A Review Study of Investigation on Titanium Alloy Coatings for Wear Resistance by PVD Method

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ABSTRACT - This paper is based on the Investigation of Titanium Alloy Coatings for Wear Resistance by PVD Method. We also looked upon many of the spraying process and coating methodologies for this review paper. Out of those we found that the PVD process is cost efficient and has many advantages while coating on Titanium Alloys. The Benefits of PVD Coatings are Superior Wear Resistance, Superior Corrosion Resistance, Superior Chemical Resistance, and Low Coefficient of Friction. The Base Material for this process is chosen as EN8 Mild Steel due to the application in the Pump Shaft Applications. We also looked after the tests conducted for this process such as X-Ray Diffraction, Ball on Disc etc…….

Keywords: Titanium Alloy Coatings, Mild Steel, Wear Resistance, Corrosion Resistance

1. INTRODUCTION:

Pumps handling seawater are used in industries ranging from power generation to desalination plants, offshore oil and gas production. In addition many other industrial processes utilize seawater cooling. The location of coastal process industrial and power generation plants, with increased demands for desalination and offshore oil and gas production, has led to an increased number of centrifugal pumps handling seawater. Seawater is used by the services where pump reliability is essential for cooling purposes, high pressure desalination, oil/gas field injection, or seawater lift and firefighting applications. The pumps handling seawater is expected to continue to rise as needs for these services increases. Limited materials are compared due to that cover the range of material running from cast-iron and coated steel to titanium that also include the copper based aluminium bronzes, nickel-based alloys and the conventional high alloy austenitic and duplex stainless steels used in seawater.

2. LITERATURE SURVEY:

In Jenny Eriksson[1], it is discussed that Galling is a tribological phenomenon associated with transfer of material from the steel sheet to the tool surface during forming resulting in seizure of the tool/steel sheet contact and extensive scratching of the steel sheet surface. The aim of the present study is to compare three different thin hard PVD coatings in terms of galling and wear properties when applied on forming tool steel and tested against four different types of high strength steel sheet including hot and cold rolled high strength steel as well as electro and hot-dip galvanized high strength steel. Under lubricated conditions using a pin-on-disc tribometer and included PVD deposited CrN, (Ti, Al)N and CrC/C coatings, the tribological evaluation was carried out.

In Richard Westergard [2], five different materials have been studied with respect to their load-carrying capacity together with PVD coatings. The materials used in the process were mild carbon steel, hardened and annealed ball bearing steel, a thick electro-deposited Ni coating, and plasma-sprayed alumina coatings with and without the pores and cracks sealed with electro-deposited Ni. A problem often encountered is that the substrate material provides inadequate support, load-carrying capacity, for a functional top coating if the contact pressure is high, giving plastic deformation of the component. This, it could lead to spallation and a higher wear rate of the coating.

Preparation of TiN coatings with the GCr15 substrate by the cathode arc deposition, medium frequency magnetron sputtering and their composite methods. Since it can achieve the high ionization rate, high energy and good cohesion, the cathode arc technique is much favourable. However, there are many large particles on the surface of the coating deposited by cathode arc, and the microstructure of the coating is not sufficiently dense, which seriously affects the quality of coating surface.

From Wang Ming'e [3] Improved adhesion between a coating and the base substrate is necessary for successful engineering applications. Generating intermediate zone between the coating and the substrate, adhesion may be achieved. One of the important aspects of thermal surface treatment at high laser power intensity is that the effect is localised in area and depth, since the heating effect occurs at or in the vicinity of the surface of the treated part. Titanium alloys find wide application in industry due to their high strength-to-weight ratio and excellent corrosion resistance. The high friction coefficient and the low wear resistance limit the usage of the alloy. The effectiveness of solid solution strengthening does not extend above room temperature, therefore, the unstable temperature range microstructural modification including precipitation is needed. In the present study, laser assisted nitriding of Ti-6Al-4V alloy is carried out.

From B.S. Yilbas [4], TiCN hard PVD coating was deposited on magnetron sputtered NiTi thin films. Cavitation occurs due to the fast formation and collapse of vapour bubbles in liquids as a consequence of strong pressure fluctuations. Since impacts of these stresses act in a very short time, they are called cavitation impulses the reversible phase transformation of austenite to martensite during cavitation absorbs a significant amount of impact energy before peeling, and presents a self-healing property. The best candidates for fulfilling this requirement are shape memory alloy (SMA) materials, especially NiTi alloys.. The Magnetron sputtering technique has some remarkable advantages such as low amount of impurities, feasible control of deposition rate, possibility of tailoring morphology, crystal structure and mechanical properties of thin films by adjusting processing parameters.

