MANUFACTURING HYPEREUTECTOID STEEL FOR MAKING FORGED FORMING ROLLS

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Abstract

The article presents high-carbon hypereutectoid steel for the production of hot rolling forged rolls. The steel contains 1.2 – 1.4 % carbon, carbide forming alloying elements Cr, Mo, V and Nb to improve the wear resistance of the roll, and Ni to increase the hardenability.

Hot ductility of the steel has been investigated considering segregation of chemical elements in ingots weighing up to 20 tons. It has been found that the possesses steel presented ductility sufficient for hot deformation (forging) with small single compressions. The temperature range of deformation ingot has been found: finite temperature deformation should not be below 900 °C, the temperature of the forging – 1150 °C.

The critical points of steel have been determined. It has been established that the transformation range is located in the AC1 temperature 750 – 790 °C. The optimum austenitizing temperature is in the range 850-880 (900) °C. The increased hardness of the hot rolling rolls of the steel (250 – 350 HB) should be provided by the normalization with temper.

The steel hardenability has been determined by the end-quench-test due to Jominy method using specimens 25 mm in diameter and 100 mm length after heating to temperatures up to 850 and 900 °C. It has been shown that the introduction of Nb in steel increases the depth of the hardened layer.

According to its properties steel C1.4Cr2NiMoWB can be recommended for manufacturing solid-forged rolls and bandages for composite rolls of hot rolling process from ingots weighing up to 10 tons.

Keywords: high-carbon hypereutectoid steel, hot forged rolls, increased hardness

1. INTRODUCTION

Operating resistance of rolls hot rolling is determined by abrasion resistance, hardness, heat resistance of rolls material under frequent temperature changes in their surface layer, as well as static strength (resistance to breakage). Required characteristics of the chemical composition of the material provided by the rolls and technology of their production.

The main materials for the manufacture of hot rolling forged rolls are generally type of chromium-nickel steel and C0.5CrNi, C0.6CrNi and steel contenting a higher carbon C0.75CrNiMo, C0.9Cr2, C0.9CrW and C0.9Cr2MoW etc. One of the key elements to determine the operational stability of the rolls is the carbon. Carbon content of forged rollers is before 0.85 - 0.95 % normally.

In recent years there is a tendency to increase the carbon content in of forged hot rolling rolls. Thus in the Central Research Institute of Heavy Engineering (USSR) steel C3CrNiMoW was developed in 1973-74 [1] (1,00 % C) to provide higher resistance of rolls in industrial environments. Later [2], this steel has been used for the manufacture of bandages of vertical rolls Universal broad camp “Nizhny Tagil Iron and Steel Works”. In 1984 C1.1Cr2WB for the production of forged rolls (1,10% C) containing niobium has been developed by Uralmashplant and USTU named S.M. Kirova [3]. It is found that the introduction of niobium in the steel in an amount of 0,02-0,05 % improves hot ductility, heat resistance and hardenability. The strength and ductility of
steel alloy niobium exceeds conventional steel C0,9Cr2MoW especially at elevated temperatures (about 500 °C).

Forged rolls have more higher strength and the same have a significant advantage over the cast. However, the application for the production of forged rolls hypereutectoid steels with higher carbon content (such C1,5CrNiMo) encounters the technological problems of low deformability of large ingots. Experience has shown that the forging of ingots steel C1,5CrNiMo carries a higher fracturing and increased labor costs for the forging in 2.0 - 2.5 times.

2. SELECTION OF THE OPTIMAL COMPOSITION OF THE STEEL

According to low our task was the development of endurance of hypereutectoid steel suitable for the manufacture of forged hot rolling rolls and bandages. Steel C1,5CrNiMo ( 1.4 ... 1.6 % C , 0.8 ... 1.25% Cr, 0.8 ... 1.25% Ni, 0.1 ... 0.3% Mo) was based at which was reduced carbon content of 1.2-1.4 % for giving greater ability to deform hot steel. In order to increase the content of carbides in the steel the chromium content is increased to 1.4 - 1.7% and strong carbide forming elements vanadium, niobium is added and providing reception grained sufficiently hard, wear-resistant steel structure, and hence increase the performance properties of the rolls.

In the final version steel C1,4CrNiMoWB was proposed containing 1.2...1.4 % C; 0,2...0,5% Si; 0,5...0,8% Mn; 1,4...1,7% Cr; 0,6...0,9% Ni; 0,1...0,3% Mo, and the summary average content of vanadium and niobium is given by (V + Nb) = C/12,where in V, Nb, and C - the average content of vanadium , niobium, and carbon in % respectively. The mean content of vanadium should be 2-2.5 times greater than niobium.

