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THE USE OF DTA FOR DETERMINATION OF THE EQUILIBRIUM DIAGRAM FOR 9-0-2+Si HIGH-SPEED STEEL

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ABSTRACT

DTA was used to investigate phase transformations taking place during melting and crystallization of 9-0-2 high-speed steels containing 0.3 - 5% Si and to develop pseudobinary phase equilibrium diagrams for steels with variable Si contents.

INTRODUCTION

In the course of search for most economical high-speed steels with the propiertes not inferior to conventional grades attempts were made to develop materials with cheap components substituted for expensive alloying elements. Especially interesting are works concerned with W-V steels without molybdenum with part of tungsten substituted with silicon.

Since quality of finished high-speed steel tools depends to a large extent on the type, size and distribution of primary carbides, it seemed worthwhile to investigate phase transformations which occur during crystallization of such steels. To date a number of works [1-10] was concerned with crystallization in laboratory conditions simulating processes in industrial ingots.

The aim of this work was to use differential thermal analysis (DTA) to investigate that part of pseudobinary equilibrium diagram which corresponds to crystallization of 9-0-2 high-speed steel with various concentrations of silicon.

EXPERIMENTAL

The experiments were carried out on samples taken from 6 laboratory heats containing approximately 1.05%C, 9.5%W, 2.5%V, 4.5%Cr and Si between 0.3 and 5% in 1% steps. Mettler TA-1 differential thermal analyzer was used; the sensitivity was 4 μV/cm. The samples were heated and cooled in helium with a rate of 10^{o}C/min. A

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sample of the steel being studied was placed in a thin-walled alundum crucible and heated or cooled simultaneously with an α-Al_2O_3 reference sample in another crucible. Temperature was recorded with the use of a macro DTA Pt-PtRh10 termocouple. The experiments were complemented with metallographic examinations of polished and etched sections of as-cast and annealed specimens, analyses of the carbide phases under an X-ray microanalyzer and qualitative and quantitative X-ray diffraction analyses of bulk specimens and carbide residues separated by an electrolytic method [11].

DISCUSSION OF RESULTS AND CONCLUSIONS

Crystallization of 9-0-2 high-speed steel begins at the liquidus temperature (1440°C) with formation from the liquid (L) of dendritic crystals of high-temperature alloyed ferrite $\alpha(\delta)$ according to reaction 1c in Fig.1b

$$L \rightarrow \alpha\ (\delta).$$

At temperatures below 1370°C a three-phase peritectic reaction 2c begins

$$L + \alpha\ (\delta) \rightarrow \gamma$$

i.e. austenite is formed from the mixture of liquid phase L and $\alpha(\delta)$ ferrite.

Peritectic reaction does not run to completion. At 1310°C the non-crystallized liquid transforms directly to austenite according to reaction 3c

$$L \rightarrow \gamma.$$

After further decrease of temperature to 1255°C the liquid remaining in interdendritic spaces and at primary crystal boundaries is transformed by an eutectic

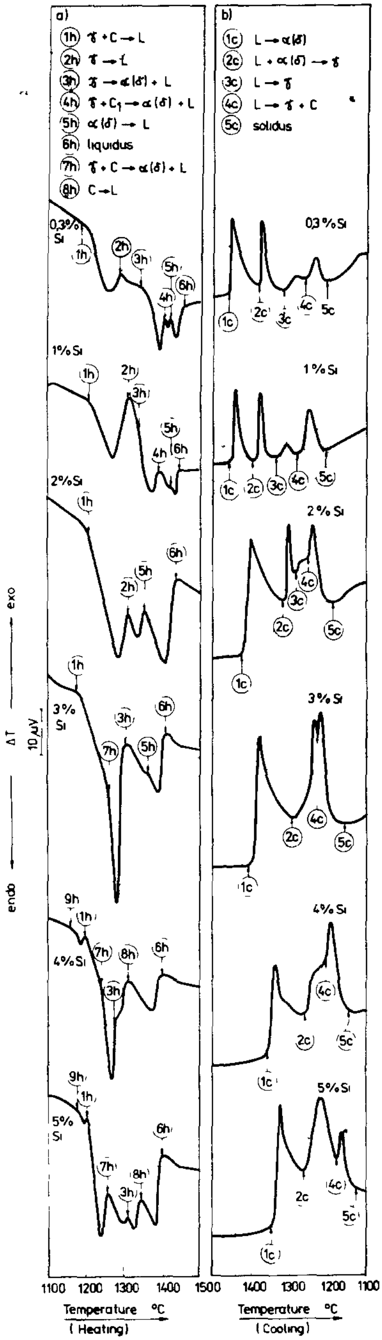

Fig.1 Fragments of DTA curves for 9-0-2 high-speed steels with various silicon contents; a. heating, b. cooling

reaction (4c) into a mixture of austenite γ and carbides C

$$L \rightarrow \gamma + C.$$

Crystallization is brought up to an end with completion of this reaction at the solidus temperature of 1205°C marked 5c in Fig.1b.

