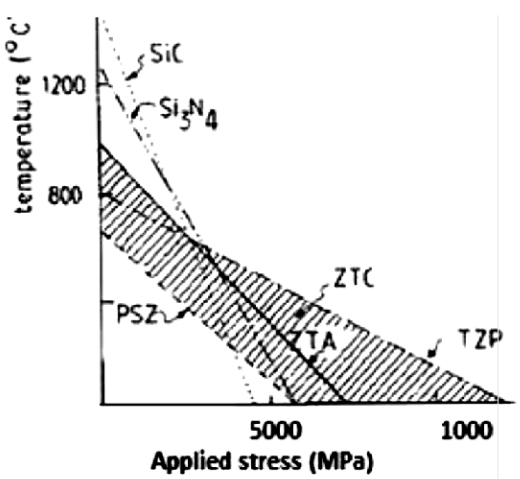

Fig. 1. Application range of ceramics

Fabrication of Nano Alumina–Zirconia

Sintering is carried in a programmable furnace, in which are walls are made up of ceramics to withstand the high temperature up to 1600°C. Sintering of Alumina is carried at 1550°C. The compacts are heated at rate of 5°C/min to the 1550°C and temperature is maintained at 1550°C for 3hrs, and then cooled at a rate of 5°C/min. Zirconia - Alumina is sintered at 1550°C at rate of 2°C/min. The heating, cooling rate, soaking temperature and duration are standardized through several experimental trails and through literature.

The wear behavior of alumina and its composites against the tool steel, Alumina exhibit more wear resistance than its composites. In wear tests, it is observed there is transfer of metal from disc to pin. With the increase in the load, it was observed that there was increase in wear rate with the reduction in coefficient of friction [2].

The effect of alumina dispersed as second phase in Zirconia is 5 mol% Yttria partially stabilized Zirconia with 14% of alumina were sintered at temperature between 1000 to 1200°C. Homogenous dispersion of the alumina second phases in Zirconia matrix resulted in improved properties of the CMC [3]

The mechanical properties and physical properties including fracture toughness, flexural strength, slow crack growth, elastic modulus, density, Vickers micro hardness, thermal conductivity and microstructures shows Alumina reinforced Zirconia composites (0% to 30% alumina) fabricated by hot pressing 10% mol Yttria stabilized Zirconia has Fracture toughness and strength increased with increase in alumina content. The 30% particulate composite have more yield strength. At 30% alumina it was found that the thermal mismatch is much reduced [4].

The wear behavior of alumina cutting tools with pure a-alumina inserts with grain sizes of 0.83 flm, 2.94 flm and 6.33 flm were produced by slip casting and pressure less sintering. The initial volume of wear increased with increase in grain size. The long and parallel ridges are observed on flank wear land during early stages of machining were the result of plastic deformation by single glide of individual aluminum grains [5].

The primary particle size and degree of agglomeration influence on the final sintered components shows low agglomerated and fine powder sizes of about (20 nm) is the best suitable for further processing. For nano sized powder of metastable state, the control of transformation into stable growth seems to be difficult, so it is better to use the stable phase [6].

In wear test alumina with steel the wear debris contains ferric oxide and ferrous oxide, which was found by Raman spectral analysis of the samples [7].

From the literature survey, it can be understood that nano alumina and nano composites are to be fabricated for high technology applications.

III. WEAR TESTER FOR THE CERAMICS AND COMPOSITES

The machine consists of a bearing housing with attachment of disc holding mechanism coupled with the shaft connected to DC motor. The speed can be varied from 10 to 1500 rpm, and controlled by an autotransformer. A step less variation of sliding speeds from 0.1 m/sec to 10 m/sec can be obtained by varying the motor speed and the distance of specimen from the center of the rotating disc. The instrument has various systems and mechanism such as loading system, Arm moving mechanism, Disc holder mechanism, Pin holder mechanism and Load cell unit; these mechanisms are mounted on a single stand (fig.2) arrangement. A control panel has been specially designed to measure and control the various parameters such as sliding speed, sliding velocity, test duration, co-efficient of friction and temperature near contact region etc. To measure the friction force a load cell unit has been designed, which is fixed on the vertical supporting stand.

