

## **THE EFFECT OF SELECTED PROPERTIES OF CHROMIUM COATING ELEMENTS AFTER PNEUMATIC BALL PEENING ON FATIGUE STRENGTH**

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### **ABSTRACT**

The chromium layers are deposited in order to take advantage of high hardness, corrosion resistance and the wear resistance or the low coefficient of friction of such deposits. Although chromium coatings have a lot of advantages, their harmful influence on fatigue strength is well-known. Pneumatic ball peening is one of treatments which could increase fatigue strength. The main aim of the performed investigations was to evaluate the effect of pneumatic ball peening on the improvement of the chromium coating elements fatigue strength and to establish the possibility of the strength increasing using the pneumatic ball peening method. Besides, this article shows the results of measurements of surface roughness and microhardness after machining.

**KEYWORDS:** Chromium coating, Pneumatic ball peening, Roughness, Microhardness

### **1. INTRODUCTION**

The use of protective coatings in industrial applications is rapidly increasing in many new areas.

The adhesive properties of the coatings are of prime importance since they limit the coatings useful life. One important factor which contributes to coating failure is the residual stress produced during its manufacture [1].

The use of hard chromium plating as an electrodeposited surface layer on other metals is now a well established industrial practice. The chromium layers are deposited in order to take advantage of the high hardness, corrosion resistance and the wear resistance or the low coefficient of friction of such deposits. Although chromium coatings have a lot of advantages, their harmful influence on fatigue strength is well-known. An efficient way of removal or considerable decrease in this negative influence on usage properties of the layers is application of burnishing process. With the appropriate selection of the layer material and burnishing conditions, increase in surface wear resistance can be repeated [2]. At the same time, depending on the requirements the surfaces received may possess additional advantages as e.g. increased corrosion resistance.

Among the burnishing methods used for layer processing the following are used most frequently: shot peening, micro ball peening and pneumatic ball peening, roller and ball burnishing as well as slide burnishing (slide planishing, slide diamond burnishing).

The combination of electrolytic processing and burnishing may appear to be more efficient way of surface usage properties improvement than individual application of each of them.

### **2. PNEUMATIC BALL PEENING**

Pneumatic ball peening process is applied mainly to irregular shape machine parts, welded joints or coated elements. This process can be also used to heat treated steels machine parts having low or high hardness alloys [2].

Pneumatic ball peening is the variation of stream ball peening. The burnishing elements are bearing rolls of the diameter from 1 to 4 mm propelled by compressed air. Pneumatic ball peening is the method that is characterized by easy and quick burnishing parameter adjustment deciding on the condition of the top layer (air pressure, balls' diameter, the number of balls) [3]. Plastic distortion effect is caused by the change of kinetic energy of the ball stream expelled at

the speed from 30 to 70 m/s on distortion energy.

The top layer shaped as a result of pneumatic ball peening differs from the core mainly in such properties as the degree of draft and an internal stress pattern.

Apart from the physical properties, pneumatic ball peening also changes the profile of the top material that is processed.

At adequately selected parameters of treatment, roughness after machine cutting is eliminated and the microirregularities of large cavities radii without sharp peaks and asperities are shaped, achieving  $R_a$  within the boundaries 0,4 – 2,5  $\mu\text{m}$ .

The supply pressure is the deciding parameter in processing efficiency. The number of balls depends on processed surface size and on pneumatic ball peening machine construction and equals from 20 in case of small heads up to 10 kG in large pneumatic ball peening machines.

The processing efficiency is strongly influenced by construction of an exhaust nozzle, shape and dimensions of which are optimised experimentally [4, 5].

The burnishing process employing pneumatic ball peening method was developed for the purpose of avoiding such inconveniences of alternative methods (particularly of shot peening) as:

- large particle charge and its substantial wear,
- demand for particle transport to throwing zone,
- dust formation and its indenting into top layer,
- surface roughness decline, particularly during processing of limited hardness materials.

Only seldom trials of pneumatic ball peening application on chromium layers have been noted.

Such rarity comes from considerable difficulties accompanying chromium layers burnishing process manifesting in peeling and exfoliation of the top layers (particularly during hard layer plating on a soft base), and also difficulties connected to durability of the device, which together induced this work to be done.

The aim of this work was to establish initially a possibility of a pneumatic ball peening of hard chromium plating coated on a soft base material.

