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## A Study on the Superiority of Sol-Gel Method over Conventional Coating Methods for A390 Aluminium.

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### ABSTRACT

Aluminum alloys with good bearing properties finds usage in various applications. A390 aluminium alloy is better suited for bearing related applications. This alloy has good surface characteristics and if possibly further improved means it can be a material for many important applications. Vaporization techniques such as Physical vapor deposition and Chemical vapor deposition are efficient methods but their cost of process is very high. Sol-gel particle synthesis and dip coating being very economical can be a good alternative to these conventional vaporization methods. In this work, the effectiveness of this sol-method over the conventional vaporization methods is analyzed.

**Keywords:** PVD, CVD, Sol-gel, Dip coating, XRD, EDAX, SEM, Pin-on-disc.

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## INTRODUCTION

Aluminium alloys are required to have good wear resistance and anti friction properties for better bearing applications. Wear of Engine bearings is the removal of the bearing material from its surface caused by sliding friction between the bearing and the crankshaft. Materials used for bearings especially aluminium alloys require a better surface treatment process like coating or any surface hardening process [1]. Sol-gel process is a wet-chemical technique widely used in the fields of Materials science and Ceramic engineering. Such methods are used primarily for the fabrication of materials from a chemical solution which acts as the precursor for an integrated network or gel.

Physical vapor deposition (PVD) is a general term used to describe any of a variety of methods to deposit thin films by the condensation of a vaporized form of the material onto various surfaces. The coating method involves purely physical processes such as high temperature vacuum evaporation or plasma sputter bombardment rather than involving a chemical reaction at the surface to be coated as in chemical vapor deposition[2]. Chemical vapor deposition (CVD) is a chemical process used to produce high-purity and high-performance solid materials. The process is often used in the semiconductor industry to produce thin films. In a typical CVD process, the wafer substrate is exposed to one or more volatile precursors, which react and/or decompose on the substrate surface to produce the desired deposit.

## EXPERIMENTAL

### Material composition

Table 1: The Nominal Chemical Composition Of The A390 In Weight %

Al	Cu	Mg	Si	Zn
77.4	4.5	0.6	17	0.5

### Methodology

Wear and friction tests were conducted on pin-on-disc machine Ducom TR201 model equipment as per standard ASTM practice (ASTM G99). In this wear test, the pins are made to rub against the rotating disc[3-6]. The test was performed first for various sliding distances of 250 m, 500 m and 1000 m under constant applied load of 3 kg and a sliding distance of 3 m/s. Second the wear test was repeated for different applied loads of 2.5 kg, 5 kg and 10 kg under a constant sliding distance of 1000 m with a sliding velocity of 0.3 m/s. The results were obtained in the form of a plot of "Wear loss (cc) Vs Sliding distance (m)" and "Wear loss (cc) Vs Load (Kg)". The wear loss and hence the specific wear rate ( $\text{mm}^3/\text{Nm}$ ) was calculated from the average mass loss of the pins during the wear test. The changes in the worn surface morphologies that accompany the wear loss and wear rate along with the wear mechanisms were investigated using SEM.

This A390 specimen of correct 8mm diameter and 42 mm length rods are taken as the Pin material in the wear testing apparatus called 'Pin-on-disc apparatus' in studying the

wear characteristics. 100ml of distilled water was mixed with 40gms of chromium nitride corresponding to its molecular weight and was stirred for 30 minutes in the magnetic stirrer [7-10]. The stirrer provides complete solubility of the powder in the distilled water and thus provides a clear solution. Now 2gms of Polyvinyl Alcohol (PVA) was weighed which acts as the reducing agent in this sol-gel process and measured in the weight machine [11-14]. 2gm of PVA was added to the clear solution of the distilled water and chromium nitride and was stirred again in the magnetic stirrer for 30 minutes.

