INFLUENCE OF NITRIDING TIME ON THE MICROHARDNESS PROFILE OF PLASMA NITRITED AISI D6 STEEL

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Abstract. *The plasma nitriding is a solution to increase the useful life of pieces and components and it has been gradually incorporated in several industrial applications aiming to obtain an increasing of its surface hardness and a higher wear resisting of some materials. Indicated for cut matrices and shears knives, cut of plates, cut perforators, pressing tools, the AISI D6 demands high resistance to abrasion and cut retention and the nitriding is one of the used processes to optimize the life of these tools. In this work, the AISI D6 steel nitriding was carried through where the influence of the process parameters was evaluated (temperature: 380 °C; time: 30, 60, 90 and 120 minutes; gas mixture: 5 to 6%* N_2*) in its microstructure, depth and hardness of obtained surfaces. The aim of this study is to show the main objective of this work is to present the influence of the cited parameters, in the plasma nitriding process. According to the treatment conditions, it hasn't been possible the identification of the nitrites layers formation. However, the best condition of treatment occurred for the time of 60 minutes, where it is reached hardness of 600 HV approximately.*

Keywords: *plasma nitriding, AISI D6, microhardness.*

1. Introduction

Currently, tool steel use in industries is expressive and the cost of its manufacture is raised. Thus, they had appeared in the last years, series of processes to optimize costs and useful life of tools. One of the used techniques is called plasma nitriding, that it is a thermo chemical treatment, which has the objective to improve the tribologic properties of the steel surface, preserving the characteristics of the substratum nucleus. The nitriding process of surfaces can be used by the mechanics, automotive, hydraulical, siderurgical, biomedical industries, of metal forge and shaping (Wisniveski and Alvarez, 2004).

According to Pinedo *et al* (2002), due to operations and materials range involved in cut operations, shaping, injection and drawing, the necessity of the quality improvement of these steel has grown and the wear resistance is one of the main properties to be optimized to improve the performance of the tools. The plasma nitriding has showed a range of advantages if compared to the traditional gas and liquid nitriding processes. The conventional processes, which have been used for decades, possess relational limitations to the control of the type and thickness of the nitriding layer, beyond environmental and human restrictions, since harmful gases and liquids have been used.

The plasma process is a clean technology and it has innumerable advantages in relation to the liquid and gas nitriding, such as: dimensional stability, reproducibility of the process, uniformity and control of the type and thickness of the nitrited layer, a better finishing of the part, reduction of the roughness of the steel, considerable increase of the superficial hardness, better metallurgic properties, makes possible to the surface of the part a low coefficient of attrition, minor operation cost, does not attack the human being and it is adjusted to the new international politics of environment, dictated for ISO 14.000 (Alves Junior, 2001).

The AISI D6 steel is used where it is required high wear resistance and great dimensional accuracy, after tempering and annealing, such as cut matrices, perforating, cold forging, cold and hot finishing; ceramics shapings, countersink, mandrills, bores, punctions and tools where it requires the maximum resistance to the abrasion and retention of cut (Villares Steel, 2000). Therefore, the plasma nitriding applied to AISI D6 steel will be able to supply specific characteristics, due to the fact that, its superficial properties could be improved in consequence of the nitrogen diffusion in the substratum.

2. Material and Methods

For this study, it was used the AISI D6 steel for cold work, whose chemical composition is presented in Tab. 1.

Table 1. Chemical composition of AISI D6 steel.

Steel	C	Si	Mn	Cr	W
AISI D6	2,10%	0,35%	0,35%	12,0%	0,70%

AISI D6 steel was supplied in these conditions: hardness 18 HRC (150 Kgf), in circular bar of 25mm of diameter. The samples had been cut parallel to the diameter of the bars and had been treated with thermally conditions under tempering between 950 - 970ºC and annealing at 480ºC, getting a final hardness between 45 - 47 HRC.

On the plasma nitriding, it was used a reactor with internal dimensions of 600 mm of diameter and 1200 mm of height, being able to deal with parts up to 200 kg. The process was lead in vacuum, under plasma in beaten direct current and used gases, such as: nitrogen (99,99%) and hydrogen (99,99%). The used parameters for plasma nitriding are presented in Tab. 2.

Table 2. Plasma parameters nitriding.

