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Effect of double source Titanium deposited in nitriding steels on their mechanical properties

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ABSTRACT

We report the improved mechanical properties of three kinds of nitriding steels modified by titanium diffusion either by depositing titanium by PVD and hot-pressing the steel with titanium sheets hot pressed at 950 °C. The steels used were AISI series: 1045, O-1 and H-13. A mixed layer of Ti and N compounds was generated by a post treatment. Hardness measurements showed an increase of approximately two times in hardness with respect to the annealed condition. The results of fracture toughness tests indicated excellent strengthening of the steels. The role of composition and microstructure on strengthening are discussed.

1. Introduction

Surface modification in steels has been the technique commonly used to achieve wear resistance improvements in different types of alloys and steels, not only in the metal-mechanical industry, but also for hand craft tools, medical devises, precision tools, etc.

It has been demonstrated [1] that the main cause for the hardness increment in steels treated by ion nitriding, can not be attributed only to solid solution hardening, but also results from the precipitation of nitrides during the diffusion process. Application of the ion nitriding technique as surface reinforcement, gives to this technique a great importance over other surface treatments due to the thickness of the produced layer [2,3], which may improve the wear resistance.

It is well known that diffusion layers are formed in two stages. In the first stage, diffusive elements are brought in contact with the surface of the substrate material, while in the second stage, the diffusion process consists of the gradual adsorption of the diffusive element into the base material [4].

The purpose of the present work is to demonstrate that the conventional efficiency of the ion nitriding technique plus the addition of a double Ti, can be improved by a controlled heat treatment process (hot pressing). In general terms, the purpose of introduce an intermediate Ti layer it is to produce a coherent surface as a base to the second Ti layer.

2. Experimental procedure

A series of three commercial steels supplied by a commercial vendor, were used to perform this study, namely AISI O-1, H-13 and 1045 (compositions are given in Table 1), The mentioned steels were nitride. The plasma system has two stainless steel circular plate electrodes. The electrodes are positioned horizontally at the center of the reaction chamber, with 5 mm of separation between them. The base pressure of the plasmas was maintained using a mechanical pump (*Varian SD-301*) and purged with the working gas at $\sim 2 \times 10^{-2}$ Torr for several times in order to remove the background gases. The plasma treatment was performed with a gas composition of 20%N_2–80%H_2, at a pressure of 3.0 Torr for 6 h. The discharge power supply was 300 V, and the discharge current was 0.12 A (36 W).

The first Ti layer was produced by PVD and deposited on the surfaces samples for a time of 30 min in a Polaron Sc7620 sputter coater at a pressure of 10^{-1} mbar/Pa and a current of 2 mA with a uniform thickness of 0.8 μm in average. Subsequently samples were placed between high purity (99.98%) Ti sheets provided by Eagle Metals Corporation and post-treated by the application of hot-pressing technique at 20 MPa using a chamber with a controlled atmosphere in a vacuum of 10^{-3} Torr and induction heated

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Table 1
Element composition in wt.% of the modified steels.

Steel type	Element composition in wt.% C	Si	Mn	Cr	Mo	Wo	V
0–1	0.90	0.30	1.15	0.50	–	0.50	0.20
H13	0.35	1.00	0.30	5.10	1.50	–	1.0
1045	0.45	0.23	0.75	–	–	–	–

at 950 °C for 8 h to produce the second Ti layer. A model of the diffusion phenomena was developed in order to understand the role of the elements involved in the strengthening process.

Specimens for fracture toughness evaluation were machined with a cross section of 4 × 3 mm and 25 mm length with a notch of 2 mm at the half of the specimen and perpendicularly opposite to the nitriding surface, following the ASTM E-399 standard (the specimens were notched after the treatment). A minimum of five tests were developed in order to obtain a good reproducibility. Fractographic analyses were performed in a LEO-1450VP scanning electron microscope, as well as the measurements of Titanium and Nitrogen concentrations were determined using EDAX (Energy Dispersive X-Ray Analysis). Vickers hardness profiles were performed on a polished cross-section of the steels samples, using a load of 0.2 kgf, with a Leco 300 AT micro-hardness tester. X-ray diffraction analyses were performed in a Rigaku model DMAX 2200 equipment, with a Radiation Cu-Kα1 (1.54439 Å).