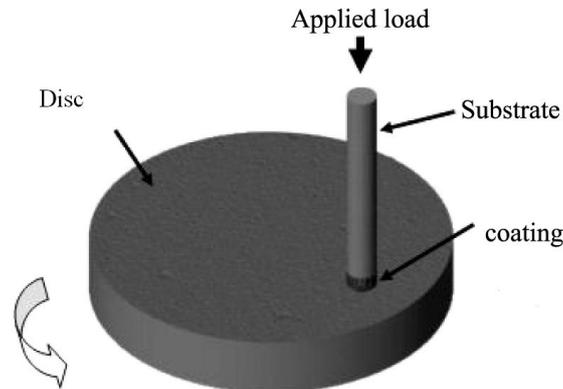


Figure 1: Schematic diagram of wear Test apparatus

### RESULTS AND DISCUSSION

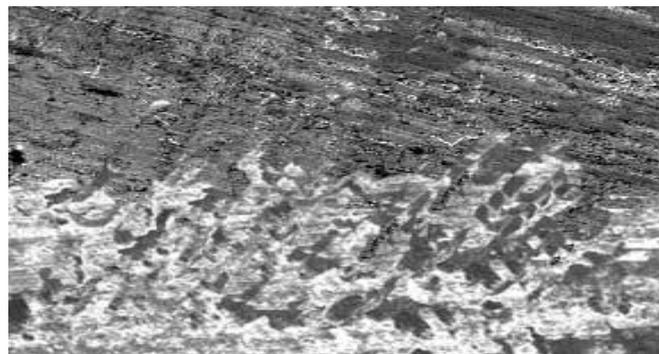


Figure 2: Microstructure of CrN sol-gel treated specimens for 11 hours showing the compound layer and base metal.

Scanning electron microscopy reveals the following information.

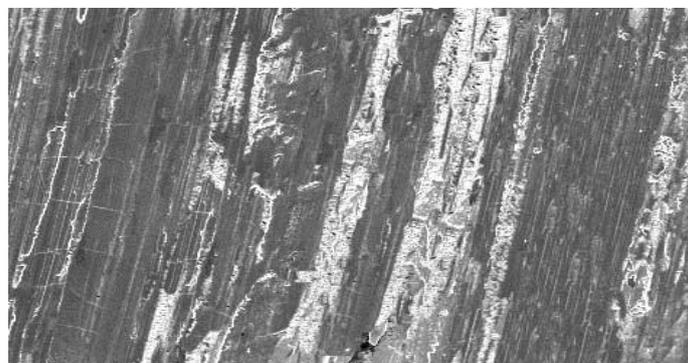


Figure 3: SEM Micrograph of CrN CVD coated specimens for 1.5 hours showing the compound layer, diffusion zone and base metal

Closer observation of the diffusion zone in all micrographs indicates the presence of more etch pits in the diffusion zone of C1F and the progressive decrease in the quantity of etch pits in diffusion zones of C1S and C1L specimens. This is attributed to the role of diffusing elements CrN. At higher diffusion times the formation of more amount of CrN restore and improve the wear resistance.

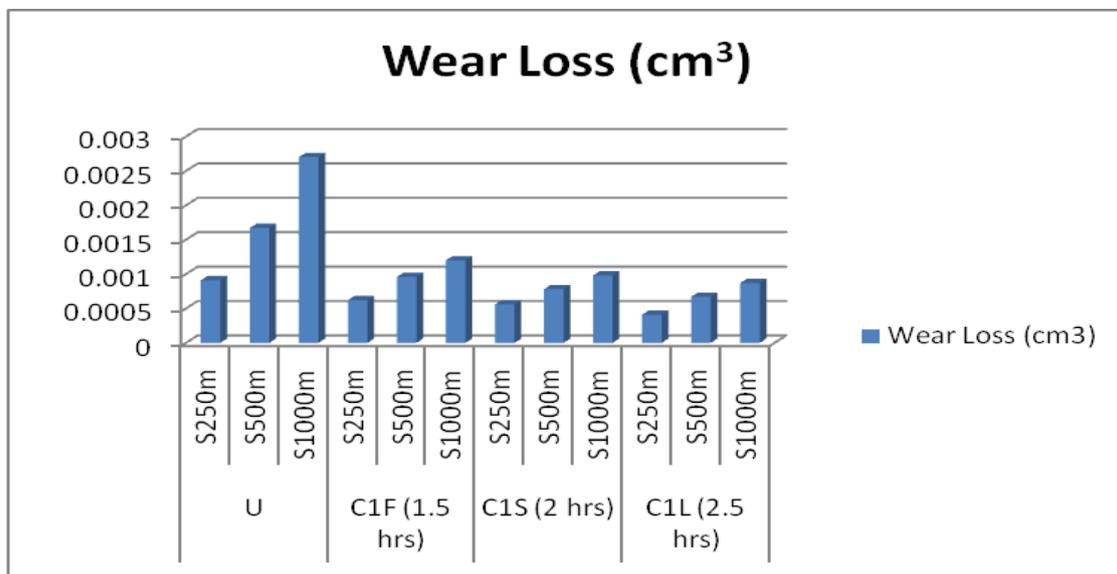
**Wear studies**

Pin-on-disc apparatus wear tests were carried out at a constant load of 3 kg and a sliding velocity of 3 m/s with different sliding distances of 250 m, 500 m and 1000 m keeping other parameters constant and the results are presented in the tables below. Secondly wear tests were carried out for a constant sliding distance of 1000 m with a sliding velocity of 2 m/s and under various load conditions of 2.5 kg, 5 kg and 10 kg. The results of these two steps of wear tests are presented in the tables below. In order to have an easier comparison, the results of the wear tests are depicted as bar charts also in the figures below.

