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A Microstructure Comparison of TiN with a Cr Metallic Interlayer and Boride Layers Formed on AISI 304 Steel: Wear Properties

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High performance machining of hard-to-cut materials is a challenge. There are two major categories of most widely used hard-to-cut materials: (1) hardened tool steels for dies and molds fabrication as well as (2) aerospace materials such as Ni-based super-alloys and Ti-based alloys. Likewise, wear and corrosion are major causes of machinery downtime and material loss in industry contributing to decreased profits. Since wear is a surface phenomenon, the use of hard coatings can be an efficient solution, allowing the substrate to maintain its impact resistance and the coating can be produced to withstand wear, corrosion, abrasions and thermal loads while at the same time reducing costs by using diminutive amounts of hard materials [1-11]. A proposed solution consists of developing a hard, dense, wear- and corrosion-resistant coating formed on a surface with certain affinity in fracture toughness, as well as the creation of a dislocation interface that prevents the propagation of the corrosive medium to the substrate and the propagation of micro-cracks [10, 11]. In particular, boriding is a recognized surface treatment for achieving high surface hardness (up to 2000 HV) and low coefficient of friction while improving the corrosion and erosion resistance and is being increasingly used in many industrial applications. Likewise, PVD (physical vapour deposition) is the one of the ways of their deposition onto tool steels substrate. The low deposition temperature is significant advantage of this method. However, these coatings show relatively low adhesion to substrate. Improvement of the adhesion may be achieved by modifying the substrate or adjusting physical proper-ties of the coating to the substrate as much as possible in order to achieve similar mechanical properties like hardness. The hard TiN (Titanium Nitride) coatings are also used for coating machine tools such as drills, lathe tool inserts, stamps and punches, and expensive forming tools such as injection molds for plastics. In the present study, the microstructure of three coating configurations (TiN, FeB, and Fe_2B) formed on an AISI 304 steel surface have been investigated at different temperatures by dehydrated paste-pack boriding and reactive PVD treatments. Moreover, the addition of a TiN coating on the boride layer is seen as a possibility of reduction in the rate of crack propagation. The material involved in the research, is the AISI 304 steel is a general purpose austenitic stainless steel with a face centered cubic structure. It is essentially non-magnetic in the annealed condition and can only be hardened by cold working. The boriding and PVD treatments were carried out in two stages: boriding and then PVD. The samples were embedded in a closed in a closed cylindrical case having a dehydrated paste of boron powder mixture inside with an average particle size of 10 µm (see Figure 1). Boriding mixture contains of B_4C (active source of boron), Na_3AlF_6 (activator), SiC (inert filler), and $SiC_8H_{20}O_4$ which is used to protect surfaces. The boriding process was carried out in a conventional furnace under a pure argon atmosphere at 1123 and 1273 K for 8 h of exposure for each temperature. Once the boriding treatment was finished the container (AISI 316L stainless steel) was removed from the furnace and slowly cooled to room temperature (see Figure 2). In the second step, the pre-boriding iron samples were cleaned using sputtering etching with 650 V, 240 kHz, 1600 ns for 15 min. The adhesion layer Cr and TiN coatings were obtained by using a target with high power impulse magnetron sputtering (HIPIMS) with 2000 W, 500 Hz, 200 ns and three targets with direct current magnetron sputtering