In Soroush Momeni [5], Cadmium being dangerous for human health and the environment. The Zn–Al coatings displayed a hexagonal structure corresponding to that of Zn. Coatings with a low melting point such as Zn (420°C) assume an open microstructure if deposited without substrate cooling and ion bombardment. The coatings were characterised with respect to their morphology, microstructure and corrosion behaviour.

In J. Creus[6], Electron-beam plasma assisted PVD-TiN coatings on active substrates such as mild steel corrosion processes occurring on PVD or CVD coatings, or on substrate materials, by monitoring the corrosion processes occurring PVD-coated systems by impedance spectroscopy techniques.

2.1. MATERIALS AND MATERIAL FACTORS:

In Jenny Eriksson [1], two different quenched and tempered low alloyed tool steels, Toolox 33 (T33) and Toolox 44 (T44). Three PVD-coatings, two hard metal nitride coatings deposited using arc evaporation, CrN and (Ti,Al)N, and a low friction metal carbide rich carbon coating deposited using sputtering (CrC/C) were evaluated. The load-carrying layers employed were electrolytically deposited Ni, plasma-sprayed alumina, and plasma-sprayed and electrolytically Ni-sealed alumina. The substrate materials were either ball bearing steel (DIN 100Cr6) or mild steel.

From B.S. Yilbas [4], pure solid sources (Ti or Al) are evaporated by means of PVD cathodic multi-arc technology in a low pressure atmosphere of pure argon. The main deposition parameters were a negative bias ranging between 100 and 150 V, a pressure ranging between 0.5 and 4 Pa and a growth rate ranging between 4 and 6 pm h-‘. The duration of coating deposition is adapted to reach a coating thickness of 15 pm.

2.2. EXPERIMENTAL FACTORS AND PROCEDURE:

The sliding wear characteristics of the sliding couples were evaluated using pin- on-disc testing using a commercial CSM tribometer. The tribological testing was performed under lubricated conditions in ambient air (21–22 °C, 25–26% RH) using a normal load of 5 N (corresponding to maximum initial contact pressure of 800 MPa) and has a relative sliding speed of 0.1 m/s. The tests were run for 2000 s corresponding to a sliding distance of 200 m, respectively, and during testing the friction coefficient was continuously recorded. The tribotested samples were investigated by field emission gun scanning electron microscopy (FEG-SEM) and energy dispersive X-ray spectroscopy (EDS) in order to evaluate the prevailing friction and wear mechanisms.

From Richard Westergard [2], the uncoated area of a plasma-sprayed coupon was covered with a dense, electrically insulating plastic resin. A wire, soldered to the back of the coupon, provided electrical conduction through the resin. The coating was then infiltrated by a low-concentration (1 wt.%) aqueous NaCl solution in order to fill the pores all the way to the substrate with an electrically conducting, neutral liquid. When infiltration was complete, the specimen was mounted as the cathode in electro-deposition equipment. A slightly acidic (pH 4.5) bright aqueous Ni solution was used as the electrolyte. By the acid electrolyte the deposition commenced immediately in order to avoid corrosion of the substrate, and subsequent detachment of the sprayed coating. A galvanostatic deposition technique was employed, keeping the applied current constant and varying the potential. The load-carrying Ni layer was deposited on mild steel using the same electrolyte, experimental set-up and deposition parameters.

GCr15 bearing steel and silicon wafer were used as the substrates. The substrates were all ground, polished, ultrasonic cleaned and dried by nitrogen before put into the vacuum chamber. Then they were fixed on the specimen holder. When the air pressure in the vacuum chamber was lower than 2×10-3 Pa, the argon gas was introduced to adjust the pressure so as to produce a plasma discharge. A negative pulse bias voltage of 0-700 V on the sample was used for the surface etching and cleaning for 30 min, and then turn on Ti target for the deposition of Ti transition layer [2]. In this stage, 100 V DC and 500 V pulse bias voltage was applied, and the deposition time was 5 min. The deposition parameters of different preparation methods 1 and the samples are denoted as S1, S2, S3, and S4.