2.1. Definition of plasticity

To investigate the processing and performance properties of the proposed steel series of heats is smelted, chemical composition and function of which are shown in Table 1.

Table 1 Chemical composition of experimental heats (wt.%)

<table>
<thead>
<tr>
<th>Composition</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>V</th>
<th>Nb</th>
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<tr>
<td>A</td>
<td>1.42</td>
<td>0.50</td>
<td>0.50</td>
<td>0.016</td>
<td>0.025</td>
<td>1.43</td>
<td>0.11</td>
<td>0.60</td>
<td>0.12</td>
<td>0.044</td>
</tr>
<tr>
<td>B</td>
<td>1.14</td>
<td>0.42</td>
<td>0.66</td>
<td>0.015</td>
<td>0.027</td>
<td>2.07</td>
<td>0.40</td>
<td>0.24</td>
<td>0.21</td>
<td>-</td>
</tr>
<tr>
<td>C</td>
<td>1.46</td>
<td>0.44</td>
<td>0.68</td>
<td>0.035</td>
<td>0.035</td>
<td>2.42</td>
<td>0.45</td>
<td>0.30</td>
<td>0.28</td>
<td>-</td>
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<tr>
<td>D</td>
<td>1.72</td>
<td>0.48</td>
<td>0.67</td>
<td>0.052</td>
<td>0.049</td>
<td>2.71</td>
<td>0.53</td>
<td>0.36</td>
<td>0.37</td>
<td>-</td>
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<tr>
<td>A</td>
<td>1.42</td>
<td>0.50</td>
<td>0.50</td>
<td>0.016</td>
<td>0.025</td>
<td>1.43</td>
<td>0.11</td>
<td>0.60</td>
<td>0.12</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>1.39</td>
<td>0.36</td>
<td>0.41</td>
<td>0.015</td>
<td>0.018</td>
<td>1.72</td>
<td>0.16</td>
<td>0.60</td>
<td>0.10</td>
<td>-</td>
</tr>
<tr>
<td>F</td>
<td>1.20</td>
<td>0.42</td>
<td>0.90</td>
<td>0.014</td>
<td>0.020</td>
<td>1.58</td>
<td>0.16</td>
<td>0.78</td>
<td>0.13</td>
<td>0.023</td>
</tr>
<tr>
<td>H</td>
<td>1.35</td>
<td>0.41</td>
<td>0.78</td>
<td>0.016</td>
<td>0.021</td>
<td>1.69</td>
<td>0.15</td>
<td>0.80</td>
<td>0.14</td>
<td>0.033</td>
</tr>
</tbody>
</table>

In the first step ductility smelting after rolling the cast wedge samples[4] was investigated to have a base sample composition A. The heating was performed in an electric furnace at temperatures 1150 and 1180 °C delayed 30 minutes, after which cooling was carried out in the test furnace to a temperature (rolling), followed by holding at this temperature and for 30 minutes.
The plasticity was evaluated by the degree of \( \Delta p \) shear strain to failure in the formulation of V.L. Kolmogorov [5]. According to test results of the plasticity diagram (Fig.1), which implies that the steel C1,4Cr2NiMoW has reduced ductility, but sufficient for hot deformation (forging) with small single compressions.

For steel, characterized by a sharp drop in ductility with decreasing temperature. End temperature deformation should not be below 900 °C, the temperature at 1150 °C. Heating to higher temperatures (1180°C) leads to a slight reduction of ductility. In industrial environments due to increasing mass and volume ingots for forging rolls increases segregation of chemical elements missing from the test samples. According to previous studies [6], in the axial zone of ingot sinkhead weighing 7.6 tons C0,9Cr2 steel carbon content, sulfur and phosphorus melting average may exceed in 1.2 times or more. In ingots has greater mass, segregation is even more important.

To assess the level of ductility of the metal in the axial zone of the actual ingots ductility metal three melting were investigated (compositions B, C, D). In the chemical composition B corresponds to that melting of metal near the surface, the chemical composition of the melting D - composition of individual sections of the axial zone of the large (up to 20 tons) ingot. This section usually enriched not only with carbon, but impurities (S, P) and the alloying elements (Cr, Mo, V). Composition C occupies an intermediate position on the content of these elements.

