

PERFORMANCE CHARACTERISTICS OF STEEL 1.2842 AFTER NITRIDATION

Michal KRBAŤA, Jana ESCHEROVÁ

Abstract: The paper deals with the change in mechanical properties and wear of 1.2842 universal tool steel after plasma nitriding, which is widely used to produce cutting tools with good durability and low operating costs. Plasma nitriding was performed at a temperature of 500 °C for 10-hour period in a standard N₂ /H₂ atmosphere with 1:3 gases ratio. Microstructure, phase structure, thickness of a nitriding layer and surface roughness of samples were measured with optical microscopes and a profilometer. Verification of a chemical composition was carried out on the BAS TASMAN Q4 device. Wear resistance was measured on a universal TRIBOLAB UTM 3 tribometer, through a, “pin on disc” method. The results of experiments have shown that plasma nitriding process, significantly improves the mechanical and tribological properties of selected materials.

Keywords: Plasma nitriding; Microhardness; Coefficient of friction; Pin on disc.

1 INTRODUCTION

The 1.2842 tool steel is suitable for the plasma nitriding process due to its chemical composition. This steel has a wide range of applications for the production of universal cutting tools. Authors Studený et al. [1] solved importance of diffusion process on the fatigue life of this type of steel in their scientific research. Investigations with the same workpiece material were also realized by the authors [9,10,12]. Authors Pilch et al. [2] solved the corrosion resistance of turbocharger stator after plasma nitriding process. The authors [4, 5] also studied and dealt with the same problem of plasma nitriding. Tribology of these parts plays an important role in their functionality and lifetime. Tribological problems can often be solved with a surface finish. Authors Doan et al. [3] have dealt with their research with the improvement of wear resistance for C45 steel using plasma nitriding, nitrocarburizing and nitriding. Other authors, such as Dubovská and Majerík [7] conducted the research analysis of surface finish and wear on the special tribological device. The effect of nitrogen on surface morphology of layers was solved by Pokorný et al. [6]. Plasma nitriding, with regard to many advantages unlike common kinds of nitriding, found an increasing industrial application [5, 11]. The main problem of nitridations in salt bathes is connected with toxicity of cyanide salts. Traditional gaseous nitriding requires a longer time for treatment to obtain a needed nitridation depth. Direct current of plasma nitriding (DCPN) has been recently one of the conventional treatments of a surface finish being used in the industry aiming to improve mechanical features and wear resistance of mechanical engineering materials. Various layers may rise on a surface due to plasma nitriding. These layers are classified by composition of particular phases. With respect to the steel composition, its layer is mainly composed of ferrous nitrides (γ' -Fe₄N or ϵ -Fe₂-3N) and nitrides of alloying elements. Research studies showed that the microstructure of nitriding layer can be affected with change of parameters of nitriding process, as temperature, time and plasma composition of the gas.

Changes in microstructure of nitriding layer effect mechanical and tribological features of the material, such as surface hardness, wear resistance and endurance strength [2, 4, 8]. For a diffusion controlled growth, thickness of nitriding layer increases with temperature and nitridation time [6]. However, maximum surface hardness is achieved only at a certain nitridation time and temperature. Previous studies showed that a chemical potential of nitrogen is important in plasma nitriding of steels. The aim of the present paper is to map the effect of plasma nitriding on the resulting values of the coefficient of friction and wear.

2 EXPERIMENTAL MATERIALS

The samples were annealed. The process of plasma nitriding was carried out using the Rubig 60/60 device. The parameters of plasma nitriding were chosen so that nitriding layer is as thick and as hard as possible, (Tab. 1).

Thermally treated and surface finished steel samples were numerically marked. Chemical composition of given steel was verified through a BAS TASMAN Q4 device and subsequently it was compared with the DIN 90MnCrV8 technical standard (Tab. 2).

