MECHANICAL AND TRIBOLOGICAL INVESTIGATION OF COATED STEEL

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ABSTRACT

In present investigation TiAlN, TiCN, CrN multilayered coatings thin films have been developed. They consist of superposing Cr, CrN, TiC, TiAl layers. These coatings were grown on AISI 4140 steel samples. The mechanical and tribological properties of these coating is to be characterized by Adhesion Test, Scratch Test, X-Ray Diffraction Test (XRD), and Scanning Electron Microscope (SEM). Characterisitics of arc PVD- CrN coatings formed on plasma nitrided and as-received surfaces of an hardened AISI 4140 steel before and after nitiriding have been examined by adhesion and wear tests. CrN coating deposited on the nitrided surface exhibited remarkable advanced properties as compared to the CrN coating deposited on the as-received surface

Keyword: - *Scanning Electron Microscope; Gas nitriding; Wear Test; Plasma Nitriding*

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1. INTRODUCTION

Gas nitriding is a thermo chemical surface treatment in which nitrogen is transferred from an ammonia atmosphere into the surface of steels at temperatures within the ferrite and carbide phase region. After nitriding, a compound layer and an underlying diffusion zone (i.e. case) are formed near the surface of the steel. The compound layer, also known as the white layer, consists predominantly of ε - Fe2-3(C, N) and/or γ' - Fe4N phases and can greatly improve the wear and corrosion resistances. The hardened diffusion zone, which is composed of interstitial solid solution of nitrogen dissolved in the ferrite lattice and nitride and/or carbonitride precipitation for the alloy steels containing the nitrides forming elements, is responsible for a considerable enhancement of the fatigue endurance. Furthermore, being a low temperature process, nitriding minimizes the distortion and deformationof the heat treated parts. Therefore, nitriding is an important surface treatment for ferritic steels.

Although the industrial use of the gas nitriding began in the 1930s, it has not gained wide applications mainly due to its low performance reliability. The properties of nitrided steels are determined by the nitrided case microstructures. To ensure the reproducible and desirable properties from batch to batch, the gas nitriding need to be controlled to ensure the microstructure evolution. The successful gas nitriding process control depends on:

1) process parameters selection to meet the specification,
2) accurate process parameters control during the process.

The gas nitriding process parameters include temperature, time, and the nitriding atmosphere. For the nitriding atmosphere control, the ammonia dissociation rate was traditionally adopted as the controlling parameter. It represents the percentage of ammonia dissociated into hydrogen and nitrogen and is manually measured by using a burette in the furnace exhaust gas. Since dissociation rate is not an in-situ measurement and the measurement is done manually, it introduces operator induced variability and cannot provide the accurate control on the nitriding process. With the development of measure and control systems, the gas nitriding process parameters can be controlled accurately. How to pre-define the nitriding process parameters to meet the specifications becomes the main challenge of the gas nitriding process control. Conventionally, trial and error methods were used to define the nitriding process parameters to meet the specifications. This method is expensive, time consuming, and hard to control. Therefore, an effective simulation tool is needed to define the process parameters based on the performance specifications of various steels. By using this tool, the properties of the nitrided steels based on the phase constitution, surface nitrogen concentration, nitrogen concentration profile, case depth, as well as growth kinetics can be simulated through variation of process parameters (temperature, time, and the nitriding atmosphere).

2. MATERIALS AND METHODS

Nitriding and Coating

Nitriding is a heat treating process that diffuses nitrogen into the surface of a metal to create a case hardened surface. These processes are most commonly used on low-carbon, low-alloy steels.

Gas nitriding is an important thermochemical surface treatment that is used to improve the wear and corrosion resistance as well as the fatigue endurance of steel parts. Accurate process control is the effective way to ensure the properties reliability of nitriding process.

Gas Nitriding

In gas nitriding, nitrogen is introduced into a steel surface from a controlled atmosphere by holding the metal at a suitable temperature in contact with a nitrogenous gas, usually ammonia, NH_3. The process represents one of the most efficient among the various methods of improving the surface properties of engineering components, especially the parts with complicated shapes requiring homogeneous hardening of the surface.

Plasma Nitriding

Plasma nitriding uses plasma-discharge technology at lower temperature to introduce nascent nitrogen on the steel surface. It is another well-established surface hardening process in steel and also known as ion nitriding. Plasma is formed by high-voltage electrical energy in vacuum. Nitrogen ions are then accelerated to impinge on the workpiece which is connected as a cathode. The ion bombardment heats the work piece, cleans the surface and provides the nascent nitrogen for diffusion into the steel material.

Pack Nitriding

Pack nitriding uses nitrogen-bearing organic compounds as a source of nitrogen. The steels are packed in glass, ceramic or aluminum containers together with the nitriding compound which is often dispersed in an inert packing media. Upon heating, the organic compounds used in the process form reaction products that are relatively stable at temperatures up to 570◦C. The reaction products are decomposed at the nitriding temperature and they provide a source of nitrogen. The process time can range from 2 hours to 16 hours.