As described above diagrams of metal plasticity these three compounds was obtained (Fig. 2). From the analysis of that metal in the axial zone of the ingot has a large level of ductility in 3 - 5 times, but lower than the metal near the surface, and allowed to heat up to a temperature not higher than 1150 °C, and deformation of the metal in the axial zone is associated with a danger of destruction. Start temperature of the metal deformation in this zone should not exceed 1100 - 1050°C.

2.2. Definition of critical points

According to the immiscibility of chemical elements ingots [6], and experimental data, we can conclude that the forging rollers of high-carbon steels with a carbon content of 1.2 - 1.4% of the ingot weight can be not more than 10 tons. Application of larger ingots entail increased defect of forged rolls due to crack.

Dilatometric definition of critical points of the steel C1,4Cr2NiMoWB was performed. It was established that the transformation range is located in the \( A_{C1} \) temperature 750 - 790°C. Optimum austenitizing temperature is in the range 850-880 (900) °C. The increased hardness of the hot rolling rolls of the steel (250 - 350 HB) should be provided by normalization with tempering.
Fig. 2 Ductility diagrams of cast steel melting B, C, D (Table 1) after heating to a temperature of 1150 °C (1) 1200 °C and (2).

The steel hardenability has been determined by the end-quench-test due to Jominy method using specimens 25 mm in diameter and 100 mm length after heating to temperatures up to 850 and 900°C. Hardenability curves (Fig.3) show that the depth of hardened layer of steel with niobium (composition H) is greater than the steel not containing Nb (composition E). The depth of the hardened layer increases with increasing heating temperature of 850 °C to 900 °C in both cases H and E.

Fig. 3 The hardenability of steel by the method Jominy: 1 - heating up to 900 °C, 2 - heating up to 850 °C.

2.3. Definition of strength characteristics

Tests of mechanical properties were carried out to assess the thermal stability on the tensile in accordance with GOST 9651-84. Test specimens was made of rods subjected to triple normalization (last - from 900 °C followed by tempering at 600 °C). The dependence of the mechanical properties of the steel temperature of two compositions is shown in Fig. 4.
The change in strength characteristics of a metal melting E with higher carbon content (1.39 %), but no niobium is different than the metal melting F low carbon (1.20 %), but with niobium. In the first case, starting from 300 - 400 °C there is a decrease dimension $\sigma_v$ and $\sigma_{0.2}$. In the second case, smelting with niobium, reduction of these characteristics begins above 400 °C ($\sigma_v$) and 500 °C ($\sigma_{0.2}$). Thus these results confirmed earlier tests - the addition of niobium increases the heat resistance steel type C1.4Cr2NiMoWB.

Resistance of steels to abrasion was investigated by special unit. Abrasion resistance was evaluated by the loss in weight of the steel plates after a certain amount of abrasion of the sand. The experimental results (Table 2) confirmed that the wear resistance of steels is determined by the contents of carbon mainly and hence by amount contained in the structure of the carbide phase.

<table>
<thead>
<tr>
<th>Provisional title of the steel</th>
<th>Carbon content , %</th>
<th>Loss in weight of steel plates, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1.5Cr2NiMo</td>
<td>1.50</td>
<td>0.191</td>
</tr>
<tr>
<td>C1.4Cr2NiMoWB</td>
<td>1.42</td>
<td>0.227</td>
</tr>
<tr>
<td>C1.4Cr2NiMoW</td>
<td>1.39</td>
<td>0.237</td>
</tr>
<tr>
<td>C1.4CrNiMo</td>
<td>1.38</td>
<td>0.261</td>
</tr>
<tr>
<td>C1.2Cr2NiMoWB</td>
<td>1.20</td>
<td>0.281</td>
</tr>
</tbody>
</table>

3. **CONCLUSION**

Thus a study of technological and operational characteristics of the steel type C1.4Cr2NiMoWB found that when the carbon content to 1.4% of the steel has a ductility sufficient for hot deformation (forging) a single small compressions in the temperature range 1150 – 900 °C. The main type of heat treatment of rollers for increased hardness (HB 250 ... 350) should be with normalization with tempering. Investigated steel retains
a high level of strength characteristics at least to a temperature of 500 °C. Steels suitable for the manufacture of small dimensions rolls and for the manufacture of bandages for forged composite rollers mainly, for rollers of the secondary cooling line continuous casting machine, etc.

The results of studies was designed heating modes for forging ingots weighing 5.5 - 10.0 tons, forging technology work rolls and bandages for composite rolls, as well as primary modes of heat treatment and final heat treatment forged rolls and bandages on the hardness of HB 350 285.

LITERATURE