18th IFHTSE CONGRESS
International Federation for Heat Treatment and Surface Engineering

INFLUENCE OF THE ION NITRIDING TEMPERATURE IN THE WEAR RESISTANCE OF AISI H13 TOOL STEEL[1]

Stênio Cristaldo Heck[2]
Frederico Augusto Pires Fernandes[3]
Ricardo Gomes Pereira[4]
George Edward Totten[5]
Luiz Carlos Casteletti[6]

Abstract

The AISI H13 tool steel for hot work is the most used in its category. This steel was developed for injection molds and extrusion of hot metals as well as for conformation in hot presses and hammers. Plasma nitriding can improve significantly the surface properties of these steels, but the treatments conditions, such as temperature, must be optimized. In this work the influence of nitriding treatment temperature on the wear behavior of this steel is investigated. Samples of AISI H13 steel were quenched and tempered and then ion nitrided in the temperatures of 450, 550 and 650°C, at 4mbar pressure, during 5 hours. Samples of the treated material were characterized by optical microscopy, Vickers microhardness, x-ray analysis and wear tests. Plasma nitriding formed hard diffusion zones in all the treated samples. White layers were formed in samples treated at 550°C and 650 °C. The treatment temperature of 450°C produced the highest hardness. Treatment temperature showed great influence in the diffusion layer thickness. X-ray analysis indicated the formation of the Fe_3N, Fe_4N and CrN phases for all temperatures, but with different concentrations. Nitriding increased significantly the AISI H13 wear resistance.

Key words: AISI H13; Plasma nitriding; Temperature; Wear.

1 *Technical contribution to the 18th IFHTSE Congress - International Federation for Heat Treatment and Surface Engineering, 2010 July 26-30th, Rio de Janeiro, RJ, Brazil.*
2 *Chemist, EESC-USP.*
3 *Chemical Engineer, Doctoral Student, EESC-USP.*
4 *Degree in Science, EESC-USP.*
5 *Engineer, Professor, Portland State University.*
6 *Materials Engineer, Professor, EESC-USP.*

1 INTRODUCTION

A niche with enormous potential for the application of the surface treatments is dies for injection molding or extrusion of aluminum and forging. Extrusion die wear is affected by factors including: process temperature, die pressure, dynamic forces and friction between the material and the die. In aluminum injection, most dies fail by fatigue caused by thermal shock, corrosion by molten aluminum or welding, and erosive wear produced by the liquid metal. Surface treatments can be used to minimize these problems.[1]

AISI H13 steel is most commonly used for these applications because of its superior characteristics and versatility. It is used in the production of dies and forging punches, hot-forging dies, forging inserts, molds and components for die casting machines for zinc and aluminum alloys, aluminum, brass and magnesium extrusion dies, mandrel and other extruder components, molds for plastics and knives for hot work. These tools are subjected to high wear caused by friction that occurs between the matrix and surface of the component in addition to stresses from mechanical and thermal shocks. Therefore, die life is limited by its surface properties friction and wear.[2]

The steel used for die manufacture requires tribological property improvements. An inadequate contact surface friction properties results in abrasive wear and reduces die life. Surface property improvement of the steel is essential to extend the useful life of these dies.[3]

Plasma nitriding can improve the tribological performance of AISI H13 steels. The wear behavior of the nitrided H13 can be influenced by the treatments parameters used in the nitriding treatment.[4]

In this work, wear experiments were carried out on plasma nitrided H13 steel. Specimens were plasma nitrided at three different temperatures to study its effect on the wear behavior.

2 MATERIALS AND METHODS

Initially samples of AISI H13 steel (chemical composition Table 1) were quenched and tempered. For the quenching treatment the samples were austenitized by 2 hours at 1050^0C and then quenched in oil. Tempering was carried out at 590^0C during 2 hours.

Table 1. Chemical composition (weight %) of AISI H13 steel

element	Fe	C	Si	Mn	Cr	Mo	V
Weight%	Bal.	0.45	1.07	0.4273	4.60	1.39	1.21

The quenched and tempered samples were plasma nitrided using the direct current method, with the following conditions: a gas mixture of 80 vol. % H_2 and 20 vol. % N_2, pressure of 4mbar and temperatures of 450, 550 and 650˚C. The treatments periods were of 5 hours for all conditions.

Samples of treated material were characterized by optical microscopy, Vickers microhardness and wear tests.

Measurements of microhardness were performed on a digital Buehler equipment using 100N of load and application time of 10s.

