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Structural Diagrams and Solid Phase Reactions of the Quaternary 7%Cr-Fe-C-N System*

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Synopsis

The isothermal diagrams of the 7%Cr-Fe-C-N system were studied at various temperatures from 1300° to 700°C in the composition range up to 0.34% carbon and 0.25% nitrogen. Resorting to the consideration of the phase relationship, the phase reaction of the 7%Cr-Fe-C-N system was clarified and the sectional diagrams were constructed at fixed contents of 0.05, 0.1 and 0.2% nitrogen. In the Fe-Cr-C-N system, two quaternary peritecto-eutectoid reactions ($\gamma + \text{Cr}_{23}\text{C}_6 \rightleftharpoons \alpha + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ and $\gamma + \text{Cr}_2\text{N} \rightleftharpoons \alpha + \text{Cr}_7\text{C}_3 + \text{CrN}$) exist at about 780° and 770°C, respectively.

I. Introduction

The respective effect of carbon and nitrogen on the structural constitutions of Fe-Cr alloys have already been clarified by many investigations.^{(1),(2)} It is important to know the mutual effects of carbon and nitrogen on the constitutions of Fe-Cr alloys, since Fe-Cr alloys using in industry usually contain nitrogen together with carbon.

Until now, the structural diagrams and phase relationships of Fe-Cr-C-N system have not been well known. The purpose of the present investigation is to determine the complete structural diagram of Fe-Cr-C-N system. The structural diagrams and the phase reactions of Fe-Cr-C-N system at 18%⁽³⁾ and 12%⁽⁴⁾ chromium have been studied by the present authors and those at 7% chromium in the present work.

II. Specimens and experimental methods

The specimens were prepared by induction melting electrolytic Fe, electrolytic Cr and the mother alloys of high N-Fe-Cr (about 6%N) and high C-Fe (about

* The 1542th report of the Research Institute for Iron, Steel and Other Metals. Published in Japanese in the J. Japan Inst. Metals, **33** (1969), 705.

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- (2) Y. Imai, T. Masumoto and K. Maeda, J. Japan Inst. Metals, **29** (1965), 866 (in Japanese); Sci. Rep. RITU, **A 19** (1967), 21, 35.
- (3) Y. Imai, T. Masumoto and M. Naka, J. Japan Inst. Metals, **30** (1966), 747 (in Japanese); Sci. Rep. RITU, **A 19** (1967), 83.
- (4) Y. Imai, T. Masumoto and M. Naka, J. Japan Inst. Metals, **31** (1967), 1399 (in Japanese); Sci. Rep. RITU, **A 23** (1972), 153.

Table 1. Chemical analyses of specimens

No.	wt%			No.	wt%		
	C	N	Cr		C	N	Cr
1	0.012	0.04	6.86	17	0.12	0.14	7.32
2	0.010	0.08	7.30	18	0.13	0.14	7.27
3	0.010	0.11	7.34	19	0.14	0.055	7.41
4	0.010	0.13	7.34	20	0.14	0.087	7.67
5	0.009	0.18	6.77	21	0.14	0.11	7.15
6	0.009	0.25	7.51	22	0.15	0.12	7.32
7	0.023	0.15	7.85	23	0.20	0.010	7.75
8	0.036	0.15	7.07	24	0.22	0.015	7.75
9	0.050	0.011	7.55	25	0.22	0.042	7.50
10	0.054	0.055	7.41	26	0.24	0.11	6.98
11	0.080	0.011	7.55	27	0.24	0.13	7.10
12	0.082	0.066	7.50	28	0.29	0.10	7.15
13	0.053	0.11	7.41	29	0.31	0.063	7.55
14	0.062	0.11	7.94	30	0.33	0.12	7.23
15	0.075	0.14	7.10	31	0.34	0.082	7.15
16	0.11	0.11	7.13				

5% C) in argon atmosphere. The chemical compositions of these thirty-one alloys are given in Table 1, in the range of composition being up to about 0.34% carbon and about 0.25% nitrogen at a constant chromium content of approximately 7%. In addition, all alloys contain about 0.1% of both manganese and silicon.

The detailed experimental procedures have been described previously.⁽³⁾ The heat treatment was carried out by enclosing the specimens in quartz tubes in conformity with the size of specimens in vacuum in order to prevent them from denitrogenization and decarburization. Optical microscope, powder X-ray diffraction and chemical analyses of the extracted residues were used to determine the phase reactions and the structural diagrams. Both iodo-metanol and hydrochloric acid-metanol method were used for the extraction of carbides and nitrides.