Measurements of micro hardness and thickness of a nitriding diffusion layer were taken on each sample using the Vickers method. Impressing of a diamond pyramid under vertex angle of 136° is essential to the method. The LECO M400H microhardnessmeter will be used to verify and compare achieved results before and after plasma nitriding. The load force will be 0.5 N and force action time in accordance with DIN 50190 standard will be 10 sec. The measurements of micro hardness will be taken on a cross-section of a nitrided sample, upright from the surface to the material core. The achieved values of hardness will be displayed as a function of distance from a surface. Thickness of a nitride layer will be taken on 18 imprints and 5 imprints in the material core. Limit value in terms of this standard is hardness value, designated as limit hardness GH) and is indicated as

the Vickers hardness and it applies: $GH = \text{average measured value in a core} + 50 \text{ HV}$ (rounded to 10HV).

Metallographic analysis is based on the polishing of samples and a subsequent etching with Nital. Etching of samples brings up their microstructures. We make out metallographical pictures of all samples with the Olympus GX51 optical metallographical microscope. With the microscope we can monitor a size of a white layer as well as an approximated size of a diffusion layer. Then we can assess a resulting structure of a diffusion layer as well as a basic material.

Tab. 1 The parameters of plasma nitriding

Pressure [mbar]	2.8
Voltage [V]	700
Atmosphere PN [N_2 / H_2]	1/3
Temperature PN [$^{\circ}C$]	500
Time PN [hour]	10

Source: authors.

Tab. 2 Chemical composition 1.2842 steel [in wt. %]

Element	DIN standard	BAS Tasman Q4
C	0.27 – 0.34	0.34
Mn	0.40 – 0.70	0.69
Si	Max 0.40	0.39
Cr	2.30 – 2.70	2.38
Mo	0.15 – 0.25	0.21
V	0.10 – 0.20	0.20

Source: authors.

Tab. 3 Measurement parameters for tribology

Sample	Heat treatment	Turning radius	Load [N]	Rotation speed [rpm]
1	Annealed	19	50	250
		21	50	
		23	50	
2	Annealed	19	100	250
		21	100	
		23	100	
3	Annealed	19	150	250
		21	150	
		23	150	
4	Plasma nitriding	19	50	250
		21	50	
		23	50	
5	Plasma nitriding	19	100	250
		21	100	
		23	100	
6	Plasma nitriding	19	150	250
		21	150	
		23	150	

Source: authors.

Roughness of surface was measured on the Talisurf CCI Lite 3D device. All samples had been

grinded on a magnetic grinder with 0.001mm precision before plasma nitriding and marking. Surface roughness was measured before and after plasma nitriding aiming to define changes of roughness.

Measurement of wear was executed on the BRUKER UTM 3 device using „pin of disc“ method. This method is based on imprinting a firmly gripped body in a ball shape into a testing material in a disc shape, being rotated with constant revolutions. The testing ball was made of the 440C stainless steel with a 6.35 mm diameter and 746 HV hardness. The measurements were taken from 6 samples at 3 loads and three measurement radiuses. The Measurement radiuses for each sample are shown in (Tab. 3).

3 RESULTS AND DISCUSSION

Microstructure of the 1.2842 steel can be seen in Fig. 1, in a treated condition and after having etched 2 % Nital and it was assessed as a perlite and secondary cement. Pearlite occurs both in lamellar and globular form. An average micro hardness had a value of 270 HV.

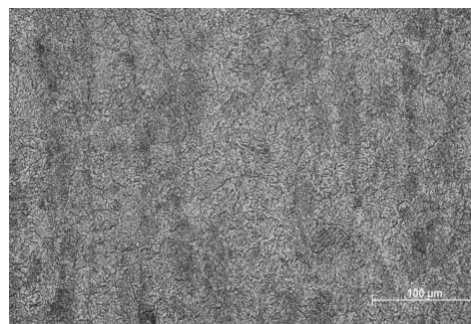


Fig. 1 Cross-sectional microstructure
Source: authors.

