Analysis of the Base Material and Hard Chrome Plated Layer in an Unloaded State

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The focus of this paper is the analysis of the chrome plated layer and base material in an unloaded state, which will be machined by grinding. Each input analysis is necessary before the experiment, so my input analysis was concerned with the surface and surface layer, where components of integrity were tracked. This research observed surface roughness and profile, circularity, microhardness, microstructure, pores and cracks. This analysis is very important due to differences in the components of surface integrity before and after machining or unloaded and loaded states. Hard chrome plating is practically always applied to parts which are made from steel, typically hardened steel and there are changes even within hard chrome plating, with some of the coatings optimized to be expressly porous for oil retention, thin dense chrome, etc. This hard chrome plating has been used classically on parts for growing abrasion resistance, maintaining accuracy of gauges, increasing tool and die life, and reconditioning worn-out or undersized parts, but practice is not limited to such applications. The whole research is based on the practical use of materials in industry.

Keywords: hard chrome coating, surface integrity, surface roughness, microhardess, microstructure

1 Introduction

Most people would not be extremely familiar with hard chrome plating. Hard chrome plating is plating that has been applied as coating for oil retention, wear resistance, lubricity and other parts which were worn-out. Some parts could be piston rings, hydraulic cylinder rods, thread guides, rollers, gun bores, mold surfaces, etc. [1, 2, 3] Hard chrome is not genuinely harder than other chrome plating. It is called "hard chromium" because it has enough thickness and hardness for measurement to be performed, however decorative chrome plating is millionths of an inch thick and can be broken like an eggshell if a hardness test is performed. Its hardness can't really be measured openly. Although galvanic chrome plating is almost 135-150 years old, it is still used. The methods of hard chrome plating were developed for aircraft during the First World War. [2, 4, 5, 6, 7]

Surface integrity is a relationship between physical properties such as residual stresses, hardness and microstructure of the material and geometric properties of the surface. After each technology of machining a new surface is formed with new different properties than the original surface. Due to these changes of surface integrity I have dealt with analysis of the surface and surface layer in an unloaded state. Surface integrity components are: surface roughness and profile, geometric accuracy, residual stresses, hardness on the surface and in the surface layer, heat changes, changes in structure and cracks. [8, 9, 10]

2 Principal of hard chrome plating

Hard chrome plating has been galvanically applied to the machined surface, where the surface rougness has to be as low as possible. For galvanic use it was necessary to use direct current. The metal compound of CrO_3 and H_2SO_4 has been dissolved in the galvanizing bath with catalyst added which can improve the mechanical properties such as hardness, strength, etc. [2, 6, 11] The application of the chromium coating is very simple. The sample on which hard chrome plating has to be applied is connected as a cathode. The cations of the metal are deposited on the cathode and the samples is coated with a very thin layer of metallic material. The plating principle is illustrated in Figure 1. [5, 6, 7]

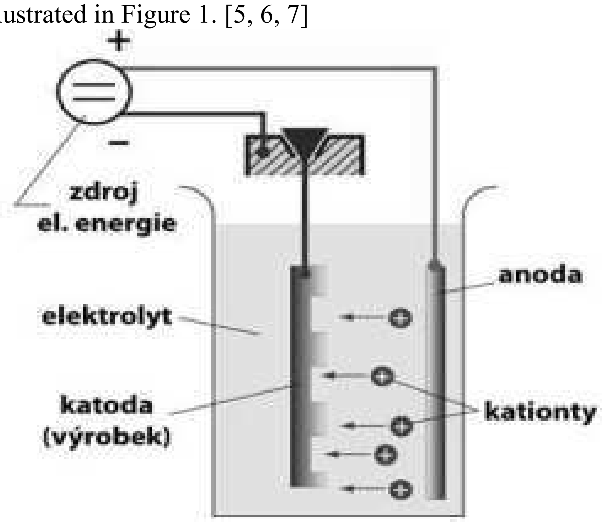

Fig. 1 Principle of chrome plating [5]

3 Required properties of the base material and chrome plated layer

The choice of base material is based on the current use in the industrial sphere. The experiment was performed on a shaft from a combustion turbine (Figure 2). This shaft is based on iron, containing alloying elements such as Cr, Ni, Mo. These alloys are referred to as chromium-molybdate. In my case this is a material that is labeled AMS 6415. Table 1 and Table 2 show the basic chemical composition and basic mechanical properties of the AMS 6415 alloy according to the material sheets. [12, 13]

Before loading (machining - grinding) all samples should have a martensitic structure, which will be examined by microscopic analysis.

