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RESEARCH PAPER

Mechanical Application of Lubricated Nano Porous Anodized Aluminium

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ABSTRACT

Today a major environmental problem is global warming that is mainly caused due to exhaust and emission of gases. The only way to reduce their ill-effect is by improvement in fuel efficiency of I.C. engines, where most of the power is lost to overcome the friction. In this work, nanoporous anodized layer is formed on an aluminium substrate surface by anodization. Anodization was carried out at different parameters such as voltage, temperature, time to find out optimum conditions to obtain well ordered nanoporous layer. Characreization of anodized porous layer was done by FE-SEM and EDS. After synthesis, anodized layer was treated with anionic surfactant and dipped in lubricant (SAE-15) for tribological applications. Tribology testing was performed on lubricated anodized surface which shows better results in wear and friction as compared to bare substrate. This technique has a lot of potential in improving fuel consumption of I.C. engines, thus may go a long way towards our goal to save environment.

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INTRODUCTION

Global warming has become today's a major issue to keep the earth warm. The past century has seen a rapid increase in the atmospheric concentration gasses, due to maximum usage of technology. If this trend continues, researchers aware that the average earth surface temperature will increase about 1.4–5.8 °C by the year 2100. Automobile industry plays a major contribution in the emission of these gases and they have committed themselves to do so in the future, too. Nanotechnology is one of them that are using in automobile applications are intended to reductions in engines emissions, safe driving, weight reduction etc [1-4]. Improved engine efficiency also concerns friction and wear reduction of reciprocating or rotating parts; in general, it deals with the tribology. A lot of information is available in open literature related to general aspects of tribology, but for the specific area concerned to development of anodized Al-oxide with surfactants and its tribological behaviour, very few research reports are available as this is a relatively new area of engineering applications. An understanding of various friction and wear mechanisms is necessary for one to make the right selection of materials, coatings, surface treatments and operating conditions for a given application, e.g., developing some novel material

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combination to get the desired properties as investigated in this work. The largest mechanical losses come from wear and tear of cylinder bore, piston, piston rings and crankshaft gear. For this low-friction coatings are necessary [5-6].

Depleting fossil fuel resources, economic competitiveness and environmental concerns has compelled to explore newer avenues to improve efficiency of automotive engines [7-9]. Various techniques have been adopted to achieve this goal. Reduction in wear of engines is a key factor in improving fuel efficiency. The use of light weight materials has become more prevalent as car manufacturers strive to reduce weight in order to improve performance, lower fuel and oil consumption, and to reduce emissions. In concern to this problem the objective of proposed work is to enhance the tribological properties by surfactant assisted anodized aluminium.

MATERIALS AND METHODS

Aluminium sheet of 99.9% pure aluminium and 0.4mm thick were taken from local market. Samples of square shaped (1cm x 1cm) were cut from aluminum sheet for experiment. After cutting, these were degreased with acetone for 2 minutes and air dried followed by electropolishing, which was performed in mixture of ethanol (C_2H_5OH) and phosphoric acid (H_3PO_4) in the ratio of 5:1 respectively. With the help of potentiostat at 15 V D.C. for 6 minutes where samples were taken as anode and Aluminium strip as cathode. Aluminium Oxide layer was formed on electropolished surface with the help of electrochemical process called anodization. For anodization, experiments were carried out by using 0.4 M phosphoric acid (H_3P0_4) at 150 V having temperature ranges 34 ±2 ^{0}C for 35 minutes.

The electropolished Al sample then be anodized in an electrochemical bath using the sample as anode plate and Al as the cathode with varying concentration of anionic surfactant sodium dodecyl sulfate. The concentration of surfactant considered was 8.7 x 10^{-2} M to 5. 5 × 10^{-1} M. The surfactant assisted anodized samples were then immersed in aqueous solution of lubricant SAE-15 for 30 minutes.

The average surface roughness factor (R_a) was measured with the help of Surfest SJ-210, MITUTOYO portable surface roughness tester. The mean average of at least six values was estimated for experimental measurement. To check the formation of oxide layer on aluminium samples FE- SEM (ZEISS) analysis was done, that confirmed about formation of the oxide layer. After that sample was taken for tribological testing, where wear and friction test were conducted at 2 Kg weight, 250 rpm for 10 minutes. The Pin-On-Disc set up was used to test the friction and wear value of dry sliding contact of a sample where was rotated against a stationary test sample.

RESULT AND DISCUSSION

Anodization effect

In Fig. 1, FE-SEM morphology were shown at different scale which confirmed about generation of nanoporous anodized alumina oxide layer by using 0.4 M $H_3P0_{4,}$ 150 V 35 min at 34 ± 2 ^{0}C as shown in table 1.