### 3. EXPERIMENTAL

The main target of the performed investigations was to evaluate the effect of pneumatic ball peening on the improvement of the chromium coated elements properties. The studies were conducted on steel 40H of hardness 230HB. The base pretreatment included turning and then pneumatic ball peening ( $R_a = 1.2 \mu\text{m}$ ), grinding ( $R_a = 0.7 \mu\text{m}$ ) or polishing ( $R_a = 0.5 \mu\text{m}$ ) depending on the chosen variant. The finishing treatment of the coating (of 25  $\mu\text{m}$  thickness) was pneumatic ball peening or polishing. The pneumatic ball peening was realized with the following parameters: air pressure – 0,5 MPa; ball diameter – 2 mm, treatment time – 20 min. The hasten pendular bending fatigue tests were carried out using an electrodynamic vibrator with resonance frequency of the samples adopting the boundary number of cycles of  $2 \cdot 10^6$ . The used technique, that consisted in cutting samples out of special shaped cylinders, was described in [6] in details. The fatigue strength was calculated using stepped method on the basis of results of experiments on 16-sampled batches [7]. The fatigue experiments results are shown in tab. 1 and on Fig 1. Surface stereometric scanning was performed with Rank Taylor Hobson TALY-SCAN inductive head and diamond contact tip with 0,002 mm rounding diameter and head speed 0.5 mm/s [8]. Profilogram was taken from the 4 mm assessment length. The results of the measurements are shown in tab. 2. Tab 3 shows the results of microhardness investigations.

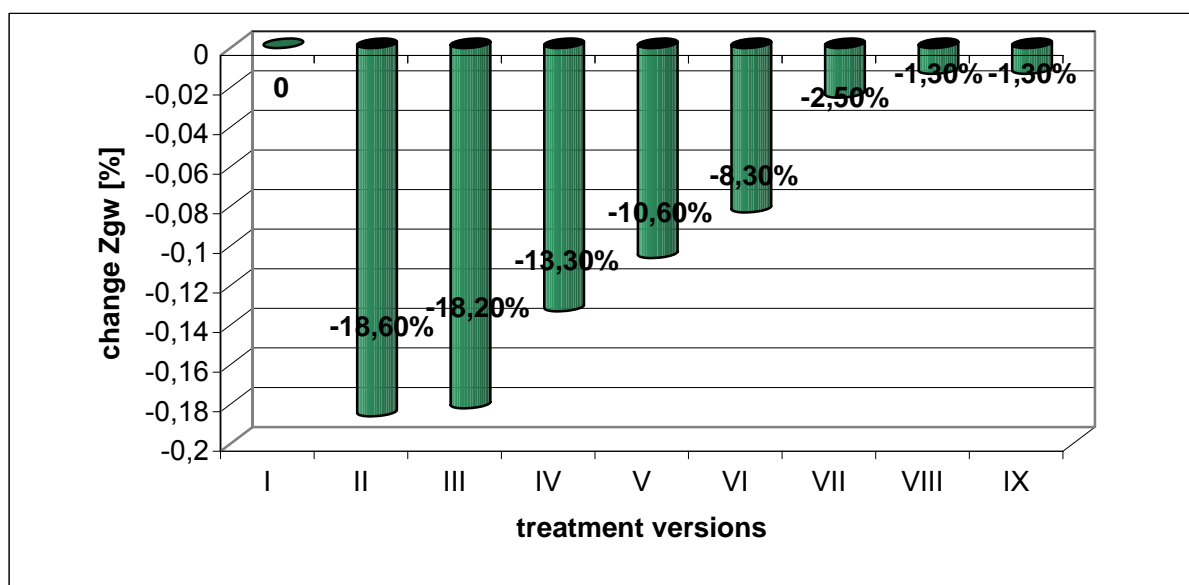
The represented treatment variants are as follows:

- Variant I – the base ground, the coating untreated;
- Variant II – the base polished, the coating untreated;
- Variant III – the base ball peened, the coating untreated;
- Variant IV – the base polished, the coating polished;
- Variant V – the base ground, the coating polished;
- Variant VI – the base ball peened, the coating polished;
- Variant VII – the base polished, the coating ball peened;

- Variant VIII – the base ball peened, the coating ball peened;
- Variant IX – the base ground, the coating ball peened.