3. Results and discussion

3.1. Microstructure and diffusion analysis.

Fig. 1 shows the nitrogen and titanium diffusion profiles obtained after the diffusion process. The diffusion layers were continuous, uniform, and very adherent to the metallic substrate. It can be observed that for the three steels used in this work, the

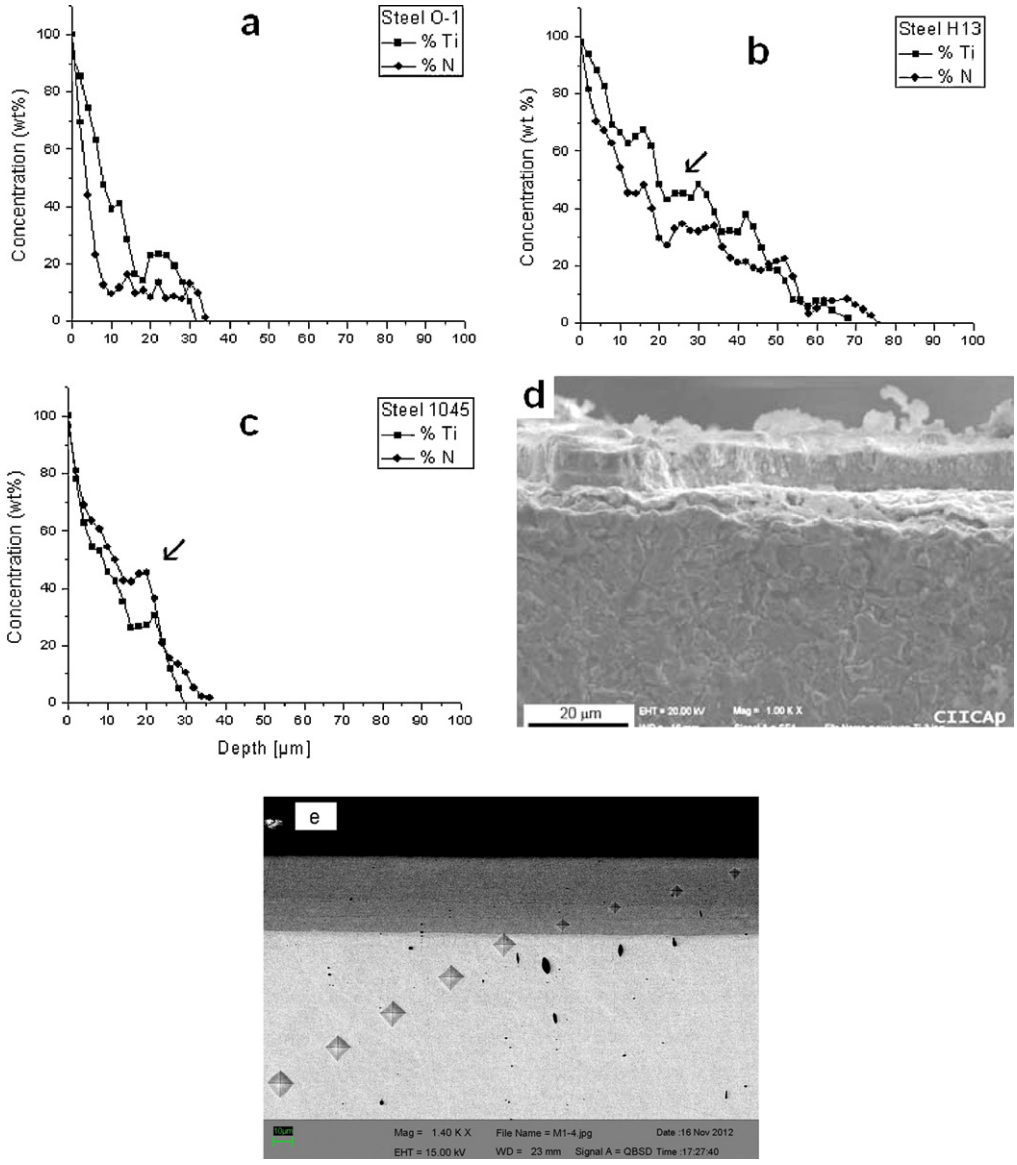

Fig. 1. Nitrogen and Titanium Diffusion profiles (a) steel O-1, (b) steel H13, (c) steel 1045, (d) Fractographic image of the twin layer produced after the treatment.