According to Eq. (1), the pseudopotential of manganese is smaller than that of iron, both because of the lower valency and the larger radius R^2_{sh}. Consequently, the amplitude of scattering in the field of the manganese ion is smaller than in the field of the iron ion. Therefore, when iron atoms are replaced with manganese atoms the diffusion of nitrogen ions in the lattice improves and the solubility increases. Chromium atoms have a similar effect.

The anomalous curves of the F–R peak can be explained on this basis. The larger the quantity of manganese and chromium in the steel, the larger the number of nitrogen atoms they hold around them. Nitrogen atoms vibrate not only in positions with iron but also with manganese and chromium. The interactions of nitrogen with these elements are similar, but the activation energies of the processes differ. Superposed on each other, the relaxation spectra give a broad F–R peak. In steel 03Kh20N16AG6 the interaction of nitrogen with manganese is so large that it leads to an anomalous shape of the F–R peak (more a plateau). In steel 03Kh19N7AG10, with 10% Mn, the F–R peak is divided into two distinct subpeaks.

CONCLUSIONS

1. It was shown by experiments with four austenitic Cr–Ni stainless steels that with increasing manganese concentrations the solubility of nitrogen increases.

2. With increasing concentrations of manganese the shape of the F–R peak on the TDIF curves is distorted – broadened, transformed into a plateau, or divided into two subpeaks (for steel with 10% Mn).

3. Using the theory of pseudopotentials, we attempted to explain the anomalous form of the TDIF curves and also the character of the interaction between manganese and nitrogen atoms in austenitic Cr–Ni steels.

LITERATURE CITED

1. I. N. Mel'kumov and V. V. Topilin, "Alloying of austenitic steels with nitrogen," Metalloved. Term. Obrab. Met., No. 3, 47 (1969).
2. D. Carney, Blast Furnace and Stech., No. 12 (1955).
3. M. Nacken and U. Kuhlmann, Arch. Eisenhüttenw., 37, No. 4, 331 (1966).
4. V. D. Verner, "Nature of the internal friction peak in interstitial solid solutions with a fcc lattice," Fiz. Tverd. Tela, 7, No. 8, 2318 (1965).
5. W. Haines, M. Cohen, and D. Weir, Theory of the Pseudopotential [Russian translation], Mir, Moscow (1973).

DETERMINING THE LIMITS OF REGULATING THE CARBON POTENTIAL DURING CARBURIZING

R. E. Gliner

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Due to the introduction of modern methods of regulating the carbon concentration on the surface of carburized steel, it is necessary to determine the limits of regulating the carbon potential during carburizing. For this purpose it is necessary to establish specific relationships

$$x_H, C_{\mathrm{sur}} = f(C_{\mathrm{lim}}, C_{\mathrm{i}}, T, \tau), \tag{1}$$

where x_H is the depth of carburizing; C_{sur} is the surface concentration of carbon (the principal indicator of the quality of carburizing); τ and T are the carburizing time and temperature; C_i is the original (before carburizing) carbon content of the steel; C_{lim} is the carbon potential of the working atmosphere, numerically equal to the limit concentration of carbon in the steel, which can be achieved in a given atmosphere with "through" carburizing of a thin sample (technological parameters of carburizing).

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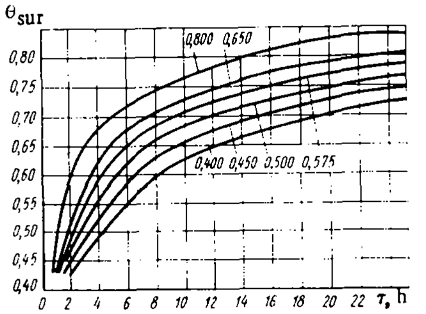

Fig. 1

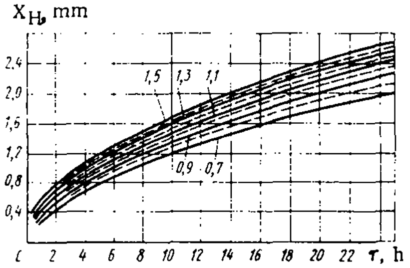

Fig. 2

Fig. 1. Variation of θ_{sur} (calculated) with carburizing time. The values of K ($h^{-1/2}$) are given on the curves.

Fig. 2. Variation of x_H (calculated) with carburizing time. The values of C_{lim} are given on the curves.

Experimental studies of these relationships involve a large number of laborious experiments and are limited by actual possibilities in the variation of the carburizing conditions. Therefore, it is expedient to solve this problem by means of calculations corrected by the results of experimental studies of separate carburizing conditions.