The galvanic deposited layer has specific data that must be observed. One of the criteria is the thickness of the chrome layer, which must be from 0.3 mm to 0.4 mm. Another criterion is microhardness, which must be in the 900 - 1050 HV range. In terms of structure, the chrome layer must appear as a cohesive layer with a minimum amount of pores and cracks. The amount of acceptable pores is up to 15 % in the area under investigation.

Figure 3 shows a schematic representation of sample preparation.

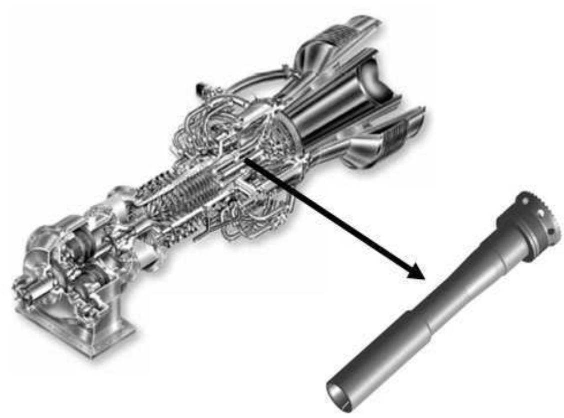

Fig. 2 *Shaft from a combustion turbine*

Tab. 1 *Chemical composition of the alloy AMS 6415 [12, 13]*

Chemical composition of the alloy [hm. %]								
C	**Mn**	**P**	**Cr**	**Mo**	**S**	**Ni**	**Si**	**Fe**
0.37 -0.43	0.6 – 0.8	Max 0.035	0.7 - 0.9	0.2 – 0.3	Max. 0.04	1.65 - 2.00	0.15 - 0.35	96

Tab. 2 *Mechanical properties of the alloy AMS 6415 [12, 13]*

Quantity	Min. value	Max. value	Unit
Tensile strength - R_m	850	1555	MPa
The yield strength - R_e	635	1125	MPa
Ductility	5	13	%
Harndess	24	45	HRC

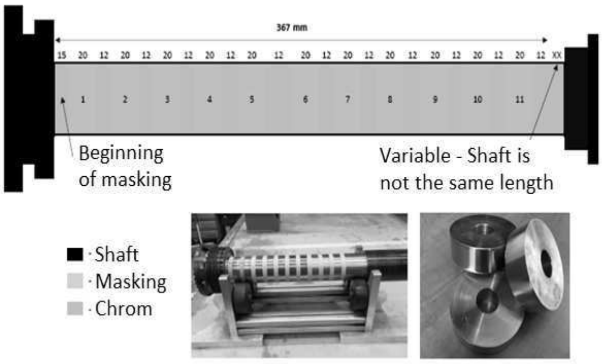

Fig. 3 *Example of pattern*

4 Analysis of the Base Material amd Hard Chrome Plated Layer in an Unloaded State in terms of surface integrity

The aim of this section is to provide analyses of the base material and chrome plated layer, where chemical composition, surface roughness and profile and circularity, microhardness, microstructure, porous and cracks were the focus.

4.1 Analysis of the Base Material and Chrome Plating Layer in Terms of Chemical Composition

To determine the chemical composition of the samples, an analysis was carried out on an optical emission spectrometer designated Q4 TASMAN. The resulting chemical composition of the parent material is shown in Table 3. In total, 5 injections were performed on different samples. Subsequently, the arithmetic mean was calculated. All findings are supplemented with standard deviation. By comparing tables 1 and 3, we can see that the chemical composition according to the technical data sheet corresponds to the chemical composition of the samples.