III. Experimental results and considerations

1. Isothermal structural diagrams

Based on the Fe-Cr-C ternary diagram at 7% chromium by Bungardt *et al.*⁽¹⁾, the Fe-Cr-N ternary diagram at 7% chromium by the present authors⁽²⁾ and the present experimental results, the isothermal structural diagrams in the 7%Cr-Fe-C-N quaternary system were obtained in the temperature range from 1300°C to 700°C. The specimens for obtaining each isothermal diagram were solution-treated at 1300°C for 1 hr and slowly cooled at the rate of 100°C per hour to the temperature required, at which they were held for long hours (for instance, 1 hr at 1200°C and about 200 hr at 700°C), and then were quenched by breaking quartz tubes in water. Figs. 1 to 7 show the isothermal structural diagrams at 900°, 875°C, 850°, 825°, 800°, 775°, and 700°C, respectively. The single phase region of γ exists at 1300° to 925°C in the range of the present composition. At 900°C, as shown in Fig. 1, two-phase region of $\gamma + \text{Cr}_7\text{C}_3$ appears in the high carbon side. At 875°C, as shown in Fig.

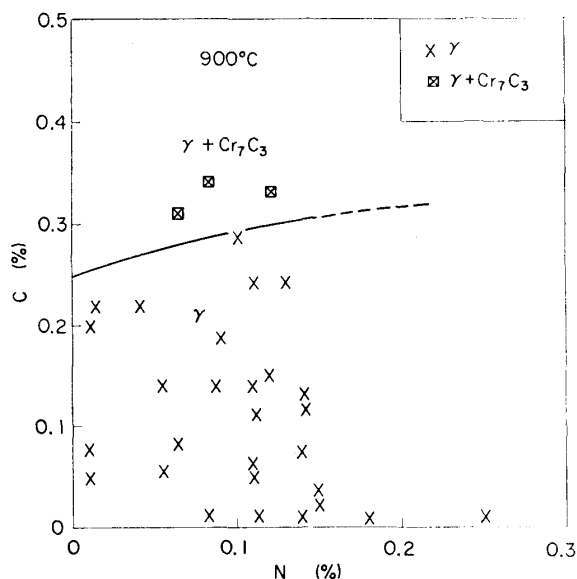


Fig. 1

Fig. 1. Isothermal structural diagram of 7%Cr-Fe-C-N system at 900°C.

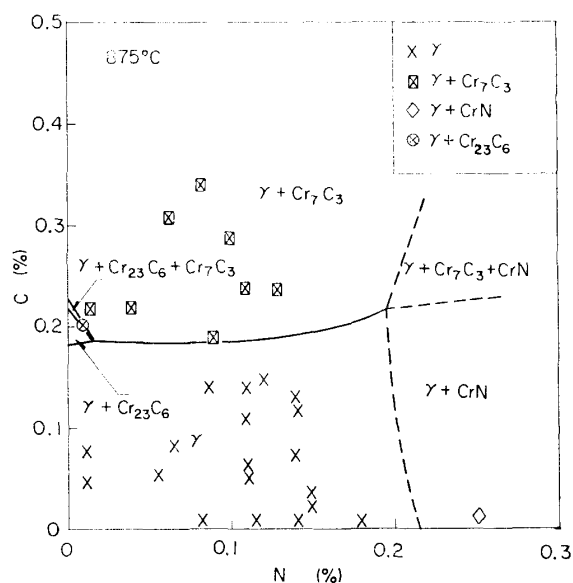


Fig. 2

Fig. 2. Isothermal structural diagram of 7%Cr-Fe-C-N system at 875°C.

2, $\gamma + \text{Cr}_7\text{C}_3$ region expands toward the low carbon side, and $\gamma + \text{Cr}_{23}\text{C}_6$ region appears newly. Besides two three-phase regions of $\gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3$ and $\gamma + \text{Cr}_7\text{C}_3 + \text{CrN}$ can be presumed. With further fall of temperature, the single phase region of γ grows narrow and transforms to the multiple phases. At 850°C, as shown in Fig. 3, Cr_2N newly precipitates and $\gamma + \text{Cr}_2\text{N}$, $\gamma + \text{Cr}_2\text{N} + \text{CrN}$ and $\gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ regions appear, and further one four-phase region of $\gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$ can be presumed. At 825°C, as shown in Fig. 4, α phase appears in the low carbon-low nitrogen field, and $\alpha + \gamma$ and $\alpha + \gamma + \text{Cr}_{23}\text{C}_6$ regions exist. At 800°C, as shown in Fig. 5, the γ phase region grows rapidly narrower and is surrounded with two-phase, three-phase and four-phase regions composed of α , γ , Cr_{23}C_6 , Cr_7C_3 , Cr_2N and CrN phases. At 775°C, as shown in Fig. 6, the γ phase in the low carbon-low nitrogen range transforms into the $\alpha +$ compounds, which are three two-phase regions of $\alpha + \text{Cr}_{23}\text{C}_6$, $\alpha + \text{Cr}_7\text{C}_3$ and $\alpha + \text{Cr}_2\text{N}$, four three-phase regions of $\alpha + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3$, $\alpha + \text{Cr}_{23}\text{C}_6 + \text{Cr}_2\text{N}$, $\alpha + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ and $\alpha + \text{Cr}_2\text{N} + \text{CrN}$, and one four-phase region of $\alpha + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$, while the four-phase region of $\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ which contains the γ phase expands in the high carbon-high nitrogen field. Besides, it can be presumed that one four-phase region of $\alpha + \gamma + \text{Cr}_2\text{N} + \text{CrN}$ expands in the high nitrogen field. At 700°C, as shown in Fig. 7, the γ phase in the present composition region transforms completely into the α structure. Although the constitution in the low carbon-low nitrogen range is the same as that at 775°C, the four-phase region of $\alpha + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$ surrounded by three three-phase regions of $\alpha + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$, $\alpha + \text{Cr}_2\text{N} + \text{CrN}$ and $\alpha + \text{Cr}_7\text{C}_3 + \text{CrN}$ appears newly in the high carbon-high nitrogen field.