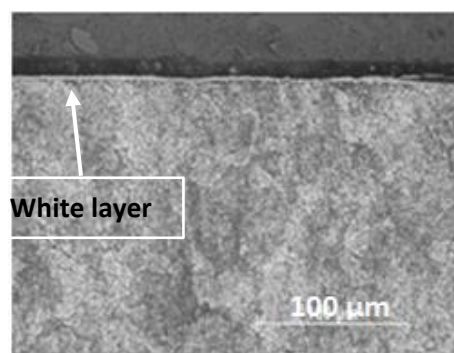


Fig. 2 Cross-sectional microstructure with white layer
Source: authors.

Only thicknesses of white layers were expressly visible and measurable after plasma nitriding on a metallographic section. There is a coherent and relatively white layer of nitrides on the samples surface. Under a white layer there is a diffusion layer. The white layer with an average thickness 6.3 μm was created at the plasma nitriding temperature of 500 $^{\circ}C$ and nitriding period of 10 hours (Fig. 2). It is optically

recognizable on the sample surface. In this case, the diffusion layer is not optically distinct from the core of the material.

3.1 Metallographic structure

Tab. 4 was developed from the measurement results, where thicknesses of particular diffusion layers of steels are documented. In Tab. 4 the values of thicknesses of white layers are also displayed on particular samples. From the table it is obvious that the results are the same for thickness of nitriding layer as well as for the white layer. In sample 5, a minimum increase of diffusion layer is visible, which shows no significant change in subsequent measurements. We can note that all samples had passed through plasma nitriding process at the same conditions and a risen diffusion layer is the same on all samples.

Tab. 4 The results of thickness diffusion and white layers

Sample	Thickness of diffusion layer [mm]	Thickness of white layer [mm]
4	0.38	6.3
5	0.37	6.1
6	0.38	6.5

Source: authors.

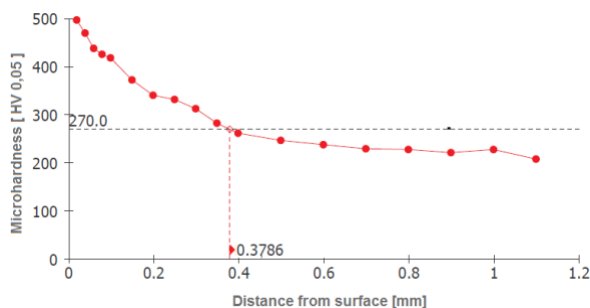


Fig. 3 Micro hardness depth profile sample No. 4
Source: authors.

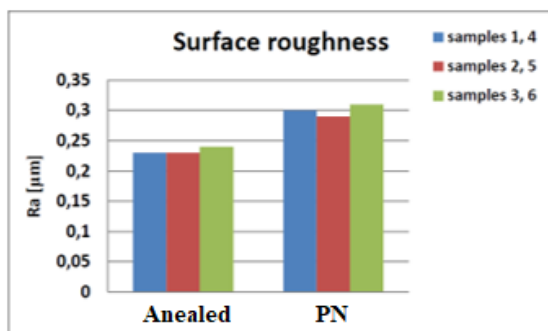


Fig. 4 Surface roughness 1.2842 before (annealed) and after (PN)
Source: authors.

3.2 Surface roughness

Qualitative data on roughness is shown in (Fig. 4). Surface roughness on all samples that have passed through the plasma nitriding process, are deteriorated in average by 30 %, comparing with samples without plasma nitriding. This deterioration was caused by a dedusting process and due to a rise of a new nitride surface layer (Fig. 5 and Fig. 6).

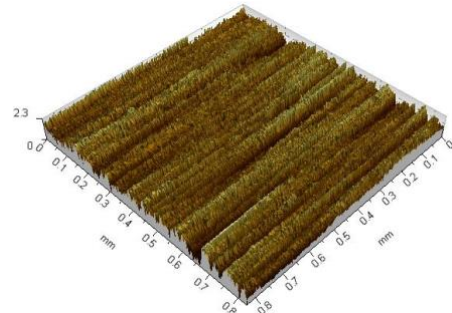


Fig. 5 3D profile steel 1.2842 without application of plasma nitriding; Sa 0.23µm
Source: authors.

