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Surface Modification Innovation for Wear Resistance Increasing

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Abstract. The surface modification is a suitable technology to increase the surface wear resistance of steels. In this way, the used substrate metal can be a low alloyed, cost-effective chemical composition steel. After the substrate metal heat treating, hardening and annealing, it needs surface modification.

It well knew some surface heat treating technologies, like carburizing, nitridation, nitrocarburizing, and surface quenching. The surface coating is also very useful technologies when by the chemical or physical process it built a new layer on the surface.

In this work, we compare different modification processes results made by the way of the traditional and new technologies advantages. The chemical composition and the structure determine the surface mechanically and wear resistance properties. The available chemical composition determines the surface modification technology [1-3].

It was prepared with different surface layers on the same substrate steel by a different process and inspected by different testing methods. On the base of the tests results needs to specification a new surface modification process for the high-level surface resistance layer.

1. Introduction

The steels are widely developed by the steel industry in the last decade. For the manufacturing of the high strength steels and the new high strength metal alloys is necessary the tool steels innovation. The challenge is the increasing of the wear resistance and rises up the lifetime of the tools. The new materials need new hardening technologies and surface treatments. The innovation is realizable by the modernization of traditional technologies, the invention of new technologies and combine the traditional and modern heat treating technologies [4].

The traditional hardening technology for steels is well known, but in the case of the new tool steels considering the chemical composition (special and high amount alloy content) and the primary manufacturing technology (f.ex. powder metallurgy) caused microstructure the heat treating technology can be different.



The required mechanical properties of the tool steels are the high wear resistance, the high strength and the long lifetime. The tool steels surface requirements are the high hardness and wear resistance [4]. The increasing of the tool steels productivity insurable by surface treatments. The traditional surface treating technologies are well known.

The modern surface coatings technologies are the Physical Vapor Deposition (PVD) and the Chemical Vapor Deposition (CVD) technologies these are suitable to establish a new, thin, high hardness and high strength layer or multilayer on the substrate surface. By the traditional surface treatment, the surface chemical composition can modify (nitriding, boriding, etc.) or can modify the surface microstructure with martensite formation (induction surface hardening, laser surface hardening, etc.) or can combine the two process (nitrocarburizing, etc.) [2].

The lifetime and wear resistance prediction in case of the treated tool steels is not simple. The industries use the hardness test because the hardness and the wear resistance show a strong correlation. Also usable the comparative experiments by model test (pin on disc test, ball cratering, etc.). In our innovation work, we used the comparative experiments method when we used the same test parameters and after the heat treating, we prepared the tested samples in the same way.

2. Used material and heat treating processes

The used tool steel is H13 (ISO 683-13, W.n. 1.2344, X40CrMoV5-1) heat treatable steel, chemical composition shown in Tab.1.

Table 1. Chemical composition (in wt. %) and the remain is the iron (Fe)

C	Mn	P	S	Si	V	Cr
0.32-0.45%	0.2-0.6%	max. 0.03%	max.0.03%	0.8-1.25%	0.8-1.2%	4.75-5.5%

Heat treatment was the hardening, austenitization and quenching by rapid cooling, the heat treatment parameters shown in Tab.2. The heat treating and the surface coating made in India supported by Surface Modification Technologies Pvt. Ltd. Research and Development Laboratory.

Table 2. Heat treating of the samples

Treatments	Parameters
Austenization temperature	1080 °C
Cooling media	Oil cooled
Plasma Nitriding temperature	480 °C
Nitriding time for 60 µm depth	5 h
Nitriding time for 120 µm depth	12 h

3. Wear coefficient determination theory

The wear coefficient is calculated by the following modified Archard equation (1) from the constant parameters (N_c , f , t) and the crater depth (h) [5]:

$$K = \frac{h^2}{2 \cdot N_c \cdot f \cdot t} \quad (1)$$

Where:

R the wear ball radius [10 mm]

h the depth of the wear crater
(calculated) [mm]

t=5 min time of the wear process

$N_c=0,86$ [N] normal load

f=570 [1/min] revolution per min

K wear coefficient [mm^2/N]

e-diameter of the crater [mm]

S length of the wear [mm]

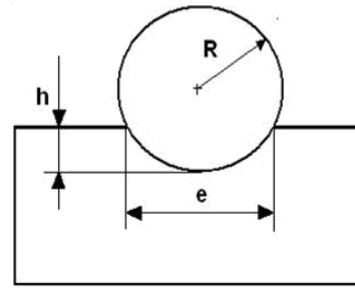


Figure 1. The wear crater parameters

4. The experiments and results

For the wear resistance determination well known several experimental setup, the ball cratering tests are suitable to investigate comparative wear tests [6-7]. The ball cratering wear tests were investigated in the laboratory of the Óbuda University by a modified ball cratering experimental setup. Disc test samples size were $\varnothing 15 \times 3$ mm. It was tested all samples 5 times under constant parameters (load, time and instruments) without any lubricant. The wear crater diameter was measured by microscopy (Neophot 21, supported by computer visual analysis software) one crater in case of every treated surface is shown in Fig. 2-5.

