COMPARITIVE TRIBOLOGICAL BEHAVIOUR OF Ni-Al_2O_3 NANO COMPOSITE COATING ON THREE DIFFERENT SUBSTANCES

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ABSTRACT

Nano – sized aluminium oxide ceramic particles were deposited with nickel using electro deposition technique to develop composite coatings. The coatings are produced in an nickel bath at different stages of current densities and we focused the effect of applied current on microstructure and thickness of the coatings. Nano crystalline materials are of great industrial importance due to their improved properties especially chemical and mechanical. Electro deposition technique is a useful method for producing Nano crystalline coatings. The pulse plating of nickel alumina composite coatings were studied and the effects of pulse parameters i.e. duty cycle and frequency on the hardness and wear resistance of these coatings were investigated in three different materials which are Mild Steel, Cast-iron, Aluminium Alloy. The Wear is decreased by increasing either the frequency or duty cycle of the pulse plating current used for deposition. The nickel-alumina coatings on mild steel are influenced their wear resistance and adhesive strength. In this deposition wear rate and co-efficient friction of nickel-alumina composite coatings are evaluated.

Keywords: Ni- Al_2O_3 composite coating, Pulse plating, Friction, Wear.

1. INTRODUCTION

1.1 SURFACE ENGINEERING

Surface engineering include the total field of research and technical activity used for design, manufacturing, investigation and utilization of surface layers for properties better than the core. Surface engineering techniques can be used to develop a wide range of functional properties, including physical, chemical, electrical, electronic, magnetic, mechanical, wear – resistant and corrosion – resistant properties at the required substrate surfaces. Surface engineering techniques are being in used in the automotive, aerospace, missile, power electronic, biomedical, textile, petroleum, petrochemical, chemical steel, cement, machine tools, and construction industries. Almost all types of materials include metals, ceramics, polymers, and composites can be coated on similar or dissimilar materials.

1.2 SURFACE DEGRADATION

Degradation of materials is defined as progressive loss of performance or property with time due to external and internal forces or influences. Surface degradation mainly occurred due to the interaction between surface and environment typically through chemical (oxidation, corrosion) and mechanical interaction (wear, fatigue, freeting etc.). These degradation ultimately entail huge lose or pentaly on all engineering system, therefore some important causes of surface degradation should be understood before going in to discussion of advanced techniques to improve surface property. Wear and corrosion are two important causes for degradation. The scientific study of degradation of engineering materials can be summarized as the rate of decline of performance.

1.3 NANOCOMPOSITES

In general, a composite is an engineered material made up of two or more materials. Composite materials are lighter, stronger and sometimes cheaper than non- composite materials. There is nothing especially "nano" about the composites. Particle board used as a building material is a very good example of a composite, as is fibreglass. From the comments that I have made so far, it is very easy to see how nanotechnology gets in to the act. The extraordinary properties of carbon nanotubes, for example, make them obvious candidate for use in new materials for electronics, building materials, automotive, and aerospace applications. There are good reasons for deploying these carbon nanotubes in the form of composite .Among these reasons is the tendency for carbon nanotubes to clump up, which can make pure nanotubes fabrics inconsistent in density and hence weak in some areas. As a result of this phenomenon, zyvex, for example, has created composites with nanotubes and polymers. Other reasons are the cost of bulk nanotubes, which would, at this point in time, make the cost of a pure nanotubes material too high for widespread use.

1.4 AREAS OF APPLICATIONS

Such mechanical property improvements have resulted in major interest in nano composite materials in numerous automotive and general/industrial applications. These include potential for utilization as mirror housings on various vehicle types, door handles, engine covers and intake manifolds and timing belt covers. More general applications currently being considered include usage as impellers and blades for vacuum cleaners, power tool housings, mower hoods and covers for portable electronic equipments such as mobile phones, pagers etc.

