SPECIAL FEATURES OF THE $\alpha \rightarrow \gamma$ TRANSFORMATION IN POWDER CARBON STEELS

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The structural state of powder steels after sintering depends on the technological regimes of their production and can markedly affect the transformations in subsequent heat treatment. The effect of the technological regimes on the nature of the $\alpha \rightarrow \gamma$ transformation is investigated.

We investigated the effect of sintering regimes on the transformations in powder carbon steels with different densities. Steel specimens were prepared from a mixture of powders of commercial iron PZh4M2 and dry colloidal-graphite agent C-1. The specimens were pressed at 500 and 800 N/mm$^2$ and sintered in a hydrogen medium (with a dew point $t_{dp} = -35^\circ C$) at 1100 and 1200$^\circ C$ for 1 - 4 h. Basic results were obtained for steels with the technological regimes, densities, and chemical compositions presented in Table 1. In order to check the results obtained we prepared specimens of powder carbon steels with 0.2 - 0.6% C using an identical technology of single pressing at 100 - 800 N/mm$^2$ and a sintering temperature of 1150$^\circ C$.

The kinetic parameters of the austenitization process, namely, the rate of initiation of centers ($v_{c.i}$) and the linear rate of growth of nuclei ($v_{n.g}$), were determined by the method described in [1]. The temperature of the critical points was determined using a UVD dilatometer in vacuum and by differential thermal analysis (DTA) using a Q-1500 derivatograph in a medium of purified argon. The kinetics of the $\alpha \rightarrow \gamma$ transformation was studied by the method of high-temperature x-ray analysis in a UVD-2000 chamber on a DRON-2 installation. We also conducted a metallographic investigation of specimens hardened after different holds. The heating rate in the determination of critical temperatures was 5 - 6$^\circ C$/min, and the temperature of the isothermal hold in the investigation of the kinetics of the transformation was $t_{th} = Ac_1 + (10 - 12)^\circ C$.

The structure of the sintered steels was a ferrite-pearlite mixture with different proportions of the components. An increase in the sintering time was accompanied by an increase in the fraction of the eutectoid. For steel sintered for 4 h at 1100$^\circ C$ the amount of pearlite corresponded to the theoretical value (with respect to the carbon content). The amount of abnormal segregations of cementite in the ferrite matrix decreased correspondingly. A similar effect on the structure was exerted by an increase in the sintering temperature.

In the critical temperature range the DTA curves had two intervals corresponding to the occurrence of endothermic reactions (Fig. 1). The low-temperature peak coincides with the appearance of an isothermal area on the thermal curve and is caused by the formation of austenite from the eutectoid (close to $Ac_1$). The second peak is extended in a rather wide temperature range and its end corresponds to the position of the point $Ac_3 = 835^\circ C$, determined by a dilatometric method. It

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|c|}
\hline
Sintering & $p$, N/mm$^2$ & $t_{sint}$, °C & $t_{th}$, h & $\rho_{rel}$, % & Content of elements, % & \\
regime & \ & \ & \ & \ & C$_{tot}$ & C$_{f}$ & O \\
\hline
1 & 800 & 1100 & 1 & 84 & 0.41 & 0.069 & 0.05 \\
2 & 800 & 1100 & 2 & 85 & 0.38 & 0.057 & 0.08 \\
3 & 800 & 1100 & 4 & 86 & 0.41 & 0.038 & 0.07 \\
4 & 800 & 1200 & 2 & 80 & 0.30 & 0.020 & 0.04 \\
5 & 800 & 1200 & 2 & 85 & 0.35 & 0.017 & 0.05 \\
6 & 800 x 2 & 1200 & 2 & 88 & 0.34 & 0.010 & 0.04 \\
\hline
\end{tabular}
\caption{Table 1}
\end{table}

Note. Before sintering the steel by regime 6 we conducted a double pressing at $p = 800$ N/mm$^2$ with an intermediate annealing of the specimens at 850$^\circ C$ for 0.5 h.
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seems that due to the high heating rate austenite is not depleted of carbon and ferrite is preserved up to $A_\gamma$.

Similar results were obtained in the DTA of powder steels with carbon concentrations equal to 0.2, 0.4, and 0.6%. It should be noted that the effect of the separation of the range $A_\gamma - A_\alpha$ into two regions in compact carbon steels seems to have been discovered for the first time by the authors of [2, 3], and its special features were considered by the author of [4]. As the carbon concentration is increased to 0.35%, this effect disappears. In powder steels the separation of the range $A_\gamma - A_\alpha$ into two regions is preserved up to 0.6% C, which seems to indicate an elevated inhomogeneity of the carbon distribution in them.

A characteristic feature of the process of isothermal formation of austenite is the presence of a maximum on the kinetic curves of the steels. Figure 2 shows kinetic curves of formation of $\gamma$-phase in steel with 0.35% C sintered at 1100°C for different times. In all the steels the proportion of austenite formed during the initial 15 - 20 min exceeds that calculated from the equilibrium diagram. As the hold at 735°C is increased further, the amount of austenite in the steels decreases. A similar kinetics of the austenitization process is observed in steels sintered at a higher temperature and having a higher density (Fig. 3).

The austenitization kinetics was investigated at a temperature exceeding $A_\gamma$ somewhat, and therefore the $\alpha \rightarrow \gamma$ transformation could be expected to occur in the eutectoid component only. However, the amount of austenite formed in the steels in the initial 15 - 20 min exceeded the equilibrium value. The difference between the actual amount of austenite and the equilibrium amount will be called excess austenite. Since the steels were prepared by different regimes, their initial structures and densities differed, and so it was of interest to determine the effect of the sintering temperature and time and the density of the material on the amount of excess austenite (Table 2). As the sintering time at 1100°C was increased from 1 to 4 h, the proportion of excess austenite de-

**TABLE 2**

<table>
<thead>
<tr>
<th>Sintering regime</th>
<th>$\rho_{rel}$</th>
<th>$P$</th>
<th>$\gamma_{max}$</th>
<th>$\gamma_{ex}$</th>
</tr>
</thead>
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<tr>
<td>1</td>
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<td>38</td>
<td>78</td>
<td>40</td>
</tr>
</tbody>
</table>

Notation. $\rho_{rel}$ relative density of the steel; $P$ pearlite; $\gamma_{max}$ maximum amount of austenite; $\gamma_{ex}$ proportion of excess austenite.