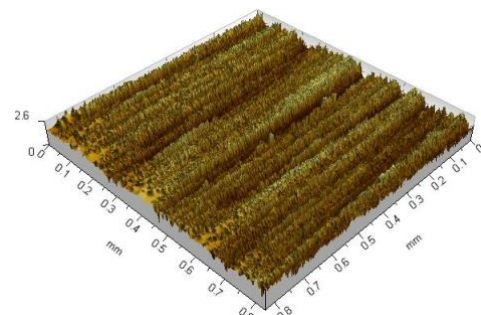


Fig. 6 3D profile of the steel 1.2842 nitrided at 500 °C and time of 10 hours; Sa 0.30 µm
Source: authors.

3.3 Surface wear

The wear shown in the picture 7a), points at a high rate of wear, as this sample had passed only through a basic type of thermal treatment. For the next samples 7b), 8c), 8d), a significant improvement of the surface profile occurred. These samples were plasma nitrided and they featured a much higher quality of surface. The comparison can be seen in Graph.2 (Fig. 9) between all the measurements of wear at different load parameters and different radiuses of rotation.

The depth of wear was measured with profile meter and the results are displayed on a plot in Graph.3 (Fig. 10). Each measurement of depth was taken on four different places. Subsequently, an average depth of an imprint was defined. The results expressly point at excellent mechanical features of plasma nitrided samples, as their depth of the imprint was ranging only in several micrometers comparing with tempered samples [13, 14].