Tab. 3 *Chemical composition of sample*

	Chemical composition of the alloy [wt. %]								
Prvek	**C**	**Mn**	**P**	**Cr**	**Mo**	**S**	**Ni**	**Si**	**Fe**
%	0.415	0.711	< 0.005	0.817	0.234	< 0.001	1.835	0.263	95.300
±σ	0.004	0.004	-	0.003	0.001	-	0.008	0.003	0.010

Fig. 3 *DELTA optical spectrometry and chemical composition of chromium layer*

To verify the chemical composition of the galvanic deposited chromium layer, the analysis was carried out using the DELTA Handheld Optical Spectrometer Fig. 4. The figure shows that the chemical composition of the galvanized layer is almost 100% chromium.

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4.2 Analysis of the Chrome Plating Layer in Terms of Surface Roughness and Profile and Circularity

Input surface integrity analysis included parameters Ra Rz, Rt, Rpk and Rvk. Also I was focused on Material ratio curve and circularity which is marked symbol E. Basic values regarding surface roughness are in tab. 4 and on fig. 4, where all parameters which have been mentioned above can be seen.

Surface roughness measurements were performed twelve times, where the arithmetic mean of the measured values and the determination of the standard deviation were calculated.

The measurement of the surface roughness was conducted with a Profilometr Hommel Tester T8000 device (Fig. 5)

Tab. 4 *Evaluation of surface roughness parameters in unloaded state*

	Ra[µm]	Rz [µm]	Rt [µm]	Rmax [µm]	Rpk [µm]	Rvk [µm]
Arithmetic average	0.69	3.19	3.53	3.49	0.88	0.38
Standard deviation	± 0.06	± 0.22	± 0.28	± 0.27	± 0.20	± 0.09

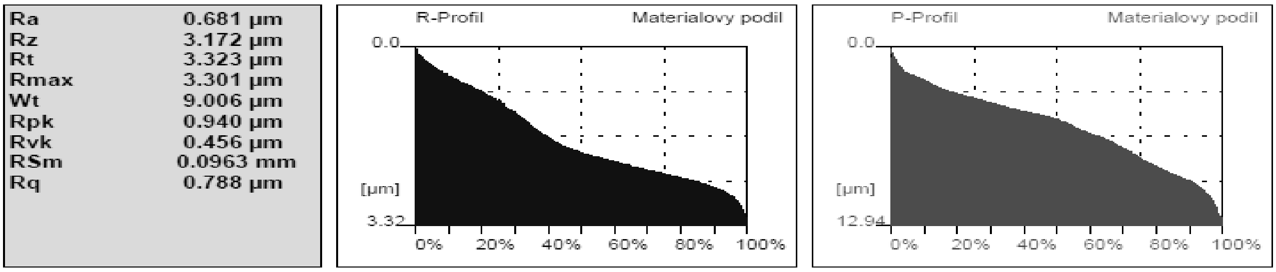


Fig. 4 *Material ratio curve of unloaded state (3. measurement)*

Fig. 5 *Profilometr Hommel Tester T8000*

From the resulting circularity values and its graphical representation across the circumference of the disc, it is clear that the trajectory of the sample profile is irregular in shape. Deviations of circularity are due to the technology of coating production in the preparation of the chrome coating layer.

Measurement was performed on the sample 3 times (at the top, center and bottom). For the sample in an unloaded state the arithmetic mean of the measurements was calculated and a standard deviation from the measured circularity values was calculated. Avarage value of circularity is shown in Tab. 5 and deviation of circularity is shown on Fig. 6.

The measurement of the circularity was performed with a Hommel Tester Form T4004 device (Fig. 7).

