THE INFLUENCE OF CARBIDE DISTRIBUTION ON THE PROPERTIES OF HOT WORK TOOL STEELS

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Abstract
Essentially, hot work tool steels are expected to resist high temperature in working conditions. Although tempered martensitic structure in hot work tool steels is the most important property that helps achieving high temperature resistance, distribution characteristic of carbides have great effect on this issue as well. Coarser carbides (especially) segregated in grain boundaries increase the brittleness of material and result in premature failure of dies. In contrast, homogeneously dispersed finer carbides provides higher toughness and increase in high temperature resistance.

In this study, carbide distribution in hot work tool steels have been modified and the results have been examined in terms of microstructural and mechanical investigations. The results have shown that gradual cooling carried out before tempering was a successful approach to achieve finer carbides (which is ideal) to increase toughness at elevated temperatures.

1. INTRODUCTION
Hot work tool steels enable the hot-forming of work-pieces made of iron and non-ferrous metals as well as alloy derivatives at high temperatures. They are utilized in processes such as pressure die casting, extrusion and drop forging as well as in tube and glass manufacturing (WILMES et al., 1990)

In hot work applications very high demands on elevated temperature properties are necessary to resist the high and varying levels of mechanical and thermal stresses. Character of microstructure and mechanical properties of hot work tool steels are primarily determined by the heat treatment and alloying processes. These two processes are both complementary for the production.

The die life in forging applications is normally limited by hot wear, gross cracking and plastic deformation. A condition for consistent and high level of performance is the use of premium hot-work tool steel with a property profile characterized by high and isotropic ductility and toughness properties at elevated temperature, high hardenability to ensure the properties also in the biggest dimensions, high hot strength properties and ability to retain strength at elevated temperature and good thermal conductivity (WILMES et al. 1990, GÜMPEL et al. 2002, HABERLING et al. 1985).

However, tool failure may occur even if a premium die steel is used. Several other factors as heat treatment procedure, tool design and of course the production conditions must be considered and optimized for specific tooling application (SANDBERG et al. 1990).

Chromium group of the H10 to H19 steels contains chromium with, in certain cases, additions of tungsten, molybdenum, vanadium and cobalt. The carbon in this group is held relatively low, around 0.35-0.40 per cent, and this, together with the relatively low total alloy content, promotes toughness at the normal working hardness of between 400 and 600 HV.

The high chromium in this group, coupled with low carbon, ensures depth hardening, therefore these steels may be air hardened to full working hardness in sections up to 30 cm. The higher tungsten and molybdenum contents of the H10 and H14 steels increase the red hardness and hot strength, but tend to slightly reduce toughness.

In this group the H11, H12 and H13 steels possibly represent the greatest tonnage used in all hot work die steels. The air hardening qualities and balanced alloy content are responsible for low
distortion in hardening. These grades are especially adapted to hot die work of all kinds, particularly white metal extrusion dies and die casting dies, forging dies, mandrels and hot shears. The chief advantage of this group is ability to resist continued exposure to temperature up to 540 °C, and at the same time, provide a tough and ductile tool with tensile strength levels of ~5 MPa at this temperature.

Chromium produces deeper hardness penetration in heat treatment and contributes wear resistance and toughness. Molybdenum increases the hardness penetration in heat treatment and reduces quenching temperatures. It also helps increase red hardness and wear resistance. So that AISI 2367 tool steel was chosen in this study to reflect the effect of carbide characteristics.

2. EXPERIMENTAL PROCEDURE

In this study AISI 2367 tool steel was investigated. The composition of specimens were given in Table 1.

Table 1. Chemical composition of tool steels used in experiments

<table>
<thead>
<tr>
<th>Chemical Composition (%)</th>
<th>C</th>
<th>Cr</th>
<th>Mo</th>
<th>Mn</th>
<th>V</th>
<th>Si</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>0.37</td>
<td>4.90</td>
<td>2.90</td>
<td>0.45</td>
<td>0.61</td>
<td>0.42</td>
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</table>

Specimens were machined into 70x70x25 mm dimensions. All specimens were austenitized 90 min at 1050 °C in vacuum furnace (nitrogen atmosphere). After austenitization, specimens were subjected to two different cooling procedures. Specimens were then tempered in 2 different tempering temperatures as well. Details of process parameters were given in Table 2.

Secondary hardening is a result of tempering carried out after austenitization which is followed by rapid cooling resulting of austenite formation. Holding at 600 °C provides formation of secondary carbides before tempering stage. Thus, while the amount of carbides increase the size of carbides decrease. Finer carbides formed in this stage results in higher hardness and toughness.

Group 2 specimens were processed by a holding stage related to theory above according to parameters given in Table 2.

Table 2. Heat treatment parameters of tool steels

<table>
<thead>
<tr>
<th>Group No</th>
<th>Heat Treatment Stage</th>
<th>Temperature (°C)</th>
<th>Time (min)</th>
<th>Atmosphere</th>
<th>Cooling Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Austenitization</td>
<td>1050</td>
<td>90</td>
<td>Vacuum (N₂)</td>
<td>Rapid Quenched</td>
</tr>
<tr>
<td></td>
<td>Tempering 1</td>
<td>500</td>
<td>120</td>
<td>Vacuum (N₂)</td>
<td>Standard (~20 °C/min)</td>
</tr>
<tr>
<td></td>
<td>Tempering 2</td>
<td>600</td>
<td>120</td>
<td>Vacuum (N₂)</td>
<td>Standard (~20 °C/min)</td>
</tr>
<tr>
<td>2</td>
<td>Austenitization</td>
<td>1050</td>
<td>90</td>
<td>Vacuum (N₂)</td>
<td>Rapid quenched to 600 °C (held for 220 min) then cooled to room temperature</td>
</tr>
<tr>
<td></td>
<td>Tempering 1</td>
<td>500</td>
<td>120</td>
<td>Vacuum (N₂)</td>
<td>Standard (~20 °C/min)</td>
</tr>
<tr>
<td></td>
<td>Tempering 2</td>
<td>600</td>
<td>120</td>
<td>Vacuum (N₂)</td>
<td>Standard (~20 °C/min)</td>
</tr>
</tbody>
</table>

Specimens were examined using optical microscopy and Rockwell Hardness method.
3. RESULTS AND DISCUSSION

Microstructural examination has shown that the amount of austenite decreased when the tempering was carried out at higher temperature. Furthermore, the amount of austenite also decreases more on the specimens processed at 600 °C before tempering. This was caused by the formation of secondary carbides in an early stage.

Figure 1. (a) Group 1 specimen which was processed by a holding stage (at 600 °C) then tempered at 500 °C, (b) Group 2 specimen which was directly tempered at 500 °C (100X)

The size of carbides also decreased by the increase of tempering temperature. The total effect of increasing tempering temperature and pre-processing was found greater than the individual effect of increasing tempering temperature in terms of both particle size and amount of carbides.

Both Figure 1 and Figure 2 show the difference of carbidic structure and amount of austenite due to tempering temperature and pre-processing carried out at 600 °C.

Figure 2. (a) Group 1 specimen which was processed by a holding stage (at 600 °C) then tempered at 600 °C, (b) Group 2 specimen which was directly tempered at 600 °C (100X).

The effect of pre-processing is also obvious on the hardness distribution diagram. Hardness evaluation has shown that holding process carried out before tempering has resulted in approximately 4 HRC increase (Figure 3).
Figure 3. Hardness distribution of specimens tempered at 500 °C and 600 °C. Dashed red line exhibits the hardness distribution of specimens processed at 600 °C before tempering.

LITERATURE REFERENCES


