RESEARCH OF THE TRIBOLOGICAL CHARACTERISTICS OF THE COATINGS OVER 100Cr6 STEEL

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Abstract: In the current work tribological characteristics are investigated of coatings on steel 100Cr6, applied method PVD. TiN, ncAlTiN/αSi₃N₄ and ncAlCrN/αSi₃N₄ were coated. To determine the adhesion, the method by dynamically loading a diamond cone (Rockwell-C impact test) and the method of scratching (Scratch test) were used. The coatings hardness was determined by Vickers method using hardness tester FISCHERSCOPE® H100, and the coatings thickness was determined using Calotest. Based on the experimental results were identified and evaluated tribological properties of the coatings (coating adhesion, hardness and thickness) created by PVD method on 100Cr6 steel.

Keywords: Hard coatings; PVD-method; Tribological characteristics

1. Introduction

Coatings are used very widely in modern technology and lifestyle. The coating properties and selection of the method for its creation depends on the properties of the construction material (substrate) on which it is applied. Same coating applied to different construction materials or articles may have substantially different properties and uses. Therefore, the functional properties of the coatings and methods of their creation depend on the requirements which are brought into the contemporary conditions of production and operation towards structural materials. In engineering are applied mainly two types of coatings: corrosion protective and enhancing the tribological properties of the parts. Corrosion resistant coatings are designed to protect the external surfaces of the parts from the weather, to pass the required vision of the product and others. The second main type coatings are to improve the tribological properties of the working surfaces of the parts and assemblies. Generally these coatings are made of metal, but in these days mainly composite coatings are develop [1].

2. Aim of the work

The aim of current work is to study the tribological characteristics adhesion, hardness and thickness of the coatings TiN, ncAlTiN/αSi₃N₄ and ncAlCrN/αSi₃N₄, created by PVD method over substrate of 100Cr6 steel. To achieve this aim it is necessary to solve the following tasks:

1. Preparation of 100Cr6 steel samples and cover them with TiN, ncAlTiN/αSi₃N₄ and ncAlCrN/αSi₃N₄ coatings by PVD method;
2. Conducting experimental studies;
3. Analysis of the results and conclusions.

3. Hard coatings

Test samples from 100Cr6 steel (chemical composition: C-0.963%; Si-0.26%; Mn-0.61%; P-0.013%; S-0.003%; Cr-1.81%; Mo-0.22%; Cu-0.05%; Al-0.011%) have been made for carrying out the experimental tests in the form of a rectangular parallelepiped with dimensions shown in Figure 1. This steel is used for roller guides of machine tools.

Figure 1: Test samples shape and dimensions
After making the samples were heat treated in sequence: annealing (200-250 HB), hardening (61-62 HRC) and tempering (59-60 HRC). After heat treatment the samples were grind and polished.

After polishing the samples were covered with three types of PVD coatings in the Central Laboratory of Applied Physics - Plovdiv - BAS:
- ncAlTiN/αSi₃N₄, gradient nanocomposite;
- ncAlCrN/αSi₃N₄, gradient nanocomposite;
- TiN.

4 Experimental research and results

4.1. Determination of the coatings thickness

A methodology to determine the coatings thickness by local delete with rotating steel sphere was used [3]. The quantitative values of the coatings thickness over 100Cr6 steel are shown in Table 1. In Figure 2 are shown photos of the imprints to determine the thickness of coatings ncAlTiN/αSi₃N₄ and ncAlCrN/αSi₃N₄. In Figure 3 is shown a photo of the imprint to determine the thickness of the coating TiN.

Table 1: The coatings thickness over 100Cr6 steel

<table>
<thead>
<tr>
<th>Coating</th>
<th>ncAlTiN/αSi₃N₄</th>
<th>ncAlCrN/αSi₃N₄</th>
<th>TiN</th>
</tr>
</thead>
<tbody>
<tr>
<td>H_coats, µm</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

The methods used for adhesion evaluation are: a method by dynamic loading of diamond cone (Rockwell-C impact test) [4] and the method of scratching (Scratch test) [2].

4.2. Adhesion evaluation using the method of dynamic load diamond cone (Rockwell-C impact test)

Rockwell hardness tester was used equipped with diamond cone indenter loaded with 1500N load force for 10 seconds. For each coating were carried out imprints in three areas (1, 2 and 3 of Figure 4) and visualized with an optical microscope MHM-10 with 100 times magnification.

The imprints obtained for the coated samples with the coatings ncAlTiN/αSi₃N₄, ncAlCrN/αSi₃N₄, TiN and the graphic illustration of the evaluation criteria are given in figure 5, figure 6 and figure 7.

