The influence of the arc plasma treatment on the structure and microhardness 100Cr6 bearing steel

W. Bochnowski*
Institute of Technics, Rzeszow University, Rejtana 16 C, 35-310 Rzeszow, Poland
*Corresponding author: E-mail address: wobochno@univ.rzeszow.pl

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Abstract

The effect of arc plasma treatment on structure and microhardness of 100Cr6 steel was investigated. Four different the current intensity has been used to remelting surface of the steel. SEM and LM microscopes have been used to evaluate microstructure of remelted zone (RZ). In the remelting zone (RZ) were obtained characteristic for rapid crystallization process the dendritic cell structure. Inside the dendritic cells in dependency to current intensity of arc, the martensite or bainite and retained austenite was observed. On the boundaries of the dendritic cells as a result of segregation of C and Cr the alloyed cementite is formed. The cooling rate of the remelted zone is higher than the cooling rate obtained in the classical heat treatment. The maximum hardness 840 HV0,1 was measured in material after treatment with a smaller current intensity of arc plasma – 60A. Increases of the current intensity of arc plasma from 60 A to 110 A (for fixed speed rate of source) lead to increases the depth of the remelted zone from 1,5 to 2,3 mm.

Keywords: Bearing Steel, Arc Plasma Treatment, Structure, Microhardness

1. Introduction

The bearing steel 100Cr6 is generally used for the manufacture of mechanics elements, such as balls, rollers, rings rollers, working in rolling or sliding contact. The conventional manufacturing process of bearing steels is continuous casting. Improving the properties of this steel can be obtained by applying tixoforming process [1] or spray forming process [2]. The surface of the steel can be modified by using surface engineering's techniques. Remelting of the surface layer by the source of concentrated energy (laser, electron beam or arc plasma) is applied technique to improve properties of the materials. After laser treatment of the 100Cr6 steel were obtained increase hardness, strength, wear resistance [3–8]. Possibility of shaping of the structure by surface remelting with electric arc plasma has been widely described in [9]. The method is particularly interesting for economic reason and because of it is technologic potential. The aim of this research was to study the influence of a arc plasma treatment on the change of the structure and microhardness of 100Cr6 rolling steel.

2. Material and methodology

The material used in this study was 100Cr6 bearing steel. Chemical composition of this steel is listed in Table 1. The 100Cr6 steel was cut into 30 x 30 x 10 mm samples. The samples were hardened (20 min. at 860°C – austenitization and oil quenching) and tempered (2 h at 190°C) to a hardness of
600 HV 0.1. After conventional heat treatment the surface (30 x 30 mm) of the samples were remelted with gas tungsten arc welding method used. In this experiment a THF 270 A conventional DC Tig welder was used. Four different current intensity have been used to remelting - 60, 80, 100, 110 A. Scan speed rate was fixed and was equal 0.2 m/min. The diameter of tungsten electrode was 1.6 mm and distance between surface and tungsten electrode tip was 2 mm. Assessment of surface microhardness was done by using Hanemann tester with Neophot microscope, with applied load100 g.

<table>
<thead>
<tr>
<th>Grade steels</th>
<th>C</th>
<th>Cr</th>
<th>Mn</th>
<th>Si</th>
<th>P</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000Cr6</td>
<td>1.05</td>
<td>1.75</td>
<td>0.4</td>
<td>0.22</td>
<td>0.016</td>
<td>0.009</td>
</tr>
</tbody>
</table>

Microhardness is calculated according to the Vickers formula. Microstructural characterizations were conducted using optical and scanning electron microscopy. For optical and SEM microscopy, the samples were sectioned, polished and etched in 2% solution Nital.

3. Results

After conventional heat treatment the bearing steel 100Cr6 exhibits a fine tempered martensite with carbides. The carbides have relatively spheroidal shape and diameters smaller than 2 μm. Distribution of the carbides inside martensitic matrix was even. Diameter of the grain former austenite was 10 μm. Structure of 100Cr6 steel prior to arc plasma treatment is shown in Fig.1.

Fig. 1. Structure of the 100Cr6 steel after conventional heat treatment, spheroidal carbides, tempered martensitic matrix

Arc plasma remelting of the surface layer leads to various morphologies on the cross section of sample. We can distinguish two areas: remelting zone (RZ), - area in which the crystallization occurred from the liquid, and heat affected zone (HAZ) - area in which the temperature was lower than the solidus temperature. The relationship between the current intensity of arc plasma (for fixed speed rate of source = 0.2 m/min) and depth of RZ and thickness of HAZ is showed in Table 2. With increased current the depth of the RZ increased too. The microstructure of RZ (Fig. 2) is characterized by dendritic cells and cells accompanied by the carbide phase on the dendritic crystals boundary. For all examined probes the average diameter of dendritic cells is about 10 μm. In the samples treated with arc plasma 60 and 80 A the plate martensite was observed inside dendritic cells. The martensite plates were to 10 μm long (Fig. 3). Between the plates of the martensite is visible retained austenite.