In Wang Ming'e [3], a scanning electron microscope (SEM, USA) was used to examine the surface and fracture microstructures. A three dimensional (3D) white-light interfering surface profiler was applied to measure the surface roughness (*R*a) of the films, and observe the scratched and worn surfaces. A scratch tester (WS- 2004, China) was employed to measure the adhesions between the films and substrates, expressed by critical loads. Micro hardness tester (Woleprt Wilson Instruments) was applied to test the hardness, with the load of 60 N.A GCr15 ball of 6 mm in diameter was used as the counterpart under a normal load of 20 N. The relative sliding velocity was 5 mm/s, and the sliding time was 40 s.

A cw CO2 laser with a nominal power intensity of 800 W was used to irradiate the target. A nozzle allowing nitrogen to impinge onto the work piece surface and co-axially with the laser beam was designed. The nitrogen gas flow rate was kept constant at 20 l/min during the laser treatment process. The variable speed *x-y* table was used to hold the work piece. The work piece speed was also kept constant at 0.4 m/s. The laser beam was de-focused to obtain the power intensity of the order of 1011 W_m2 at the work piece surface. It was observed from the SEM microphotographs that the coverage area of coating defects was less than 1% of the surface area coated. XRD was carried out, employing a Siemens 5005 facility ŽMoK radiation. With typical voltage current settings of 40 kV and 20 mA. SEM was used to obtain micrographs of laser treated work piece cross-sections.

The wear tester had a steel ball of 4.5-mm diameter and a horizontally rotating disc of 5.5-mm diameter with 8-mm thickness. The hardness of the ball was 800 HV. The rotation of the disc was actuated by a D.C. motor with a variable speed within the range of 5_3500 rev. per min. The friction coefficient was measured continuously during the tests.

From B.S. Yilbas [4], one single-layer NiTi coating as well as three sets of bilayer composite NiTi/TiCN coating systems were deposited with total thickness in the range of 3-4 µm. These bilayer coatings were categorized in three different coating architectures in which the thickness of individual layers was varied. The description of the investigated coatings is mentioned. As can be seen, for (NiTi/TiCN)2 coating systems, NiTi interlayer is thicker than TiCN coating layer while in (NiTi/TiCN)0.5 coating systems NiTi interlayer is thinner than TiCN coating layer. The deposition of NiTi and bilayer NiTi/TiCN thin films were carried out on plasma nitrided hot work tool steel (X38CrMoV51) substrates by means of an magnetron sputtering device (Cemecon MLsinox800, Germany). The plasma nitriding process of the substrates. The size of the NiTi sputtering targets was 200 × 88 mm. These alloy targets (Ni-51.82 at.%Ti) with high purity (99.99%) were employed at sputtering power of 1.4 kW for deposition of near equiatomic NiTi thin films.

In Soroush Momeni[5], Deposition of NiTi coatings were conducted on the heated substrate at the temperature of 425 °C (in-situ annealing at 425 °C). After deposition of NiTi interlayers, TiCN coatings were reactively deposited by sputtering from Ti targets (99.99%) at the power of 9.5 kW. During the sputtering process, the reactive gases of C2H2 (65 ml/min) and N2 (30 ml/min) were injected inside of the coating chamber. In this step, the sputtering temperature and/or substrate temperature was 300 °C. The dimension of Ti targets was 500 × 88 mm. More details about the processing route and properties of these TiCN coatings are mentioned. All substrates were ultrasonically cleaned in an ethanol bath for 15 min prior to deposition. The sample holder was rotated on a horizontal table during the sputtering process in order to achieve a uniform film composition. The targetto- substrate distance was fixed at approximately 9.5 mm.

3. TESTING AND PARAMETERS:

Rather to PVD coating deposition, the top surface of all specimens was polished to obtain smooth surfaces, and for the sealed PSC also to remove excessive amounts of Ni. All coatings were cleaned using an alkaline solution and rinsed in distilled water. A thin adhesion layer of metallic Cr was initially deposited. From Richard Westergard [2], All coatings were characterised using scanning electron microscopy (SEM). Surface roughness and texture measurements (*R*q values and Abbot Curves) were undertaken with a white-light interferometer (Wyko NT2000). The hardness of the substrate materials and the load carrying layers was assessed using Vickers indentation on ground and polished coating cross-sections using a load of 300 g.

