THE INFLUENCE OF THE KIND OF SURFACE TREATMENT ON THE WEAR OF MACHINES ELEMENTS APPLIED IN THE TEXTILE INDUSTRY

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Abstract
The paper presents the examinations of yarn guide made of steel 16MnCr5, subjected to different types of treatment: heat, thermo-chemical and surface: hardening and tempering; plasma spraying with Al₂O₃ powder; titanizing and chromium plating. Yarn guides were tested in industrial conditions, and next subjected to laboratory examinations: microscopic - optical and scanning microscope; RTG analysis; hardness measurements. The surface topography and the corrosion resistance were also evaluated. Examinations showed that yarn guides after plasma spraying with Al₂O₃ powder reveal the greatest durability - after 12000 working hours there is practically no wear traces at the guiding surface.

Key words: surface treatment, textile industry, spinning, corrosion resistance

1. INTRODUCTION
The presented paper is the continuation of previous authors’ works [1-4] that regarded among others the lifetime of machines elements applied in textiles industry - the wear of the yarn guides of the ring spinning frames used for balloon-less spinning units. Further development of textile industry needs finding the new product, the processing technologies that guarantee not only "environmentally friendly" but also the more competitive economically products where the production costs resulting from spinning machines maintenance plays a not inconsiderable role. It is well known that steel elements lifetime applied in textiles production is still not satisfying, especially during yarn production being the mixture of 30-55% polyester and 70-45% wool [1]. During testing the 30% polyester / 70% wool yarn blend, the intensive eyelet wear was observed, because wool very often contains small foreign particles such as grass, tree bark, straw and quite often grains of dust (Fig. 1).

![Fig. 1. The view of yarn containing foreign elements: 1 – grass, 2 - straw, magnification 100x](image-url)

There are many factors affecting yarn friction: fibre parameters (surface roughness, molecular orientation, fibre material); yarn structural and bulk parameters (yarn denier, twist; spinning method), operational parameters (sliding speed, temperature, humidity, contact geometry); and finishes [5, 6]. On the other hand
friction coefficient strongly depends on the stereometric structure of the metallic elements surface resulting from the kind of conducted treatment (chemical, thermo-chemical) that create with yarn the tribologic couple. To improve the surface properties of different machine parts – decreasing the wear and increasing the corrosion resistance different methods of chemical heat treatment are used. Among the others the chromizing, titanizing or even chromizing – titanizing have been investigated that improve essentially not only the wear but also corrosion behavior of carbon or low alloy steel [7]. The above mentioned treatments result in steel surface hardness increase up to 1500 HV [8-10]. Created coatings except Al₂O₃ are relatively thin: chromizing - chromium carbides layer 0.005-0.04 mm [10], titanizing in gas medium - 0.010-0.015 mm, Al₂O₃ - thickness can reach 0.7 mm. The aim of presented investigation was to verify the different thermo-chemical treatment (chromizing, titanizing, plasma spraying with Al₂O₃ powder and hardening) as the way of the lifetime increasing of knocking off insert threshold of feeding channel of spinning point of open end spinning machine.

2. EXPERIMENTAL

2.1. The object of investigation

The tested element - knocking off insert threshold of feeding channel of spinning point of open end spinning machine is presented in Fig. 2. Investigated part was made of steel grade 16MnCr5 (0.14-0.19 %C; 1.0-1.3 %Mn; 0.17-0.37 %Si; max. 0.035 %P max. 0.035 %S; 0.8-1.1 %Cr; max. 0.3 %Ni; max. 0.2%W; max 0.05 %V; max. 0.3 %Cu).

![Fig. 2. The drawing of the insert of the fibres feeding channel to spinning chamber – a; the general view and the surface of used up threshold - b](image)

2.2. Investigation methodology

Before application inserts were thermo-chemical treated: hardened (sample no. 1), plasma sprayed with Al₂O₃ (sample no. 2), titanized (sample no. 3) and chromized (sample no. 4). The surface state of inserts was controlled during the operation and after founding of the visible damage (Fig. 2b) part was replaced and subjected to the investigation. Structure was observed using both optical, scanning and stereoscope microscopes. The hardness measurement (HV10) was carried out using Vicker’s method according to PN –
EN ISO 6507 – 2007. The elements distribution was tested with application of X-ray analyser “JXA – JEOL”. Sample’s surface quality was described additionally by roughness measurements - „MAHR“ profile measurement gauge with “Perthometer Concept” software. Corrosion resistance was evaluated by application of potentiostat SI 1286 that enables registration of polarization curves in three electrodes system. Before measure start, samples were placed in corrosion solution – 0.5M NaCl (pH =5.5), in temperature 25 °C, within 24 h. Samples were subjected to polarization in the same solution, from potential -500 mVNEK in anode direction, with rate 1 mV/s. Results of treatment were evaluated basing upon the following parameters: hardness, roughness, surface topography, corrosion resistance measured by potentiodynamic method and the lifetime.