Table 2. Parameters of RZ and HAZ of 100Cr6 steel

<table>
<thead>
<tr>
<th>Current intensity [A]</th>
<th>depth of RZ (max.)</th>
<th>thickness of HAZ</th>
</tr>
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<tbody>
<tr>
<td>60</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>80</td>
<td>1.7</td>
<td>1.3</td>
</tr>
<tr>
<td>100</td>
<td>2.0</td>
<td>1.9</td>
</tr>
<tr>
<td>110</td>
<td>2.3</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Fig. 2. Remelted zone of the probes after treatment with current intensity of arc plasma – 80 A, dendritic cell, in the grain boundaries the carbide and cementite are visible

Fig. 3. Remelted zone of the probes after treatment with current intensity of arc plasma – 80 A, carbides, plate martensite and retained austenite

On the bottom of RZ on the grain boundaries of the former austenite the carbides eutectic can be observed. In this area the
diameter of the grain former austenite was 20 μm. The high thermal stresses associated with rapid solidification and cooling to ambient temperature are relieved by fracture of the RZ. In the case of deep remelting of the material (in the specimen treated with 110 A current intensity of arc plasma) the trans-crystalline cracks in the RZ was detected (Fig. 4). The crystallization crack begins at the surface and runs into the RZ. Maximum length of the crack was 500 μm. Smaller cracks (about length 50 μm) are visible inside the dendritic cells.

Microhardness measurements showed gradual hardness profiles on the cross section of treated probes Fig. 6, 7. The results show that the surface hardness of sample treated by plasma arc was higher than for the samples treated by conventional heat treatment. Microhardness of RZ is dependent on current intensity of arc plasma. High microhardness (around 840 HV0,1) was obtained for working with the current intensity 60 A. Lowest microhardness (average 630 HV0,1) of RZ was measured in sample treated plasma arc of an intensity 100 A.

![Fig. 4. RZ of the probes after treatment with current intensity of arc plasma – 100 A, trans-crystalline cracks](image)

On the base of the microhardness measurements and observations of the structure the HAZ can be divided into areas: the first area - heated to a temperature higher than Acm and hardened, the second - the area tempered. Structure of the first area consisted of plate martensite and retained austenite. Inside of the grain former austenite sporadic occurrence of carbide can be observed. The local presence of carbides in area in which the temperature was higher than the Acm temperature is results the short time of austenitizing. In the tempered area the dissolved eutectic carbides and secondary carbides in the high-tempered matrix of martensite were observed (Fig. 5). Volume fraction of carbide phase dissolved in the matrix is decreasing in the direction of the substrate of the samples.

![Fig. 5. HAZ of the probes after treatment with current intensity of arc plasma – 80 A, zone of material heated bellow A1 temperature and tempered](image)

Comparable hardness of this steel can be also obtained after the conventional heat treatment, using cooled at a rate greater than 30°C/s (Fig. 8). Use the cooling rate of 100°C/s gives the hardness approximately 800 HV (structure of martensitic and retained austenite). Increase of the current arc plasma from 60 to 110 A lead to the decrease of cooling rate. The smaller cooling rate was the reason to create structures about smaller microhardness (retained austenite, bainite). Directly under the RZ in a narrow area (approximately 500 μm) of HAZ a significant decrease of hardness was occurred in the all tested samples. The lowest hardness of HAZ (about 290 HV0,1) was measured in the
samples treated plasma arc 110 A. In the HAZ after reaching of minimum the hardness, the hardness increasing to 600 HV0.1 (hardness of substrate). This area was heated to a temperature with range: 200°C – A1 and tempered. The hardness of bearing steel after arc plasma treatment (630±840 HV0.1) is similar to the hardness obtained after laser remelting [4]. For the scanning speed 0.2 m / min, the average the time of impact of heat source on the material was 1.5 s. Obtained cooling rate (around 100°C/s) did not allow creating a structure with hardness 1400 HV01, which was measured in the 100Cr6 steel after laser treatment by author [3].

![Fig. 8. CCT diagram for a bearing 100Cr6 steel [10]](image)

### 4. Conclusions

In the remelting zone (RZ) were obtained characteristic for rapid crystallization process the dendritic cell structure. During arc plasma treatment the structure hardness obtained is higher than after conventional hardening. The best results (840 HV0.1) for hardening obtained with current intensity of arc plasma – 60 A. The cooling rate of the RZ was estimated on around 100°C/s on the basis of microhardness, structure and CCT diagram. In the subsequent tests, change of the parameters of GTAW process (speed rate, current intensity of arc plasma), should lead to increased cooling rate. Higher cooling rate of RZ will make possible to create structures about microhardness 1400, which can be received in this steel after laser treatment [3].

### References


[10] C.C.T. diagram of the 100Cr6 steel, IMS S.p.A. Special steels