The abrasive wear behaviour of alloy cast steel in SiC-water slurry

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Abstract

The results of abrasive wear tests carried out in an environment of SiC-water slurry on four grades of cast steel, i.e. carbon cast steel with microadditions of vanadium, low-alloy L70H2GNM cast steel, and high-alloy L120G13 cast steels, without and with microadditions of vanadium, were discussed. Tests were carried out on a Miller machine. A measure of the abrasive wear resistance was the loss of mass in specimens during 16 hour test cycle. It has been proved that the L120G13 cast steel is definitely less resistant to abrasive wear than its L70H2GNM counterpart. On the other hand, no distinct differences in the abrasive wear resistance were noticed between the L120G13 cast steel without vanadium, and the L120G13 cast steel and carbon cast steel, both with microadditions of vanadium.

Keywords: Wear resistance cast steel; Hadfield cast steels; Wear resistance

1. Introduction

The large variety of cast steel grades offering resistance to abrasive wear is determined, first of all, by the operating conditions of the cast parts. When selecting the cast steel grade, particular attention should be paid to various and complex phenomena that occur in casting during its operation (operating temperature, environment, type of forces acting between the mate parts) [1-3]. Therefore, one versatile grade of the cast steel that would satisfy equally well all the requirements of high abrasive wear resistance, irrespective of the operating environment, simply does not exist. Some grades of steel are used for castings only in well justified cases. A good example is high-alloy manganese L120G13 cast steel. It is used only for elements, like hammers, mail beaters in cement mills, parts of breakers and crushers, and lining of ball mills (fig.1) [1,3], and so in all those cases when large dynamic pressures arrest the dislocation slip, resulting in the strain hardening effect. An important drawback of the L120G13 cast steel is its relatively poor resistance to abrasive wear under low unit pressures and the operating temperatures > 300°C [4]. In spite of this, the L120G13 cast steel is subject to continuous modifications, which mainly aim at an improvement of its abrasive wear resistance, adding elements, like Cr, Ni, Mo and V [1,5]. Numerous publications also describe the technique of explosion hardening of the casting surface when castings are made from this particular material [6].

Fig. 1. A coal mill lining cast from L120G13 steel suffering heavy abrasive wear [7]
Table 1.
Chemical compositions of the investigated cast steel grades and heat treatment

<table>
<thead>
<tr>
<th>Material</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>Cr</th>
<th>other</th>
<th>heat treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - cast carbon steel</td>
<td>0.31</td>
<td>0.92</td>
<td>0.54</td>
<td>0.17</td>
<td>0.08%V</td>
<td>N,Q,T:450°C</td>
</tr>
<tr>
<td>2 - L120G13 cast steel</td>
<td>1.11</td>
<td>13.3</td>
<td>0.89</td>
<td>0.33</td>
<td>-</td>
<td>sample from the lining of a coal mill</td>
</tr>
<tr>
<td>3 - L120G13 cast steel + V</td>
<td>0.98</td>
<td>13.1</td>
<td>1.53</td>
<td>0.33</td>
<td>0.43%Ni; 0.1%V</td>
<td>solution treatment</td>
</tr>
<tr>
<td>4 - L70H2GNM cast steel</td>
<td>0.68</td>
<td>0.96</td>
<td>0.42</td>
<td>1.88</td>
<td>0.6%Ni; 0.4%Mo</td>
<td>quenching and tempering</td>
</tr>
</tbody>
</table>

The aim of the present studies was to compare the abrasive wear behaviour of two typical cast steel grades resistant to this kind of wear (L70H2GNM and L120G13) with the abrasive wear behaviour of vanadium-alloyed L120G13 cast steel and carbon cast steel characterised by high mechanical properties. In all cases, the abrasive medium was composed of hard SiC particles mixed with water [8].