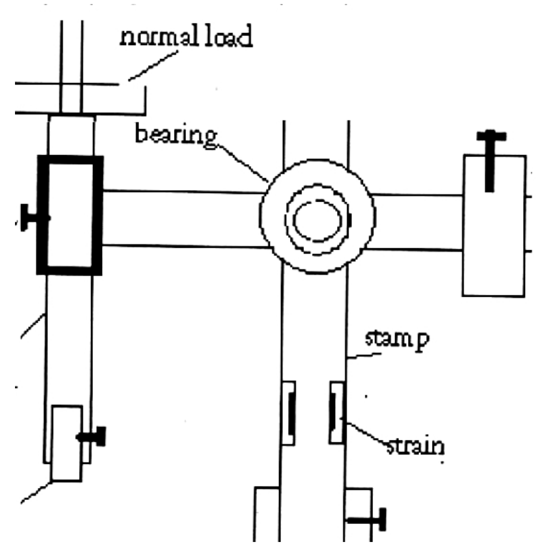

Fig. 2. Arrangement of the loading arm and sensor

For measuring the coefficient of friction, four resistance strain gauges were fixed on an elastic member in the vertical-supporting stand. The small signal obtained from the strain gauge bridge circuit is amplified and measured by a mill i-voltmeter, which was calibrated by the application of known loads. To determine the friction force the milli-voltmeter reading is noted during the test and the corresponding friction force is obtained from the calibration curve.

IV. WEAR CHARACTERISTICS OF PIN – DISC

Samples of size 10 mm diameter are mounted in the wear testing machine after calibration. Then the normal weight is added and the wear testing is performed. After each 10 km of the sliding distance, the reduction in weight is found by the digital weighing balance. Before weighing, the disc is cleaned with acetone to remove the wear particles sticking to the disc. From the weight reduction the wear volume is calculated. The readings from the strain gauges are noted from the digital display for calculating the coefficient of friction and from the calibration curve the tangential force is calculated. Wear rate is wear volume per kilometer distance.

The wear test has been conducted for different sliding velocities 1 m/s, 2.5 m/s, 3.5 m/s with Fig. 6. Micrographs of the wear track of load of 23.5 N. Due to the lower amount of wear disc at 23.5 N - 3.5 m/s of alumina, wear of the steel discs is measured. (Fig. 3-5, 8-11)

