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Multipass Scratch Behavior of Borided and Nitrided H13 Steel

R.C. Vega-Morón, G.A. Rodríguez-Castro, L.F. Jiménez-Tinoco, A. Meneses-Amador, J.V. Méndez-Méndez, J. Escobar-Hernández, C.D. Reséndiz-Calderón, and J.L. Nava-Sánchez

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AISI H13 steel was subjected to boriding and nitriding; its performance was evaluated by the progressive load scratch test, and then by the multipass scratch test (MPST), to evaluate the accumulated damage. Boriding and nitriding were carried out at a temperature of 800 and 580 °C, respectively, both treatments for 1 and 5 h of exposure time. In scratch test, a load range of 3-90 N was used for borides; a higher range (3-180 N) was chosen for nitrides. Critical loads (L_c) were estimated based on optical microscope observations of the scratch tracks. Failure mechanisms and residual depths were examined by scanning electronic microscope and optical profilometry. Finally, using fractions of L_c, MPST was applied on uncoated and coated samples, for 25, 50, 75 and 100 unidirectional scratch cycles. The coefficient of friction (COF) evolution was recorded and analyzed. A decrease in COF was observed as cycles go through; it was initially higher in uncoated sample; moreover, it was observed that normal load was determinant in its behavior, regardless of the treatment time. Nitrided samples exhibited less catastrophic failures over borided ones, also showed a better volume loss/load ratio performance, from 6 to 8 times better compared to borided samples.

Keywords boriding, coefficient of friction, damage, multipass scratch, nitriding, scratch

1. Introduction

AISI H13 steel is known as a chromium hot work steel, with medium C content and alloying elements such as Cr, Si, Mo and V. Hot work steels are used mainly in punching, forging and extrusion, hot shear blades, stamping dies and plastic molds. H13 steel needs a great set of properties like good performance at high temperature, good wear resistance, and high toughness and resistance to thermal fatigue cracking in order to withstand associated operations (Ref 1).

Due to the severe working conditions, H13 is subjected to thermochemical treatments to improve its wear resistance. Both, nitriding and boriding, are diffusion methods, they modify the chemical composition of the surface with a hardening species: nitrogen and boron. The atoms (nitrogen or boron) are introduced to the substrate surface usually within a temperature range of 500-580 °C or 850-1000 °C, respectively. Both processes can be carried out in liquid, gaseous and solid mediums, mainly (Ref 2).

In liquid nitriding (using a molten salt containing either cyanides or cyanates), a compound (or "white") layer is formed on the steel surface and a diffusion zone immediately below (Ref 2). The compound layer is usually hard, may exceed 9.8 GPa (Ref 3), and is brittle and it is a mixture of $Fe_{2-3}N$ epsilon (ε) and Fe_4N gamma-prime (γ') phases. The diffusion zone is composed of nitrides formed by the reaction with nitride-forming elements such as Al, Cr, V, Mo and W; this region is responsible for fatigue and load-bearing resistances (Ref 4). Gas and salt nitride systems have run an almost parallel course since the early part of the twentieth century. Molten salt nitriding have some advantages over other types of nitriding: relatively low operating cost, low maintenance, easy operation, requiring a lower skill level, energy efficiency and stability (Ref 4, 5). This method of nitriding is considered as a highly promising industrial process for surface modification of iron-based steels and has solved environmental problems and can be used to increase the hardness of stainless steels (Ref 5). On the other hand, powder-pack boriding is the most common process to obtain boride layers. Usually, the process takes place during a period of time between 1 and 10 h, creating layers with superficial hardness that can exceed 20 GPa (Ref 6). This process applied in different steel grades results in the formation of either a single phase Fe_2B or a double phase FeB/ Fe_2B (Ref 7), with a flat or sawtooth morphology interface depending on the alloying elements.

Tribological behavior of plasma nitrided H13 has been reported previously (Ref 8-11), but liquid nitriding have received lesser attention (Ref 12). Also, borided H13 has been studied from the perspective of growth kinetics, corrosion, mechanical and a tribological approach (Ref 13-21). Aforementioned studies predominantly use pin or ball on disk configurations for the tribological characterization; there are no studies of borided and/or nitrided H13 steel conducting

R.C. Vega-Morón, G.A. Rodríguez-Castro, A. Meneses-Amador, and **J. Escobar-Hernández**, Instituto Politécnico Nacional, Grupo Ingeniería de Superficies, SEPI-ESIME, U.P. Adolfo López Mateos, Zacatenco, 07738 Ciudad de México, Mexico; **L.F. Jiménez-Tinoco**, Instituto de Ingeniería y Tecnología, Universidad Autónoma de Ciudad Juárez (UACJ), 32310 Ciudad Juárez, Chihuahua, Mexico; **J.V. Méndez-Méndez**, Instituto Politécnico Nacional, Centro de Nanociencias y Micro-Nano Tecnologías, U.P. Adolfo López Mateos, Zacatenco, 07738 Ciudad de México, Mexico; and **C.D. Reséndiz-Calderón** and **J.L. Nava-Sánchez**, Universidad Tecnológica de México – UNITEC MÉXICO – Campus Cuitláhuac, 02870 Ciudad de México, Mexico. Contact e-mail: garodriguezc@ipn.mx.

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