The wear tests were performed on a fixed-ball micro-wear machine, with rotation of 500rpm and load of 2.46N, without use of abrasive, in order to simulate the adhesive wear. Balls of AISI 52100 steel with hardness of 850 HV, average surface roughness (Ra) of 0.08μm and diameter of 25.4mm were used

3 RESULTS AND DISCUSSION

Figure 1 presents the cross-section optical micrographs of plasma nitrided samples at 450, 550 and 650˚C. Only a diffusion zone was formed in the sample treated at 450˚C (Figure 1A). From the temperature of 550˚C it can be seen white layers formed, that increased with the increase in temperature to 650˚C (Figure 1B and 1C). In all the cases diffusion zones were formed, and their thickness increased with the treatment temperature.

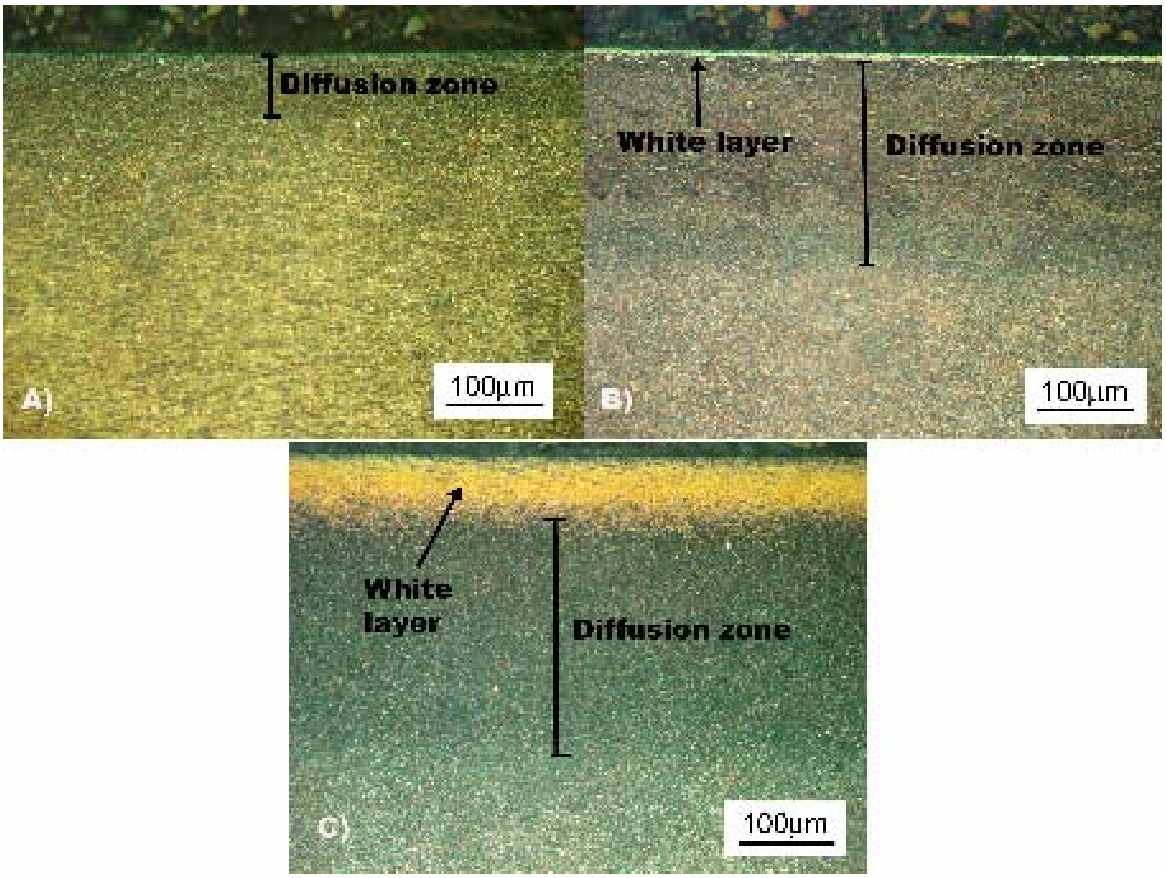

Figure 1. Optical micrographs of plasma nitrided samples. A) Nitride at 450˚C, B) Nitrided at 550˚C and C) Nitrided at 650˚C.

Figure 2 shows the relationship between thickness of nitrided regions (white layer + diffusion zone) and the plasma nitriding temperature. A great variation in the total layer thickness occurred increasing the treatment temperature.