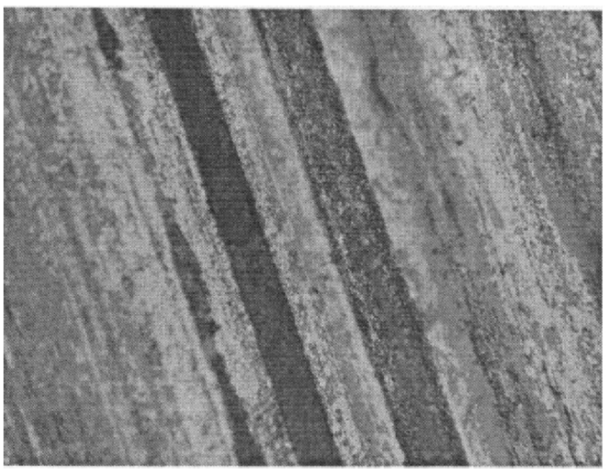

Fig. 3. Micrograph of the wear track of disc at 23.5 N - 3.5 m/s at 100X

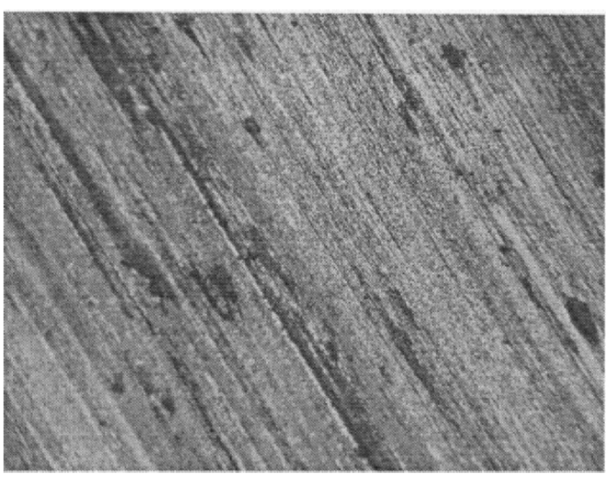

Fig. 4. Micrograph of the wear track of Disc at 23.5 N - 3.5 m/s at 50X

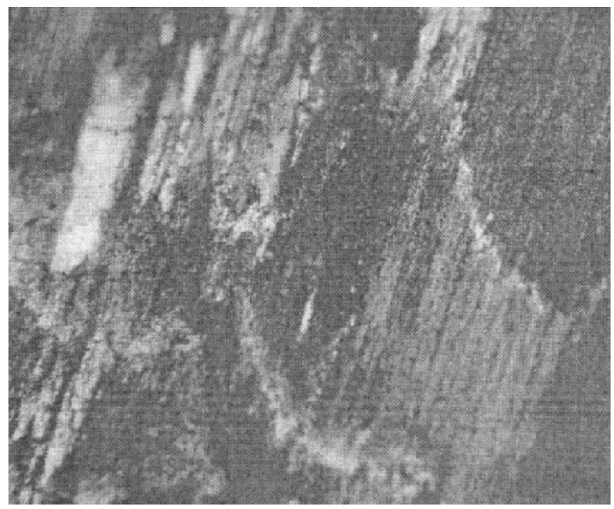

Fig. 5. Micrographs of the ceramic pins sliding at 23.5 N - 3.5 m/s at 100X

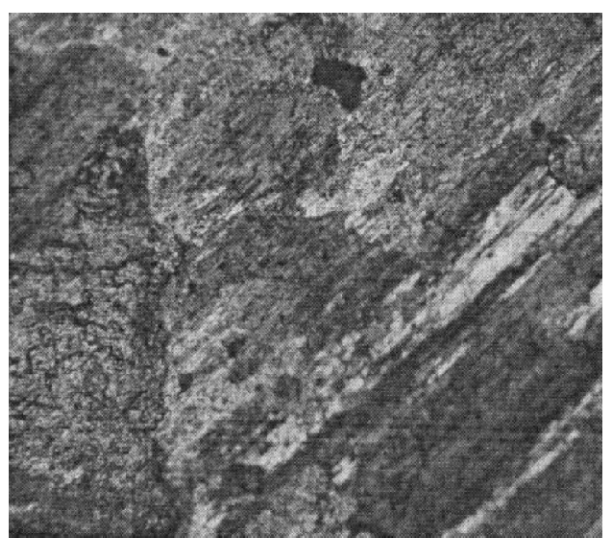

Fig. 6. Micrographs of the ceramic pins sliding at 23.5 N - 3.5 m/s at 50X

A. Coefficient of friction at various loads

During the wear test, the ceramic pin slides on the steel disc causing metal transfer from disc to the ceramic pin. Within 10 minutes, the perfect contact between the pin and disc started to establish. The coefficient of friction is less, after certain amount of sliding distance, due to contacting members, the coefficient of friction increases. (Fig. 7).