Salt Bath Nitriding

Salt bath nitriding process is carried out in a molten salt bath. It can be applied to carbon steels, low-alloy steels, tool steels, stainless steels and cast iron. The case hardening medium is a nitrogen-bearing salt bath containing cyanides or cyanates. During the process, the dimensional stability of the work piece can be preserved, thus processing of finished parts is possible. This implies that it can be used to complement engineering properties developed during carburizing and carbonitriding.

- **Name of Base Material**- AISI 4140
- **Chemical Composition** (% Weight)

C	Si	Mn	Cr	Ni	Fe
0.4	0.3	0.1	1	0.2	97

- **Sample Size**

For Wear Test On Pin On Disc Machine- Ø 8mm × 30 mm (length)

Procedure to Prepare Sample

1. Nitriding
2. Coating of TiAlN, TiCN
3. Wear Test on Pin on Disc Machine

3. RESULTS AND DISCUSSIONS

Wear Test

Experimental Setup: -

In pin-on-disc tribometer TR-20, a flat pin is loaded onto the test sample with a precisely known weight of 17.63 kg. The pin is mounted on a stiff lever, designed as a frictionless force transducer. The deflection of the highly stiff elastic arm, without parasitic friction, insures a nearly fixed contact point and thus a stable position in the friction track. The friction coefficient is determined during the test by measuring the deflection of the elastic arm. Wear coefficients for the pin and disc material are calculated from the volume of material lost during the test. This simple method facilitates the study of friction and wears behavior of almost every solid-state material combination with or without lubricant. Furthermore, the control of the test parameters such as speed, contact pressure and varying time allow a close reproduction to the real life conditions of practical wear situations.

It also facilitates study of friction and wear characteristics in sliding contacts under desired conditions. Sliding occurs between the stationary pin and a rotating disc. Normal load, rotational speed and it wear track diameter can be varied to suit the test conditions

Specification of Pin-On Disc Friction And Wear Monitor Tr-20

Table 1: Specification of Pin-On Disc Friction and Wear Monitor Tr-20

Make	Magnum Ltd., Bangalore, India
Pin Diameter Range	Φ3mm to 12mm
Disc Size	Φ160mm × 8mm thick
Wear Track Diameter	Φ5mm to150mm
Sliding speed Range	0.25 to 12 m/s
Disc Rotation Speed	100-3000RPM
Drive	1.1KWDC motor, Constant Torque
Motor Controller	Thyristor converter, with full motor protection
Frictional Force	0-250 N, Digital readout with recorder output
Normal Load	0 to250N
Disc Material	EN-31 with hardness 60 HRC and Ra 0.3.
Wear Measurement Range	±2 mm, Digital readout with recorder
Power	230V, 15A, 1phase, 50Hz AC

Scanning Electron Microscopy (SEM)

- **Sample Size-** ø 8 mm × 10 mm (length)

Scanning electron microscopy (SEM) is one of these characterization techniques, whose data is used to estimate the properties, determine the shortcomings and hence improve the material. The phenomenon of superconductivity initially develops within the grain and eventually crosses over the grain boundaries, leading to the bulk. Hence SEM can be a useful tool to probe the microstructure of the superconductors and the properties related to it. Along with this the Energy Dispersive Spectroscopy (EDS) can tell about the chemical composition of compounds. Grain size and its connectivity can be seen through SEM and can be correlated with the corresponding properties.

In SEM electron beam is scanned across a sample's surface. When the electrons strike the sample, a verity of signals arises and produces elemental composition of the sample. SEM with EDSis a major tool for qualitative and quantitative analyses which is done by bombarding a finely focused electron beam (electron probe) on the specimen, and measuring the intensities of the characteristic X-ray emitted. The three signals in SEM are the secondary electrons, backscattered electrons and X-rays, provide the greatest amounts of information. Secondary electrons are emitted from the atoms occupying the top surface and produce interpretable image of the surface. The contrast in the image is determined by the sample morphology. Backscattered electrons are primary electrons which are "reflected"from atoms in the solid. The contrast in the image produced is determinate by the atomic numbers of the elements in the sample. Therefore the image shows the distribution of different chemical elements in the sample. Since these electrons are emitted from the depth of the sample, the resolution of the image is not as good as for secondary electrons

4. CONCLUSIONS

From scratch test measurements the yield stress of steel and nitrided steel can be determined. A comparison of scratch test results on untreated and nitrided steel showed that nitriding makes the steel harder and more brittle. It is shown that duplex coatings with good adhesion between the nitrided substrate and Cr2N layer can be obtained even if some iron nitride is present at the interface.

Samples made of AISI 4140 steel pre-treated with plasma nitriding and coated with different PVD coatings (TiAlN, TiCN, CrN) investigation showed improved mechanical and wear properties of the plasma nitrided hard-coated specimens compared to the uncoated and pre-hardened ones.

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