JMEPEG
https://doi.org/10.1007/s11665-018-3150-z

Adhesive and Cohesive Strength in FeB/Fe_2B Systems

A. Meneses-Amador, D. Blancas-Pérez, R. Corpus-Mejía, G.A. Rodríguez-Castro, J. Martínez-Trinidad, and L.F. Jiménez-Tinoco

(Submitted May 8, 2017; in revised form August 14, 2017)

In this work, FeB/Fe_2B systems were evaluated by the scratch test. The powder-pack boriding process was performed on the surface of AISI M2 steel. The mechanical parameters, such as yield stress and Young's modulus of the boride layer, were obtained by the instrumented indentation technique. Residual stresses produced on the boride layer were estimated by using the x-ray diffraction (XRD) technique. The scratch test was performed in order to evaluate the cohesive/adhesive strength of the FeB/Fe_2B coating. In addition, a numerical evaluation of the scratch test on boride layers was performed by the finite element method. Maximum principal stresses were related to the failure mechanisms observed by the experimental scratch test. Shear stresses at the interfaces of the FeB/Fe_2B/substrate system were also evaluated. Finally, the results obtained provide essential information about the effect of the layer thickness, the residual stresses, and the resilience modulus on the cohesive/adhesive strength in FeB/Fe_2B systems.

Keywords advanced characterization, boriding, cohesive/adhesive strength, residual stress

1. Introduction

Modern tool materials such as powder metallurgical high-speed steels are used as cutting tools in the metal cutting industry. In order to improve cutting performance, these tools are frequently subjected to surface hardening processes (Ref 1). Surface hardening by diffusion involves the chemical modification of a surface with elements such as carbon, nitrogen, or boron (Ref 2-4). Compared with conventional surface treatments such as carburizing, nitriding, or nitrocarburizing, boriding has better tribological characteristics (Ref 5-8). During the boriding process, boron atoms diffuse into the surface at high temperature to form boride with the base material (Ref 9, 10). Depending on the experimental conditions of boron potential, temperature, exposure time, and chemical composition of the base material, a monolayer (Fe_2B) or a bilayer (FeB/Fe_2B) may be formed (Ref 11, 12).

The effect of the residual stresses caused by the thermochemical treatment on the cohesive and adhesive strength of boride layers is an important aspect because of its contribution to the mechanical performance of boride steels. Among the techniques available to assess cohesive and adhesive strength is the scratch test, which consists in drawing a hard stylus over the surface of a sample under a normal load. The applied load is increased either stepwise or continuously until a critical normal load is reached, at which a coating failure occurs (Ref 13-15). The onset of coating failure during the scratch test can be determined by monitoring the friction force and acoustic emission signals or by posttest examination using optical or scanning electron microscopy (Ref 16). The failure modes that take place in the coating during the scratch test are complex and associated with multiple mechanisms (properties of both substrate and coating, residual stresses, friction at the interface, indenter geometry, etc.) which are simultaneously active.

The scratch test has been used to evaluate the mechanical performance of titanium borides and borided steels (Ref 17-20), where the main failure mechanics reported were Hertzian fractures, cracks that developed on the scratch side, and cohesive scaling. The aim of this study is to assess the adhesive and cohesive strength in the FeB/Fe_2B systems by means of the scratch test. In this work, the effect of the layer thickness, the residual stresses, and the resilience modulus on the cohesive/adhesive strength of a high-speed steel (AISI M2) subjected to the powder-pack boriding process has been evaluated.

2. Experimental Procedure

2.1 The Powder-Pack Boriding Process

The powder-pack boriding process was performed on a commercial sample of AISI M2 steel. The samples were embedded in a stainless steel container (AISI 304) containing a B_4C Ekabor II powder mixture. Three different treatment conditions were performed in a furnace at a temperature of 900 °C with exposure times of 6, 8, and 10 h. Once the boriding was complete, the container was removed from the furnace and slowly cooled to room temperature.

2.2 Boride Layers Characterization

The boride samples were cross-sectioned for metallographic preparation and to observe the growth and morphology of the boride layers FeB and Fe_2B by the use of optical microscopy with a GX51 Olympus instrument. The average thickness was obtained by twenty thickness measurements of the boride layers in different sections of the samples because the borides grow as needles in the crystallographic direction where the strength of the substrate is minor. Figure 1 shows the flat morphology of

A. Meneses-Amador, D. Blancas-Pérez, G.A. Rodríguez-Castro, J. Martínez-Trinidad, and **L.F. Jiménez-Tinoco**, Instituto Politécnico Nacional, Grupo Ingeniería de Superficies, SEPI-ESIME, U.P. Adolfo López Mateos, Zacatenco, Ciudad de México 07738, Mexico; and **R. Corpus-Mejía**, Sección de Estudios de Posgrado e Investigación, ESIME Azcapotzalco, Instituto Politécnico Nacional, Av. de las Granjas no. 682, Col. Santa Catarina, Ciudad de México 02250, Mexico. Contact e-mail: amenesesa@ipn.mx.

Published online: 19 January 2018