Anodization experiments were carried out at all the parameters detailed above and it has been investigated that the best ordered nanoporous oxide film was obtained when anodization was carried out by using 0.4 M H_3PO_4 at 150 V having temperature range 30 ± 5 ^{0}C for 1 hr.

It can be seen in figures that the nanoporous structure of equally distributed pores are formed on surface which is helpful for their application in different sectors.

To analyze the formation of nanoporous anodic oxide film in the presence of phosphoric acid an energy dispersive spectroscopy (EDS) has been explored. Fig. 2 shows the energy dispersive spectra (EDS) of anodized film obtained at optimum conditions. EDS spectra identifies the presence of C, O, Na, Al, P and K.

Table 1. Shows the Details of Parameters Considered for Obtaining Optimum Conditions for Anodization

S.NO.	PARAMETERS	RANGE
1.	Voltage (in volts)	120 V-180 V
2.	Concentration(in molars) of H_3PO_4	0.4 M-1.8 M
3.	Time(in minutes)	15mins- 120 mins.
4.	Temperature (in Celsius)	0^oC- 30 ^oC
5.	pH	0.9-1.2

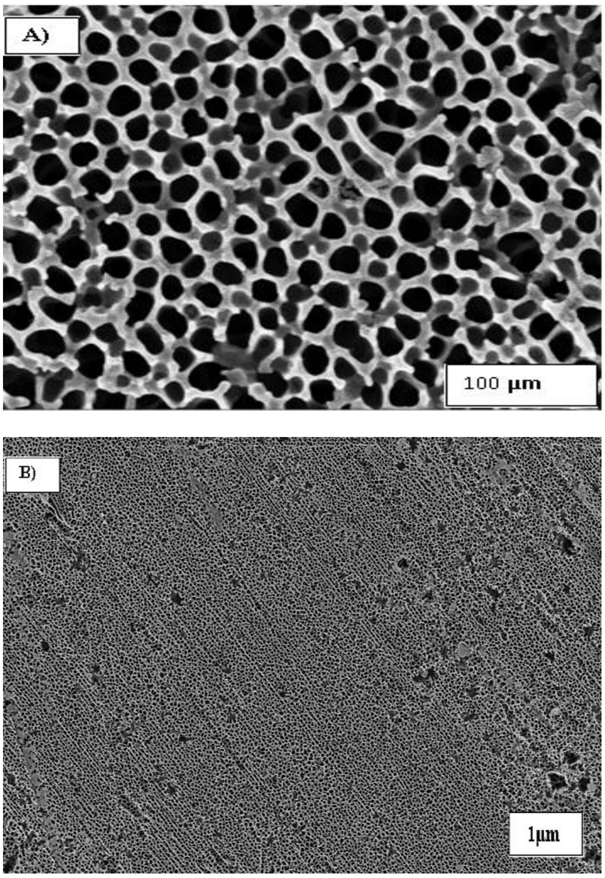


Fig. 1. FE-SEM morphology of anodized alumina oxide sample in 0.3 M H_3P0_4, 150 V 35 min at 34 ± 2 ^{0}C (A) Top view at 100μm scale (B) Top view at 1μm scale

