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MICRO-ABRASIVE WEAR OF DUPLEX TREATED VANADIS10

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Abstract. *Sub-zero treatment, film deposition, nitriding and duplex treatment were applied in Vanadis 10, obtaining 7 different surface conditions. Micro-abrasion wear tests were carried out in order to evaluate the wear performance of the obtained conditions. A fixed ball micro-abrasion tester was used and SiC was the abrasive. Slurry concentration, speed and load were respectively 0.50 g/cm³, 75 rpm and 0.49 N. Craters produced on the samples were evaluated using Scanning Electron Microscopy. Nitriding treatment promoted the formation of a compound layer in some conditions impairing samples performance. Volume of removed material was obtained and indicated that the film protected the surface against wear. Wear mechanisms observed were rolling abrasion for the samples with film deposition, sliding abrasion and the combination of these two mechanism for the other conditions.*

Keywords: *Micro-abrasion, Vanadis 10, Duplex treatment, Film deposition.*

1. INTRODUCTION

The configuration of hardened substrate (by a diffusion process) and film deposition (single layer or multilayer coatings) is known as duplex treatment (Sun et al., 1995). This combination of processes provides high hardness and high wear performance of PVD coatings allied to the enhanced fatigue resistance and load bearing capacity of the nitrided substrate. It is desirable that only the formation of a diffusion layer occurs because the compound layer (white layer – Fe₂₋₃N/Fe₄N) reduces the adhesion of the coating to the substrate according to the works of Ma et al. (2001) and Rosseau et al. (2015). As discussed by Tan et al., (2016), some studies revealed that the formation of the phases Fe₂N/Fe₃N or Fe₂₋₃N deteriorates the adhesion of the coating to the substrate, and that the formation of a Fe₄N phase only can lead to higher hardness, higher corrosion resistance of the nitrided and layer and better adhesion of the coating.

In layered systems, substrate plays an important role giving load support to the hard coating enabling the coating to perform its function (Komarov et al., 2016). Nitriding can increase the load support of the substrate, increasing the composite hardness and consequently the micro-abrasive wear resistance. This system proved to be effective for single-layered TiAlN and TiN coatings and uncoated AISI H13 steel substrates (Batista et al., 2001). Adhesion of multilayer coating can be improved by substrate nitriding as observed by Recco and Tschiptschin (2012) where plasma nitriding was carried out in conditions where no white layer can be formed, fact that would promote a better protection of the substrate. Zappelino (2017), observed the formation of a compound layer on the surface of nitrided Vanadis 10 that impaired the adhesion of TiCN/AlTiN/CrAlTiN/CrN multilayer coating. This reduced adhesion and the formation of a brittle layer of compounds on the surface of the substrate contributed to an increase of removed material amount during sliding tests due to the formation of hard particles from the coating and from the compound layer.

In this work, micro-abrasive wear of seven experimental conditions were studied: Vanadis 10 without treatment (Vanadis 10), sub-zero+triple tempered Vanadis 10 (QT), QT followed by nitriding at an atmosphere of 5% nitrogen

(Nit 5%), QT followed by nitriding at 25% nitrogen (Nit 25%), nitrided at 5% with film, (Nit 5%+Film), nitrided at 25% with film(Nit 25%+Film) and QT Vanadis 10 with film (QT+Film).

2. MATERIALS AND METHODS

Hot Isostatic Pressing (HIP) Vanadis 10 samples (Ø26 mm×9 mm) were cut and machined from soft annealed bars. Samples were pre heated at 540 °C for 60 min, at 850 °C for 30 min and 1050 °C for 30 min until austenizing temperature of 1100 °C. Then the samples were tempered for 2 h at 540 °C, exposed to deep cryogenic treatment at -198 °C in liquid nitrogen for 1 h and finally double tempered for 2 h at 540 °C. Surfaces were polished to $Sa = 0.028 \pm 0.001$ µm. Pulsed plasma nitriding was performed in two conditions: at 500 °C for 3 h in a 5% N₂, 75% H₂, 20% Ar atmosphere (Nit 5%) and 25% N₂, 75% H₂, 20% Ar (Nit 25%). Coating was carried out in an industrial-scale cathodic arc plating system. Surface hardness obtained is shown in Figure 1.