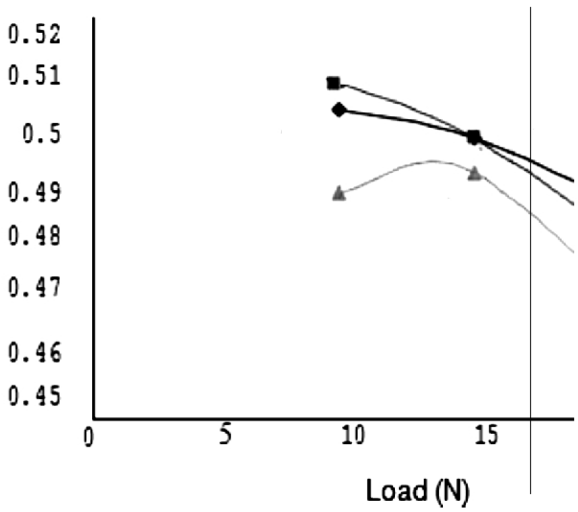

Fig. 7. Coefficient of friction for the Alumina at various load conditions

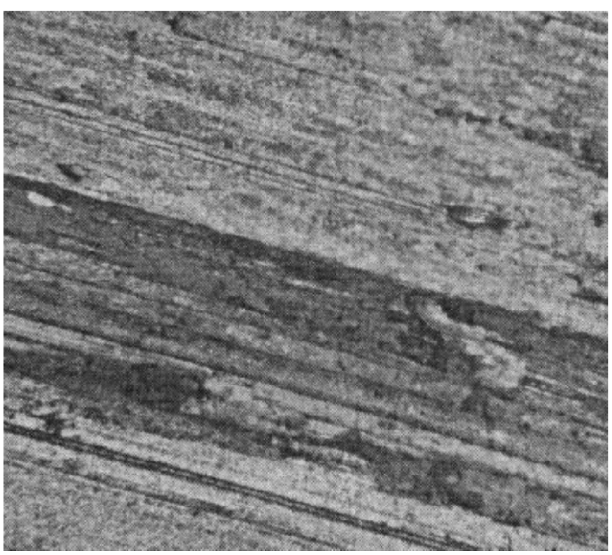

Fig. 8. Micrographs of wear track of the disc at 23.5 N – 2.5 m/s at 100X

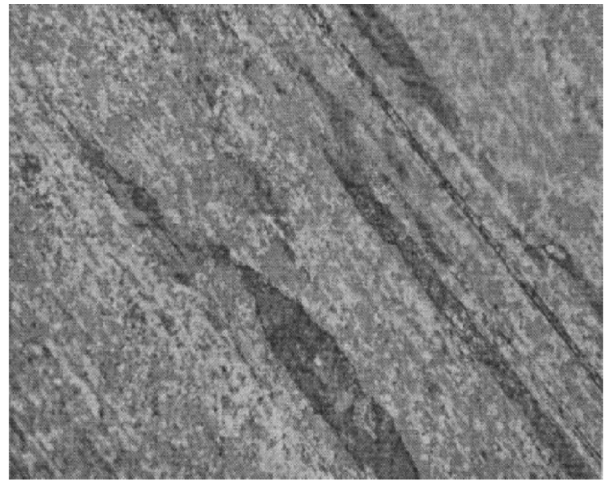

Fig. 9. Micrographs of wear track of the disc at 23.5 N – 2.5 m/s at 50X

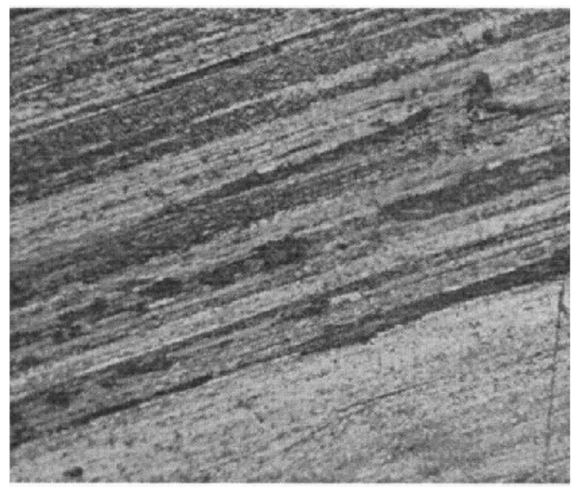

Fig. 10. Micrographs of wear track of the disc at 23.5 N – 1 m/s at 100X

Fig. 11. Micrographs of wear track of the disc at 23.5 N – 1 m/s at 50X

B. Observations from the Micrographs of the wear specimens

Wear test is being performed for load of 23.5 N at the various sliding speeds. The wear out specimens is analyzed in the optical microscope. (Fig. 12-15)

