IMPACT RESISTANCE OF Ni-COATINGS

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Abstract

In surface treatment are often used coatings based on Ni. Their properties include signifiant corrosion resistance, hardness and abrasion resisant. In this paper we attempted to measure the shock resistence of these layers using the method of impact test. This method offers a simulation of very intensite local loads that occur mainly during overload and violations.

Keywords: NI-P coatings, impact test, UDDG

1. INTRODUCTION

Ni surfaces offer promising opportunity for substitution of hard Cr in protecting against wear of machine parts (eg: bearings, piston rings). There must be solved a problem that such coatings have lower hardness and wear resistance compared to hard chromium, on the other hand, coatings can offer higher toughness. The aim of the experiment is to investigate how will content UDDG - Diamond-dispersed graphite powder on the resistance to shock loads. This often occurs in many technical applications. For the simulation of degradation was used impact test method.

2. CHEMICAL NI-PLATING

Ni is applied often to improving of corrosion protection. Principally it is cathodic coatings that form a barrier against atmospheric agents. Electroless nickel plating is an auto-catalytic reaction used to deposit an alloy of Ni and P on the substrate. Using this process can be easily made uniform thickness coating even on complex shaped parts. After the plating is material of coating in amorphous state. In this can achieve hardness according to the content of P (5 - 12%) to 400 to 650 HV. Abrasion by TWI unit reaches 14 to 24.After the heat treatment (annealing at 400 ° C for 60 minutes) is possible to obtain hardness to 800 - 1,100 and TWI abrasion resistance 8-15. The surfaces offer very good tribological properties in contact with steel parts, the coefficient of friction is typically 0.2 to 0.4 without lubricant. Thickness can be created till 80 µm [1].This method is demanding on energy - the reaction proceeds at 90 ° C and is difficult to clean and accuracy. This method can except NiP produce NiB, NiCoP, NiWP alloys too. Most used are NiP alloy is up to 98% [2]. Creating of the coating takes place according to the equations 1 and 2

$$NiSO_4 + 3\,NaH_2PO_2 + 3\,H_2O = Ni + 2\,H_2 + H_2SO_4 + 3NaH_2PO_3 \tag{1}$$

$$3\,NaH_2PO_2 = NaH_2PO_3 + 2\,P + 2\,NaOH + H_2O \tag{2}$$

3. UDDG ADITIVE

To improve the operating properties of Ni coatings, particularly abrasion resistance are added further substances, such as technologies NiKlad Ice Ultra, which incorporate to creating layer submicron particles of polytetrafluoroethylene (Teflone). In the extreme case it is possible with this technology to achieve a friction coefficient to 0.15 [3].In this test, the additive incorporated into the coating UDDG (highly disperse Diamond-graphite powder). This is a cluster of particles based on graphite-diamond in a ratio of approx. 50:50. These ingredients are used in polishing and electrolytic coating. The particle size ranges from 2 to 10 nm. [4]

4. IMPACT TEST

It is a progressive method for studying the surface properties of materials. It is based on the cumulative repeated impact loading surface layers of impact energy. The assumption is that the material under impact load acts in a characteristic way. The basic principle of the test is illustrated on **Fig. 1a**. The indenter made of a carbide ball repeatedly impacts sample of material in one place.Shock load involves surface characteristics very negative. Result of that is surface degradation named impact crater. Example is on **Fig. 1b**. The size of this degradation (impact crater) is mainly dependent on the impact energy, the number of strokes, state of the material etc.Treatment indenter occurs intensive compacting of the material in the immediate vicinity of impact. The layers, however, reinforce occurs irregularly and exhaustion of their strength for their delamination and destruction.The crater formed surface degradation phenomena such as cracking, cracking and peeling particles.