2. Considerations on phase reaction and phase relationship

From the phase reactions of 18%Cr-Fe-C-N⁽³⁾ and 12%Cr-Fe-C-N⁽⁴⁾ systems

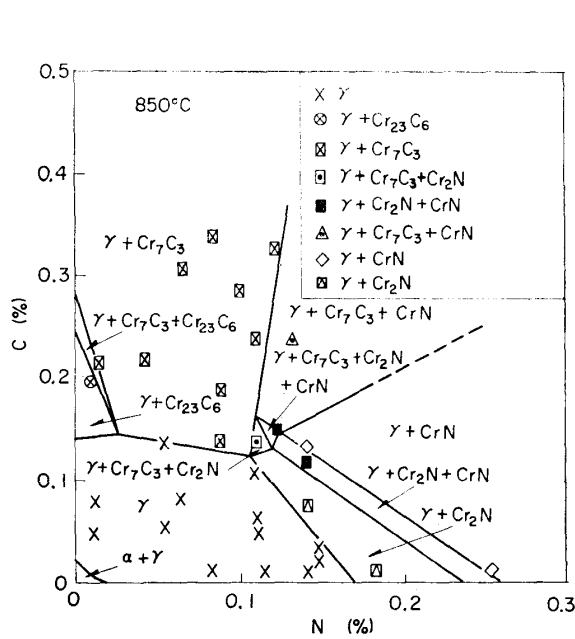


Fig. 3

Fig. 3. Isothermal structural diagram of 7%Cr-Fe-C-N system at 850°C.

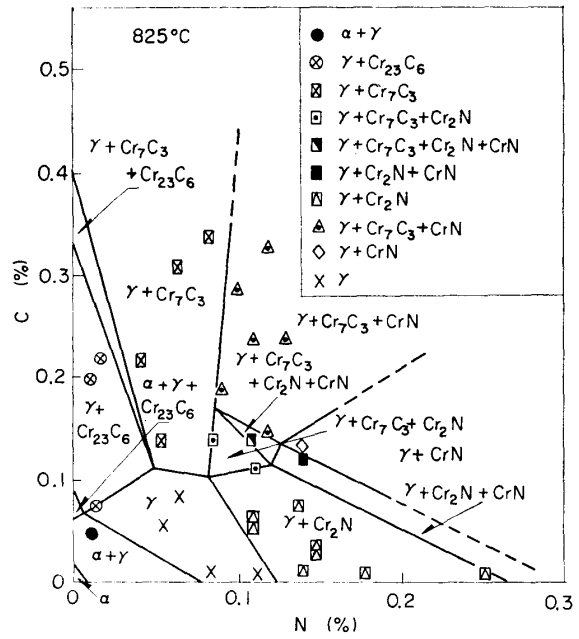


Fig. 4

Fig. 4. Isothermal structural diagram of 7%Cr-Fe-C-N system at 825°C.

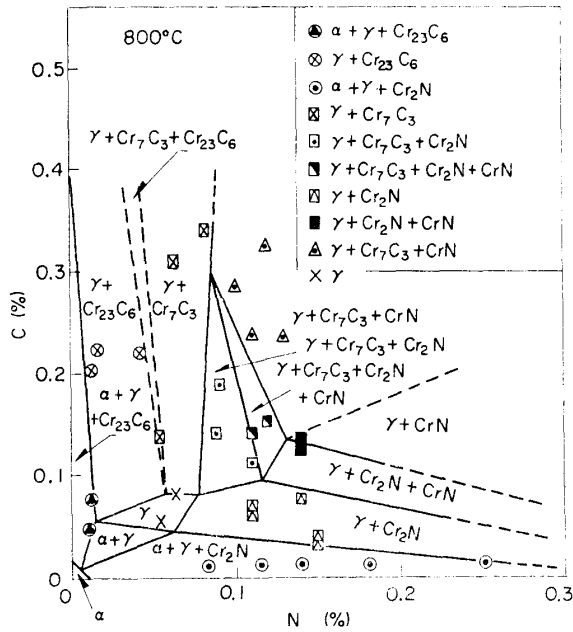


Fig. 5

Fig. 5. Isothermal structural diagram of 7%Cr-Fe-C-N system at 800°C.

