Effect of the microstructure on tribological phenomena occurring on the surface of a mill roll made of SA5T cast iron (GJSL-HV600 - GJSL-330NiMoCr12-8-3)

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Abstract

This paper deals with the role of the microstructure in the tribological wear processes occurring in a cast iron mill roll. For this purpose, a piece of a broken roll, made in Italy, was collected. Its microstructure consisted of modular graphite, transformed ledeburite and a matrix composed of bainite and martensite. Metallographic investigations were performed on the roll working surface in conjunction with metallographic tests effected within its surface layer. There was established the relation between the microstructure of the roll and the process of its tribological wear. The following was ascertained: micro-shrinkages or graphite precipitations nearby the working area cause cracks between those places and the working area; in the surface layer, cracks occur usually in the zone of ledeburitic cementite. At places of considerable precipitations of ledeburitic cementite, the tribological wear intensity of the roll is lower. A banded layout of precipitations of ledeburitic cementite facilitates a selective spalling of some parts of the roll material. The results of this study allow broadening the data base related to the effect of the microstructure on tribological wear of mill rolls, which in future will permit one to design their proper microstructure of cast iron mill rolls.

Keywords: Metallography; Wear resistant alloys; Mill rolls; Mottled cast iron; Tribology.

1. Introduction

An essential problem in material technology is designing the microstructure of iron matrix cast materials from the viewpoint of their applications [1-7]. Phase Transformations Research Team of the Physical Metallurgy and Powder Metallurgy Department of the Faculty of Metals Engineering and Industrial Computer Science, University of Science and Technology in Cracow (AGH), collected the data related to tribological phenomena occurring on working surfaces of mill rolls [8-10].

Those data are to help one design new materials for the production of mill rolls characterized with optimum tribological properties. This design concerns the chemical composition as well as the microstructure of such tools [11-13]. The difficulty in preparing tribological tests to simulate the working conditions of mill rolls makes one utilize each possibility of gaining information from processing. It is yet more important that mill rolls are ranked among the most expensive tools used in metal forming.
This paper was aimed at determining the role of the microstructure in tribological wear of a cast iron roll, made in Italy, working until its breakage at CMC Zawiercie S.A.

2. Test material

This study deals with a cast iron roll, made in Italy, whose surface was damaged during its operation. That roll was made of cast iron, marked SA5T by its manufacturer. According to the manufacturer, SA5T cast iron belongs to the group of nodular acicular (nodular bainitic) cast irons. According to the rules given in PN-EN 1560, it is hard to mark such a cast iron. The standard does not provide such a complex cast iron microstructure; then, there are also problems in its unambiguous determination in view of the chemical composition. Seeing that, one might postulate a marking based upon the microstructure and properties in the form of GJSL-HV600, whereas from the viewpoint of the microstructure and chemical composition, it would read GJSL-330NiMoCr12-8-3. The marking assigned from the viewpoint of chemical composition was put forward according to the content ranges of alloy elements as specified by the manufacturer (Table 1). The chemical composition of investigated roll is given in Table 2.

Table 1.
The content ranges (weight %) of alloy elements in investigated cast iron (according to the pertinent company standard) [14]

<table>
<thead>
<tr>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.90</td>
<td>0.20</td>
<td>1.30</td>
<td>0.45</td>
<td>2.50</td>
<td>0.60</td>
</tr>
<tr>
<td>3.70</td>
<td>1.00</td>
<td>1.70</td>
<td>0.90</td>
<td>3.70</td>
<td>1.10</td>
</tr>
</tbody>
</table>

Table 2.
Chemical composition (weight %) of investigated roll

<table>
<thead>
<tr>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.45</td>
<td>0.65</td>
<td>1.40</td>
<td>0.70</td>
<td>3.07</td>
<td>0.86</td>
</tr>
</tbody>
</table>

According to the manufacturer, that roll should be characterized with hardness 72÷77 ShC (580÷64 0 HV, 545÷601 HBW – as converted according to ASTM E 140). Moreover, the manufacturer specifies the expected changes in hardness [14] in relation to the function of distance from the surface of such a roll (Fig. 1).

