Research on ion nitriding temperature effect on wear resistance of Cr12MoV steel

G.X.Pang, Z.L.Li, Z.Y.Chen

Abstract

The main purpose of this paper is to research on the different ion nitriding temperatures of Cr12MoV effect on the surface hardness, wear resistance of the work-piece. With series of experiment and test of micro-hardness, ring-block wear, metallographic observation, to select the optimization temperature for the ion nitriding process of Cr12MoV steel.

1. Introduction

Ion nitriding is one important method of chemical heat-treatment, and is with many advantages. The surface hardness, wear-resistance, fatigue strength and corrosion-resistance of the work-piece can be increased with ion nitriding (Liang jun and Lu yanjun, 2011), so it is widely applied to the cast iron, carbon steel and alloyed steel for making precision gears, shaft, cylinder, screw etc.. For Cr12MoV steel as mold steel, it requires this steel with high surface wear resistance and enough toughness in the core (), but common heat-treatment can not meet the surface properties requirement of mold steel, Ion nitriding technology can improve them, so this paper will focus on ion nitriding effect on wear resistance of Cr12MoV steel (Zhi xin, 2010, Freidrich Homebeck 2006).

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1. Experimental procedures

The Cr12MoV steel bar is as experimental material, and with process of turning and milling. The sizes of specimen are 12.5×12.5×19.2mm, then with heat-treatment of hardening (heating temperature 1050-1080°C, quenching in oil) and tempering three times in 490-520°C, with HRC62. After heat-treatment of hardening and tempering, the specimen is through finish machining to the sizes of 12.32×12.32×19.05mm, as Fig. 1.

The Taking LDM2 as the equipment for ion nitriding process. Before ion nitriding, the specimens are cleaned out oil, rust etc., then to clean the surface with the ethanol. The technique parameters of ion nitriding are: voltage 980V, air pressure 230Pa, to select conduction ration as 0.65, gas flow rate 0.35m³/h. The research temperatures of ion nitriding are in five levels, as 510°C, 520°C, 530°C, 540°C, 550°C (holding time is 6h in each process of ion nitriding)

2. Results and Discussion

2.1. The effect on the depth and hardness of ion nitrided layer with different ion nitriding temperature

The effect on the depth and hardness of ion nitrided layer with different ion nitriding temperature are illustrated on Table.1.

<table>
<thead>
<tr>
<th>Ion nitriding temperature /°C</th>
<th>The Max. hardness of ion nitrided layer /HV</th>
<th>The depth of ion nitrided layer /μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>510</td>
<td>1157.49</td>
<td>240.70</td>
</tr>
<tr>
<td>520</td>
<td>1138.62</td>
<td>241.59</td>
</tr>
<tr>
<td>530</td>
<td>1210.83</td>
<td>246.78</td>
</tr>
<tr>
<td>540</td>
<td>1154.71</td>
<td>313.27</td>
</tr>
<tr>
<td>550</td>
<td>1092.59</td>
<td>336.59</td>
</tr>
</tbody>
</table>
From Table 1, the Max. hardness of ion nitrided layer will be increased at first, and then decreased with ion nitriding temperature increased. When ion-nitriding temperature at 530°C, the surface hardness of ion nitrided-layer is gotten to Max. value. But the depth of ion nitrided is increased with ion nitriding temperature. From this result, the optimum ion nitriding temperature for Cr12MoV steel is selected as 530°C.

2.2. The microstructure of ion nitrided layer

Before ion nitriding, the specimen of Cr12MoV is treated with high temperature hardening and three times high temperature tempering, so the microstructure of base is tempered Martensite with little carbides, and the microstructure of ion nitrided layer is chemical layer (including ε phase (Fe₄N) and γ' phase(Fe₂N and Fe₃N)) and diffusion layer from the surface to the core part, shown in Fig.2. From Fig.2, the base microstructure is uniform tempered Martensite with little carbides. The white and bright layer on the right is the ion nitrided layer. There is the obvious transition area between the ion nitrided layer and the base. The depth of the ion nitrided layer is about the 0.3mm.

![Fig.2 The microstructure of Cr12MoV after ion nitriding: the base on the left, the nitrided layer of the white and bright on the right.](image)

2.3. The experiment and discussion of wear-resistance test for the ion nitrided layer

- The wear test

Taking one specimen in the optimum ion nitriding temperature (530°C), and another one specimen of without treatment of nitriding for wear-resistance test with MR-H3 block-ring wear machine, to assess their wear-resistance with weight-loss method.

<table>
<thead>
<tr>
<th>Specimen type</th>
<th>Weight before wear-test/g</th>
<th>Weight after wear-test/g</th>
<th>Weight loss/mg</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen ion nitrided (530°C)</td>
<td>21.6376</td>
<td>21.6373</td>
<td>0.3</td>
<td>Little weight-loss, non-obvious wear</td>
</tr>
<tr>
<td>Specimen without treatment of ion nitriding</td>
<td>21.5689</td>
<td>21.5580</td>
<td>10.9</td>
<td>With weight-loss, and obvious wear traces</td>
</tr>
</tbody>
</table>

From table 2, the weight-loss of ion nitrided specimen is not obvious before and after wear-test, that is, its wear-resistance is very high, but the weight-loss of the specimen without treatment of ion nitriding is very obvious, even caused adhesive wear appearance after the period of experiment operation. The wear-resistance of the ion nitrided specimen of Cr12MoV steel is increased 36.3 times compared with specimen without treatment of ion nitriding.

- The discussion for the worn surface

The worn surfaces are investigated with SEM (S-3400N) in low and high amplification factor for the nitrided specimen and the specimen without ion nitriding of Cr12MoV steel, shown in Fig.3 and Fig.4.
The worn surface with SEM indicates further that the wear-resistance of ion nitrided specimen of Cr12MoV steel is increased obviously. The worn surface of ion nitrided specimen with SEM in low amplification factor shows regular long narrow strip trace, but the worn surface of specimen without treatment of ion nitriding shows irregular long narrow strip trace. The worn surface of ion nitrided specimen with SEM in high amplification factor shows still regular long narrow strip trace, but the worn surface of specimen without treatment of ion nitriding shows full of bumps and hollows trace and even the part of material in the area is lost, to demonstrate the adhesive wear happened.

3. Conclusions

(1) In this experiment, the surface hardness of the nitrided specimen is increased obviously. In condition of ion nitriding temperature at 530°C, the hardness of nitrided layer may get Max. 1210.83HV, the depth may get Max. 0.247mm.

(2) The wear-resistance of ion nitrided Cr12MoV steel specimen is increased 14 times compared with specimen without treatment of ion nitriding.

Acknowledgements

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