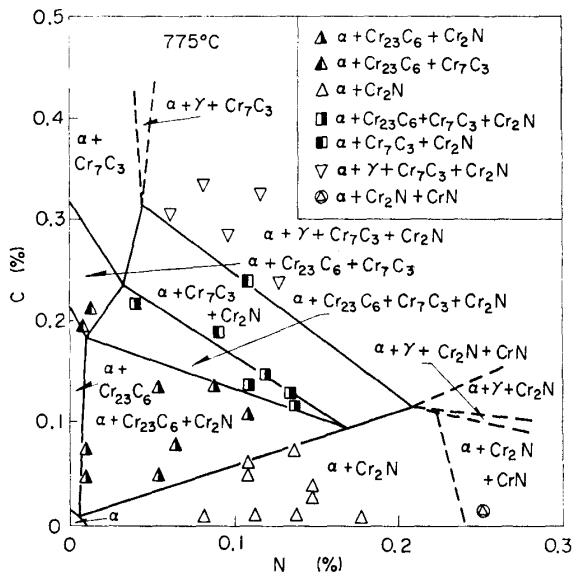


Fig. 6

Fig. 6. Isothermal structural diagram of 7%Cr-Fe-C-N system at 775°C.

reported in the previous papers and the isothermal structural diagrams of the present quaternary system, the phase reactions and phase relationships in 7%Cr-Fe-C-N quaternary system were considered.

The four four-phase regions of $\alpha + \gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_2\text{N}$, $\gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$

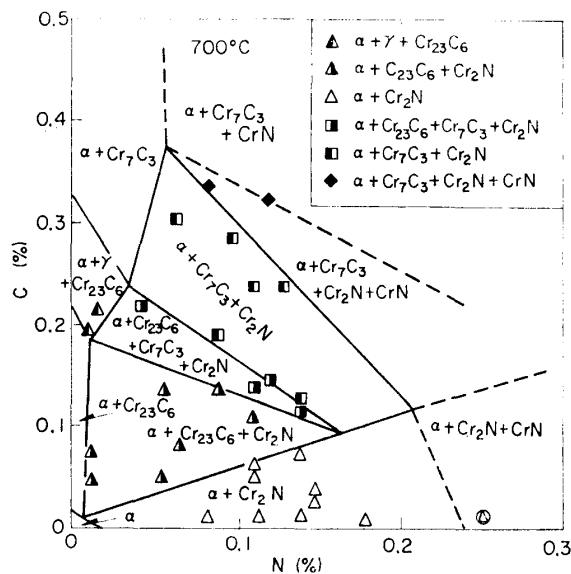


Fig. 7. Isothermal structural diagram of 7%Cr-Fe-C-N system at 700°C.

and $\alpha + \gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3$ at higher temperatures and $\alpha + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ at lower temperatures were confirmed in the previous papers.^{(3),(4)} It has been made clear that the four-phase region of $\alpha + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ arises from one quaternary peritecto-eutectoid reaction, $\gamma + \text{Cr}_{23}\text{C}_6 \rightarrow \alpha + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$. In this invariant reaction, three four-phase regions of $\alpha + \gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_2\text{N}$, $\alpha + \gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3$ and $\gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ joint each other and divide into two four-phase regions of $\alpha + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ and $\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$. In the present paper, on the other hand, five four-phase regions of $\gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$, $\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ and $\alpha + \gamma + \text{Cr}_2\text{N} + \text{CrN}$ at higher temperatures and $\alpha + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$, $\alpha + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$ at lower temperatures are observed.

Since the two regions of $\alpha + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ and $\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ take part in the above-mentioned invariant peritecto-eutectoid reaction, there is a possibility that the remaining three four-phase regions take part in the other reaction. Then, we consider the course of phase reaction through that four-phase region of $\alpha + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$ confirmed at the lower temperature was formed.

In general, the four-phase region is formed by passing through the three or five-phase region descending from higher temperature. If it passes through the three-phase regions, the three-phase regions must consist of α and two kinds of compound. But the existence of these three-phase regions cannot be considered by the phase relationships. Consequently, the above-mentioned four-phase region should be considered to be formed by passing through the invariant reaction of the five-phase region composed of $\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$ descending from higher temperature. These considerations are reasonable from the phase relationships in Fig. 6. This five-phase invariant reaction is discussed in the following.

Generally, the five-phase invariant reaction in a quaternary system can be the following with A, B, C, D and E present.