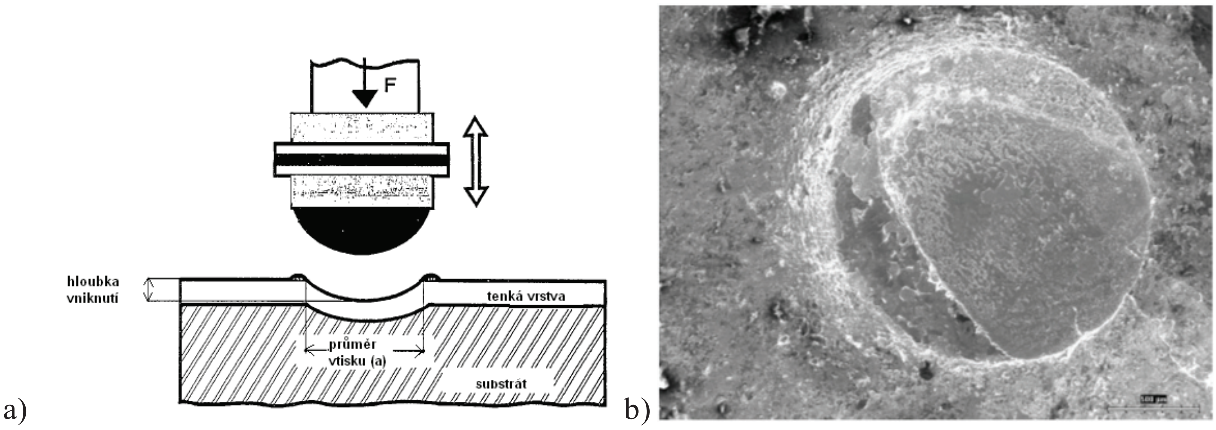


Fig. 1 a) ordering of impact test; b) impact crater

Impact crater grows in three phases:

- in the first phase, when thesurface is not affected the reoccurs massive local plastic deformation hen the indenter acts on a relativem small area, and crater is expanding rapidly.
- in the second phase, the junction area between the indenter and ball considerable, for this mason already increasing crater lower speed. Here it is mainly due to the depletion of plasticity Nera the walls of the crater formed.
- in this third phase is to cracking and chipping hard parts. Further expansit of the crater is now possible thanks to this mechanism.

In this test it is possible to mimic such conditions that produce damage to instruments or orbits rolling bearings which are formed later preventing their proper operation. One of the most important results obtainable from the impact test, the dimensions are formed crater. Each material is characterized by varying degrees of hardness, toughness, which is otherwise in violation of the surface occurs. Measurement is relative to the crater (tens to hundreds of micron) performed on metallographic microscope. The measurement accuracy is mainly influenced on the edge of the craters, because the extruded material flows outward from the crater. The result is depending on the development of fatigue damage, depending on the impact energy at a constant number of cycles, or increasing the number of cycles at constant energy. More information about this type of testing can be found in reference [5]

4.1. Electronically controlled impact tester

The apparatus - **Fig. 2** used in this experiment is own construction and works on the following principle: The sample is attached to the table. Above the sample arm is positioned the indenter, in this case it is a carbide ball with a diameter of 6 mm.

The arm is alternately drawn by the electromagnet, and after the stroke, the force is turned off and the arm returns to its original position by springs. Below the sample is placed piezzoelectric strain sensor Kistler which records the peaks at a frequency of 17 kHz. The signal is then processed by a computer program LabView. Because is a problem to measure dynamic quantities, in this case is used unit daN - dynamic Newton. The instrument is calibrated to the static load by a weight, but is measured dynamical loading. Because of that is assumed that there can occur some deviation. It is important to observe particularly when testing constant loading conditions that help to influence the result of the nature of testing to maintain a constant size. It is therefore a ratiometric measurement.

Fig. 2 Electronically controlled impact tester

5. SAMPLES

As a material for samples was used non-alloy structural steel C15 (CSN 412020). It is used mainly for steel hardening after cementation, the medium-strength in the core. It is suitable for the less strained machine components of medium density in the core, as they are less stressed gears, larger sprockets, bushings, guides, etc. In the annealed condition can be used for crane hooks. When using the sheet metal blank can also be cemented.

Table 1 Chemical composition of steel C15

C	Mn	Si	Cr	Ni	Cu	P	S
0.13 - 0.15	0.6 - 0.9	0.15 - 0.4	< 0.25	< 0.25	< 0.3	< 0.04	< 0.04

Steel has been used in the annealed condition. In the **Table 1** is representated chemical composition. Samples were produced in the form ofacylinder.Diameter was determined on25 mm and a height of 20mm.Samples were grounded and polished on metallographic papers 240 - 400 - 600 - 800 - 1200. Samples were coated with chemically excluded Ni - P coating thickness of 10 ± 1 microns. The coating thickness was verified by calotest. The aim of the test is to examine how the impact resistance of the surface reflected the content of the ingredients UDDG.