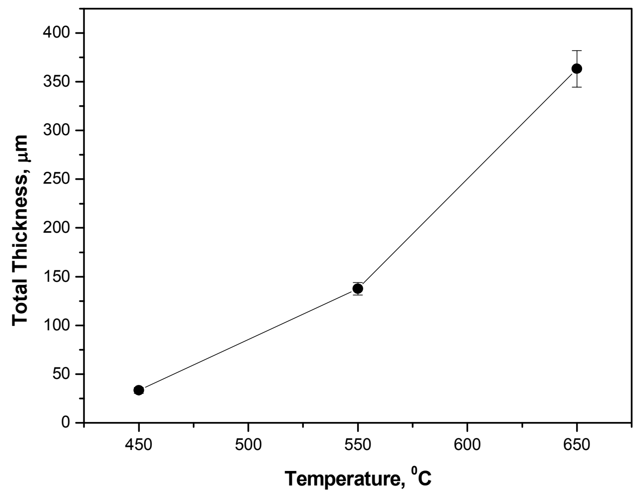

Figure 2. Total thickness against plasma nitriding temperature.

The x-ray patterns of the nitrided samples are shown in Figure 3A, and Figure 3B shows the phases intensity variation with the different treatment temperatures. It can be seen that increasing the temperature a decrease in the nitrogen-rich phase occurred, as well as an increasing in αFe phase signal. According to Zagonel et al.,[5] for high plasma nitriding temperatures, the nitrogen diffusion from surface to the interior of the material is faster than the surface adsorption of nitrogen atoms from the plasma source, producing this phases distribution pattern.

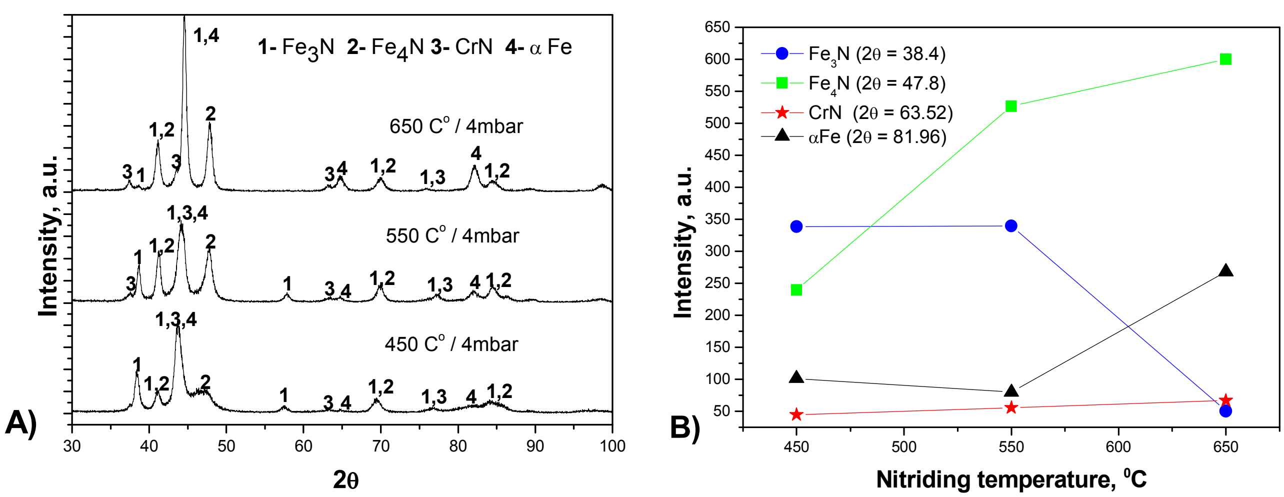

Figure 3. X-ray patterns of the nitrided samples (A) and phases concentration as a function of treatment temperature (B).

Figure 4 shows the microhardness profile of nitride samples. In the case of the sample nitrided at 650˚C, the surface hardness was the same of the nitride at 550˚C (946HV), but in the case of the samples nitride at 550˚C, the hardness increased until reaches its maximums (1140HV) at 54µm and then decrease to the substrate hardness. The highest hardness reached for the nitriding treatment occurred for the sample treated at 450˚C (1225HV). Another important characteristic to note after nitriding treatment was the core hardness change. A great core hardness increase occurred for the 450˚C treatment temperature in comparison with the hardness of the quenched and tempered sample, probably due to carbides precipitation. A less significant increase occurred for the temperature of 550˚C. In other hand, for the treatment temperature of 650˚C the core hardness decreases significantly. This behavior was expected due to the characteristic temperability behavior of this alloy (Metals Handbook, 8th ed. 1964).