Tab. 5 *Average values of circularity in unloaded state*

Circularity	Arithmetic average [µm]	Standart deviation [µm]
E	31.11	±10.20

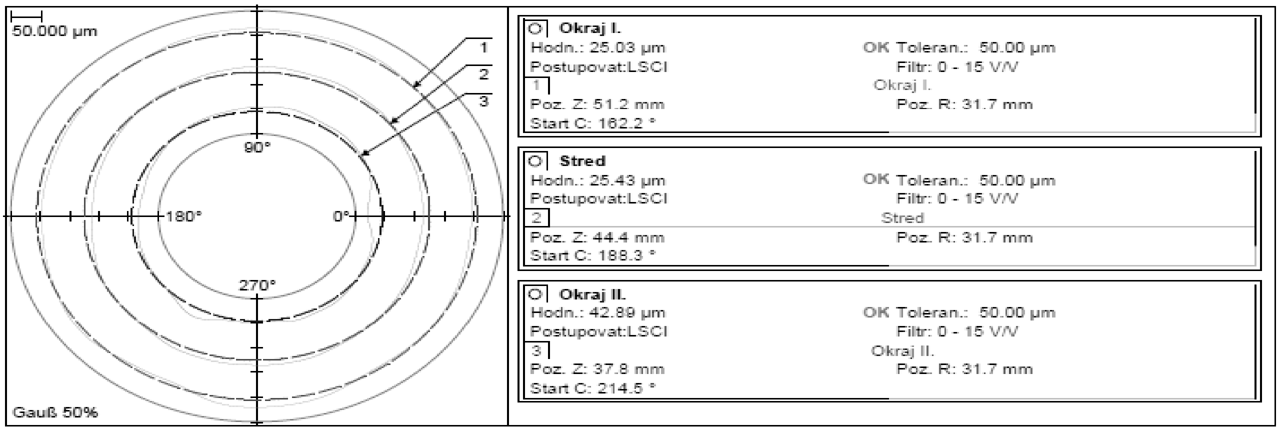


Fig. 6 *Deviation of circularity in an unloaded state*

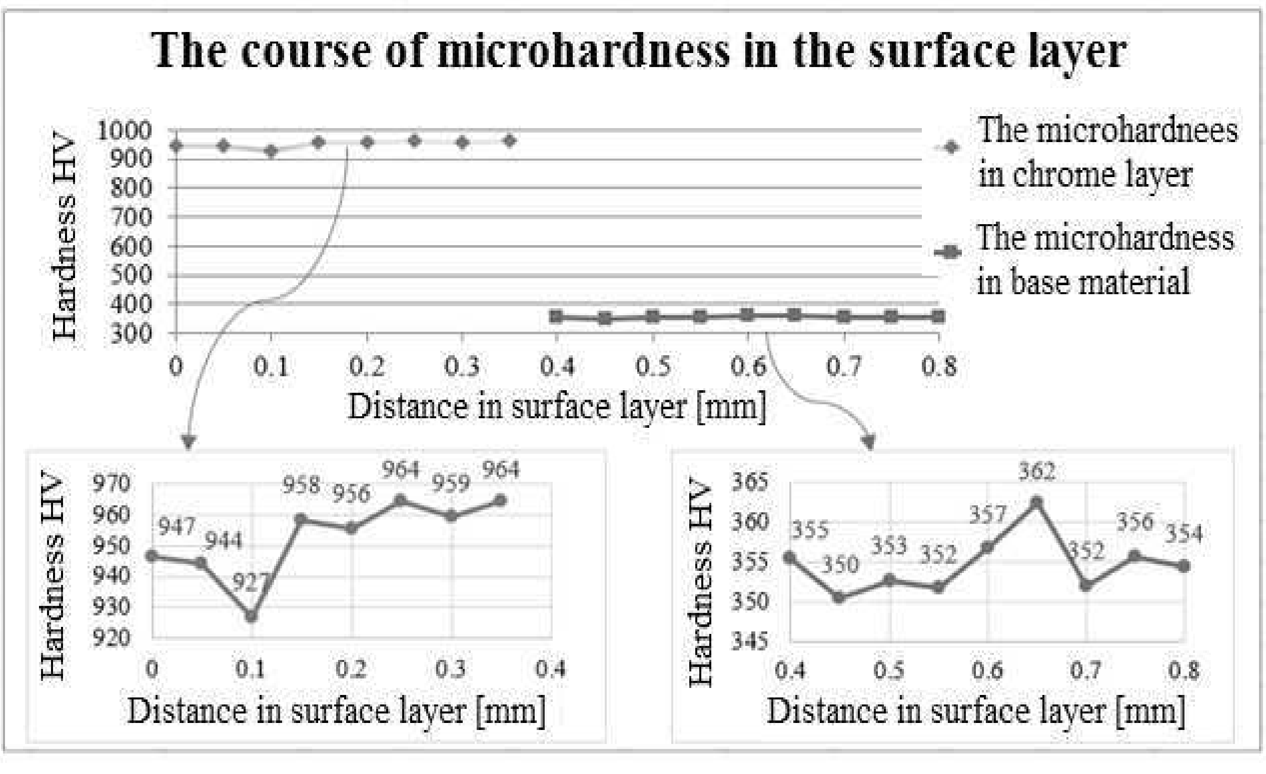
***Fig.** 7 Device for measuring of circularity - Hommel Tester Form T4004*

