ISSN (online): 2349-6010

Impact of CrN PVD Coating Thickness on 316l Austenitic Stainless Steel Wear Resistance

P. Giridhar
M. Tech. Student
Department of Mechanical Engineering
GRIET, Hyderabad, Telangana, India

Kosaraju Satyanarayana
Associate Professor
Department of Mechanical Engineering
GRIET, Hyderabad, Telangana, India

Dr Ram Subbiah
Associate Professor
Department of Mechanical Engineering
GRIET, Hyderabad, Telangana, India

N. Sateesh
Professor
Department of Mechanical Engineering
GRIET, Hyderabad, Telangana, India

Abstract

In this thesis CrN is used as PVD coating material on 316L grade austenitic stainless steel material at different coating thicknesses and the variation in wear resistance is observed. 316L is a low carbon composition grade of austenitic stainless steel with properties like corrosion resistance, anti-bacterial and bio compatibility increases its range of applications. But it still lacks the properties like wear resistance and hardness which impose its limitation in the field of cutting tools. In this, the specimens were PVD coated with CrN, each at different coating thicknesses of 2-3, 4-5 and 9-10 µm. The coated specimens were tested for their wear resistance on a Pin on Disc wear testing machine at various loads. The specimens were then analyzed under Optical Microscope (OM) and Scanning Electron Microscope (SEM) to find the case depth and nature of wear respectively. The final calculated value of the wear of all samples is calculated and the rate of wear resistance derived. The results indicate an increase in wear resistance and hardness with continuous increase of coating thickness and making the 9-10 µm samples more reliable compared to the other.
Keywords: Scanning Electron Microscope, Optical Microscope, Pin on Disc, PVD

I. Introduction

Stainless steel is used along wide range of applications because of its properties like high strength, low weight, heat Conductivity, high strength and low gas permeability. 316L is on among the grades of stainless steel with the added corrosion resistance property because of its low carbon content which make it successful to be applicable in wide range of applications like marine for ship building and as bio implants in medical field. But 316L grade of stainless steel is poor in wear resistance and suffers plastic deformation due to the adhesion with the mating part during movement.

To overcome the above problem, surface coating technology is used to give required properties by coating with a material that produces desired results. Here PVD coating process is chosen because of its uniform coating and providing good adherence with the base material. The type of PVD coating process followed for the current coating material was sputtering arc method. There are various surface coating technologies to impart the given properties on to the base material. Substrate materials incorporate steels, non-ferrous metals, tungsten carbides and also pre-plated plastics. The reason to choose PVD coating for a particular material is constrained just by its steadiness at the coating temperature and electrical conductivity. The reason behind choosing CrN as coating material on to the substrate is because of its properties like high temperature hardness, wear resistance and adhesion with other materials. In sputtering, the vapor is formed by a metal target being bombarded with energetic gas ions and is deposited on to the substrate. All PVD processes are carried out under high vacuum conditions.

II. Materials and Experimental Test Conditions

A. *Sample Preparation*

The base material here is 316L stainless steel rod of diameter 10mm. The rod is cut into equal pieces of length 30mm along its length, in this way 4 samples are cut. The sliced samples are checked to be free from any edge burrs or surface impurities along the whole surface. Any surface roughness or surface burrs formed during the cutting are removed by rubbing them against various grades of emery paper. The specimen surface should also be from surface impurities like grease, dirt etc. and can be removed by dipping the specimens in an acetone solution before they are given for the coating to eliminate any minute variation in the coating material properties because of impurities.

B. Specimen Coating

The PVD coating procedure followed to coat the material is Magnetron sputtering arc method. Magnetron sputtering is to some degree not the same as general sputtering technology. The distinction is that magnetron sputtering technology utilizes attractive fields to keep the plasma before the objective, increasing the assault of particles. Exceptionally thick plasma is the consequence of this PVD coating technology. The process usually takes around 450 °C under vacuum. The coating thickness ranges from 2 to 10 µm, on all the 3 samples as 2-3 µm, 4-5 µm and 9-10 µm. The final specimens coated with CrN were silver in color.

C. Experimental test conditions

The coated specimens are then received to be tested for their wear and hardness. The wear resistance of the samples is calculated by Pin on Disc wear testing machine and hardness is determined by Rockwell Hardness testing machine.