**Table 2: Symbolic Name for The Different Specimens Used**

S.No	Specimen name	Specimen symbol
1	Untreated A390	U
2	CrN CVD coated A390	C1
6	CrN PVD coated A390	C2
9	CrN sol-gel treated A390	C3

**Figure 4. Comparison of Wear Losses for Untreated U and CrN CVD Coated C1 Specimens for Various Sliding Distances.**



**Table 3: Wear Data of Untreated, CrN CVD Coated, CrN PVD Coated And CrN Sol-Gel Treated A390 Aluminium Alloys for a Sliding Distance of 250m with a Sliding Speed of 3m/S and applied load of 3kg.**

S. No	Specimens	Frictional force (N)	Co-efficient of friction ( $\mu$ )	Weight before testing (gms)	Weight after testing (gms)	Weight loss (gms)	Volumetric wear loss ( $\text{cm}^3$ )	Specific wear rate ( $\text{mm}^3/\text{Nm}$ )
1	U	16.134	0.67	18.385	18.349	0.036	0.00091	0.000081
2	<b>C1(1.5 hrs)</b>	15.231	0.66	18.245	18.237	0.008	0.00062	0.000043
3	<b>C1(2 hrs)</b>	15.223	0.65	18.138	18.129	0.009	0.00056	0.000035
4	<b>C1(2.5 hrs)</b>	15.322	0.64	18.122	18.117	0.005	0.00041	0.000033
5	<b>C2(3 hrs)</b>	15.033	0.59	18.096	18.087	0.009	0.00045	0.000029
6	<b>C2(8 hrs)</b>	12.099	0.54	17.892	17.762	0.130	0.00045	0.000027
7	<b>C2(9 hrs)</b>	11.435	0.51	17.687	17.598	0.089	0.00037	0.000025
8	<b>C3(11 hrs)</b>	10.765	0.47	17.597	17.543	0.054	0.00028	0.000021
9	<b>C3(15 hrs)</b>	9.786	0.38	17.518	17.492	0.026	0.00032	0.000019
10	<b>C3(20 hrs)</b>	9.567	0.37	17.342	17.298	0.044	0.00029	0.000018

### Comparison of wear loss of all the three processes

Wear resistance of the CrN CVD coated, CrN PVD coated and CrN sol-gel treated specimens for various sliding distance and loads were compared and presented in the Figures 4.60 and 4.61. From the figures, it could be observed that there are no noteworthy differences in the wear loss of CrN CVD coated, CrN PVD coated and CrN sol-gel treated specimens. The wear resistance of the CrN CVD coated and CrN sol-gel treated specimens is marginally better than CrN PVD specimens and this could be due to the fineness of the particles formed.

### CONCLUSIONS

Surface modification is an important technique to enhance the wear resistance of the aluminium alloy materials. Several researchers investigated effects of various surface modification methods on the mechanical, surface and wear behavior of the aluminium alloys. Present study focused in the direction of investigating the effect of CrN CVD coated, CrN PVD coated and CrN sol-gel treatment on the microstructure, hardness and wear resistance properties on the A390 aluminium alloys. The EDAX line scan across the layer/base material interface of the surface treated specimens in particular CrN sol-gel treatment indicates that the quantity of CrN diffused into the surface layers is high in CrN sol-gel treated specimens in comparison with the other two surface treated specimens. The XRD analysis indicates the broadening and shifts that are occurring at lower angles. The main reason for this is the high compressive stresses induced resulting in lattice expansion. There is an increase in hardness in the CrN CVD coated specimens.

Maximum hardness of about 150 Hv0.01 is observed in CrN CVD coated specimens due to the presence of hard nitrides in large quantities. Maximum hardness of 155 Hv0.01 is found in the CrN PVD coated specimens due to the formation of a blend of nitrides in moderate quantities. Wear resistance of the surface treated specimens is found to be superior to the untreated specimens. Wear loss is found to increase as the sliding distance and applied loads increase. However the progression of the wear loss is found to be increasing with the increase in the sliding distance and applied load. The Specific Wear Rate

(SWR) is observed to be increasing with the increase in the sliding distance and the applied loads. The combined action of strong adhesion, abrasion and severe plastic deformation are the primary reasons for the continuous material loss in the untreated specimens. Whereas the wear on the sol-gel treated specimen in mild form is dominated by micro abrasion. With optimal sol-gel treatment parameters, CrN CVD coated and CrN PVD coated processes increase the wear resistance without much compromise in surface hardness.

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