(DCMS) with 2500 Won each (see Figure 3). The sputtering targets were Cr (= 99.95%) and Ti (> 99.8%). Interlayers of pure Cr (metallic interlayer) were deposited with 400 V bias-voltage on all substrates. Next, TiN layers were deposited by using bias-voltages of 75 V and 150 V. The TiN layers had thicknesses of approximately 1 µm and 2 µm. The coatings were deposited at 450°C with an Nitrogen/Argon (99.97% pure) atmosphere (Ar:N_2 Ratio = 24:5) and total pressure of 350 mPa and 120 min of exposure time. The hard samples were grinded with SiC abrasive paper up to grit 2500. Afterwards, the samples were polished using a diamond suspension with particle size of 6 µm, finishing with particle size of 3 µm. The depth of the surface coatings and morphology were analysed by SEM and EDS (JEOL JSM-6360 LV at 20 kV). The CSM tribometer was used to determine the scratch wear test consists of scratching the surface of a sample by using an LG Motion Ltd. (scratch) with a single-pass under increasing normal load at a rate of 10 N mm of covered distance. Applied loads ranged from 0 to 90 N. This permitted determination of the critical load (L_C) corresponding to the apparition of the layer damage. The scratch wear tests were carried out in dry sliding conditions (at ambient conditions without lubrication) using an LG Motion Ltd. This technique of characterization involves generating a controlled scratch with a sharp tip on a selected area. The tip material (commonly diamond or hard metal (WC)) is drawn across the borided surface under constant, incremental, or progressive load. Figure 4 shows the cross-sections and the EDS analysis obtained by SEM at the TiN coating and FeB/Fe_2B interphase for the AISI 304 steel (see Figure 4). These results demonstrate that the formed the TiN-FeB-Fe_2B top layer produced a hardness in the expected range, around 2500 HV, and no incompatibility with the supporting boride layer was observed. Figure 5(a) and (b) shows some areas undergoing a plastic deformation for the substrate and TiN coating. TiN coating show relatively low adhesion to substrate. However, Figure 5(c) and 5(d) shows better adhesion to the substrate. The duplex treatment proved to be effective in the production of high hardness and wear resistant layers.

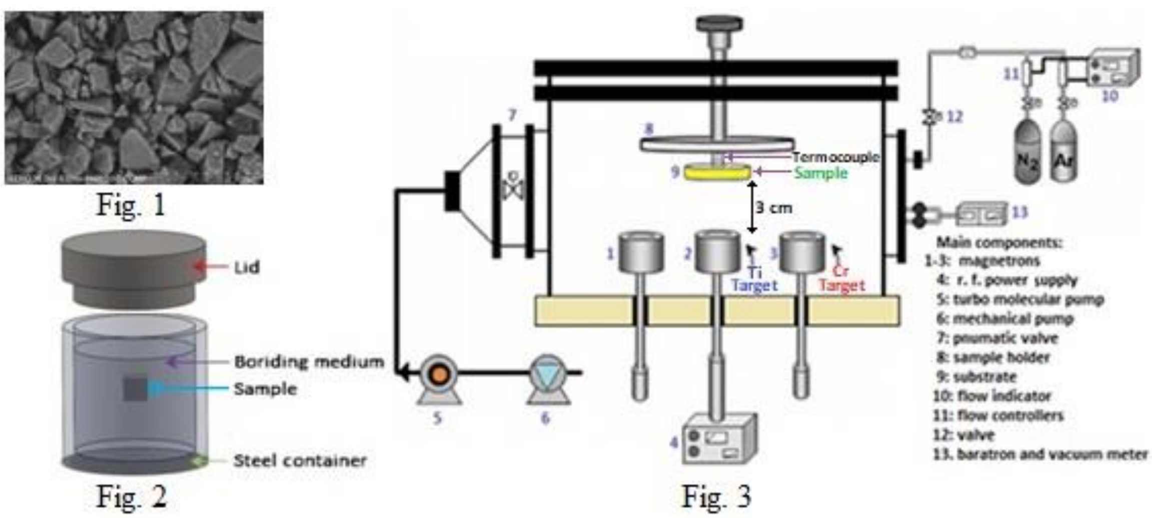

Figure 1. (Figure 1) Powder-pack boriding mixture, schematic view of the stainless steel AISI 316L container for the powder-pack treatment (Figure 2) and the schematic representation of the deposition reactor (Figure 3).