These composite coatings are widely used in applications which require abrasion and heat resistant coatings, corrosion resistant coatings, self-lubrication films and thermally graded structures. Nickel composite coatings prove to be a good alternative for chromium coatings. Ni-alumina composite coatings finds application for coatings of engine cylinders, high pressure valves, and dies, in the production of musical instruments, drill fitting, car accessories, small aircraft, and electro technical parts. One of the most promising applications for these composite coatings is in micro devices.

2. EXPERIMENTAL PROCEDURE

2.1 ELECTRO DEPOSITION COATING

Electro Deposition Coating is also a process of applying a layer to the substrate surface. Coating material is different from the substrate material and it permits achieving special surface properties of the part without changing its bulk properties.

Coating may improve the following surface properties

1. Hardness
2. Corrosion and oxidation resistance
3. Anti – friction properties (wear resistance, low coefficient of friction).
4. Cosmetic appearance

2.2. COATING TECHNIQUES

There are several methods used for surface modification of materials. The following techniques are few of them used for applying coatings on metals:

Electroplating - electroplating is a process of coating, deposition on a cathode part immersed in to an electrolyte solution, where the anode is made of the depositing material, which is dissolved in to the solution in form of the metal ions, travelling through the solution and depositing on the cathode surface.

Electroless plating – the process of deposition of metal ions from electrolyte solution on to the substrate, when no electric current is involved and the plating is a result of chemical reactions occurring on the surface on the substrate.

Conversion coating – the process, in which the coating is formed as a result of chemical or electrochemical reaction on the substrate. These are non – metallic coating obtained on metal surface in the form of compounds of the substrate metals.

Hot dipping – immersing the part in to a molten metal, followed by removal of the substrate from the metal bath, which results in formation of the metal coating substrate surface.

Physical vapour deposition (PVD) – the process involving vaporization of the coating material in vacuum, transportation of the vapour to the substrate and condensation of the vapour on the substrate surface.

Chemical vapour deposition (CVD) – the process, in which the coating is formed on the hot substrate surface placed in an atmosphere of a mixture of gases, as a result of chemical reaction or decomposition of the gases on the substrate material.

Thermal spraying – deposition of the atomized at high temperature metal, delivered to the substrate surface in a high velocity gas stream.

2.3. ELECTRODEPOSITION PROCESS

Electrodeposition process is a conventional technique, but it is used vastly due to its certain advantages over other as it is low cost, low energy requirement, capability to handle complex geometry, simple scale – up with easily maintain equipment, good chemical stability, easily maintained equipment and after all very important potential of it is avery large number of pure metals, alloys, composites, ceramics, which can be electrodeposited with grain size less than 100nm.

Metals, alloys and polymers can be deposited in this process. Ni,cu cr, co,au zn etc. are preferred metals in this field and co- cu, ni – co etc, multilayer deposition done in this process polystyrene, perplex, PTFE, rubbers are the polymers materials apply for coating used in industrial application. The coating materials over the large area of applications as coatings of engine cylinders, high pressure valves, musical instruments, car accessories. Nickel

Deposition is very popular for electrodeposition because nickel coating shows the properties of good mechanical properties, excellent corrosion resistance, high electrical conductivity, good thermal conductivity and good magnetic property. Deposition of ceramic particles on metal substrate can be used to improve the mechanical properties of substrate such as hardness, wear resistance, protection against high temperature , corrosion and oxidation.

In nickel plating electroplating method, nickel plate is used as anode and the material which we have plated used as cathode i.e. negatively charged with the DC supply. The direct current to the anode is oxidizing the metal atoms and allows them to dissolve in the solution.