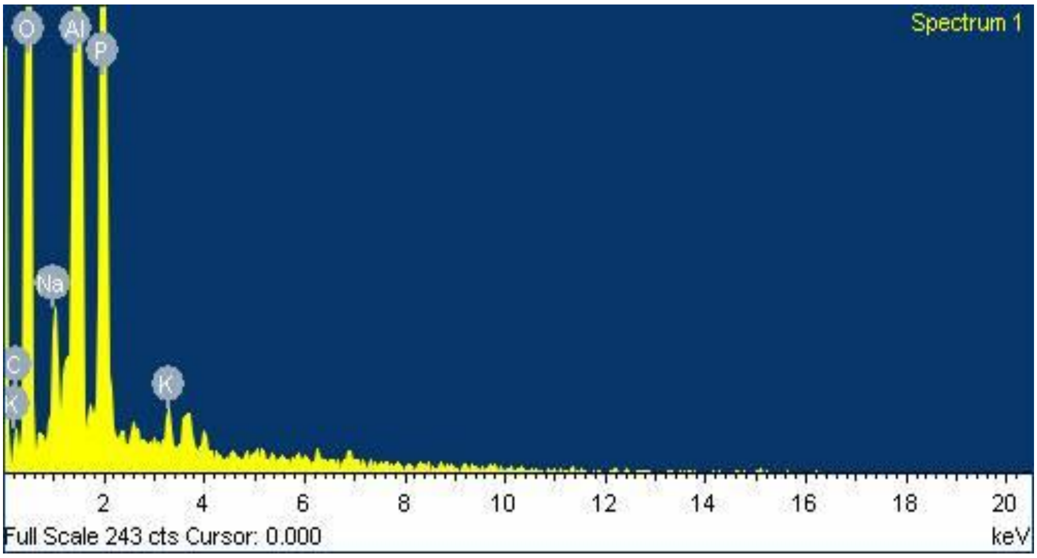
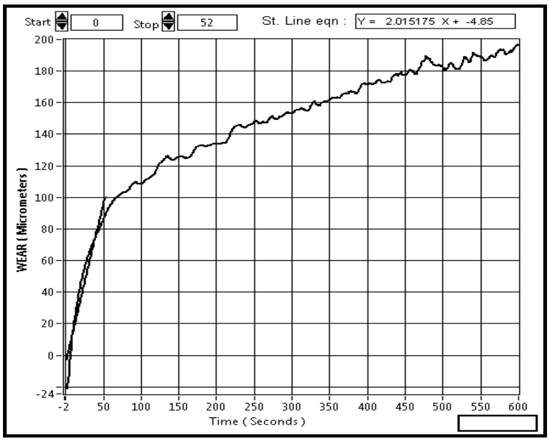
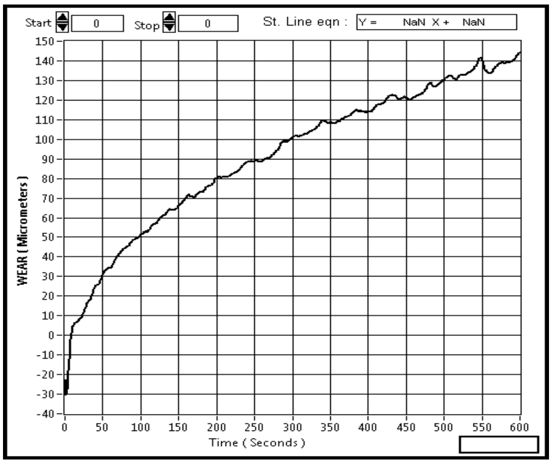


Fig. 2. Energy Dispersive Spectroscopy analysis of nanoporous anodized aluminumoxide film, identifies that the anodic film contains the elements such as C, O, Na, Al, P and K.



(A)



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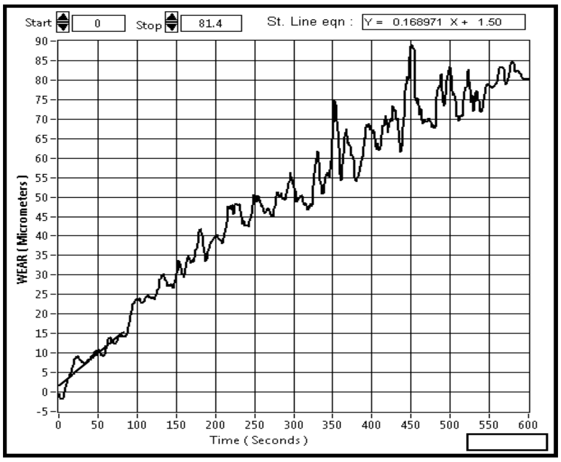
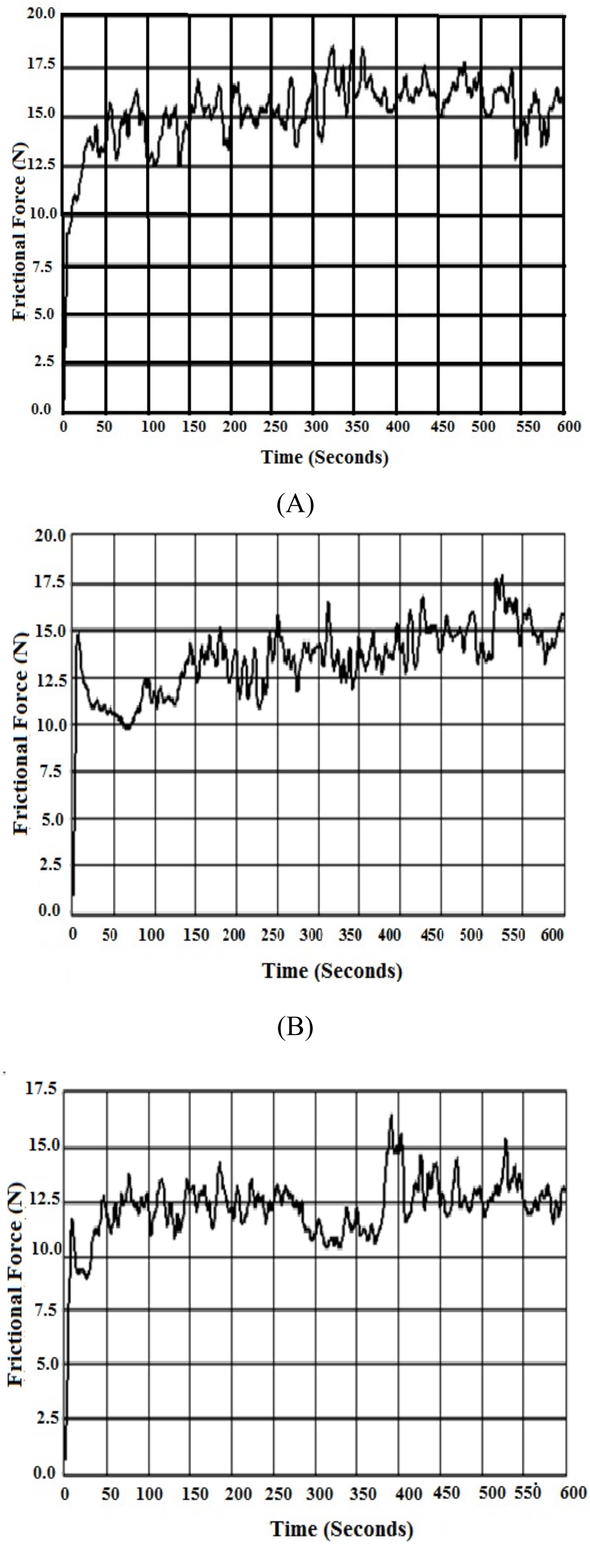