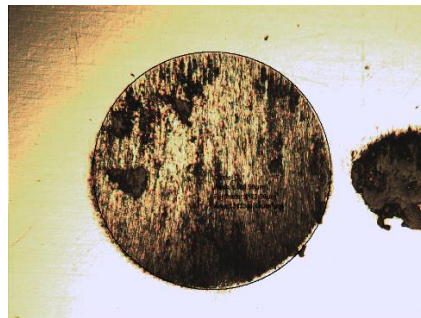


Figure 2. Wear crater of N.1. sample

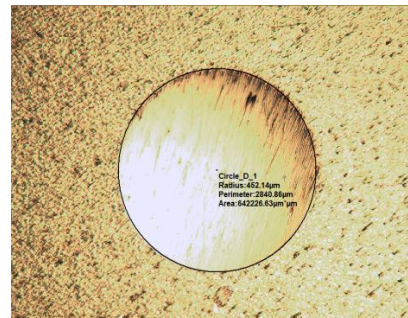


Figure 3. Wear crater of N.1. sample

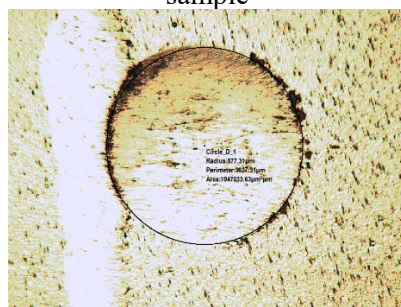


Figure 4. Wear crater of N.1. sample

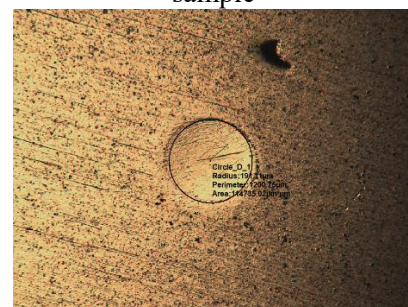


Figure 5. Wear crater of N.1. sample

The Tab.3. shown the average value of the hardness (HV) and the wear coefficient of the measured test samples. The hardness in case of the plasma nitrided surface samples (N.2. and N.3.) it can not find the relevant difference even that the layer thickness is different. The hardened and PVD coated surface hardness is the highest, more than then 5 times harder than the used tool steel hardened value. The special metal (chromium) and ceramics layers (titan nitride, zirconium tungstate, etc.) hardness can be incredible high because of the special crystal structure [8].

The wear coefficient was calculated by the (1) equation from the measured wear crater radius. The Fig. 2-5 shown some typical crater and their radius.

Table 3. The test samples properties

N.	Heat and surface treatment	Treated layer thickness (μm)	Hardness HV	Wear coefficient K (mm^2/N)
1	Hardening	0	549	$6,32 \cdot 10^{-9}$
2	Hardening + Plasma nitriding	50 μm	1130	$1,37 \cdot 10^{-9}$
3	Hardening + Plasma nitriding	200 μm	1140	$1,95 \cdot 10^{-9}$
4	Hardening + PVD coating Cr/CrN	2,67 μm	2775,4	$4,23 \cdot 10^{-11}$

The wear coefficient K which characterizes the wear performance of treated surfaces were calculated, the Fig.6 shows the wear coefficient in case of the different treated surfaces as a function of the hardness.

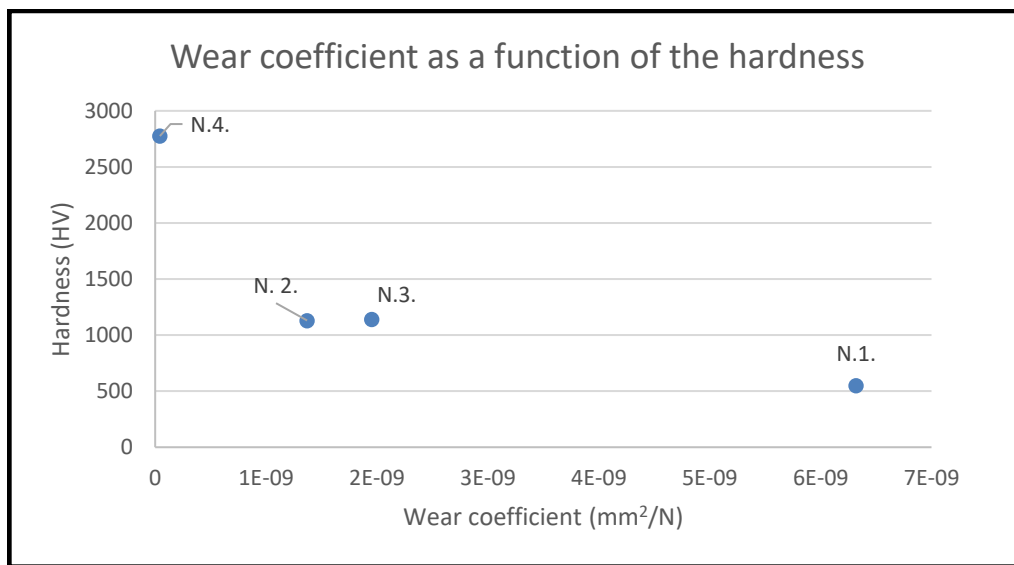


Figure 6. Wear coefficient as a function of the hardness (HV)

5. Conclusion

The correlation between the hardness and the wear resistance is well known we waited for the comparative results also on the base of this knowledge. We concluded after the experimental results evaluation :

- I. The PVD Cr/CN coated surface showed the highest wear resistance under the used experimental methods and parameters.
- II. The plasma nitride surfaces even that the thickness of the treated layer was significant (4 times) showed same hardness, even that the wear resistance in case of the thinner layer given a higher value. To justify this result we need to know the real surface roughness, because this parameter was not tested only we supposed the surfaces roughness equality.
- III. We concluded, that by the traditional hardening heat treating process the used tool steel hardness and wear resistance much lower than the surface teated values.

IV. The used tool steel hardening and wear resistance can increase by surface treating technologies.

Acknowledgement

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