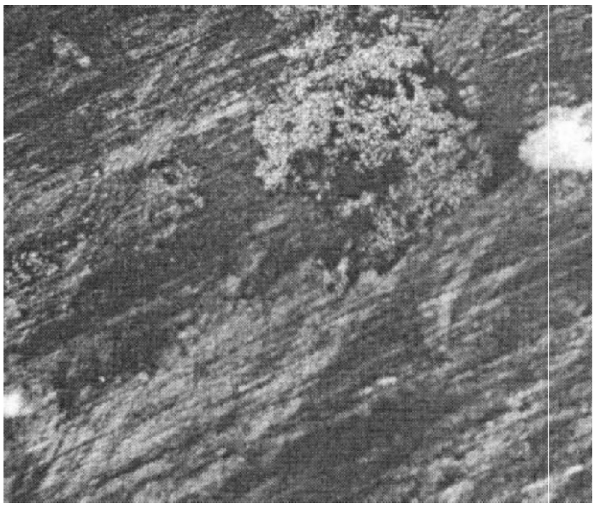

Fig. 12. Micro graphs of the ceramic pin 23.5 N - 1 m/s at 100X

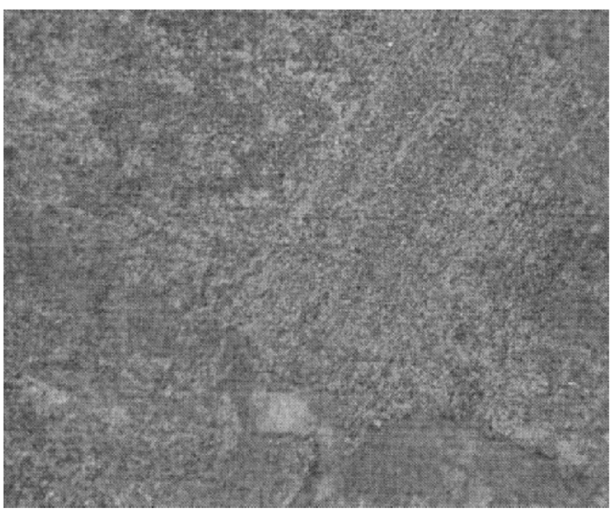

Fig. 13. Micro graphs of the ceramic pin 23.5 N - 1 m/s at 50X

When the sliding takes place, there is transfer of the metal to the alumina and its composites, there is strong adhesion between the alumina and it's composite to the steel. The red color patches are found in the alumina pins are the oxides of iron, these results are agreeing with the findings of Yuji Enomoto and Kazuyuzi Mizuhara [3]. There is more metallic film is found at higher sliding velocity than at lower sliding velocity. From micrographs it's found that large grooves are found at higher loads and higher velocities.

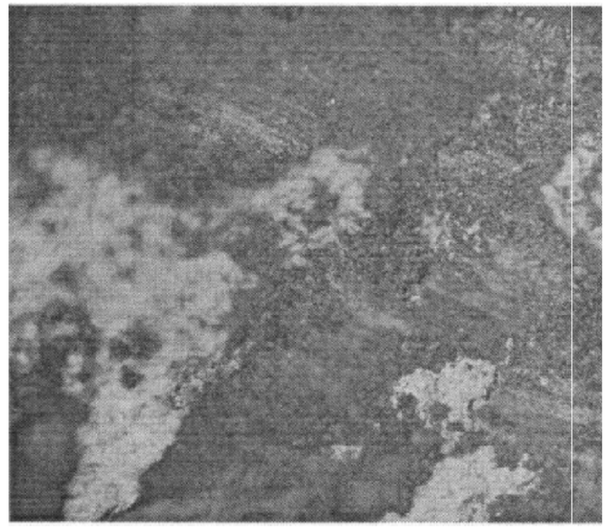

Fig. 14. Micro graphs of the ceramic pin 23.5 N - 1 m/s at 100X

Fig. 15. Micro graphs of the ceramic pin 23.5 N - 1 m/s at 50 X

C. Wear characteristics Alumina-Zirconia

The wear test is conducted for Alumina- Zirconia on the two types of specimens. One with the starting phase as gamma phase (B) and another with alpha phase (A) before sintering. As the normal load increases the wear rate increases, similar trend is observed with increase in velocity. Though the starting phase of alumina is powder is varied (A & B), there is no remarkable difference in the wear volume of the disc. (fig 16-18).

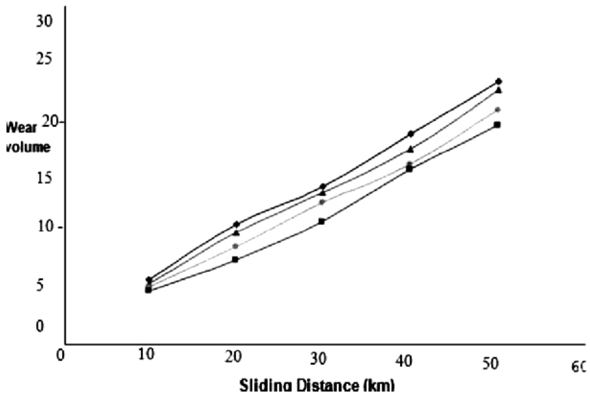

Fig. 16. Wear of steel disc for 3.5 m/s sliding velocity

V. CONCLUSIONS

From the detailed experimental investigation and several observations, the following conclusions are