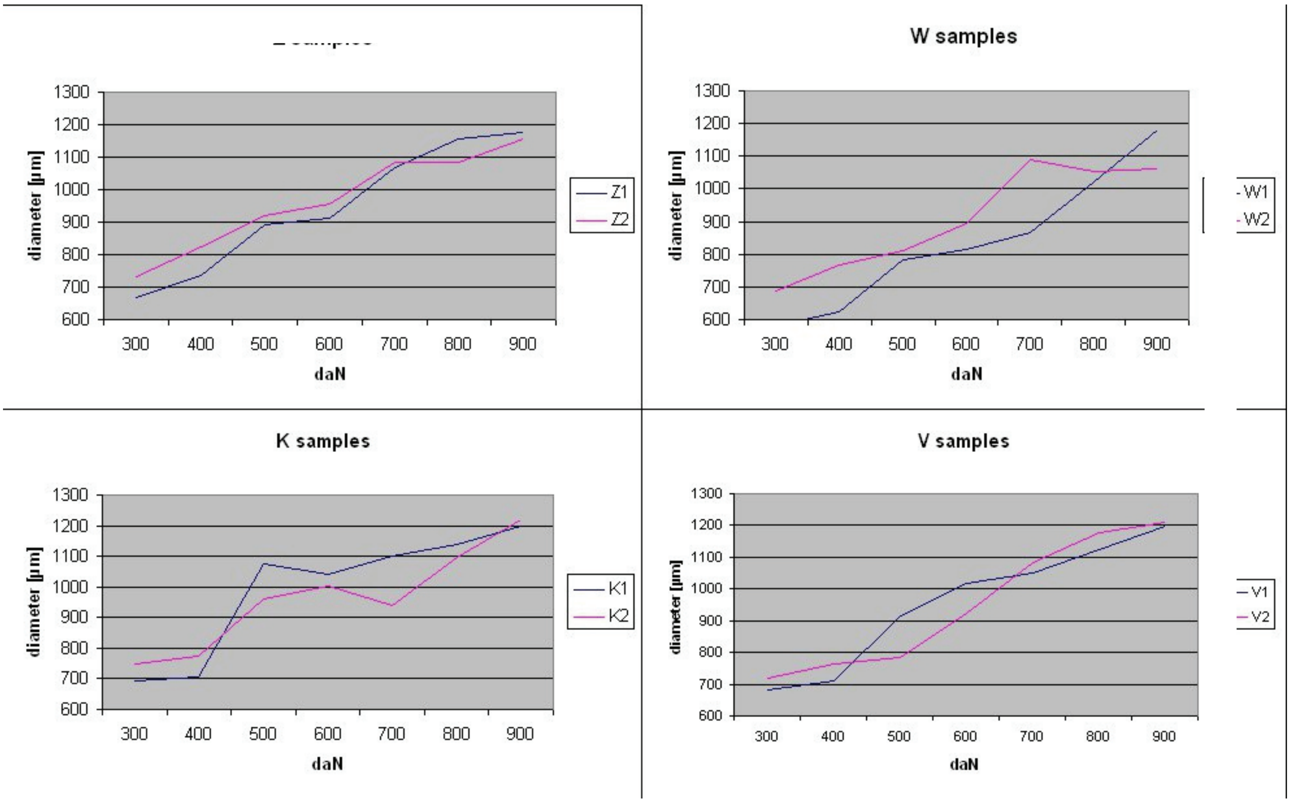
Table 2 Samples

group	UDDG (g/l)
Z	0
W	0.5
V	1
K	1.5

For the experiment were prepared four series of samples. Amount of UDDG is in the surface is illustrated in **Table 2**. In the solution were dissolved nickeling appropriate amount of the aqueous emulsion UDDG for regular spacing in the resulting coating solution was stirred continuously. For each series of samples 2 were used. These were mounted on the measuring table, were formed in them impact craters. For each loading intensity were each formed two craters in one sample. Impact frequency was set to 8 Hz, the number of strokes in each test was for every crater 10 000. Force of the blow was always determined in a number 300-400-500-600-700-800-900 N.

6. RESULTS

Samples, which were created on impact craters were cleaned in ethanol and then measured diameters of craters using metallographic microscope. The following chart shows the development of the craters with increasing impact energy. Selected craters were subsequently documented using a scanning electron microscope.



Graph 1 Growth of impact crater diameter in depends of load force

a) b)