The character of transformations remains the same in 9-0-2 steel with silicon content increased to approximately 3%. However, liquidus temperature (1c) and temperature of the begining of peritectic transformation (2c) are much reduced, to 1385 and 1285°C, respectively. Another effect of increasing silicon content is reduction of the difference between the temperatures of the begining of direct crystallization of austenite from the liquid (3c) and of eutectic reaction (4c). It seems that during solidification of steels containing more than 3%Si both reactions occur simultaneously. Granular form of some of MC type carbides suggests that they are produced directly from the liquid.

The results were used to compose a fragment of cooling equilibrium diagram for 9-0-2 steels with variable silicon contents (Fig.2b).

Melting of conventional 9-0-2 steel begins at the solidus temperature of 1220°C (1h in Fig.1a) and is related to the begining of reverse eutectic reaction:

$$\gamma + C \rightarrow L.$$

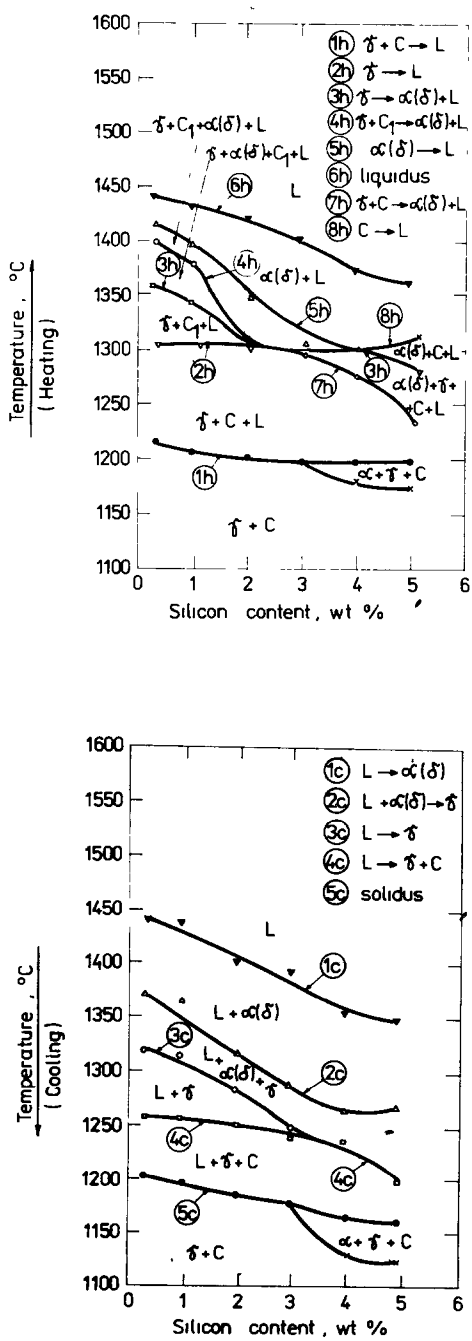

Fig.2 Fragments of pseudo-binary system for 9-0-2+Si steel
a. heating, b. cooling

On heating to 1305°C direct melting of austenite grains begins (2h)

$$\gamma \rightarrow L.$$

At 1360°C reverse three-phase peritectic reaction begins (3h)

$$\gamma \rightarrow \alpha(\delta) + L.$$

Thermal effects marked at 1405°C (4h in Fig.1a) are probably related to a reverse four-phase peritectic reaction:

$$\gamma + C_1 \rightarrow \alpha(\delta) + L.$$

It seems that in this reaction only those carbides (C_1) take part which have not been converted to the liquid in reverse eutectic reaction (1h). High stability of interstitial phases suggests that C_1 carbides are in the main of the MC type.
Melting of high-temperature ferrite (5h in Fig.1a)

$$\alpha(\delta) \rightarrow L$$

begins at 1420°C; this process is terminated at the liquidus temperature or 1440°C (6h in Fig.1a).

Increased silicon contents shift downwards all temperatures of reactions taking place during heating and sometimes change their character. With silicon contents up to approximately 2% four-phase peritectic reaction (7h in Fig.1a)

$$\gamma + C \rightarrow \alpha(\delta) + L$$

begins before reverse eutectic reaction (1h) is complete. It is possible that the former reaction is accompanied by direct melting of austenite (2h in Fig.1a)

$$\gamma \rightarrow L.$$

It is also possible that four-phase peritectic reaction (4h) terminates before three-phase peritectic reaction (3h) does so. In steels containing more than 4%Si there is also a reverse reaction involving direct dissolution of carbides in the liquid phase (8h in Fig.1a)

$$C \rightarrow L.$$

Fig.2b shows a fragment of the equilibrium diagram composed on the basis of DTA data obtained on heating.

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