Figure 2: Photos of imprints to determine the thickness of coatings ncAlTiN/αSi₃N₄ and ncAlCrN/αSi₃N₄ over 100Cr6 steel

Figure 3: Photo of imprint to determine the thickness of coating TiN over 100Cr6 steel

Figure 5: Experimental imprints obtained for coating ncAlTiN/αSi₃N₄, compared with the adhesion evaluation criteria

Area 1

Area 2

Area 3
Figure 6: Experimental imprints obtained for coating ncAlCrN/αSi₃N₄ compared with the adhesion evaluation criteria

Figure 7: Experimental imprints obtained for coating TiN compared with the adhesion evaluation criteria

4.2.2. Determination of coatings adhesion by scratching process (Scratch test)

The results from the experimental tests are given in table 2 and represent the quantitative values of the critical loads \( F_{C1} \) - appearance of the first cracks over coating surface and \( F_{C2} \) - destruction of the coating (75% fully separated from the substrate coating).

Table 2: Quantification of the experimental results

<table>
<thead>
<tr>
<th>Coating</th>
<th>Load, N</th>
<th>( F_{C1} )</th>
<th>( F_{C2} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>ncAlTiN/αSi₃N₄</td>
<td>24</td>
<td>25</td>
<td>37</td>
</tr>
<tr>
<td>ncAlCrN/αSi₃N₄</td>
<td>38</td>
<td>52</td>
<td>65</td>
</tr>
</tbody>
</table>

The photos of the signs from Scratch test for coatings ncAlTiN/αSi₃N₄, ncAlCrN/αSi₃N₄ and TiN are shown in Figures 8, 9 and 10.

4.3. Determination of the coatings hardness

The coatings hardness was determined by Vickers method using nanohardness tester FISCHERSCOPE® H100 [5]. Obtain quantitative values for the measured parameters are given in table 3. In figure 11, figure 12 and figure 13 are given the diagrams force - deformation of indenter penetration into the coating during the hardness measurement.

Table 3: Coatings hardness over 100Cr6 steel

<table>
<thead>
<tr>
<th>Coating</th>
<th>( F ), mN</th>
<th>( H_U ), MPa</th>
<th>( H_{plast} ), MPa</th>
<th>( E^* ), GPa</th>
<th>( W_{tot} ), nJ</th>
<th>( W_r ), %</th>
</tr>
</thead>
<tbody>
<tr>
<td>ncAlTiN/αSi₃N₄</td>
<td>10</td>
<td>15912</td>
<td>19427</td>
<td>164</td>
<td>0,63</td>
<td>21,68</td>
</tr>
<tr>
<td>ncAlCrN/αSi₃N₄</td>
<td>10</td>
<td>17676</td>
<td>20695</td>
<td>181</td>
<td>0,61</td>
<td>22,67</td>
</tr>
<tr>
<td>TiN</td>
<td>10</td>
<td>23302</td>
<td>27502</td>
<td>235</td>
<td>0,60</td>
<td>27,97</td>
</tr>
</tbody>
</table>

Figure 10: Photo of the sign from Scratch test for TiN coating over 100Cr6 steel

Figure 11: Load-unloading diagram of the process for hardness measuring of ncAlTiN/αSi₃N₄ coating
2. From the obtained experimental results using Scratch test to evaluate the adhesion of ncAlTiN/αSi$_3$N$_4$, ncAlCrN/αSi$_3$N$_4$ and TiN coatings over 100Cr6 steel can be summarized as follows:

- the traces on coatings ncAlCrN/αSi$_3$N$_4$ and TiN indicate for a good adhesion evaluation. In none of the traces on the both coatings there was no presence of delamination areas and quantitative values of the strength $F_{C2}$ occur after securing 40% of the length of the trace;

- TiN coating as one of the best established, universal and commonly used coatings showed the most high power for $F_{C1}$ and $F_{C2}$:

- good performance in terms of forces $F_{C1}$ and $F_{C2}$ showed ncAlCrN/αSi$_3$N$_4$ coating;

- The forces $F_{C1}$ and $F_{C2}$ values for ncAlTiN/αSi$_3$N$_4$ coating are lowest. $F_{C2}$ occurs before securing 40% of the track length. There are also delamination areas most visibly at the end of the trace. This indicates that the adhesion of this coating is not good.

3. Tested coatings have high hardness and considering their good performance in terms of adhesion they can be offered for use in hard tribocouples.

Acknowledgments

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Reference

[1] Дишпьев С.И., Повишаване на износустойчивостта на детайли и възли на производствената техника, Дисертация, Пловдив 2012