Steel	Temperature (ºC)	Time (minutes)	Gas mixture
AISI D6	380	30, 60, 90 e 120	5%N_2 + 95%H_2

Concluded the plasma nitriding stage, the samples had been parted and prepared metalographicaly, in the perpendicular section to the nitriding surface and its microstructure was evaluated by optic microscopy. The profile of microhardness of the nitrited surface was carried through measures of microhardness Vickers, HV 0,025. The evaluation of the obtained results relational to the used parameters of processing was carried through.

3. Results

Figures 1 and 2 present the results of this work.

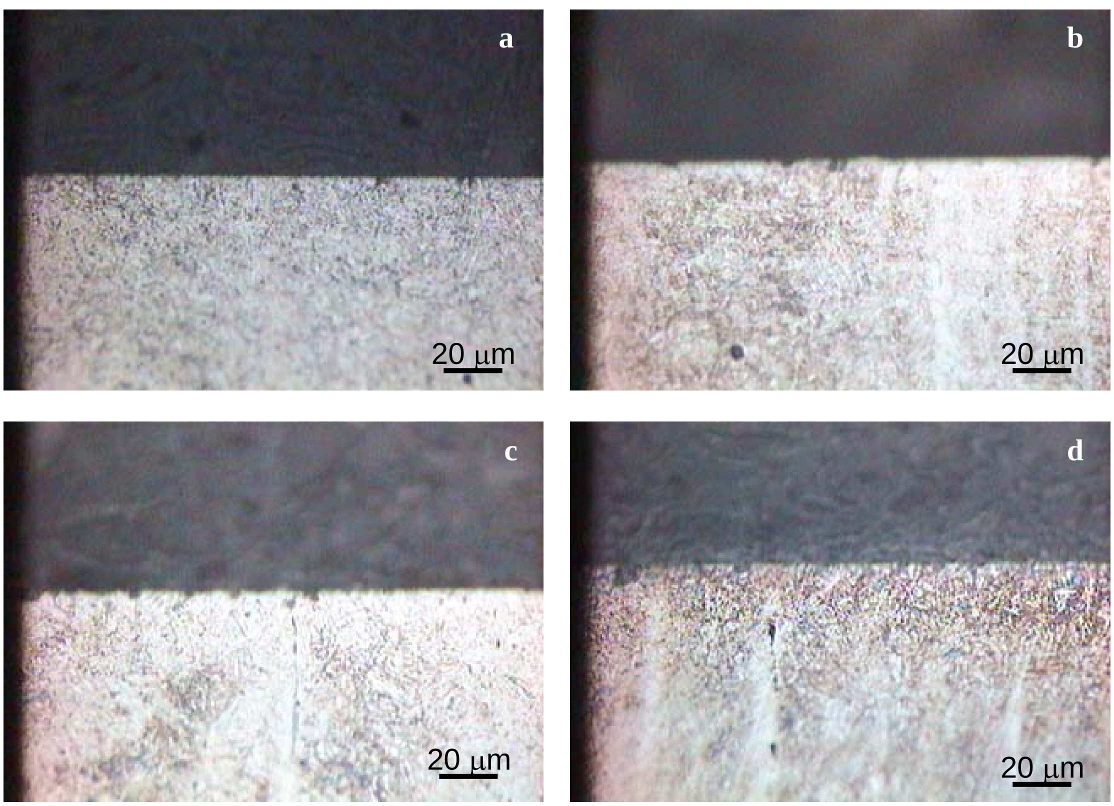

Figure 1. Micrographics of the transversal section showing the nitriding surface of the AISI D6 steel samples: (a) 30 minutes, (b) 60 minutes, (c) 90 minutes e (d) 120 minutes.