4.3 Analysis of the base Material and Chrome Plating Layer in Terms of Microhardness

Graph 1 shows the microhardness in the surface layer for an unloaded state (sample before grinding). From the graph it can be seen that the hardness value on top of the surface of the chrome layer is 947 HV. At a depth of 0.1 mm, microhardness dropped to 927 HV, and then the depth of the chrome layer (0.4 mm) increased the microhardness to 964 HV. Just below the surface of the base material 355 HV microhardness was measured. The microhardness values of the base material, which was measured in the surface layer from 0.4 to 0.8 mm was varied within 10 HV.

4.4 Analysis of the base Material and Chrome Plating Layer in Terms of Microstructure, Porosity and Cracks

For the input characteristic of the microstructure there are a few images of the initial microstructure (fig. 8). The microstructure images are taken prior to the grinding process in a non-stressed state for the purpose of proofing the material structure for the grinding process when the cutting conditions will be changed. Monitoring of the unloaded layer is very important because the influence of grinding causes excessive mechanical and thermal loading. The initial state will be used to compare structure, pores and cracks that will appear due to mechanical stress. In terms of the acceptable structure, up to 20% of the porosity and fine cracks are acceptable, when not leading to the surface layer.



***Graph 1** The course of microhardness in the surface layer in unloaded state*

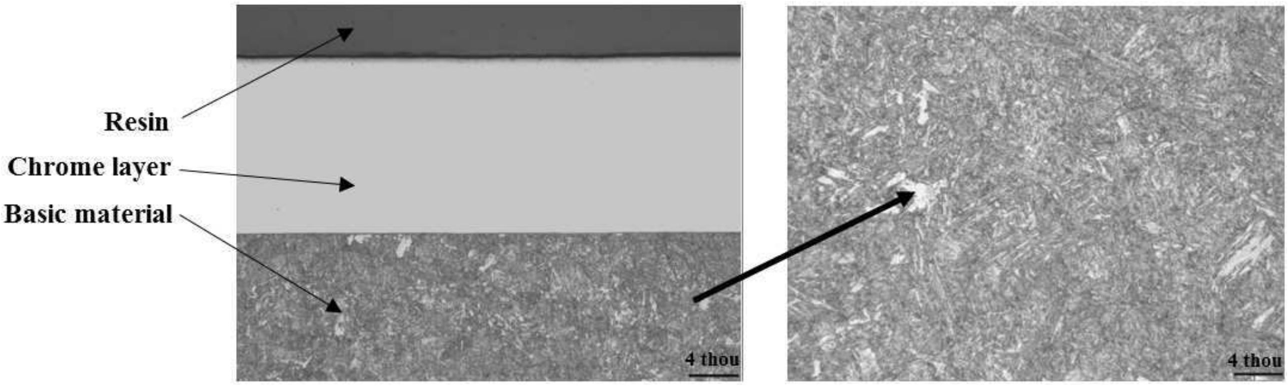


Fig. 8 *Microstructure of unloaded chrome layer of sample*

5 Summary

The essence of this article is to familiarize the reader with the starting state of the unloaded chrome layer. This part of the thesis is formulated on the basis of theoretical knowledge. The work focuses on the experiment itself, which includes the preparation of the experiment, the experimental plan, the initial state of the samples and also the methodology of the quality assessment of the machined surface, where the surface roughness and profile, the geometrical tolerance, structural changes, cracks and microhardness in the surface layer.

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