The Pin on Disc wear testing machine consists of a specimen holding arm and hard coated rotating disc against which the specimen is to be held in contact with the coated face touching the rotated disc. The specimen is made to be held against the disc and the loads are applied form 10KN to 25KN with a time interval of two minutes. During the process the rate of variation in the height of the specimen before the load application and after the load are measured and tabulated. In the similar way the rate of change in the height of the specimen is calculated at each and every load for all the samples. By considering the change in height of the specimen volume loss is calculate for all the samples at all the loads. The volume loss is used to determine the wear loss and from this rate of wear resistance is calculated.

The hardness testing of the specimen is done on a Rockwell Hardness testing machine. The Rockwell method is used to measures the depth of indentation produced by a force/load on to the specimen. First, a preload is applied to the sample using a diamond indenter. This load is taken as the zero or reference position that breaks through the surface to reduce the effects of surface finish. After the preload, an additional load, call the major load, is applied to reach the total required test load. This force is held for a predetermined amount of time (dwell time) to allow for elastic recovery. This real load is then discharged and the last position is measured against the position got from the preload, the space profundity change between the preload esteem and real load esteem. This separation is changed over to a hardness number.

III. RESULT AND DISCUSSION

A. Optical Microscopic Analysis

Optical Microscopic analysis is the process of examining the specimens at very close levels to know the surface variation at microscopic level. The process is followed after testing the specimen for its wear and hardness. For the process the specimen surface have to be clear from all the impurities.

A small piece of specimen is cut along and fixed into a mold by cold setting process. The cold setting process is done by placing the cut specimen into the cold mounting disc and adding the cold mounting powder as quartz sand and phenolic acid as catalyst for the cold setting to take place. The whole process usually takes place in 30-40 minutes, after this the mold is removed from the mounting disc. Then the mold specimen is made to run against various grades of emery paper to obtain a smooth mirror faced finish. The whole process was done to remove any impurities that may present on the surface and interfere with the calculation of the coating thickness.

For this purpose Optical Microscope Olympus GX51 version with a magnification range of 5X - 100X is been used. The mold specimen is placed on the mounting table and the light is moved to the edge of the specimen, the table has knobs to adjust the X-Y movement of the table. The magnification lenses are placed just below the mounting table and are moved to the required magnification until a clear image of the surface coating is obtained. Knobs are adjusted to attain a clear image of the coating through the eye piece. The intensity of the light falling on to the specimen can also be adjusted by the knob present on right side of microscope. Finally after obtaining a clear image, the coating thickness is measured by moving the selected horizontal/vertical line along the surface selecting the initial point on specimen base material edge and second point on coating thickness edge the value is obtained in micrometers. The obtained values are captured using the software provided along the microscope. In the similar way case depth of the entire specimen is taken.