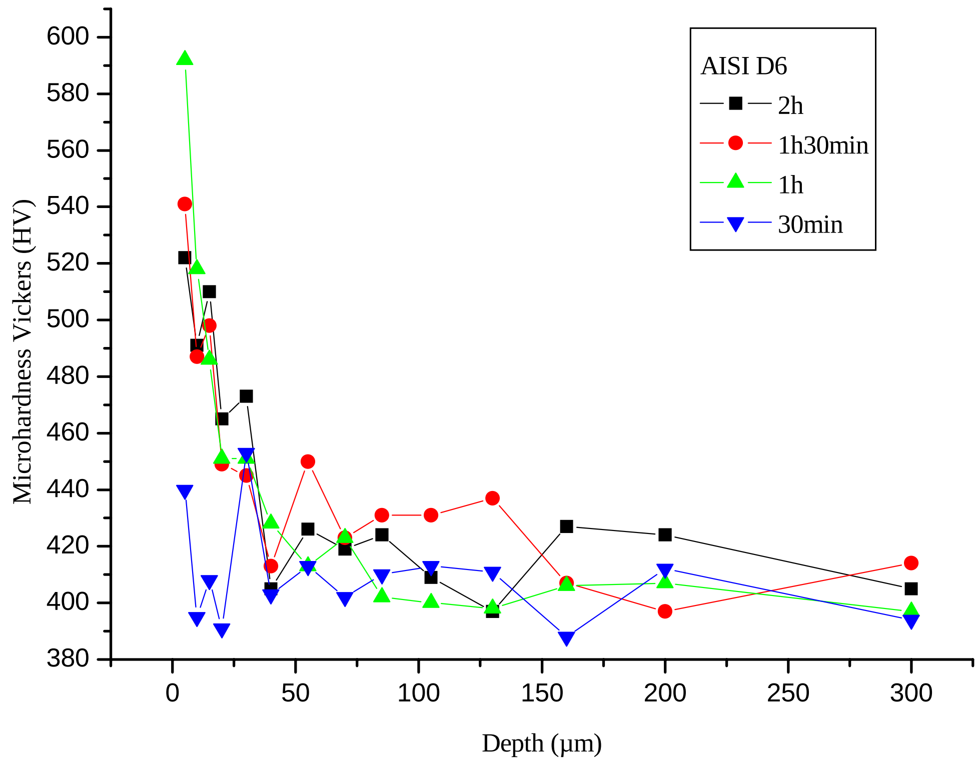

Figure 2. Microhardness profiles of AISI D6 steel samples nitrited at 380°C.

4. Discussion

Through Fig. 1, it's possible to watch that after the plasma nitriding treatment, the samples microstructure practically remained unchanged and it was not possible to disclose the nitrited layer by the metallographic attack, and it also hadn't been possible to identify clearly the diffusion zone for all the treatment conditions.

Figure 2 presents the profiles of microhardness of the nitriding samples in different times. The practical difficulties in the determination of the depth of the nitriding come from the microhardness profiles and are associated with the impossibility to identify the formed layer. It must be justified, that the thermal treatment by tempering and annealing for conditioning of the microstructure of the substratum was not adjusted, due to the annealing to be carried through the superior temperature to the curve of annealing of this steel, that was of 480 ºC, that lead to a substratum with low hardness, 45 HRC. The temperature of nitriding used for the thermal plasma treatment, at 380 ºC also can have contributed for low diffusion of ions into the interior of the substratum.

Anyway, in function of the variation of the treatment time, it had been a growth of the hardness of the samples surface, intensifying the formation of reactions during the treatment of plasma nitriding. The results had approximately demonstrated to a hardness of 600 HV during 60 minutes of treatment and a decrease of the hardness for bigger times, 90 and 120 minutes. In relation to the time of 30 minutes, it was verified that the treatment time was not enough for diffusion of ions for formation of the nitrites.

As Franco Junior *et al* (2003), in its work carried through on numerical analysis of the kinetic of the reactions of the D6 steel, are not adjusted to the treatments with long times of nitriding, because of the dissolution of carbonates M_7C_3 and the thickening of the nitrites of chromium diminish in a considerable way the wear resistance of this steel. Thus, for this material, the use of low potential of nitrogen and times of approximately 60 minutes provide the formation of a free nitriding layer of iron nitrites, without intense dissolution of M_7C_3 carbonates M7C3.

5. Conclusion

According to the displayed results, it could be concluded:

- The used gaseous mixture prevents the formation of white layer, favoring formation of a zone of diffusion, desirable for applications in cut tools, that in this study, did not make possible its identification;

- Under the treatment conditions, at the time of 60 minutes, it got the biggest values of hardness of this study samples;

- In these used conditions of treatment, in function of the time and temperature, the high microhardness of the surface of the material had not been reached. A solution would be to use a low temperature under bigger time of nitriding or a bigger temperature for the same times used at this work, considering the adequate temperature of annealing for this steel before the plasma nitriding;

- The plasma nitriding has a great potential of application in tools during cold work, due to the characteristics that make these types of steel adjusted for the nitriding (composition of league elements, annealing temperature) allied to the main characteristic of the plasma nitriding process (control of the formed layers), being able to determine the best layer for one pre-determined tool and type of operation.

6. Acknowledgement

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