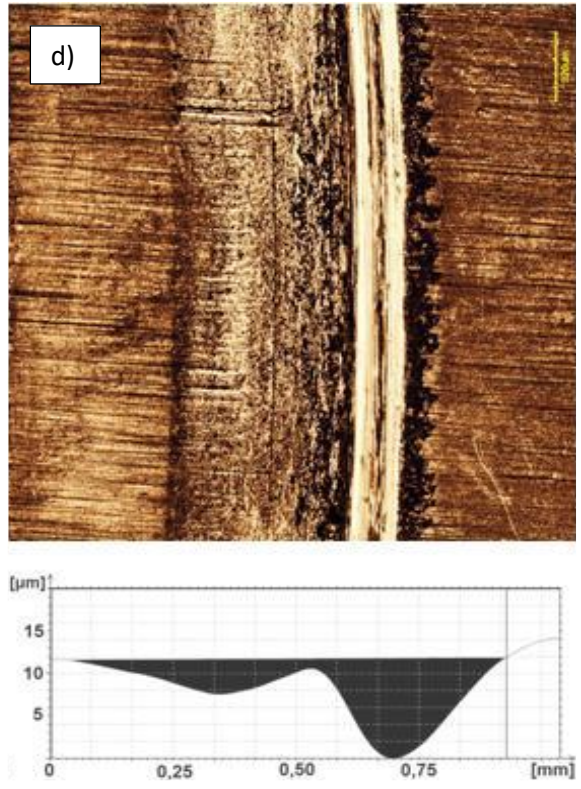
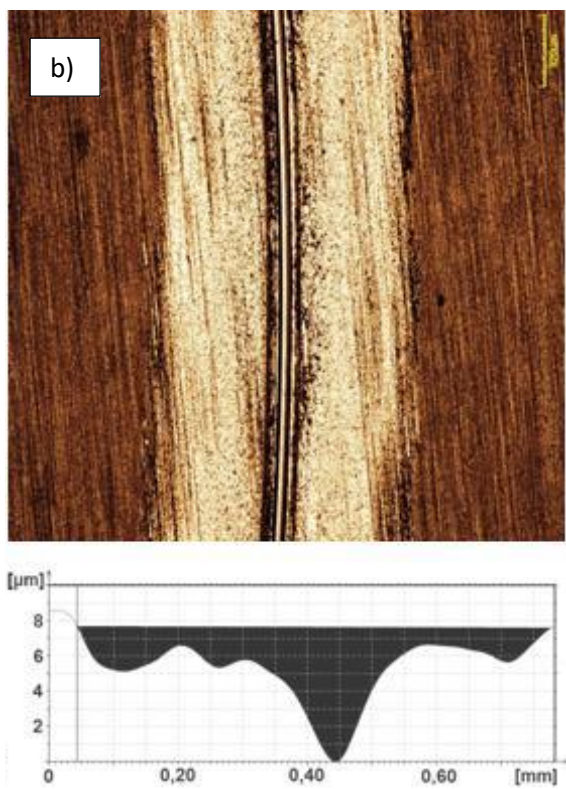
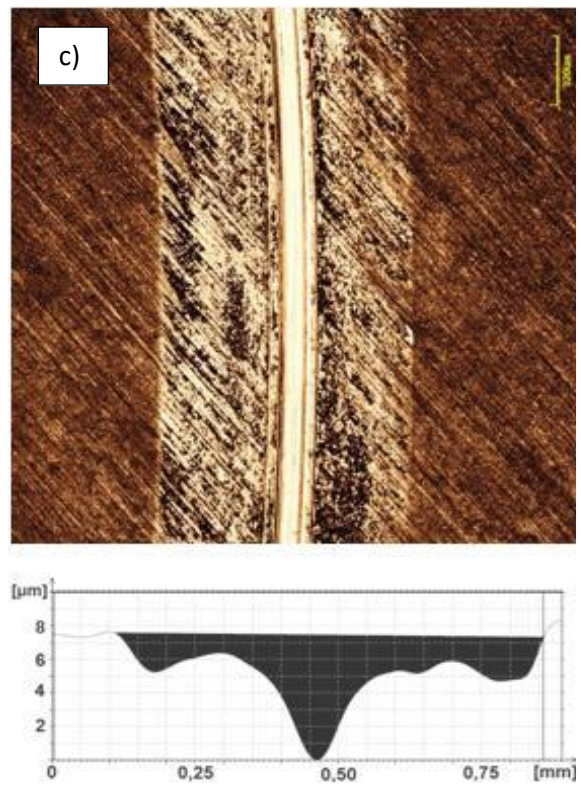
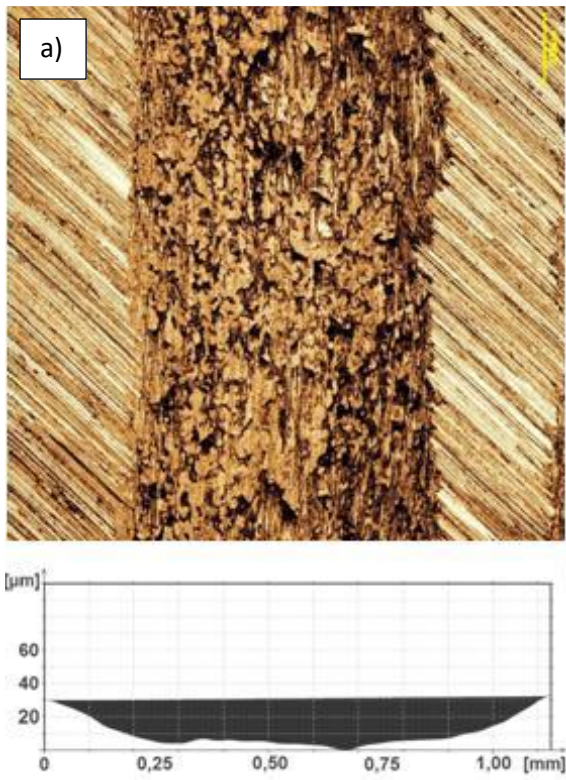


Fig. 7 Surface profiles of wear and depth tracks: a) before PN, COF $0.59 \mu\text{m}$, h $31 \mu\text{m}$, b) after PN, COF $0.42 \mu\text{m}$, h $7.2 \mu\text{m}$
Source: authors.

Fig. 8 Surface profiles of wear and depth tracks after PN: c) COF $0.40 \mu\text{m}$, h $7.6 \mu\text{m}$, d) COF $0.39 \mu\text{m}$, h $10.1 \mu\text{m}$
Source: authors.

