EFFECT OF ELECTROCHEMICAL TECHNIQUES OF HARD COATING ON FRICTION AND WEAR PROPERTIES OF LIGHT METAL ALLOYS: A REVIEW

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ABSTRACT

This paper includes Investigation of Friction and Wear behavior of Chemically Hard Coated light metals alloys. In this paper various researches related to electrochemically hard coated techniques on light metals alloys have been discussed along with their experimental outcomes. Study of commonly known hard coating technique like anodizing, chrome plating and PEO coating has been included here.In all researches, the experimental work to investigate friction and wear properties of metals is performed on Pin-on-Disk machine. After experiments specific wear rate and coefficient of friction obtained is analyzed for different coatings. It was found that PEO coating is the most economical and effective technique on light metals alloys.

Keywords: Aluminum, Chrome, Coating, Friction, Wear

I. INTRODUCTION

Low wear rate and low coefficient of friction (COF) is always require in any applications where rubbing actions (one material slides or rubs over another) takes place. Some of areas are Gears, Bearings, Brake and Clutch pads, automotive engine, metal forming processes, Stamping, Grinding and Polishing in which it is important to reduce wear and COF. High Friction and wear rate usually cost money in the form of energy loss and material loss, it can decrease productivity of a mechanical system, it can affects properties of engineering materials, and it may cause accidents.

Wear is one of the most commonly encountered industrial problems leading to the replacement of components and assemblies in engineering. Therefore, many efforts have been made to produce more durable materials and techniques to reduce the wear of tools and engineering components. These include modification of bulk properties of the materials, surface treatments and application of coating, etc. Over the last few years, many efforts have been made to understand the wear behavior of the surfaces in sliding contact and the mechanism, which leads to wear.

In recent years, coating on different metals and alloys are gaining attention due to their various advantage and cost effectiveness. Coated material has many advantages such as it improves wear resistance, good corrosion resistance, improve hardness, improve electrical and mechanical insulating properties etc.Anodizing, Plasma

Electrolytic Oxidation (PEO) and Hard Chrome plating are the commonly known electrochemical technique of hard coating. In the present papers various researches on the effect of these coating techniques on friction and wearbehavior of light metal alloys like Al alloy, Mg alloy and Titanium alloy have been included.

II. RELATED WORK

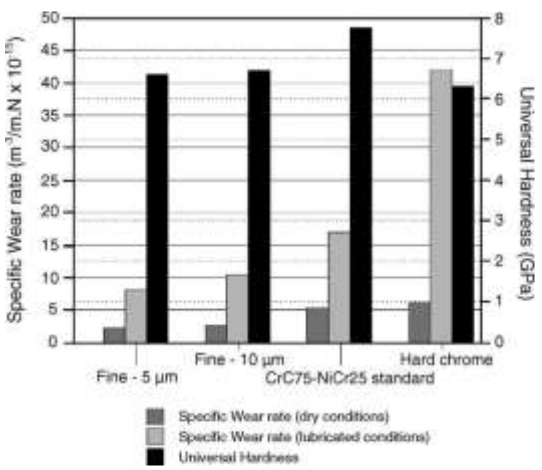
J.A. Picas et al [1]proposed HVOF coatings as an alternative to hard chrome for piston and valves materials. Automotive manufacturers have specified chromium plating for decades because of its appearance, wear and corrosion resistance, howeverchromium plating cause effects on human health because of the use of substances in the galvanic process whose toxicological features have notalways been recognized. The improvements of the high-velocity oxy-fuel thermal spray process allow the chromium coating replacement with acomparable or superior surfaces and more environment friendly.

The coatings studied in this work were Cr3C2 75% + NiCr2025% weight deposited on a steel substrate with a thicknessof approximately 150 µm, using a high-velocity oxy-fuel system(HVOF). Further tribological properties of HVOF coated material were described. Theseresults have been compared with conventional hard chromium plating.

Experiments using a pin on disc tribometer under lubricated and dry conditions have been performed in order to evaluate the friction and wear properties of the different coatings. HVOF coating sprayed from three different agglomerated feedstock powders with various powder size distributions.The friction coefficient and specific wear rate during sliding wear tests are reportedin Table 1 and fig 1.