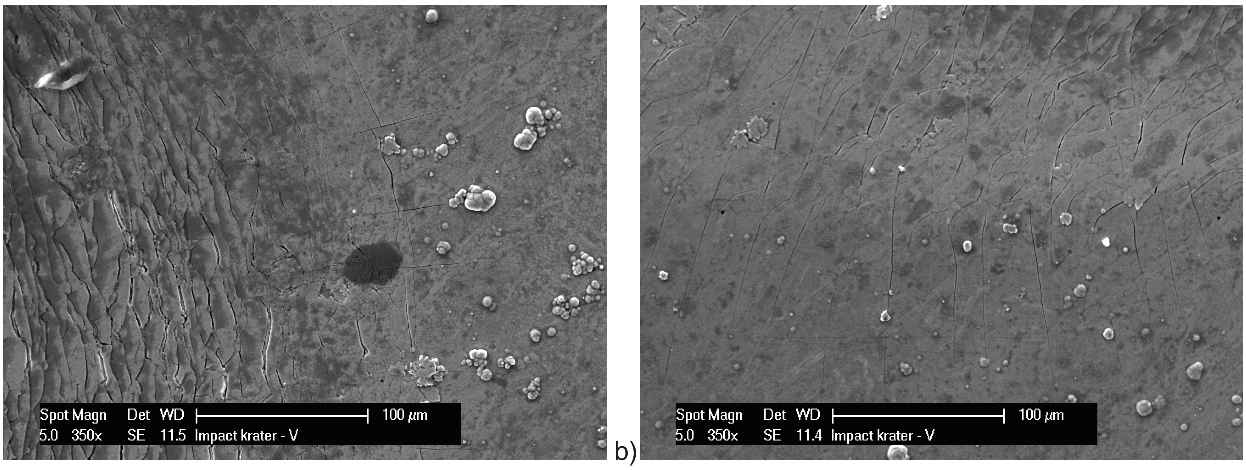
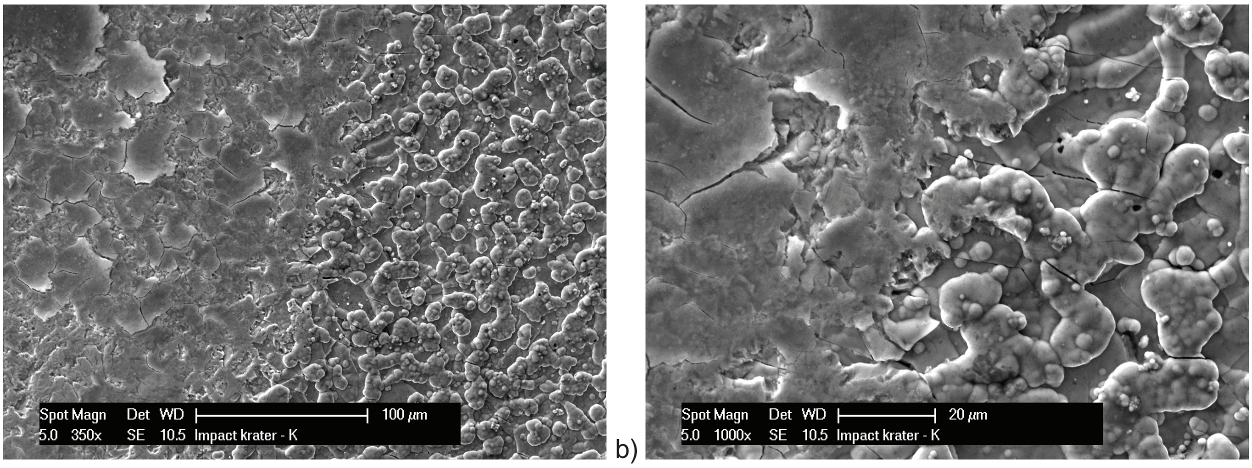
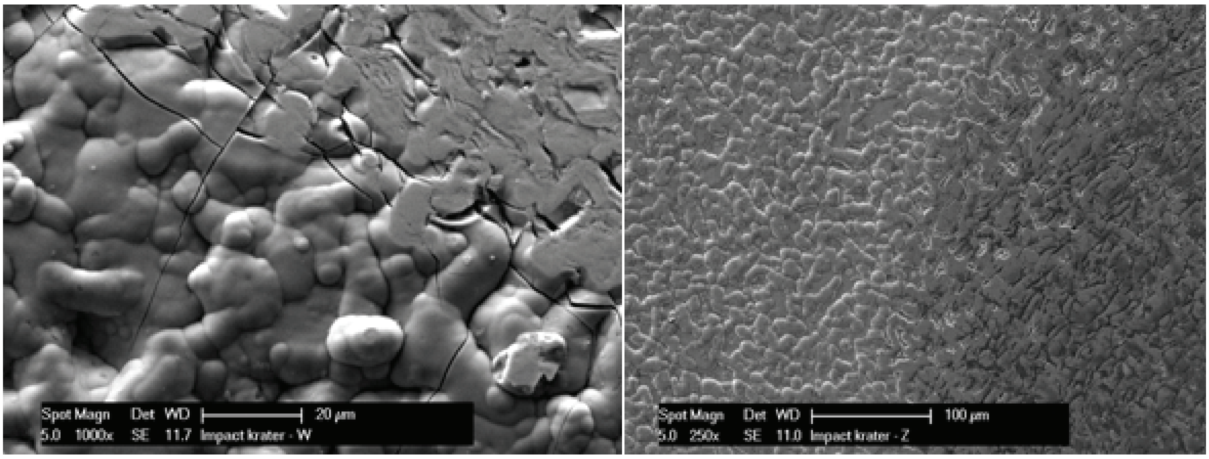