(C)

Fig. 3. The variations of wear as a function of time at 2Kg weight, 250 rpm, 10 minutes (A) For Without anodized sample (B) With anodized sample (C) Surfactant assisted lubricated anodized sample.



(C)

Fig. 4. Frictional behavior vs. time plot at 2Kg weight, 250 rpm, 10 minutes for (A) Without anodized sample (B) With anodized sample (C) Surfactant assisted lubricated anodized sample.

Table 2. Comparison in the values obtained in tribology (wear and coefficient of friction)

S.No.	Type of Substrate	Wear(µm)	Coefficient of friction	Average of Coefficient of Friction
1.	Aluminium metal as recieved	180	16.3	0.776
2.	Anodized Aluminium	145	15.8	0.745
3.	Anodized Aluminium +Surfactant +Lubricant	80	13.2	0.623

Tribological effect

After anodization experiment, we directly compared the effect of AAO layer coating on the wear resistance, and coefficient of friction. By using pin on disc setup at 2 Kg weight, 250 rpm for 10 minutes the wear resistance (µm) vs. time (sec.) graph was generated as shown in Fig. 3 which depict that with the formation of AAO treated with lubricant coating the wear resistance decrease to 146µm (Fig. 3C) as compared to bare substrate, 196µm (Fig. 3A) which is near about 25% improvement in wear resistance.

Similarly in parallel, friction behavior of the aluminium substrates was investigated using tribology. Results of friction test in Fig. 4 show that friction coefficient first increases rapidly, again increase with time and become linear vs. time. At 2Kg weight, 250 rpm for 10 minutes, without anodization sample Fig. 4 (A) depicts that during first 2 minutes of cycle time the friction coefficient directly touches 15.0 value line and then in rest of cycle time their average lies near 0.8 line, while in case of anodized sample Fig. 4(B) depicts that in first 2 minutes of cycle time it touches directly 0.7 line, while in 4 (C) average value concentrate on 0.6 line. Finally, it has been concluded that with formation of anodized alumina oxide layer treated with lubricant on aluminium surface, friction coefficient reduced to great extent as compared to without anodization, which is helpful for less wear and tear of friction causing materials.

CONCLUSION

Aluminium sample were finished in mixture of ethanol and perchloric acid by electropolishing process followed by nanocoating of AAO layer were formed by using anodization process. The anodized surface was then passed through FE-SEM to check the formation of oxide layer and its orientation. The tribological testing was carried out by using pin on disc configuration, where wear resistance of anodized AAO sample decreases by 25% compared to non-anodized sample. Similarly coefficient of friction range value was also low down to an average value of 0.1 for anodized sample so these reductions show wide range of their applications when used in I.C. engines to improve their fuel economy by reducing wear and friction of engine parts and hence to reduce exhaust emission and subsequently meet with environment challenges.

CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript.

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