- (a) $A \rightarrow B + C + D + E$ quaternary eutectoid.
- (b) $A + B \rightarrow C + D + E$ quaternary peritecto-eutectoid.
- (c) $A + B + C \rightarrow D + E$ quaternary peritecto-eutectoid.
- (d) $A + B + C + D \rightarrow E$ quaternary peritectoid.

In the reaction (a), the γ phase belongs to the reactants, so $\gamma \rightarrow \alpha + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$ is considered to occur. The vanishing of γ through the (a) reaction is contradictory to the observation that Fe_3C carbide and Fe_4N nitride precipitate from lower chromium alloys in Fe-Cr-C-N system. In the peritectoid reaction of (d), the fifth phase occurs owing to the peritectoid reaction with four phases, but in this 7%Cr-Fe-C-N system, as shown in Fig. 6, above the invariant temperature there are already five phases concerning with the reaction. Therefore, the reaction of (d) cannot be considered to occur in this system.

On account of these discussions, either of the quaternary peritecto-eutectoid reaction of (b) or (c) is considered to occur in Fe-Cr-C-N system, and the peritecto-eutectoid reaction of (b) is represented by three four-phase tie-tetrahedra descending from higher temperature, joining to form an tie-hexahedron which represents the five-phase equilibrium. After the reaction this hexahedron separates into two tie-tetrahedra descending to lower temperature. The reaction of (c) is the reverse of reaction of (b), that is, two tie-tetrahedra join and divide into three tie-tetrahedra. As γ phase belongs to the reactions in the present system, there are ten combinations of phase that could conceivably partake in the peritecto-eutectoid reaction. As above-confirmed in the isothermal diagrams, the four-phase tie-tetrahedra of $\gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$, $\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$, $\alpha + \gamma + \text{Cr}_2\text{N} + \text{CrN}$ exist before the invariant reaction and the four-phase tie-tetrahedra of $\alpha + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$ exists after the invariant reaction. The equation corresponding to these experimental facts is (b), namely, $\gamma + \text{Cr}_2\text{N} \rightarrow \alpha + \text{Cr}_7\text{C}_3 + \text{CrN}$. Three tie-tetrahedra of $\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$, $\gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$ and $\alpha + \gamma + \text{Cr}_2\text{N} + \text{CrN}$ react and then separate into two tie-tetrahedra of $\alpha + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$, $\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{CrN}$. The sequence of these five tie-tetrahedra on cooling through invariant reactions are considered in the following.

Fig. 8 shows the relationships between the quaternary peritecto-eutectoid reaction $\gamma + \text{Cr}_{23}\text{C}_6 \rightarrow \alpha + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ confirmed in 12% chromium system and the above-mentioned peritecto-eutectoid reaction $\gamma + \text{Cr}_2\text{N} \rightarrow \alpha + \text{Cr}_7\text{C}_3 + \text{CrN}$. In this figure, tie-tetrahedron ⑥ of $\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ is one of two tie-tetrahedra resulting from the reaction of the three tie-tetrahedron of ①, ② and ③. The tie-tetrahedron ⑧ of $\alpha + \gamma + \text{Cr}_2\text{N} + \text{CrN}$ in the quaternary system is developed from the trepezium of the ternary invariant reaction at 790°C in Fe-Cr-N system, on the other hand, the four-phase tie-tetrahedron ⑦ of $\gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$ is formed in the Fe-Cr-C-N system. The tie-tetrahedra of ⑥, ⑦ and ⑧ joint to form the isothermal tie-tetrahedra of ⑩ and ⑪. Although the tie-tetrahedron ⑩ of $\alpha + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$ containing no γ phase does not change, the γ phase in another tie-tetrahedron ⑪ of $\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{CrN}$ further decomposes and

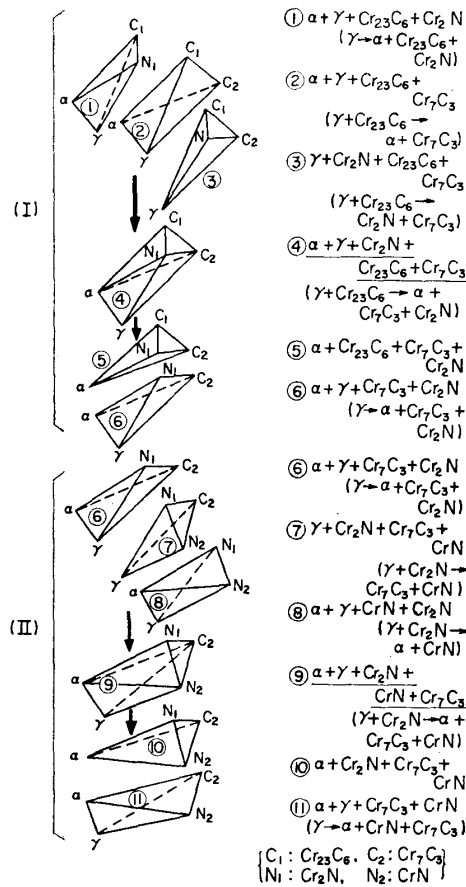


Fig. 8. Sequence of tie-tetrahedra on cooling through the quaternary peritecto-eutectoid temperature in Fe-Cr-C-N system.