Tests aimed at investigating the wear process were performed on a part of the roll comprising the working surface (Fig. 2). That part was collected from the place where the roll had cracked. Fig. 3 shows the procedure for making a polished specimen for metallographic investigations.

Investigated cast iron is characterized with nodular graphite (Fig. 4). The microstructure of the roll is shown in Fig. 5. Typical are precipitation bands of ledeburitic cementite vertical to the roll working surface. Apart from precipitations of graphite and ledeburitic cementite, the matrix of investigated roll consists mainly of upper bainite. Nevertheless, there may be distinguished small areas with a microstructure typical of lower bainite, or even martensite.
3. Research results and discussion

On the roll working surface one can observe (see Fig. 2) uniformly arranged nodular shaped roughness nodes. Therefore, they can be related to microstructural components, similarly arranged on the roll surface. Microscopic observations of the roll working surface confirmed the occurrence of typical nodes of irregularities, already noticed (Fig. 6). In order to illustrate the shape of zones of lower tribological wear, they were subject to extended focus technique observations. A picture obtained this way is shown in Fig. 7.

Therefore, it can be noticed that the zones less prone to tribological wear are approximately nodular. A brighter color of the parts of tribologically worn surface, if contrasted to the matrix color, may attest that in those zones occur considerable precipitations of carbides (most probably of ledeburitic cementite).

A metallographic profile was prepared so as to determine the intensity of tribological wear of the roll at the area from which samples were taken. Fig. 8 shows the wear profile for the roll working surface. Visible are irregularities noticed before, while observing the surface of this roll (Figs. 2, 6 and 7). A strong development of the working surface is an evidence of intensive tribological wear.

Observations were performed on firstly unetched specimens, and then on etched samples (Fig. 9) were performed to determine the process of tribological wear on the roll working surface.
Fig. 9. Microstructure of the surface layer of the roll: a,c,e,g,i) unetched specimens; b,d,f,h,j) places shown on unetched specimens after their etching working surface electroplated with nickel film. Etched with 2% nital.
It can be noticed that micro-shrinkages or graphite precipitations nearby the working surface cause cracks between those places and the working surface (Figs. 9a-d,g,h). No lubricating effect of graphite (spread all over the roll working surface) was observed. Instead, graphite precipitations on the roll surface are subject to intensive tribological wear (or are burnt out); the resulting craters favor the initiation of cracks (Figs. 9c-h). Some cracks occurring in the surface layer occur in the area of ledeburitic cementite (Figs. 9c,d,g,h). Those cracks usually propagate vertically or parallelly to the roll working surface. This is probably related to the occurrence of stresses generated by overbending the roll (cracks vertical to the roller surface) and those related to the situation of the so-called Bielayev point [15] (highest tangential stresses – cracks parallel to the roll surface). Cracks vertical to the roll surface (caused by its overbending) may propagate along the banded precipitations of ledeburitic cementite (Fig. 9 i,j). The irregularities noticed on the tribologically worn roll surface (see Figs. 6 and 7) result from the distribution of ledeburitic cementite. At the places with considerable volumes of precipitations, the wearing intensity of the roll (Fig. 9f) is smaller. A banded layout of precipitations of ledeburitic cementite are precipitated, the tribological wear of the roll is lower. The role of transformed ledeburite is small additions vanadium and niobium, Archives of Foundry Engineering, vol. 7, iss. 1 (2007) 81-84.

4. Conclusions

The research results presented hereunder allow to draw the following conclusions:
1. The occurrence of semi-shrinkages or graphite precipitations nearby the roll working surface cause cracks between those places and the working surface.
2. No lubricating effect of graphite was noticed.
3. Graphite precipitations on the roll surface are subject to intensive tribological wear (or burning out), and the resulting craters facilitate the initiation of cracks.
4. Cracks occurring in the surface layer can be seen mainly in the zone of ledeburitic cementite.
5. Cracks vertical to the roll working surface (caused by its overbending) may propagate along the banded precipitations of ledeburitic cementite.
6. Irregularities / roughness noticed on the surface of the tribologically worn roll surface results from the distribution of ledeburitic cementite.
7. At the places where considerable volumes of ledeburitic cementite are precipitated, the tribological wear of the roll is lower.
8. A banded layout of precipitations of ledeburitic cementite facilitates a selective spalling of roller parts.

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References