[1]Table 1 Pin on Disc Test Results

	Friction Coefficient		Specific Wear Rate($m^3/mN \times 10^{-15}$)	
	Dry	**Lubricated**	**Dry**	**Lubricated**
Standard	0.24	0.11	17.0	5.3
Fine-10 µm	0.25	0.11	10.4	2.5
Fine-5 µm	0.25	0.11	8.1	2.2
Hard chrome	0.22	0.12	36.0	6.1



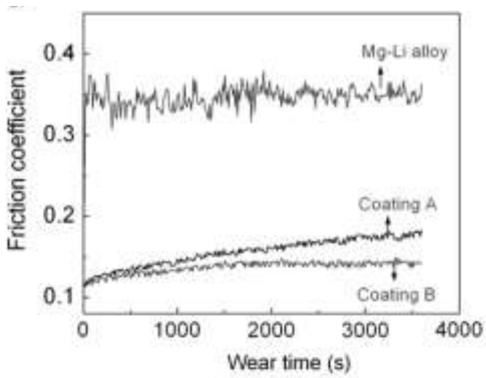
[1]Fig. 1.Specific Wear Rate and Universal Hardness Ofstudied Coatings

It was found that the CrC–NiCr coating, obtained with the lowest feedstock powder size, presented the best wear resistance under all the studied conditions. The Fine CrC–NiCr coatings have demonstrated superior performance to hard chrome with regard to mechanical and tribological properties, and they can be proposed as an alternative to hard chrome coatings.

F. Viejo, A.E. coy et al [2]evaluated the potential of laser surface melting (LSM) as a pre-treatment prior to conventional anodising on an AA2050-T8 (Al–Cu–Li) aerospace alloy. A KrF excimer laser was utilized, of wavelength of248 nm, with variation of the number of pulses received per unit area. After LSM, the specimens wereanodised at a constant voltage of 12 V in 0.46 M sulphuric acid for 240 s. Material characterization, in termsof surface morphology, microstructure and phase transformation, was performed using scanning and transmission electron microscopies, interferometry and scanning Kelvin probe force microscopy (SKPFM). The corrosion behavior was evaluated based on the standard ASTM G34-01 EXCO test, revealing the distinct improvement in performance of the combined laser and anodizing treatments.The work showed the significantly improved corrosion protection of the AA2050-T8 alloy through combined LSM-anodizing treatments.

Chunxiang Ma et al [3]used plasma electrolytic oxidation coatings. In this work, Plasma electrolytic oxidation coatings were fabricated on the surface of Mg–8Li–1Al. The tribological behavior of the coated and uncoated Mg–Li alloy was investigated under dry friction conditions against a Si3N4 ball as counter-face material. The results indicated that the tribological behavior is greatly affected by the microstructure and phase compositions of the coatings. The PEO coatings significantly improved the properties of friction and wear of Mg–Li alloy. ThewholePEOprocess wascarriedoutat5Ad/m^2 and 500Hzwithadutyratioof15%in the alkalinesilicateelectrolytewithandwithouttheadditionof titaniasol(4vol%)for10min.

Fig.2. showsavariationoffrictioncoefficientversussliding time forMg–Lialloysubstrateandbothcoatingsunder dry friction conditions.



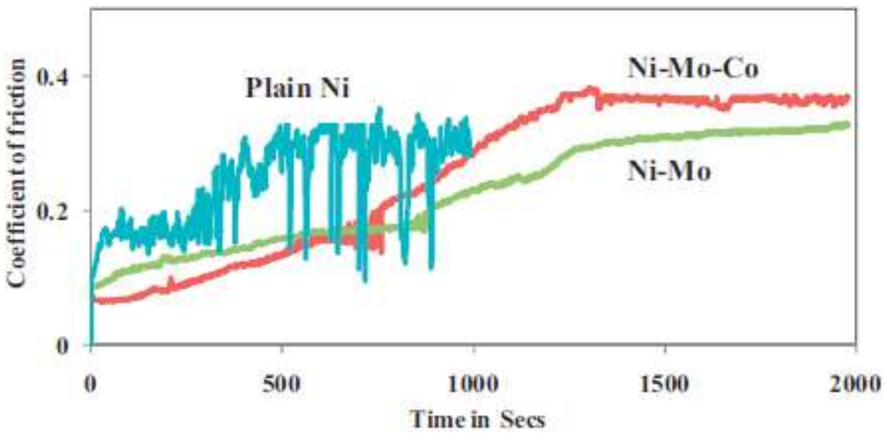
[3]Fig 2 Variation of Friction Coefficients Versus the Sliding Time for Mg Li Alloy and Both Coatings

Meenu Srivastava et al [4] developed a Ni–Mo–Co coating as a replacement of hard chrome coating. The coating was characterized for its micro hardness, wear resistance, coefficient of friction and corrosion resistance. The coating was also subjected to heat treatment at temperatures in the range of 200°–600°C. The tribological properties like the wear rate and coefficient of friction of the 400°C heat treated Ni–Mo–Co coating were noticed to be better compared to hard chrome coating.