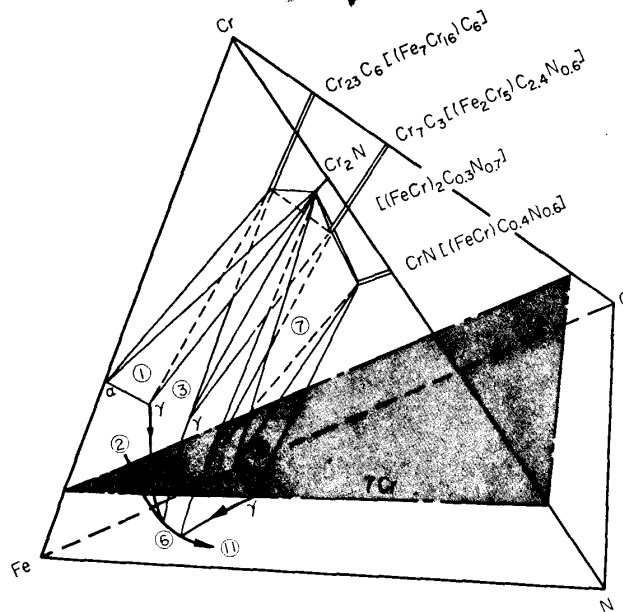


Fig. 9. Schematic illustration of the tetrahedra formed by α , γ , $Cr_{23}C_6$, Cr_7C_3 , Cr_2N and CrN on cooling in Fe-Cr-C-N system.

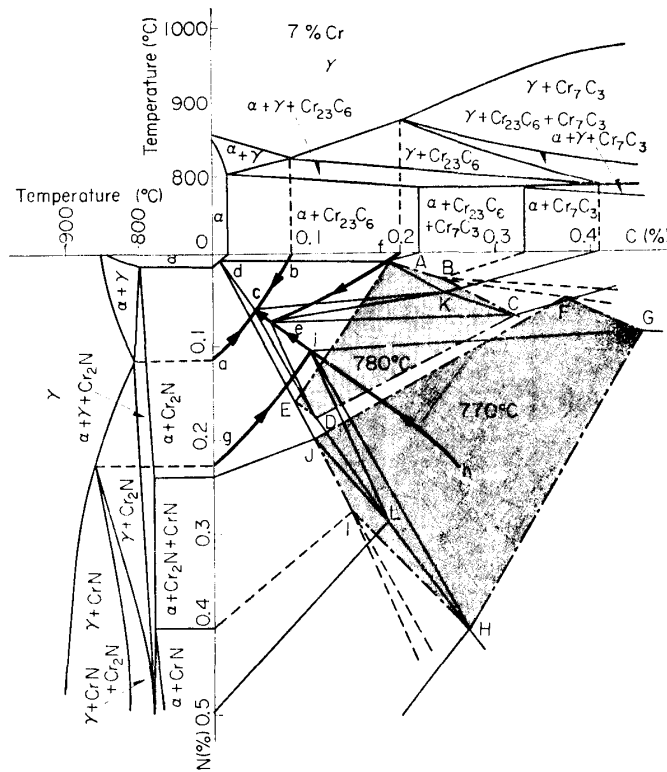


Fig. 10. Projection of phase reaction in 7%Cr-Fe-C-N system on the concentration plane.

proceeds to the other reactions. These two invariant reactions are represented in the quaternary composition tetrahedron of Fe-Cr-C-N system as shown in Fig. 9. In five-phase equilibrium the compositions of each phase are constant and the approximate locations are Cr_{23}C_6 (5.6% C, 0.05% N, 28% Fe), Cr_7C_3 (7.0% C, 2.1% N, 26.6% Fe), Cr_2N (about 2.4% C, 7.8% N, 2.3% Fe) and CrN (about 3% C, 19% N, about 6% Fe).^{(4),(5)} Taking account of the location of α and γ in Fe-Cr-C system and Fe-Cr-N system, α phase is in the higher chromium-lower nitrogen-lower carbon side than γ phase. Therefore, the sequence of the tie-tetrahedra in Fig. 8 descending the temperature is shown in Fig. 9. Since 7%Cr-Fe-C-N system is situated on a plane in the figure, the four-phase regions in the isothermal sections during the temperature change are shown by the intersection of this plane with the each tie-tetrahedron. The existence of the four-phase regions in Fig. 3~Fig. 7 is explained from Fig. 9. The tie-tetrahedron ⑦ intersects first with the 7%Cr section, and then the tie-tetrahedra of ③, ①, ② and ⑧ intersect in sequence descending from high temperature. Since the latter four tie-tetrahedra shift rapidly with the fall of temperature range 50°C between 800°C and 750°C, these four tetrahedra are thought not to have been confirmed. From the isothermal constitutional diagrams of 7%Cr-Fe-C-N system in Fig. 1~Fig. 7, the projection of each region at each temperature on the concentration plane is constructed in Fig. 10. The γ phase of the $\gamma+\text{Cr}_7\text{C}_3+\text{CrN}$ three-phase region shifting along the $h \rightarrow i$ with the fall of temperature connects with the γ phase of the $\gamma+\text{Cr}_2\text{N}+\text{CrN}$ three-