Impedance determinations are made with a Solar&on 1254 frequency response analyser (FRA) for frequencies ranging from 4 mHz up to 64 kHz. The amplitude of sinusoidal signals is set at 10 mV around the free corrosion potential. Knoop hardness measurements were made by using a 25 gf load with a duration of 10 s.

cracking and delamination of the coatings after scratching were observed by optical microscopy.

In C. Liu, A. Leyland [8], A.C. impedance data for the coated systems were obtained using a Solartron 1260 impedance gain-phase analyser with a Solartron 1286 electrochemical interface. The system was computer-controlled using CML software. Measurements were performed in 3% NaC1 solution in the three-electrode (potentiostatic) mode using a saturated calomel reference electrode (SCE).

4. RESULTS:

From Jenny Eriksson[1], The results show that in contact with the hot and cold rolled steel the material pick-up tendency of the PVD coatings tend to increase in the order CrC/C–CrN–(Ti,Al) N while in contact with the two galvanized steel sheets, the CrC/C and the (Ti,Al)N coating show a significantly lower material pick-up tendency as compared with the CrN coating In Richard Westergard[2], hot and cold rolled steel sheets with the contact the ranking was found to be CrC/CNCrNN(Ti, Al)N while in contact with the two galvanized steel sheets the ranking was found to be CrC/C≥(Ti,Al)NNCrN.

From Wang Ming'e[3], The reason for the observed differences in friction behaviour between (Ti,Al)N and CrN is not fully understood In the present study the galling and wear characteristics of PVD coated CrN, (Ti,Al)N and CrC/C in lubricated sliding contact with different high strength steel sheets have been evaluated using pin-on- disc testing.

The material pick-up tendency when in contact with the hot and cold rolled steel of the PVD coatings tend to increase in the order CrC/C– CrN–(Ti,Al)N while in contact with the two galvanized steel sheets, the CrC/C and as compared with the CrN coating the (Ti,Al)N coating show a significantly lower material pick-up tendency.

For the coatings investigated, the cracking tendency tends to increase with increasing coating hardness (brittleness), i.e. in the order CrC/C–CrN–(Ti,Al)N.

From B.S. Yilbas [4], all surfaces of the metallic specimens were found to be smooth, while the sealed material, and in particular the PSC specimen, was found to be rougher. Plasma-sprayed alumina coatings were also sealed, but also the unsealed, behaved surprisingly well as a load carrier for thin PVD coatings, despite their brittle behaviour, porosity and low cohesion. The cohesion and microstructure can be improved by spray process optimisation. Hard materials tended to function better where large amounts of plastic deformation are involved.

From Soroush Momeni [5], the roughness of the surface is got by the three dimensional (3D) white-light interfering surface profiler. However the effect of sputtering on the large grains is not obvious. The surface of the coating deposited with the composite technique, S3, is smooth. The roughness is 0.105 μm. There are only a few micro pores. Both the size and density of the particles are much smaller than those of the single cathode arc deposition. S4 is deposited with magnetron sputtering. It has the minimum roughness of 0.065 μm.

Due to the substrate bias, large particles are sputtered into small particles, and thus a part of the particles are decomposed before stabilized on the surface of the coating. Secondly, the high density of plasma is another possible reason of the improvement of the quality of surface. The XRD patterns of the samples prepared by different methods are shown in. We can see that crystal structures in the films and the preferential orientation of the XRD patterns of sample S1, S2, S3, and S4 crystalline are different. This is decided by the different energy produced during the preparation by different methods

In J. Creus[6], When comparing the friction coefficients corresponding to laser-treated TiN coated and TiN-coated work pieces, the steady state duration of the friction coefficient is longer in the case of laser-treated TiN-coated work piece.

In M.A. Baker [7] The results obtained in this study revealed that the combination of super elasticity of NiTi interlayer with high hardness of TiCN protective coatings could effectively postpone the complete removal of the coatings under cavitation stress pulses. Varying the thickness individual layers in such bilayer coatings could change the elastic modulus of the coating systems.

In C. Liu, A. Leyland [8], the results of corrosion-potential vs. time measurements and of immersion tests did not reveal a significant difference between the corrosion behaviour of the two types of Zn–Al coatings.