In this work the ternary Ni–Mo–Co alloy coating was electrodeposited under ambient condition from a citrate based sulphate electrolyte. The electro deposition was carried out on a mild steel substrate (cathode) using a Ni plate as the anode. The tribological behavior of the coatings was evaluated under dry sliding conditions using pin-on-disc tribo-tester. The wear rate and the average co-efficient of friction values are listed in Tables 2 and result are shown on Fig. 3. The dry sliding wear studies showed that the Ni–Mo–Co ternary alloy displayed the least wear volume and the 400°C heat treated coating displayed a low coefficient of friction (0.2) and also low wear volume. The properties were better than that reported for hard chrome and Co–P coatings. The polarization and impedance studies revealed the better corrosion resistance of 400°C heat treated Ni–Mo–Co coating. The XPS studies indicated the formation of stable oxide layer on the surface of heat treated Ni–Mo–Co coating which was responsible for its improved tribological properties and corrosion resistance.

[4]Table 2: Comparative Wear Results

Coating	Wear coefficient	Wear Rate(mm3/Nm)	Avg. Coefficient of friction
Plain Ni	$1.027x10^{-5}$	$2.38x10^{-5}$	0.5
Ni-Mo	$2.71x10^{-6}$	$4.85x10^{-6}$	0.3
Ni-Mo-Co	$1.94x10^{-6}$	$2.67x10^{-6}$	0.5



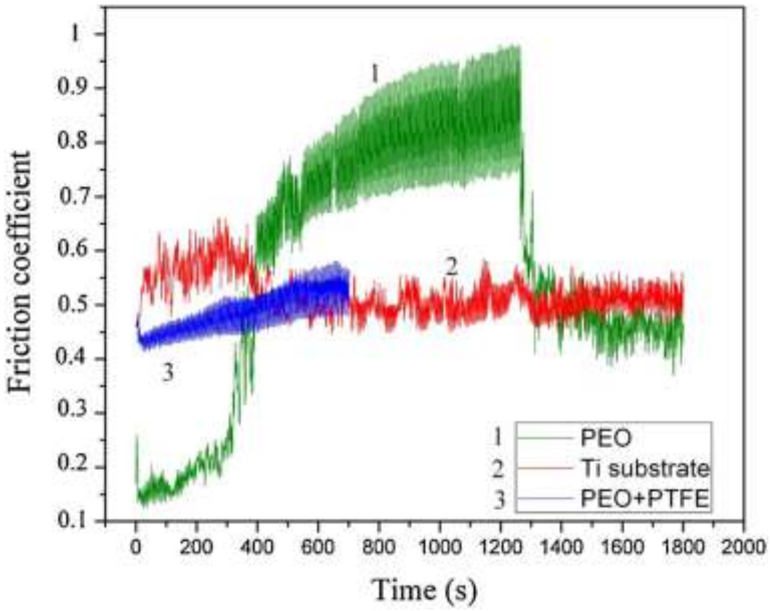
[4]Fig. 4: Variation in Coefficient of Friction With Respect to Tribology Testing Time

Mehdi Javidi and Hossein Fadaee [5] used plasma electrolytic oxidation to improve wear resistance of 2024-T3 aluminum alloy. In this study, PEO treatment was performed on 2024-T3 aluminum alloy in an optimized electrolyte. A complex alkaline electrolyte was used in order to decrease the applied voltage during PEO. The electrolyte contained simple and inexpensive constituents and a conventional DC power source was used for applied voltage. It was found that with increase in oxidation treatment time the micro-hardness of the coating were decreased while the friction coefficient increased. It was seen that deposition at optimum treatment time of 10 min resulted in the highest micro-hardness and lowest friction coefficient and weight loss.

The variation of friction coefficient with time is depicted. The friction coefficient of coated specimens in different treatment time of 10 min, 20 min, 30 min and 40 min is considered. It was seen that with increase in the treatment time the value of friction coefficient is increased. It was seen that deposition at optimum PEO treatment time of 10 min resulted in the highest micro-hardness and lowest friction coefficient. Also, the coated specimen showed lower weight loss and friction coefficient indicating much more wear resistance relative to other specimens which experienced higher PEO treatment time.

S. Aliasghari el al[6] investigated Plasma electrolytic oxidation of titanium using a phosphate/silicate electrolyte with a square wave form and a frequency of 50 Hz. A range of constant rms current densities, duty cycles and negative-to-positive current ratios was employed. The coatings, which were limited in thickness to 40 to 50 µm, contained anatase, rutile, Ti2O5and silicon-rich, amorphous material. The tribological behavior was investigated using a ball-on-disc test, revealing a coefficient of friction against steel of 0.8, which reduced to ~0.4 by incorporation of ptfe particles from the electrolyte. However, due to the composition and morphology of the coatings, their wear life was relatively short.

The results of the ball-on-disc friction tests, under a 5 N load, are presented in Fig. 6 for the uncoated titanium and the PEO-coated titanium with and without ptfe.