**Tab. 1 The results of the fatigue strenght experiments according to different treatment variants**

|           | Var. I | Var. II | Var. III | Var. IV | Var. V | Var. VI | Var. VII | Var. VIII | Var. IX |
|-----------|--------|---------|----------|---------|--------|---------|----------|-----------|---------|
| Zgw [MPa] | 341    | 338     | 359      | 354     | 336    | 370     | 370      | 407       | 407     |



**Fig. 1. The change of the fatigue strenght after different versions of treatment**

**Tab. 2. Chosen proprieties of roughness for particular variants of machining**

|           | Ra [ $\mu\text{m}$ ] | Rz [ $\mu\text{m}$ ] | Rt [ $\mu\text{m}$ ] | Rq [ $\mu\text{m}$ ] | Rp [ $\mu\text{m}$ ] | RSm [mm] | RΔq [°] |
|-----------|----------------------|----------------------|----------------------|----------------------|----------------------|----------|---------|
| Var. I    | 0,81                 | 4,85                 | 5,89                 | 1,03                 | 2,36                 | 0,090    | 3,7     |
| Var. II   | 0,47                 | 2,90                 | 3,68                 | 0,61                 | 1,07                 | 0,137    | 2,1     |
| Var. III  | 1,86                 | 7,92                 | 8,88                 | 2,19                 | 4,29                 | 0,355    | 2,78    |
| Var. IV   | 0,45                 | 2,65                 | 4,07                 | 0,56                 | 1,21                 | 0,183    | 1,85    |
| Var. V    | 0,54                 | 3,68                 | 5,25                 | 0,68                 | 1,80                 | 0,313    | 2,36    |
| Var. VI   | 1,41                 | 5,76                 | 8,50                 | 1,68                 | 2,64                 | 0,106    | 3,21    |
| Var. VII  | 1,34                 | 6,07                 | 9,26                 | 1,56                 | 3,39                 | 0,437    | 2,31    |
| Var. VIII | 1,78                 | 7,36                 | 8,07                 | 2,09                 | 4,20                 | 0,324    | 2,02    |
| Var. IX   | 1,53                 | 6,39                 | 8,15                 | 1,77                 | 3,66                 | 0,577    | 1,87    |

**Tab. 3 The results of microhardness experiments**

|                     | Var. I | Var. II | Var. III | Var. IV | Var. V | Var. VI | Var. VII | Var. VIII | Var. IX |
|---------------------|--------|---------|----------|---------|--------|---------|----------|-----------|---------|
| H <sub>m</sub> [HV] | 684    | 668,6   | 695,6    | 687     | 700    | 703     | 708      | 732       | 712     |

The performed fatigue investigations showed the nearly 20% decrease in the fatigue strength of both ground and chromium plated

samples and polished and chromium plated samples in relation to samples without chromium plating. The distinct, nearly 14%

decline of the fatigue strength was also observed in case of the ball peened and chromium plated samples. The application of polishing as a finishing treatment allowed on reduction of the adverse effect of chromium plating on the fatigue strength to the level about 10% lower in relation to the strength before the plating. The pneumatic ball peening treatment of the coatings produced the fatigue strength only 2,5 – 1,5 % lower than before the chromium plating and the decrease was affected by the used base pretreatment method.

Greater roughness has coating from more roughness surface base (after pneumatic ball peening) than coating from ground or polished surface. Whereas profilograms of coating surface after pneumatic ball peening are distinguished by rises and depressions with great rounded radius, made by shot of ball on surface.

The performed microhardness investigations showed the biggest increase of hardness in case of variant VIII (the base ball peened, the coating ball peened).

#### **4. CONCLUSION**

Performed investigations of a chromium plating burnishing process have revealed the possibility of shot peening process realization without fear of cracks, scalings or other defects.

Performed exams proved significant impact of preparatory machining of surface on later roughness of chromium coating. They showed characteristic for pneumatic ball peening surface without sharp corners and tops. The results of the realized fatigue experiments showed the distinctly advantageous effect of pneumatic ball peening on the improvement of the fatigue strength of the elements with chromium coatings. Particularly beneficial findings were obtained with the ground or the ball peened

base and with the ball peened coating. The conclusion of the investigations is the necessity of the further studies on this topic.

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