Fig. 3 Impact crater 800 daN 10 000 strokes sample V.
a) Edge of the crater - radial microcracs in the rating; b) Detail of impact crater



a) b)

Fig. 4 Impact crater 800 daN 10 000 strokes sample K.
a) Radial cracs in the same resolution allmost invisible at the edge of crater; b) In resolution 1000 small cracs



a) b)

Fig. 5 a) Impact crater 800 daN 10 000 strokes sample W;
b) Impact crater 800 daN 10 000 strokes sample Z

7. DISCUSSION OF RESULTS

From the results shown in **Fig. 1** it can be seen that the addition UDDG has no significant effect on the growth of damage on a macro scale at shock loads. Size impact crater with growth additive content does not change much. The **Graph 1** shows that the growth in the size of the impact crater after an initial growth retards, thus apparently allows finding an optimal size of the shock load on the durability of components, which coating will operate in optimum conditions, when the risk of surface fatigue (pitting) as low as possible. Eventually, the dynamics of the growth impact crater increases significantly. When examining craters, which is in the **Fig. 3** displayed in samples V - 1 g UDDG were in all created craters found radial cracks in the surround. For craters on samples K - 1.5 g UDDG and W - 0.5 g UDDG radial cracks were detected only after a considerable bigger zoom, which is recorded on **Fig. 4** and **Fig. 5**. Samples from the free agents UDDG cracks were observed. This result was subsequently validated using so-Mercedes test. On the sample were detected in the vicinity of indentation cracks which mean reduced cohesive strength of the coating. In samples Z were not found cracks (**Fig. 6**).

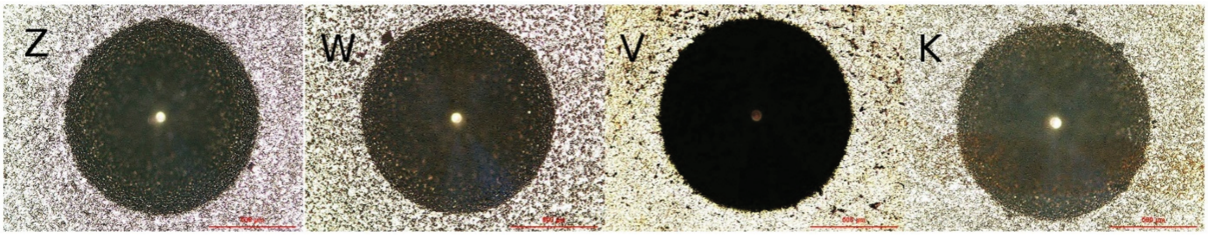


Fig. 6 Mercedes test - on sample V small cracks

CONCLUSION

Ni-P coatings are an interesting alternative for the future development of surface protection of steel components. In the future, they could partially replacing hard chrome plating, which is produced for a lower price and their technology is already very well known. These layers are characterized by their high hardness and abrasion resistance. Their problem is that for their creating are used highly toxic hexavalent chromium compounds which are also carcinogens. Because of that is building of new workplaces legislatively very demanding. Ni coatings show higher toughness but a lower hardness and abrasion resistance. This can be corrected by additives containing hard, or self-lubricating particles. Their problem is likely to affect the cohesive properties of the coating. With increasing content of non-homogeneous particle will probably raise susceptibility to breakage and decomposition layer and thus its destruction. Subject to further examination will check to find the optimal content of this hard component. In this contribution, it was found that, when increasing the content UDDG apparently increases susceptibility to decohezion.

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REFERENCES

[1] Chemical nickeling. Materials of company Bomex. Online available at: http://www.bomex.cz/cz/3-technologie/7-chemicke-niklovani.html

[2] OBR L., New researches in technology of electroless nickeling, available online at: http://www.atotech.com/data/cz/chemicky_nikl.pdf

[3] NiKladIce Ultra process, Mac Dermid New Hudson Technical Centre. November 2009

[4] Material list of UDDG, available online at: www.nanogroup.cz/products/db.html

[5] BENEŠ, P., KŘÍŽ, A., ŠIMEČEK, J. Using of Impact Test by Studies of Surface Layers. In Applied Mechanics 2009. Bratislava: Institute of Applied Mechanics and Mechatronics, 2009. s. 59-60. ISBN: 978-80-89313-32-7