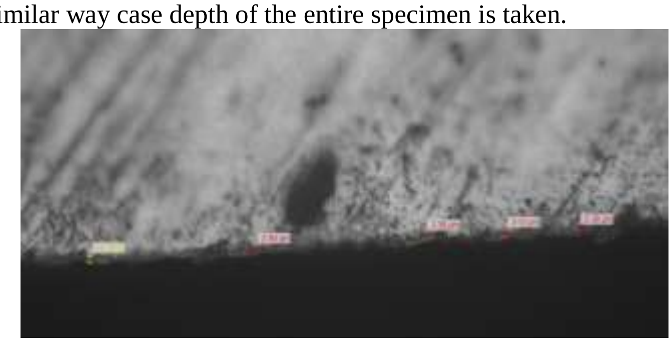

Fig. 1: OM image of the CrN coated specimen with 2-3 µm

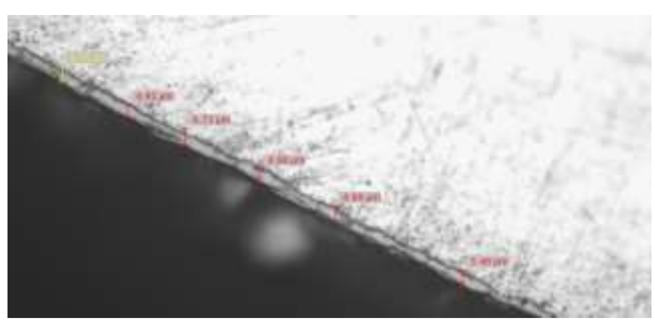

Fig. 2: OM image of the CrN coated specimen with 4-5 µm

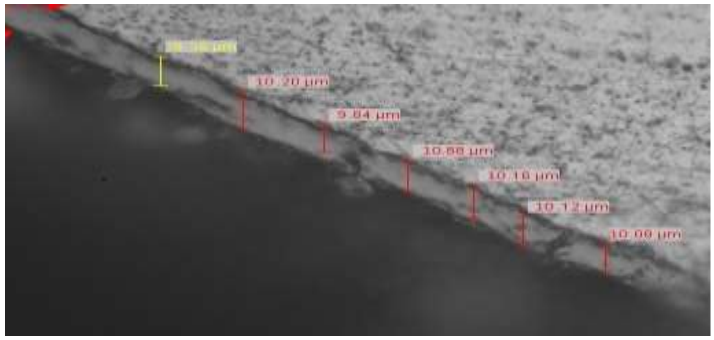

Fig. 3: OM image of the CrN coated specimen with 9-10 µm

B. Wear Analysis

The wear analysis of the specimen was also done on the Optical Microscope at 100X magnification. From the images obtained the wear was found to deep on the surface of specimen with low thickness and the wear depth decreased with increase in the coating thickness this was due to the hardness and wear resistance provided by the coating material. During thee wear test the coating material acts as a boundary and decrease the rate of wear of the material and results in the increasing performance of the tool.

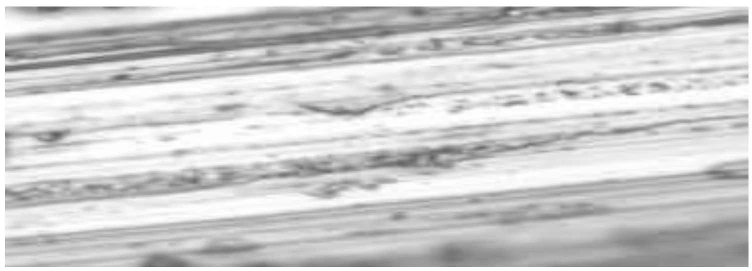

Fig. 4: OM image of the wear tested specimen magnified to 100X

C. SEM Analysis

The SEM analysis of the specimen was done at a higher magnification than the Optical Microscopic analysis to find the in depth nature of the wear specimen. From the SEM analysis of the specimen we can observe that the nature of wear of the specimen is uniform along the whole surface from the uniform parallel lines along the whole tested face.

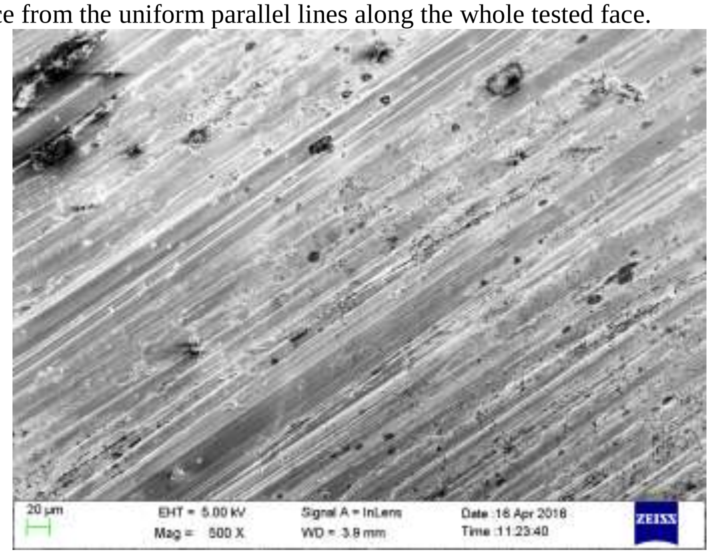

Fig. 5: SEM image of the wear tested specimen magnified to 500X

IV. Conclusions

The calculated results have shown an improvement in the wear resistance in the CrN coatings. Since the coating has good wear resistance, it can there by resists chipping and roughening and the surface quality of the machined part remains exceptionally high throughout the lifetime of the tool. This makes the CrN coatings reliable across various operations leading to increased productivity of cutting tools across a wide range of materials, speeds and feeds.

ACKNOWLEDGEMENT

In the current work, the PVD coating of the specimens was done at IONBOND COATINGS PRIVATE LIMITED, PUNE. The laboratory support for the SEM (Scanning Electron Microscope) and OM (Optical Microscope) were provided by University of Hyderabad (UOH), Hyderabad. I heart fully thank both of them for their help and valuable support.

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