5. DISCUSSIONS:

From Wang Ming'e [3], they concluded that there were some observations

1) We have prepared TiN coatings with the cathode arc, magnetron sputtering and the composite methods.

2) The coating hardness, adhesion and thickness, as well as the microstructure and surface quality of the coating have an important influence on the friction performance.

3) The coating prepared by the composite technique (S3, 2.1 μm) has a smooth surface and a compact structure, due to the alternate deposition of different technique4) The thick coatings prepared by the composite method will have more advantages in wear resistant properties when used under high loading conditions.

From B.S. Yilbas[4], Laser-treated TiN-coated work pieces give better wear test results as compared to TiN-coated work pieces.

From Soroush Momeni [5], It was found that the deposition of hard TiCN coatings as a protective layer on NiTi thin films can significantly improve cavitation erosion resistance of NiTi interlayers.

From J. Creus [6], Porosity is an important criterion for the corrosion resistance of Al coated steel and could lead to a shortening of the sacrificial properties of an aluminium coating for long immersion times. It considerably reduces the porosity and also reduces the galvanic effect between steel and aluminium.

From M.A. Baker [7], Depending on the substrate temperature, two different microstructures were observed: at lower temperatures a compact and columnar type, and at higher temperatures an open woollen-like microstructure.

From C. Liu, A. Leyland [8], electrochemical impedance spectroscopy can provide a wealth of information concerning the electrochemical degradation of PVD-coated metals exposed in corrosive environments as a function of time of exposure.

From O.P. Oladijo [11], Deposition Zn-Sn alloys was successfully carried out on mild steel surface by plasma spraying technique. The coated Zn-Sn samples in different ratio were carried out on the surface of mild steel substrate.

In C.N. Panagopoulos [12], from the present experimental investigation, the following deductions could be drawn:

• Zinc-fly ash composite coatings were electrodeposited on mild steel substrate.
• The addition of fly ash particles was found to increase the hardness of the coating.

In Mai M. Khalaf [13], series of TiO2 thin films co-doped with NiO and ZrO2 coatings produced by sole gel and dip-coating techniques were studied for corrosion protection of mild steel. The coating systems were characterized in detail by XRD, SEM, TEM, EDAX and FTIR. The cooping of TiO2 with NiO and ZrO2 has improved resistance to loss of surface area and preserved the morphology of Titania coating.

The corrosion of mild steel with partial PANI-benzoate coatings in three different environments (3% NaCl, atmosphere and the Sahara sand) has been investigated. It has also been shown that partial benzoate-doped PANI coatings could protect mild steel in the case of a cathodic protection failure.

The scanning vibrating electrode technique (SVET) is a very useful tool in characterizing local corrosion events on alloys. In this work, the SVET clearly reveals the relationship between the bulk anodic activities on AA2024T3 and mild steel when the solution temperature is varied, with maps showing a clear agreement with the visual and optical images.

The conversion coating by using silica sol and aluminium oxyhydroxide followed by heat treatment at 500 °C produced mild steel surface suitable for sol gel Al2O3 coating. The conversion coating formed a composite oxide containing Al2O3, SiO2, α-Fe2O3 and Fe3O4 on the surface.

A major focus of the presented research was the progressive studies of surface transformations within the TiAlCrSiYN-based PVD coatings during the running-in stage of wear when the self-organization process starts and finalizes.

The angularity observed in the shape of diamond is quite different from the globular shape of WC particles. The globular nature imparts agglomeration tendency to WC particles which is evident from the respective micrograph.

The electrodeposition of homogenous and adherent PPy film has been achieved by two electrochemical techniques on mild steel in aqueous medium of sodium tartrate and pyrrole monomer

Ball-on-disc experiments showed that (Ti, X) N coatings wear gradually by micro-abrasion caused by coating particles that are trapped in the contact. The oxide nature of the debris was revealed by composition and structure analysis and accounted for the observed differences in coating wear us. Sliding speed for different coating compositions. Ti(C, N) coatings showed promising Perspective as a low-friction coating.

CONCLUSION:

From the Literature survey we have found out by conducting various tests we can ensure our process is sufficient for the coating of PVD in mild steel as a base material. From this we concluded that PVD process is sufficient to overcome the corrosion defects and comparing with many process we have concluded that the best suitable process for pump shaft application is PVD coating. We have many advantages from the pvd process.

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