This work was done at the Gorki Automobile Factory in association with the introduction of automatic control of the carbon potential in carburizing equipment from the Aichelin Company. A partial solution of the diffusion equation was used, which can be presented in the form:

$$\theta_x = f(\mathrm{Bi}_x, \mathrm{Ti}_\tau), \tag{2}$$

where

$$\theta_x = \frac{C_x - C_i}{C_{lim} - C_i}; \quad \mathrm{Bi}_x = \frac{\alpha}{D} \quad x = H_x;$$

$$\mathrm{Ti}_\tau = H\sqrt{D\tau} = K\sqrt{\tau},$$

where Bi_x is the Biot number; Ti_τ is the Tikhonov number.

These equations [1] make it possible to use graphs, and the values of D and α (diffusion coefficient and proportionality coefficient characterizing the intensity of the interaction of the surface and the carburizing atmosphere) found from experimental data make it possible to compare the calculated results with specific technological conditions.

Experimentally determined values of H and K are sufficient for analysis of relationship (1).

The values of H were determined by layer-by-layer chemical analysis of carburized samples [1].

To find the value of K we determined (by means of chemical analysis) the values of C_{sur} and C_i for samples carburized with fixed C_{lim} and τ

$$\theta_{sur} = \frac{C_{sur} - C_i}{C_{lim} - C_i} = f(\mathrm{Ti}) \tag{3}$$

and from the well-known graph of relationship (3) we determined the corresponding values of Ti. Knowing τ and Ti, and using Eq. (2), we determined the value of K characterizing the given carburizing conditions.

Figure 1 shows auxiliary graphs calculated from the graph of relationship (3) for relationship

$$\theta_{sur} = f(\tau) \tag{4}$$

for different values of K. The existence of previously plotted graphs simplifies finding these values.

The results of such analyses made at the Gorki Automobile Factory lead to the conclusion that for carburizing in an endothermal atmosphere with C_{lim} = 0.9-1.3% and T = 900-920°C of various carbon, low-alloy, and medium-alloy steels with C_i = 0.1-0.3% one can take

$$K = 0.5\,\mathrm{h}^{-1/2} \text{ and } H = 2\ \mathrm{mm}^{-1}.$$

Using these values and relationship (2), we calculated the values of x_H for different τ and C_{lim}, and from the results plotted graphs to find the values of C_{lim} from the given values of x_H and τ (Fig. 2).

TABLE 1

Treat. No.	C_{sur}, %	x_H, mm	τ, h	θ_{sur}	Limit values C_{lim}, %		
					x_H	C_{sur}	optimal
1	0,8–0,9		4	0,56	0,7–1,1	1,27–1,44	–
2		0,7–0,9	6	0,62	0,6–0,7	1,17–1,33	–
3		0,7–1,0	4	0,56	0,7–1,4	1,27–1,44	1,27–1,40
4	0,9–1,0	1,0–1,2	6	0,62	0,9–1,3	1,33–1,49	–
5			7	0,64	0,7–1,1	1,28–1,43	–
6	0,8–0,9		6	0,62	0,9–1,3	1,17–1,33	1,17–1,30
7	0,9–1,0	1,0–1,3	6	0,62	0,9–1,5	1,33–1,49	1,33–1,49
8		1,3–1,5	9	0,68	0,9–1,3	1,22–1,37	1,22–1,30
9		1,6–1,8	12	0,70	1,0–1,4	1,20–1,34	1,20–1,34
10		1,9–2,1	15	0,72	1,2–1,5	1,17–1,30	1,20–1,30

Note. $C_i = 0.2\%$, $K = 0.5\ h^{-1/2}$, $H = 2\ mm^{-1}$.

Relationship (3), presented in the form

$$C_{lim} = \frac{C_{sur} - (1 - \theta_{sur})C_i}{\theta_{sur}}, \tag{5}$$

makes it possible to solve a similar problem for given C_{sur} and τ.

On the basis of the requirements and the accepted technology, let us assign minimal and maximum values for C_{sur}, x_H, τ, K, and H.

From the graphs in Fig. 2 let us determine the range of control C_{lim} ensuring given values of x_H in time τ.

From the graph in Fig. 1 we find θ_{sur} for the given τ, and from Eq. (5) we calculate the limit values C_{lim} for given values of C_{sur}.

Comparing the values found by this method, we find the limit values C_{lim} ensuring given values of x_H and C_{sur}. If the ranges obtained separately for each of these values do not overlap, then it is necessary to correct the original values (see Table 1).

LITERATURE CITED

1. A. A. Popov, Theoretical Basis of Chemicothermal Treatment [in Russian], Metallurgizdat, Sverdlovsk (1962).