phase region from 7%Cr-Fe-N system ($g \rightarrow i$) at the point i and forms the $\gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$ four-phase region. The trigonal pyramid with the point apex i is formed by the intersection of the four-phase tie-tetrahedron with the 7% chromium section at each temperature. The γ phase of the $\gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ three-phase region shifting from i to e with further fall of temperature meets of the γ phase of the $\gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3$ three-phase region from 7%Cr-Fe-C system ($f \rightarrow e$) at the point e and forms the $\gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ four-phase region. This four-phase trigonal pyramid corresponds to the tie-tetrahedron ③ in Fig. 9 and at the point c (about 800°C) the three γ phases of the $\gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_2\text{N}$ region ($e \rightarrow c$), the $\alpha + \gamma + \text{Cr}_2\text{N}$ region from 7%Cr-Fe-N system ($a \rightarrow c$) and the $\alpha + \gamma + \text{Cr}_{23}\text{C}_6$ region from 7%Cr-Fe-C system ($b \rightarrow c$) joint each other and form the tie-tetrahedron of $\alpha + \gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_2\text{N}$ with apex c . Hereupon, the temperatures of points i , e and c were estimated to be about 860°C, 795°C and 790°C, respectively. Further, the quaternary peritecto-eutectoid reaction (I) in Fig. 8 occurs at about 780°C. The ABCDE plane is the section of this tie-hexahedron ④ in Fig. 8. This plane is constructed with three parts of the $\alpha + \gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3$ four phase region (ABCK) from 7%Cr-Fe-C, the $\alpha + \gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_2\text{N}$ four-phase region (AEDK) and the $\gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ four-phase region (DKC). Below this invariant temperature, this five-phase region separates into two four-phase regions (ABE and BCDE). With further fall of temperature, the $\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ four-phase region (BCDE) moves to the region (FGLJ) of the next invariant plane (this is the section of tie-hexahedron ⑤ in Fig. 8 at about 770°C). This invariant plane (FGHIJ) is constructed with the $\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ region (FGLJ), the $\alpha + \gamma + \text{Cr}_2\text{N} + \text{CrN}$ four-phase region (HIJL) from 7%Cr-Fe-N system and the $\gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$ four-phase region (GHL). With further fall of temperature, this five-phase region separates into $\alpha + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$ region (FIJ) and $\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{CrN}$ region (FGHI). Further, the region (FGHI) moves to the high carbon-high nitrogen side.

3. Sectional diagrams at various compositions

Based on the above-mentioned discussions of the isothermal structural diagrams and the phase reactions of 7%Cr-Fe-C-N system, the sectional diagrams at various contents of 0.05%N, 0.1%N, 0.2%N were constructed as shown in Fig. 11 ~ Fig. 13. At the sectional diagram of 0.05%N, the invariant reaction (I) exists at 780°C. At the sectional diagram of 0.1%N, two invariant reaction of (I) at 780°C and (II) at 770°C are shown. At the sectional diagram of 0.2%N, the invariant reaction of (II) exists at 770°C.

Summary

The isothermal structural diagrams of 7%Cr-Fe-C-N quaternary system in the composition range up to 0.34%C and up to 0.25%N were investigated in the temperature range from 1300° to 700°C and the phase reactions and the phase

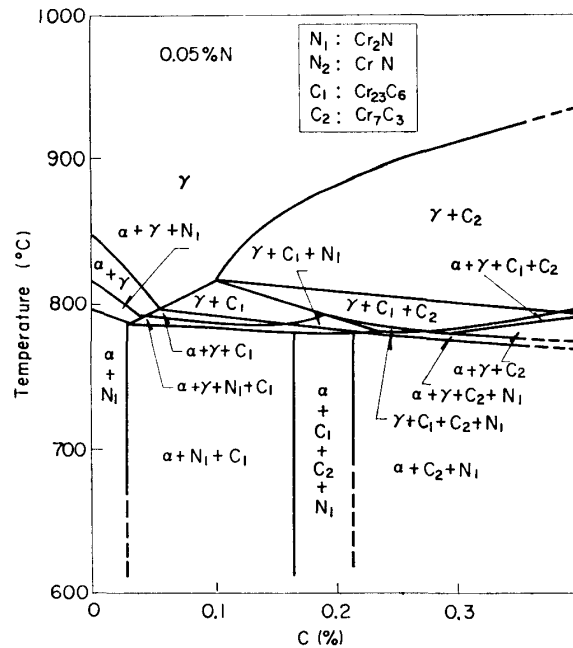


Fig. 11. Sectional diagram of 7%Cr-Fe-C-N system at 0.05% N.