![Image](image1)

**Fig. 3.** The surface of the threshold surface observed under stereoscope microscope together with corresponding profilogram; S1 – a, b; S3 – e, f; S4 – g, h – after 2000 h; S2 – c, d after 12000 h
3. ANALYSIS OF RESULTS

The surface of the threshold observed under the stereoscope microscope is presented in Fig. 3 together with corresponding profilogram. Because of essential differences in topography (deep grooves) of investigated samples the measurement of typical characteristic parameters, i.e. $R_a$, $R_p$, $R_v$, $R_z$ is pointless.

It is visible that the most smooth surface was achieved for the steel after plasma sprayed with $\text{Al}_2\text{O}_3$ (grooves depth up to 8 µm, where even long-time operation didn’t changed surface quality. The deepest grooves are observed on steel surface after hardening (sample 1) which reach even 140 µm and after chromizing (sample 4) – grooves depth up to 100 µm.

![Steel sprayed with $\text{Al}_2\text{O}_3$ after 12000h operation; a – steel outside surface; b – the surface layer cross section; c – EDS diagram from point 5 – Fig.4b](image)

The analysis conducted using the scanning microscope was made in the wide spectrum. Observations regarded both outside surface as well as the coating cross section. The chemical composition was verified qualitatively (EDS) and quantitatively. Because of the limitation imposed to herewith study the wider results will be presented in the other publication. Structure presented in Fig. 4 confirms the wear of $\text{Al}_2\text{O}_3$ layer stated in “macro” scale – 8 µm spallings.

Tests conducted in industrial conditions proved that considering the surface wear the best solution is steel plasma spraying with $\text{Al}_2\text{O}_3$ powder. The lifetime of the threshold knocking inserts made of carburized and hardened steel grade 16MnCr5 was about 1500 h. After application of the additional thermo-chemical treatment – chromizing, titanizing the lifetime increased up to 3000 hours. Inserts with the threshold with plasma sprayed coating with $\text{Al}_2\text{O}_3$ and thickness about 0.2-0.3 mm of ceramic powder were in operation within 12000 h practically without traces of the wear.

The results presented in Table 1 and Fig. 4 confirm that corrosion resistance of investigated samples in applied corrosion solution is similar. It can be stated that potentiodynamic curves of samples 1 and 2 are comparable. In the case of samples no. 3 and 4 the density of corrosion current is a little bit lower and additionally the curve run confirms better coating passivation.
### Tab. 1. Measured parameters of corrosion process

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>$E_{\text{corr}}$ [mV]</th>
<th>$E_{\text{K-A}}$ [mV]</th>
<th>$R_p$ [$\Omega \text{cm}^2$]</th>
<th>$i_{\text{corr}}$ [A/cm$^2$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-512</td>
<td>-399</td>
<td>3068.6</td>
<td>$8.5 \times 10^{-6}$</td>
</tr>
<tr>
<td>2</td>
<td>-520</td>
<td>-398</td>
<td>3157.7</td>
<td>$8.26 \times 10^{-6}$</td>
</tr>
<tr>
<td>3</td>
<td>-390</td>
<td>-361</td>
<td>3998</td>
<td>$6.52 \times 10^{-6}$</td>
</tr>
<tr>
<td>4</td>
<td>-384</td>
<td>-327</td>
<td>2539.4</td>
<td>$1.02 \times 10^{-5}$</td>
</tr>
</tbody>
</table>

**Fig. 5.** Polarization curves registered in the case of different thermo-chemical surface treatment of investigated steel

The hardness values measured at the surface cross section of investigated samples are presented in Fig. 6. The achieved results differ from theoretic assumption (1500HV) because the first measurement was made in point distant from the surface at 25 $\mu$m, i.e. deeper even than thickness of $\text{Al}_2\text{O}_3$ layer. It is clear that the highest hardness was measured in sample no. 2 (ab. 700HV), but generally diversity of measured hardness is caused by temperature level of additional diffusion thermo-chemical treatment (chromizing – 1050 °C; titanizing – 1000 °C; $\text{Al}_2\text{O}_3$ – 500 °C (substrate temperature)). The hardness level characteristic of the sample core (ab. 460HV) was achieved in every sample in distance 1.5 mm to the surface.

**Fig. 6.** The hardness changes measured at the samples cross sections
4. CONCLUSIONS

1. Among the applied thermo-chemical treatment the greatest lifetime of the insert of the fibres feeding channel of spinning machine guarantees the spraying with Al₂O₃ powder - after 12000 working hours there is practically no wear traces at the guiding surface.

2. The dominating factor deciding on the lifetime of the coating created on steel is probably the surface hardness and coating thickness. In the case of Al₂O₃ surface layer he highest HV10 values were measured.

3. Considering achieved results we can state that using proper surface treatment of tested steel inserts its lifetime can be increased even more than ten times.

4. There is no direct relation between the corrosion and wear resistance in analysed tribologic couple. The highest corrosion resistance was achieved for chromized steel where the lifetime was only 1500 h.

LITERATURE


