Experimental Wear Analysis of Boron Carbide (B₄C) Coated High Speed Steel Substrate

Sunil S
M. Tech. Student
ICET Muvattupuzha, India

Jayaram C Sasi
Assistant Professor
ICET Muvattupuzha, India

Abstract

The aim of the present work is to minimize the wear rate by nano-coating Boron Carbide (B₄C) on the high speed steel (HSS) substrate. For this purpose the B₄C is being coated on the substrate using sputter deposition method and the wear rate is being analysed by performing pin-on-disc experiment on the coated and uncoated substrate to compare the wear rate on both substrate. For application purpose the same coating is made on the HSS drill bit and surface morphology of the tools were studied by using Scanning Electron Microscopy (SEM) after performing same number of drilling operation by using both coated and uncoated drill bit to determine the effect of coating.

Keywords: High Speed Steel, Scanning Electron Microscopy, Boron Carbide

I. INTRODUCTION

Wear takes predominant role in reducing the cutting life time of tool materials. This investigation focuses on the influence of Boron Carbide nanocoating on the HSS tool material. Boron carbide powder was coated on the high speed steel pin by using sputter deposition technique. High speed steel was selected as the work piece material.

A coating is a covering that is applied to the surface of an object, usually referred to as the substrate. The purpose of applying the coating may be decorative, functional, or both. The coating itself may be an all-over coating, completely covering the substrate, or it may only cover parts of the substrate. It is necessary to have an insight into the effect of B₄C nanocoating on the surface of the tool bit in order to investigate the wear on the surface during machining. Based on physical models used to calculate stress in the substrate and in various coating layers, it is possible to recommend PVD(Physical Vapour Deposition) and CVD(Chemical Vapour Deposition) coatings for interrupted cutting operations such as milling, parting, and drilling or in some cases also for continuous operations like turning and threading. The use of B₄C coating has the advantage in dry and high-speed machining compared to the TiN and TiCN coatings. Here the commercially available PVD coating technique is used for nano coating the tool surface by B₄C. Physical vapour deposition (PVD) describes a variety of vacuum deposition methods used to deposit thin films by the condensation of a vaporized form of the desired film material onto various work piece surfaces.

II. SCOPE AND OBJECTIVE

A. Scope

Boron carbide which has a high melting point of 2763°C and low density of 2550 kg/m³ compared to TiAlN and TiN, can be used for providing the coating for high speed steel machine tool instead of TiAlN and TiN which is the commonly available coating for HSS. Boron carbide which is abrasive in nature can be able to provide an extra role in the cutting action process of the machine tool.

B. Objectives

- Deposition of B₄C on the HSS pin using sputter deposition technique for producing a nano coating.
- Evaluation of wear characteristics of the coating by using pin-on-disc experiment on the coated substrate
- The surface morphology of the nano coated tool is being studied by performing scanning electron microscopy

III. METHODOLOGY

A. Literature Review

B. Procurement of Materials

- Boron carbide, HSS pin, HSS drill bit.
C. **Deposition of coating on the HSS substrate**

D. **Tests**
- To determine the wear rate of the nano coating, pin-on-disc experiment is done
- To determine the surface morphology of the tools

IV. **MATERIALS AND METHODOLOGY**

A. **Boron Carbide**

<table>
<thead>
<tr>
<th>Properties of Boron Carbide</th>
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<tbody>
<tr>
<td><strong>Density (Kg/m³)</strong></td>
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<tr>
<td><strong>Elastic Modulus (Gpa)</strong></td>
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<tr>
<td><strong>Poissons Ratio</strong></td>
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<tr>
<td><strong>Melting Point (°C)</strong></td>
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<td><strong>Thermal conductivity (W/mk)</strong></td>
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B. **Sputter Deposition**

Sputter deposition is a physical vapor deposition (PVD) method of thin film deposition by sputtering. This involves ejecting material from a "target" that is a source onto a "substrate" such as a silicon wafer. Resputtering is re-emission of the deposited material during the deposition process by ion or atom bombardment. Sputtered atoms ejected from the target have a wide energy distribution, typically up to tens of eV (100,000 K). The sputtered ions (typically only a small fraction of the ejected particles are ionized — on the order of 1%) can ballistic ally fly from the target in straight lines and impact energetically on the substrates or vacuum chamber (causing resputtering). Alternatively, at higher gas pressures, the ions collide with the gas atoms that act as a moderator and move diffusively, reaching the substrates or vacuum chamber wall and condensing after undergoing a random walk. The entire range from high-energy ballistic impact to low-energy thermalized motion is accessible by changing the background gas pressure. The sputtering gas is often an inert gas such as argon. For efficient momentum transfer, the atomic weight of the sputtering gas should be close to the atomic weight of the target, so for sputtering light elements neon is preferable, while for heavy elements krypton or xenon are used. Reactive gases can also be used to sputter compounds. The compound can be formed on the target surface, in-flight or on the substrate depending on the process parameters. The availability of many parameters that control sputter deposition make it a complex process, but also allow experts a large degree of control over the growth and microstructure of the film.
C. Pin-on-disc Experiment

As outlined by ASTM G99-04, pin-on-disk testing consists of a rotating disk in contact with a fixed pin with a spherical top. The pin is being forced against the abrasive disc to perform the wear process to determine the wear rate and coefficient of friction.

D. Scanning Electron Microscopy

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition. The electron beam is generally scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image. SEM can achieve resolution better than 1 nanometer. Specimens can be observed in high vacuum, in low vacuum, in wet conditions (in environmental SEM), and at a wide range of cryogenic or elevated temperatures.

The most common SEM mode is detection of secondary electrons emitted by atoms excited by the electron beam. Number of secondary electrons depends on angle at which beam meets surface of specimen, i.e. on specimen topography. By scanning the sample and collecting the secondary electrons with special detector, an image displaying the topography of the surface is created.

V. Results and Discussions

A. Pin-On-Disc Experiment

The pin-on-disc experiment conducted on both coated and uncoated HSS pin gives the following output.
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B. Scanning Electron Microscopy

The SEM analysis is done on the coated and uncoated HSS drill bit after performing equal number of drilling operation on an MS plate and the SEM images are as follows

VI. Conclusions

- Boron carbide coating is deposited on the HSS pin and HSS drill bit.
- Wear and SEM analysis is done on both coated and uncoated HSS specimen.
- Wear rate is much more in uncoated pin and is reaching about 1000 μm after 800 sec whereas it is 720 μm for boron carbide coated pin.
- SEM analysis investigation finds that the wear rate of the uncoated drill bit is much more compared to that of the coated drill bit and some more particles are thrown out from the surface during drilling which cause more wear and decreases the life time of the tool.
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REFERENCES