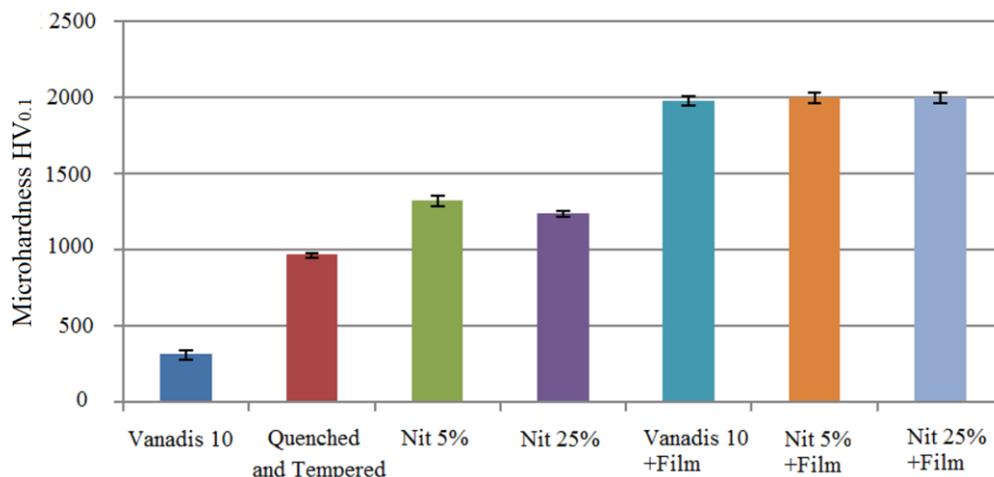


Figure 1. Surface Microhardness HV_{0.1}

Micro-scale abrasive wear tests were carried out using a fixed ball configuration equipment (Plint TE-66 SLIM). The counter-body was AISI 52100 steel ball with 25.4 mm diameter. The samples were subjected to three tests for each condition. The abrasive used was SiC F1200 with a concentration of 0.5 g/cm³. Normal load of 0.49 N and tangential speed of 0.1 m/s were established. Craters' diameters produced on the samples were optically measured after 100, 200, 300, 500, 700 and 1000 rotations. The volume loss calculated, and the steady state regime was identified when volume loss varies linearly with sliding distance. Equation (1) was used in order to calculate the volume loss, as observed in a previous work of Adachi and Hutchings (2003), considering the samples that were not coated. In this equation, b represents the crater diameter and R represents the radius of the counter-body.

$$V \approx \frac{\pi b^4}{64R} b \ll R \quad (1)$$

3. RESULTS AND DISCUSSION

The cross section micrograph of Nit 5%+Film is shown in Figure 2. A layer of nickel was deposited on the sample to protect the multilayer film for metallographic preparation, even so, some film layers suffered delamination. The multilayer film and the diffusion layer obtained from the plasma nitriding treatment are observed in this image. Typical carbides from powder metallurgy are homogeneously distributed in the matrix.

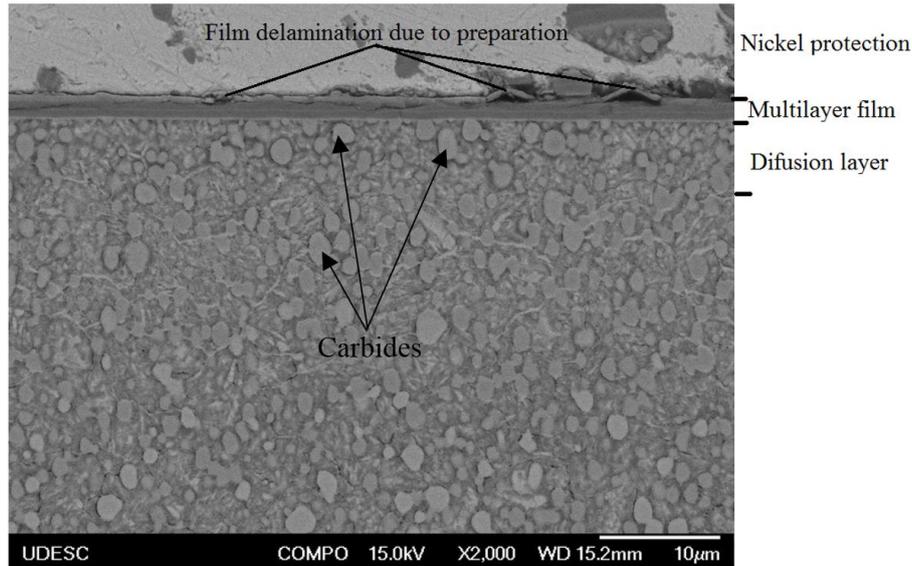


Figure 2. Cross section micrograph of Nit 5%+Film

Volume loss after 1000 rotations is shown in Figure 3.