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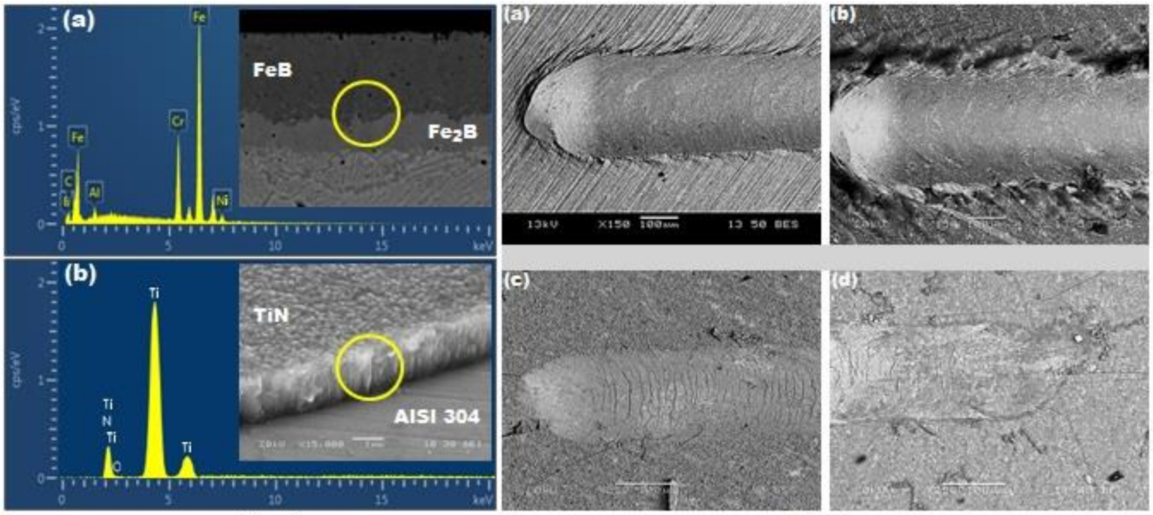

Fig. 4 Fig. 5

Figure 2. (Figure 4) SEM cross-sectional micrograph and EDS analysis of: (a) borided AISI 304 steel with 1123 K for 8 h and (b) TiN coating deposited on AISI 304 steel; and SEM (Figure 5) cross-sectional micrographs of the wear scar on surfaces of: (a) substrate surface, (b) TiN coating surface, (c) borided AISI 304 with 1123 K for 8 h and (d) TiN coating + borided AISI 304 with 1123 K for 8.

References

[1] J. R. Davis. “Surface Hardening of Steels: Understanding the Basics”, 1st ed. ASM, Ohio, p. 213.
[2] M. Ortiz-Domínguez, I. Morgado-González, A. Cruz-Avilés, A. Soto-García, R. Trujillo-Sánchez, M. L. Moreno-González, G. Moreno-González, O. A. Gómez-Vagas, J. Zuno-Silva, Microsc.Microanal. 25 (Suppl 2) 2019, p. 2400.
[3] M. Ortiz-Domínguez, O. A. Gómez-Vargas, I. Simón-Marmolejo, M. A. Flores-Rentería, L. E. Martínez-Martínez, A. Cruz-Avilés, M. A. Paredes-Rueda, Microsc. Microanal. 24 (Suppl 1) 2018, p. 1076.
[4] O. A. Gómez-Vagas, M. Ortiz-Domínguez, A. Cruz-Avilés, I. Morgado-González, J. Solis-Romero, V. A. Castellanos-Escamilla, E. Coronel-Guerra, E. Cardoso-Legorreta, Microsc. Microanal. 25 (Suppl 2) 2019, p. 770.
[5] O. A. Gómez-Vargas, M. Ortiz-Domínguez, J. Solís-Romero, A. Arenas-Flores, I. Morgado González, J. Zuno-Silva, F. R. Barrientos-Hernández and J. Medina-Marín, Microsc. Microanal. 25 (Suppl 2) 2019, p. 796.
[6] M. Ortiz-Domínguez, O. A. Gómez-Vargas, G. Ares de Parga, G. Torres-Santiago, R. Velázquez-Mancilla, V. A. Castellanos-Escamilla, J. Mendoza-Camargo, and R. Trujillo-Sánchez, Advances in Materials Science and Engineering. 2019 (2019), p. 1.
[7] K. Y. Li and Z. D. Xiang, Surf. Coat. Technol. 204 (2010), p. 2268.
[8] H. Du and J. Agren, Z. Metallkd. 86 (1995), p. 522.
[9] K. H. Habig, Mater. Eng. 2 (1980) p. 83.
[10] M. Flores, S. Muhl, L. Huerta, Surf. Coat. Technol. 200 (2005) p.1315-1319.
[11] J. L. Bernal, E. Vera, A. I. Martínez, A. García, Microsc. Microanal. 24 (Suppl 1) 2018, p. 1102.