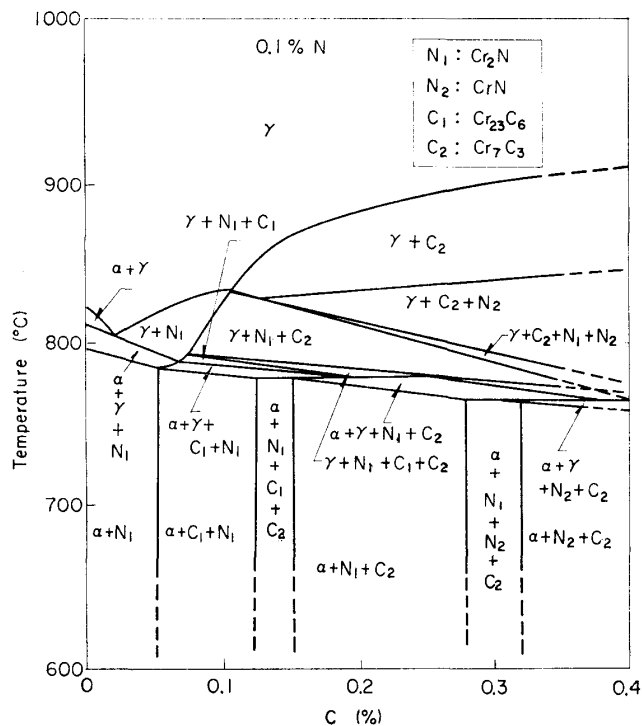


Fig. 12. Sectional diagram of 7% Cr-Fe-C-N system at 0.1% N.

relationships were considered.

Six phases of α , γ , $Cr_{23}C_6$, Cr_7C_3 , Cr_2N and CrN exist in this quaternary system. Below $925^\circ C$, two-phase and three-phase regions involving $Cr_{23}C_6$ and Cr_7C_3 appear from the high carbon side. Below $875^\circ C$ the two-phase and three-

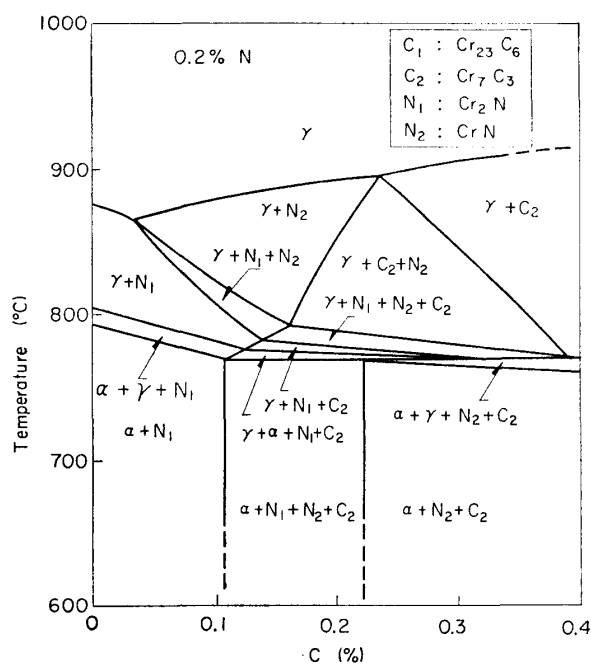


Fig. 13. Sectional diagram of 7%Cr-Fe-C-N system at 0.2% N.

phase regions involving Cr_2N and CrN appear from the high nitrogen side. In this system two following quaternary peritecto-eutectoid reactions exist. At about 780°C , $\gamma + \text{Cr}_{23}\text{C}_6 \rightarrow \alpha + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$ ($\alpha + \gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_2\text{N}$, $\alpha + \gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3$, $\gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} \rightarrow \alpha + \gamma + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} \rightarrow \alpha + \text{Cr}_{23}\text{C}_6 + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$, $\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$) and at about 770°C , $\gamma + \text{Cr}_2\text{N} \rightarrow \alpha + \text{Cr}_7\text{C}_3 + \text{CrN}$ ($\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N}$, $\gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$, $\alpha + \gamma + \text{Cr}_2\text{N} + \text{CrN} \rightarrow \alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN} \rightarrow \alpha + \text{Cr}_7\text{C}_3 + \text{Cr}_2\text{N} + \text{CrN}$, $\alpha + \gamma + \text{Cr}_7\text{C}_3 + \text{CrN}$) reactions occur.