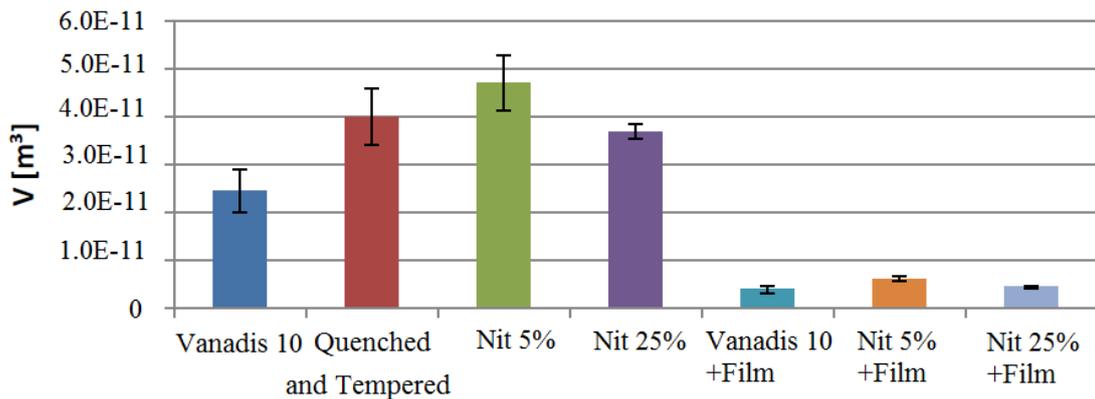


Figure 3. Volume loss after 1000 rotations

Statistical analysis showed that Quenched and Tempered, Nit 5% and Nit 25% are statistically the same at a 95% confidence level. These conditions represent the highest volume loss. The film provided a significant decrease in the volume loss under all conditions, representing a reduction of approximately 75% of the sample Nit 5%+Film compared to Vanadis 10 and 84% of the sample Vanadis 10+Film compared to Vanadis 10. Vanadis 10+Film and Nit 25%+Film conditions volume loss are statically the same. Volume loss obtained for these conditions are the lowest values.

Through the images of Figure 4, it is possible to observe the transition of the wear mechanism considering the samples examples, Nit 5% and Nit 5%+Film. Nitrided samples presented risks inside the wear crater that represents two-body abrasion or sliding abrasion, on the other hand samples that were coated presents a reduction of these risks formation because the wear mechanism changed to three-body abrasion (rolling abrasion) where the abrasion particles roll between the sample and the counter-body reducing the volume loss.

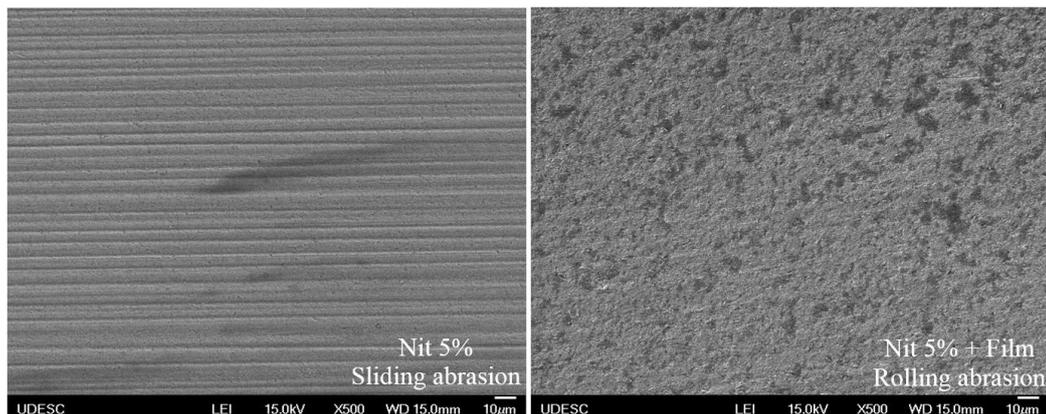


Figure 4. Wear mechanisms transition

4. CONCLUSIONS

TiCN/AlTiN/CrAlTiN/CrN multilayer film deposition lead to a reduction in the volume loss and a change in the wear mechanism. Composite (Substrate+Film) hardness could be responsible for this increase in wear resistance.

Considering nitriding conditions, the high values of volume loss can be explained by the brittleness of the obtained layer in the conditions used in this study, so the particles removed during the test eventually increased the volume of material removed. In these conditions, the wear mechanism observed was sliding abrasion.

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6. RESPONSIBILITY NOTICE

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