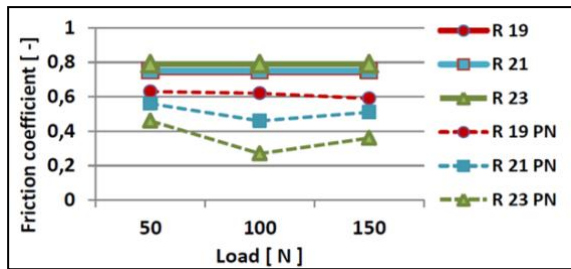


Fig. 9 Comparison of friction coefficient for all samples
Source: authors.

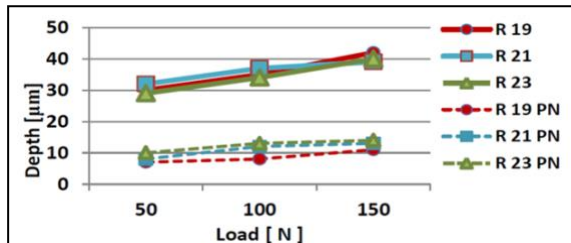


Fig. 10 Comparison indentation depth in all samples
Source: authors.

4 CONCLUSION

All measurements were focused on a study of the 1.2842 structural nitride steel. Plasma nitriding was carried out at standard conditions and parameters were chosen in such a way to achieve the best possible diffusion layer. The research brought us some valuable information about mechanical features of the 1.2842 steel. From a study of microstructure and based on the results, the following conclusions can be made:

- The 1.2842 tool steel is suitable for a plasma nitriding process due to its chemical composition and the results of micro structure point at a rise of the diffusion layer of 0.38 μm thickness, mainly composed of ϵ - phase ($\text{Fe}_2\text{-3N}$).
- A surface hardness of tempered samples had a value of 270 HV, it increased after plasma nitriding on average to a value of 500 HV, i.e. We can note, that plasma nitriding significantly increases surface hardness and the lifetime, as well as the majority of degradation processes start spreading from the surface into the material core.
- Material roughness before nitriding process was ranging on the level of 0.23 μm , after plasma nitriding the sur-face quality decreased by 30 % to the value of 0.30 μm . Such deterioration is caused by a dedusting process, when the nitride cations bombard a material surface and subsequently atoms of various elements being on a material surface are shot out.
- Resistance to wear plays one of the most important roles in the material lifecycle. Plasma nitriding process significantly decreases friction coefficient. The friction coefficient decreased at plasma nitrided samples comparing with samples that had passed only a basic thermal treatment in all three loads. The

same results are obtained from an imprint depth, left by a measuring ball. These findings are connected with a rise of a hard diffusion layer on a surface after plasma nitriding process.

From the results of the experiment, we can state that the plasma nitriding improves a quality of mechanical features of the 1.2842 steel except of material roughness. It brings a great benefit in area of improvement of tribological features of materials as well as their application in various sectors of mechanical engineering industry and cutting tools.

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Dipl. Eng. Michal **KRBAŤA**, PhD.
Department of Engineering Technologies and Materials
Faculty of Special Technology
Alexander Dubček University of Trenčín
Ku kyselke 469
911 06 Trenčín
Slovak Republic
E-mail: michal.krbata@tuni.sk

Dipl. Eng. Jana **ESCHEROVÁ**
Department of Engineering Technologies and Materials
Faculty of Special Technology
Alexander Dubček University of Trenčín
Ku kyselke 469
911 06 Trenčín
Slovak Republic
E-mail: jana.escherova@tuni.sk

Michal Krbaťa – was born in Trenčín, Slovakia in 1988. He received his engineering and PhD. degrees at Alexander Dubček University of Trenčín, Faculty of Special Technology in Trenčín. In his research he focuses on materials research, tribology and dilatometry.

Jana Escherová – was born in Banovce nad Bebravou, Slovakia in 1995. She received engineering degree at Alexander Dubček University of Trenčín, Faculty of Special Technology in Trenčín. In his research he focuses on materials research and technological research.