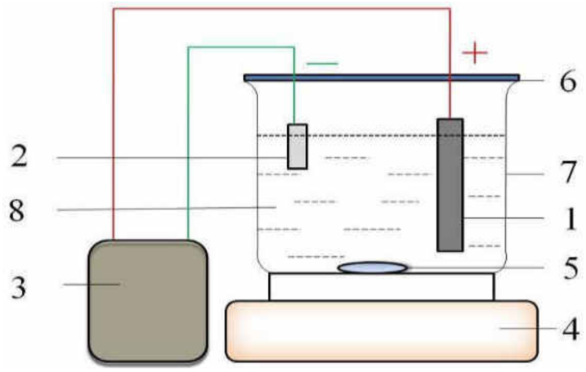


Fig 2.1 Nickel Electroplating Schematic diagram of the electro deposition system: 1. Nickel plate, 2.Mild steel plate, Cast-iron, Aluminium alloy 3. Power generator, 4. Hot plate

stirrer, 5. Stirring bar, 6. Locating plate, 7. Beaker, and 8. Electrolyte.

The following solutions are used for nickel electroplating:

1. Watts nickel plating solutions
2. Nickel sulfamate solutions
3. All- chloride solutions
4. All –sulfate solutions

Watts's solution was developed by Oliver P. Watts in 1916 and it is most popular nickel electroplating solution. Plating operation in watts solutions in low cost and simple. Bath compositions for watts solutions are shown in the table

Table 2.1. Nickel Electroplating solutions

Electrolytes (watt's bath)	Nickel sulphate (NiSO4,6H2O)
	Nickel chloride (Nicl2.6H2O)
	Boric acid (H3BO4)
Conditions	pH= 3.0 – 4.5
	Temperature ; 55 -65°C
	Cathode current density: 5 A/dm^2

3. RESULT AND DISCUSSION

3.1 MICROSTRUCTURAL ANALYSIS

Microscopic studies to be examine the morphology, particle size and distribution of particles were done by a scanning electron microscope (SEM)equipped with an energy dispersive X- ray (EDX) detector system. The secondary electron imaging was used with suitable accelerating voltages for the best possible resolution. Along with as coated surfaces, cross sectional plane was also observed under SEM. Some samples were observed under a field emission gun assisted scanning electron microscope (FESEM) for higher resolution micrographs.

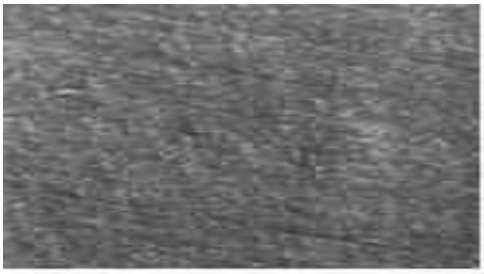


Figure 3.1: SEM image of Ni - Al_2O_3Composite coating

3.2 SURFACE MECHANICAL PROPERTY STUDY

3.2.1 Micro Hardness Measurement

Micro hardness measurements were carried out on the surface of Ni Al_2O_3 coated samples. Tests were conducted using Vickers indenter with 50 g load (Buhler microhardness tester). Each hardness value reported here is an average of 4 – 5 measurements on the same sample at equivalent locations. As the coating thickness uses where not wide one is, microhardness measurement on the cross section was not carried out.

Fig 3.2 Micro Vicker Hardness Tester

Also, for all the deposition conditions, the hardness of composite coatings is higher than pure nickel coatings. This seems to be a direct consequence of dispersion strengthening effect where reinforced hard particles in the matrix obstruct the motion of dislocations. Furthermore, the Ni- Al_2O_3 composite coatings exhibit highest hardness and the Ni coatings exhibit lowest hardness for each deposition condition.

As such, the highest hardness of Ni- Al_2O_3 composite coatings seems to be due to relatively larger content of Al_2O_3 (in Ni- Al_2O_3) coatings for each deposition condition.