[6]Fig 6. Dependence of the Coefficient of Friction on Time for Titanium for Three Coatings

H.R. Masiha et al [7] Prepared AA1230 aluminum alloy samples. These samples were coated by plasma electrolytic oxidation (PEO). The samples with and without surface mechanical attrition treatment (SMAT) was coated in phosphate and silicate-based electrolytes and in the presence of Si3N4 nanoparticles. Besides, morphology and properties of the produced coatings were examined. To determine the corrosion resistance of the coatings, potentiodynamic polarization technique was used. All coated samples were subjected to wear test in order to compare coating wear properties of the SMATed and unSMATed samples. Then the effects of SMAT preprocessing and its duration on the properties of the coatings prepared by PEO were investigated. The results indicated that the mean coefficient of friction of the coated samples decreased by near 83% with respect to the uncoated (raw) samples. Furthermore, the SMATed samples showed thicker coatings as compared to unSMATed samples due to an increase in their matrix reactivity.

M. Sieber et al [8] produced Wear-resistant coatings on aluminium by plasma anodizing. In this study, Coatings with a high abrasive wear resistance and a hardness of up to 12 GPa were produced in an electrolyte of 5 g/l sodium metasilicate and 5 g/l potassium hydroxide at a current density of 30 A/dm2. The coatings offer a high hardness and provide an excellent bonding to the substrate material, thus preventing spallation under mechanical or tribological load. To understand the reasons for the high wear resistance, the morphology as well as the phase composition and distribution within the coating were examined globally and locally using X-ray diffraction with conventional and grazing incidence and electron backscatter diffraction. The analyses show that the coating globally is comprised of approximately one third of α-alumina, one third of γ-alumina and one third of amorphous alumina with locally varying phase content. Despite of the low hardness and low α-alumina-content compared to plasma anodised coatings presented by other research groups, the wear resistance of the produced coatings is better This is attributed to the compact morphology, which outweighs the phase composition in terms of wear resistance.

R. Arrabal et al [9] formed Plasma electrolytic oxidation (PEO) coatings with incorporated α-Al_2O_3 particles on 6082-T6 alloy. Effects of particle concentration on phase composition and wear behavior were investigated. Tribological performance was compared with that of electrolytic hard chrome. Results suggested that α-Al_2O_3 particles are incorporated into the outer layer of the coatings either by deposition, electrophoresis or mechanical entrapment by the material ejected from the discharge channels. As a result, the outer layer shows lower porosity and increased hardness.

Friction coefficients of untreated 6082-T6 alloy and hard chrome coating did not vary significantly as the normal load increased from 2 to 10 N. Friction coefficients of PEO coatings were similar to those of hard chrome, although they slightly increased with the applied load. PEO coatings produced in the electrolyte containing 10 g L^{-1} α-Al_2O_3 particles showed the lowest wear damage, suggesting that they could be a promising alternative to hard chrome coatings.

Kang Min Lee et al[10] examined the coating structure formed on Mg–3 wt. %Al–1 wt. %Zn alloy sample subjected to plasma electrolytic oxidation field-emission transmission electron microscopy. The plasma electrolytic oxidation process was conducted in a phosphoric acid electrolyte containing K_2ZrF_6 for 600 s. Microstructural observations showed that the coating consisting of MgO, MgF_2, and ZrO_2 phases was divided into three distinctive parts, the barrier, intermediate, and outer layers. Nanocrystalline MgO and MgF_2 compounds were observed mainly in the barrier layer of ~1 μm thick near to the substrate. From the intermediate to outer layers, various ZrO_2 polymorphs appeared due to the effects of the plasma arcing temperature on the phase transition of ZrO_2 compounds during the plasma electrolytic oxidation process. In the outer layer, MgO compound grew in the form of a dendrite-like structure surrounded by cubic ZrO_2.

III. CONCLUSIONS

(1) PEO is considered as a most economical and effective surface modification technique for on light metals alloys in suitable electrolytes. The surface properties of PEO coatings such as wear resistance, corrosion resistance, heat resistance and adhesion to substrate are considerably improved.

(2) Better friction and wear properties of light metal alloys can be achieved by varying the process parameters of PEO coating. These parameters include Selection of optimum electrolyte, current density, applied voltage, frequency, types of power source, treatment time.

(3) Much advancement in conventional hard anodizing process has been noticed. This includes LSM as a pre-treatment prior to conventional anodizing and plasma anodizing.

(4) Hard chrome is the most extensively used electroplated coating in the aerospace and automotive Industries due to its attractive properties such as high hardness and excellent wear resistance. But there is health risks associated with the use of hexavalent chromium baths during electroplating. So there is a need to identify an alternative to this hard chrome plating process. We have also found HVOF coatings, Ni–Mo–Co ternary alloy coating as an alternative to hard chrome plating.

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