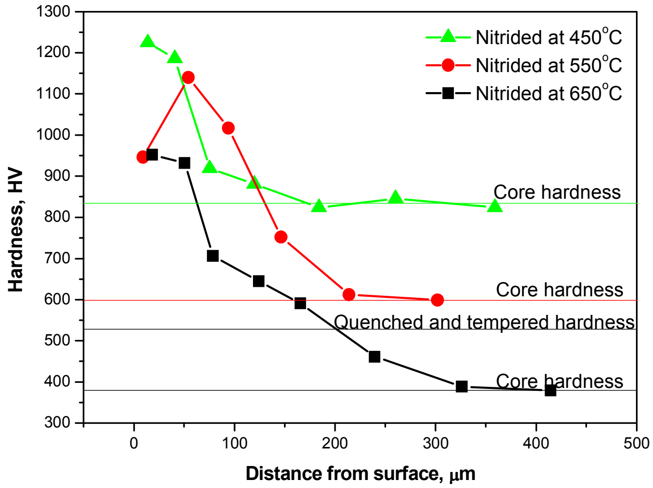

Figure 4. Microhardness profiles of plasma nitrided samples.

With respect to the wear resistance of nitrided samples, after the treatment a significant increase occurred for all temperatures, in comparison with the respective substrates (Figure 5). The decrease in worn volume for the samples after nitriding treatment was about 800 times. In the case of the un-treated samples, the worn volume decreased with the core hardness increase. Although in nitride samples this behavior did not occurred, being the sample nitride at 550˚C the one who showed the lower worn volume, followed by 650 and 450˚C, The difference between the worn volumes among the nitrided samples were too small to be considered (10^{-4} mm^3).

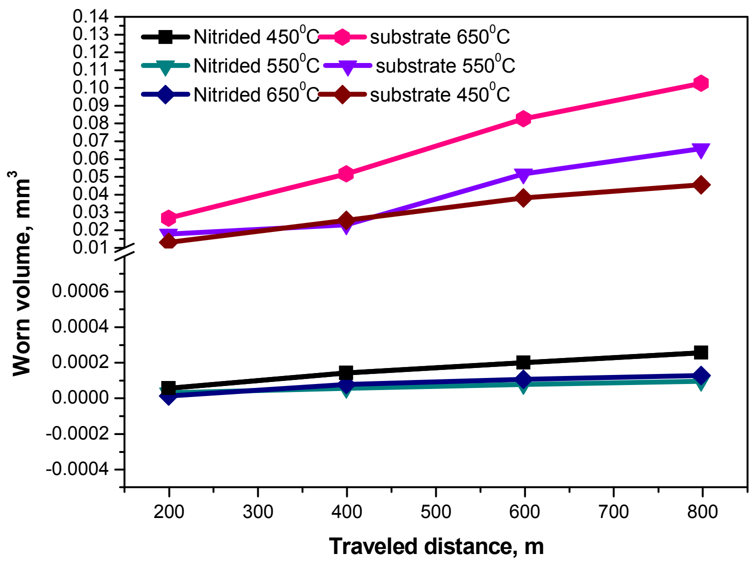

Figure 5. Wear behavior of nitrided and un-treated samples.

4 CONCLUSIONS

The plasma nitriding treatment produced diffusion zones for all tested conditions, and the increase in nitriding temperature increased its thickness. From the temperature of 550˚C white layers were formed above the diffusion zones.

For all treatments temperatures the phases Fe_3N, Fe_4N, CrN and αFe were identified, and increasing temperature decreases nitrogen-rich phase due to the differences in the nitrogen diffusion rate and adsorption rate for high nitriding temperatures.

The sample nitrided at 450˚C showed the highest hardness, followed by 550 and 650˚C.

Plasma nitriding increase significantly the wear resistance of H13 tool steel, for all treatments temperatures.

REFERENCES

1 WANG, Y. A study of PVD coatings and die materials for extended die-casting die life. *Surf. and Coat. Technol*. V.94-95, p.60-63, 1997.

2 ROBERTS, G.A.; CARY, R.A. “Tool steels”, Fourth edition, American Society for Metals, Metals Park, Ohio, 1980, 579-592.

3 YILBAS, B.S.; SAHIN, A.Z.; SAID, S.A.M.; NICKEL, J.; COBAN, A. Investigation into some tribological properties of plasma nitrided hot-worked tool steel AISIH11 *Journal of Materials Engineering and Performance*. V.5, p.220-224, 1996.

4 KARAMIS, M.B. An investigation of the properties and wear behaviour of plasma-nitrided hot-working steel (H13). *Wear*. V.150, p.331-342, 1991.

5 ZAGONEL, L.F.; BASSO, R.L.O.; ALVAREZ, F. Precipitates Temperature Dependence in Ion Beam Nitrited AISI H13 Tool Steel. *Plasma Processes and Polymers*, v. 4, p. S736–S740, 2007.

6 Metals Handbook, 8th ed., V.7, American Society for Metals, 1972.