3.2.2 Microhardness Calculation

Micro hardness = $1.854xF/d^2$

Where,

F = load

Load for Mild steel = 1 Kg (constant)

d = ac_1+bc_2

$c_1 = 0.025$

$c_2 = 0.0005$(constant values)

Micro hardness of Ni coating

For Mild Steel:

a= 3, b=48

Micro hardness = 1.854x1/ $(4x0.025+45x0.0005)^2$ = 180.1344

For Cast-Iron:

a= 3, b=45

Micro hardness = 1.854x1/ $(3x0.025+35x0.0005)^2$ = 170.0296

For Aluminium Alloy:

a= 3, b=43

Microhardness = 1.854x1/ $(3x0.025+25x0.0005)^2$ = 175.465

Micro hardness of Ni- Al_2O_3 composite coatings

For Mild Steel:

a= 4, b=0

Micro hardness = 1.854x1/ $(4x0.025+0x0.0005)^2$ = 185.4

For Cast-Iron:

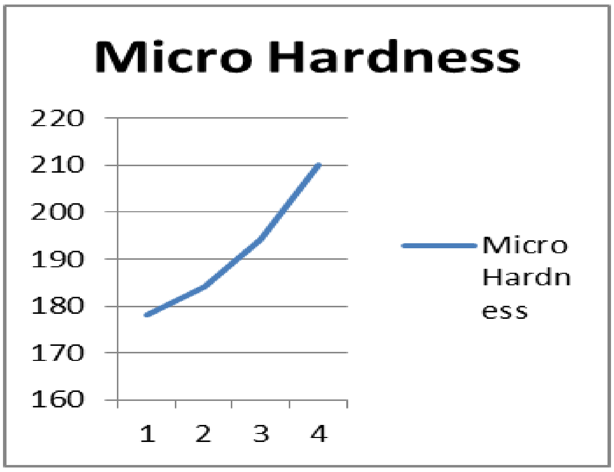
a= 4, b=1.5

Micro hardness = 1.854x1/ $(4x0.025+1.5x0.0005)^2$ = 182.65

For Aluminium Alloy:

a= 4, b=0.8

Micro hardness = 1.854x1/ $(4x0.025+0.8x0.0005)^2$ = 183.9

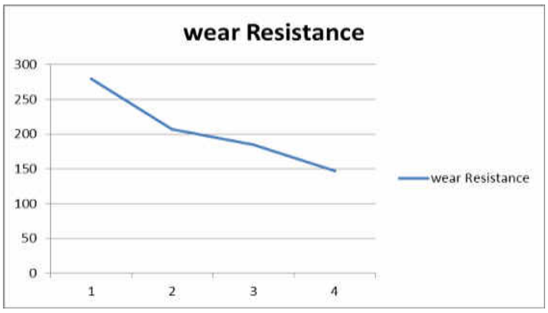


1-Nickel 2-Aluminium Alloy
3-Cast-Iron 4- Mild Steel

Fig. 3.3 Micro Hardness Survey Results

3.2.3 Wear Behaviour of Coatings

Tribological property including sliding resistance of the samples was evaluated using a ball on plate type wear testing instrument having a hardened steel ball indenter of 2 mm of diameter. Ball on plate wear tester was used for this study to evaluate the wear resistance of the Ni, Ni-Al2O3 coated samples.



1-Nickel 2-Aluminium Alloy
3-Cast-Iron 4- Mild Steel

Fig.3.4 Wear Behaviour of Coatings

4. CONCLUSION

Under the experimental conditions used in these investigations, the application of electro deposition improves the micro hardness and wear properties of the Ni-Al_2O_3composite coatings significantly.

Micro hardness and wear properties of the Ni- Al_2O_3 coated mild steel is very less compared to the nickel coated mild steel. The reinforcement content of Al_2O_3 in the composite coatings increased with increasing content of Nano particle loading in the electrolyte bath.

Except with the coatings deposited from electrolyte bath with Nano particle content, the Ni-Al_2O_3 composite coatings showed relatively random/weak crystallographic texture compared to pure nickel coatings. For similar electro deposition condition, the Ni- Al_2O_3 composite coatings were thinner compared to pure nickel coatings due to more random/weak crystallographic texture in composite coatings.

The micro hardness and wear resistance of the Ni- Al_2O_3 composite coatings increased with increasing content of reinforced nanoparticles in the coatings (and also the content of Nano particle loading in the electrolyte bath) due to enhanced dispersion strengthening effects.

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