Made. There is transfer of the metal to the ceramic pin during wear testing due to the strong adhesion between Alumina and the metal. But the transfer of the metal is decreased in the case of Alumina Zirconia composite. The wear rate of the steel disc is higher when the pure alumina pin is used as counter surface than the Alumina Zirconia composite. Coefficient of friction for the Alumina Zirconia velocity composite is more than the pure Alumina.

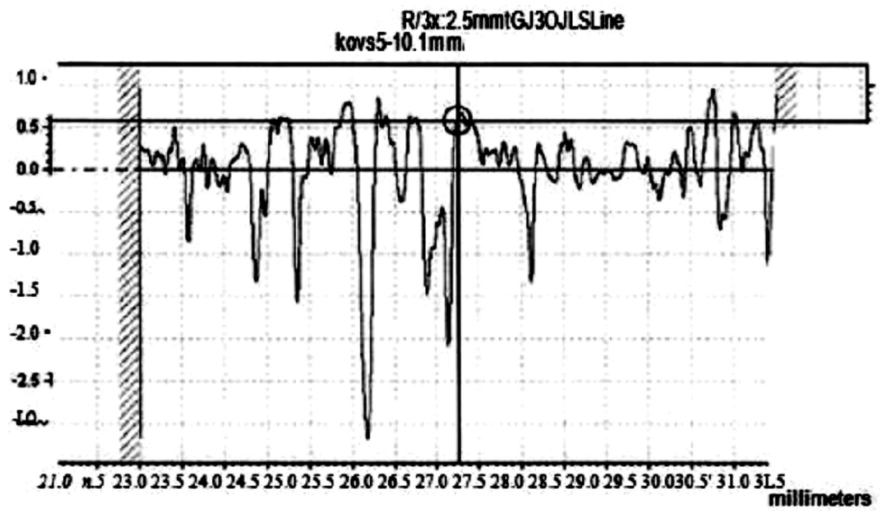

Fig. 17. Wear profile Alumina pin - Steel disc

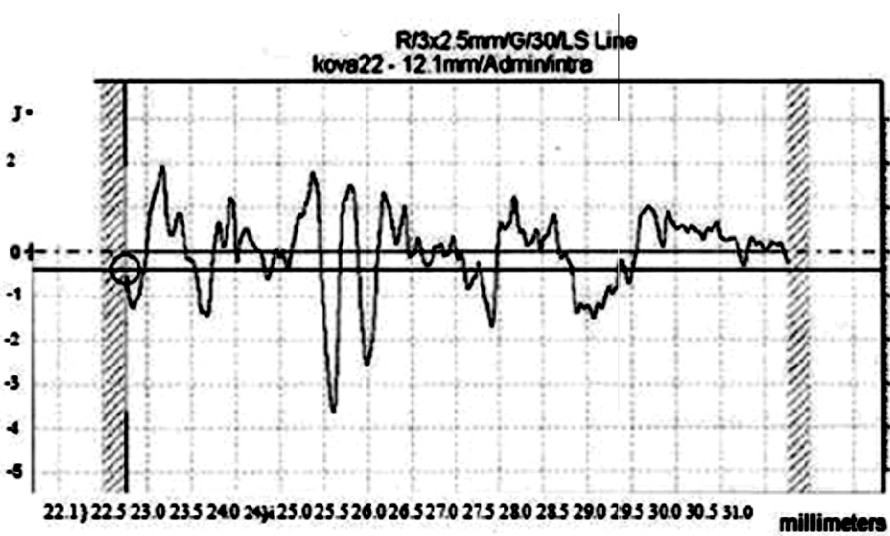

Fig. 18. Wear profile Alumina Zirconia pin – Steel No remarkable difference in the wear volume of Disc

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Muthukumar S. currently is a Research Scholar in School of Mechanical. VelTech Dr. R.R & Dr. S.R Technical University. His area of interest includes Wear testing of composites.