2. Methods of investigation

The abrasive wear tests were carried out on a group of cast steels resistant to this type of wear. From this group the following materials were selected for investigations: the L70H2GNM cast steel and austenitic high-manganese L120G13 (Hadfield) cast steels without and with microadditions of vanadium. The abrasive wear resistance was also tested on carbon cast steel with microadditions of vanadium (designated as “1” in Table 1). The specimens originated from industrial melts. In the case of Hadfield cast steel (designated as “2” in Table 1), the specimen was cut out directly from the lining of a coal mill. The remaining cast steel grades were heat treated first, and then the specimens were taken for abrasive test. The abrasive wear resistance was tested on a Miller machine, which enabled simultaneous testing of four specimens. A sixteen hour testing cycle was carried out in SiC – water slurry (in 1:1 ratio), using specimens of 24.5x12x8 mm dimensions. During this test, the cumulative losses of mass were calculated. This was the total sum of losses starting with the constant load application registered after 4, 8, 12 and 16 hours of the cycle [9,10]. The abrasive wear rate tested on the Miller machine was calculated as a total loss of mass after 16 – hour cycle.

After the wear test, the surface of the specimens was examined under a scanning electron microscope, paying particular attention to the degree of surface degradation.

3. Results and discussion

Total changes in specimen mass when exposed to abrasive effect of SiC – water slurry during 16-hour testing cycle are plotted in Fig. 2 and 3.

Comparing the obtained results it has been noticed that the weight of the specimen taken from the coal mill lining (L120G13 cast steel) decreased by 15% respective of its initial weight. During the same time, the weight of the vanadium-alloyed L120G13 cast steel specimen decreased by 14.5%, and the specimen of carbon cast steel with microadditions of vanadium reduced its weight by 14.1%. Therefore it seems useless to apply the high-alloy L120G13 steel for castings operating under the conditions of abrasive wear induced by a mixture of hard SiC particles and water. The loss of mass was the least prominent (10.5% only) in a specimen of low-alloy L70H2GNM cast steel.

Comparing changes in the loss of mass in specimens after different number of hours of the testing cycle (4, 8, 12 and 16 hours) it has been concluded that only in the specimen of the L70H2GNM cast steel, the mass of losses was systematically decreasing in the successive hours of a testing cycle. In all other cases no such relationship was observed.

![Fig.2. Summary weight loss of investigated cast steels](image1)

![Fig.3. Changes of weight loss of investigated cast steels](image2)

The type of degradation observed in the surface layer of specimens is the result of the processes recurring in cycles and taking place in the zone of interaction between the specimen
surface and the SiC – water slurry. The processes taking place in this system (friction, decohesion, plastic deformation in the SiC – water slurry/specimen surface contact area) as well as a to-and-fro motion of the specimen promote the formation of “waves” on the surface of the examined specimens. This effect is best visible on the surface of specimens made from the L120G13 cast steel.

The preliminary visual examination of the specimen surface exposed to abrasive wear in a slurry of SiC particles and water shows a well visible plastic deformation of the surface of the high-alloy manganese L120G13 cast steel, compared to the L70H2GNM cast steel. The scanning microscopy of the specimen surface layer topography confirmed the presence of severe plastic deformation on the surface of the high-manganese cast steel before and after the inoculation with vanadium (Fig.4-6).

In the case of L70H2GNM cast steel, characterised by the lowest wear rate expressed as a total loss of mass (Fig. 3, 6), the examined surfaces did not reveal any scratches that would reflect the direction of the specimen movement during the test. Only at magnifications of 1000 and 2000x, some scarce regions indicating the direction of specimen motion during the test were observed. In low-alloy L70H2GNM cast steel no significant effect of the specimen motion during the test on the orientation of surface deformations has been reported.
In spite of severe abrasive wear, the degradation of the surface of carbon cast steel alloyed with microadditions of vanadium resembled the surface of the L70H2GNM cast steel rather than that of the L120G13 cast steel.

4. Conclusions

a) The lowest wear rate was observed in the low-alloy L70H2GNM cast steel.

b) Inoculation with vanadium of high-manganese L120G13 cast steel did not result in the expected improvement of abrasive wear resistance under the adopted test conditions. The total loss of mass decreased from 15% to 14.5%. The obtained results were comparable to the results obtained on carbon cast steel with microadditions of vanadium.

c) Under the conditions of abrasive wear, in the surface layer of the examined cast steels, plastic deformation of orientation reflecting the specimen to-and-fro motion during the test is visible. It is particularly well visible in specimens of the L120G13 cast steel.

References