CONSTRUCTIONAL STEELS


EFFECT OF THE COMPOSITION ON THE HARDENABILITY AND PROPERTIES OF COMPLEXLY ALLOYED STEEL FOR LARGE-SIZE PARTS

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Large-size parts are usually produced from steels with high hardenability. Intermediate-carbon improved chromium-nickel steels containing 1 – 3% Ni are used successfully for this purpose in Ukraine and in foreign countries. However, nickel is an expensive and scarce alloying element. The present work is devoted to steels with different compositions with the aim of choosing the most suitable one for large-size parts. The effect of alloying elements on the hardenability and mechanical properties of steels is investigated. A mathematical model is obtained.

Investigators from different countries have attempted to develop low-nickel and nickel-free compositions with high hardenability. In our country the problem was solved successfully at the Novokramatorsk Machine Building Plant at the beginning of the 1960s [1]. Nickel-free steels 30KhGVT and 30Kh2GMT were developed and widely used for a number of years. Later, investigators from the Urals [2, 3] suggested steels with a low content of nickel. At present the Novokramatorsk Plant (NKMZ) uses 35Kh2N2M steel instead of 34KhN3M, which results in a certain reduction in the consumption of nickel (see Table 1).

The present work is aimed at further optimization of the composition of complexly alloyed steels with deep hardenability for the production of large parts. We solved two problems, namely, (1) evaluation of the effect of the principal alloying elements on the hardenability of improved steels by developing the appropriate mathematical model and (2) experimental estimation of the effect of the alloying elements on the mechanical properties with modeling of the heat treatment of a part having a cross section of 1000 mm.

The first problem was solved by analyzing the thermokinetic diagrams of the decomposition of austenite presented in [4] and implemented at the NKMZ. We analyzed 74 diagrams for steels containing different amounts of chromium, manganese, silicon, nickel, and molybdenum. The hardenability was evaluated by the time of minimum stability of

Table 1

<table>
<thead>
<tr>
<th>Steel</th>
<th>C</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>Mn</th>
<th>Ti</th>
<th>Si</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>30KhGVT</td>
<td>0.28 - 0.35</td>
<td>0.9 - 1.2</td>
<td>-</td>
<td>-</td>
<td>1.0 - 1.2</td>
<td>0.05 - 0.10</td>
<td>0.17 - 0.37</td>
<td>0.7 - 0.9</td>
</tr>
<tr>
<td>30Kh2GMT</td>
<td>0.28 - 0.35</td>
<td>1.7 - 2.0</td>
<td>-</td>
<td>0.40 - 0.60</td>
<td>1.1 - 1.3</td>
<td>0.02 - 0.08</td>
<td>0.17 - 0.37</td>
<td>-</td>
</tr>
<tr>
<td>34KhN3M</td>
<td>0.37</td>
<td>0.9</td>
<td>3.1</td>
<td>0.35</td>
<td>0.41</td>
<td>-</td>
<td>0.36</td>
<td>-</td>
</tr>
<tr>
<td>35Kh2N2M</td>
<td>0.32</td>
<td>1.7</td>
<td>1.9</td>
<td>-</td>
<td>0.50</td>
<td>-</td>
<td>0.21</td>
<td>-</td>
</tr>
</tbody>
</table>
The relationship between the bainitic hardenability evaluated by the logarithm of the time of minimum stability of austenite in the bainitic region and the chemical composition turned out to be less obvious. The value of the multiple correlation coefficient is 0.74, which corresponds to a 55% fraction of the explained variance. We obtained the following regressions:

\[
\log \tau_p = 3.04 + 3.77C' + 0.95Mn' + 0.90Cr' + 1.18Ni' + 1.90Mo' + 0.0024dT - 0.98(Si')^2 + 2.46(Mn')^2 + 7.16(V')^2 - 10.46Mn'Cr' + 1.91Mn'Ni' - 16.59V'Si' + 1.91Mn'Cr' + 1.83Mn'Ni' - 4.52Mn'V' + 1.24Cr'Ni' - 2.07Ni'Mo';
\]

and

\[
\log \tau_B = 1.56 + 2.98C' + 0.37Cr' + 1.70Mo' + 0.84Si'Cr' - 7.03Si'V',
\]

where \(C', Mn', Cr', Ni', Mo', Si',\) and \(V'\) are the differences between the actual content of the elements in a charge and their mean concentrations in the mixture. The mean concentrations of elements are 0.37% C, 0.82% Mn, 1.20% Cr, 0.72% Ni, 0.26% Mo, 0.43% Si, and 0.87% V.

An analysis of the values of partial correlation coefficients shows that the relationship between the pearlitic hardenability and the concentrations of nickel and chromium is the closest, which corresponds to existing concepts. The relationship between the pearlitic hardenability and the concentrations of carbon and molybdenum is less close, and that for