

Phase Analysis of Materials for Steam and Gas Turbines

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The necessity for receiving phase time-temperature diagrams of high-alloyed materials and alloying elements redistribution between phases is associated with the choosing of optimal thermal treatment conditions, providing phase stability for steels and alloys during operation. The present paper deals with investigations of phase diagrams for high-temperature Ni-base alloy and for Cr-Mo-V steel have been received. The type of phase transformations (carbide, boride and intermetallic) has been determined during long-term ageing.

Experimental. The study was performed by a method of physical-chemical phase analysis. In order to isolate phases from a metal matrix, an electrochemical method using the methanol solution of HCl cooled to -3°C was employed. Phase structure were determined by X-ray structure analysis using Co radiation. Temperature-time diagrams are obtained from X-ray analysis results. This article presents data for steel 0.25C-1.6 Cr-1.0 Mo-0.3V, study of carbide formation during martensite aging has been carried out at temperatures between 450°C and 750°C for times up to 3000 to 5000 hours. The composition of Ni-base alloy melting (17.7% Cr; 5.3% Co, 5.3% Mo, 3.3%W, 3.8% Al, 2.3% Ti, 1.4% Nb, 0.10% C, 0.15% Si, 0.04% B) was studied during aging in temperature region of $750\text{-}1100^{\circ}\text{C}$ after homogenization at 1180°C .

Cr-Mo-V steel. The diagrams show the regions of carbide phase existence during metal aging in the martensite state (Fig. 1). The following carbides are found to be present: V-based carbide of MC-type, Mo-rich M_2C carbides, and Cr- and Fe-rich M_3C , M_7C_3 , and M_{23}C_6 carbides. The dotted line in steel diagram indicates the existence of boundaries of M_3C cementite. The increase in relative amounts of M_{23}C_6 carbides in the high-temperature metal component is associated with carbide formation during service; moreover, M_{23}C_6 carbide is the major carbide phase in some cases, and this state cannot be achieved during heat treatment. M_3C cementite decomposes during metal service. Generally, carbide reactions in steel proceed as follows:
 $\text{M}_3\text{C} \rightarrow \text{MC} + \text{M}_2\text{C} + \text{M}_7\text{C}_3 \rightarrow \text{M}_{23}\text{C}_6 \rightarrow \text{M}_6\text{C}$. Fig. 2 shows changes in alloying elements amounts in carbide phases with aging temperatures. The amounts of Mo, Cr and V present in carbides are found to increase with longer aging times.

Ni-base alloy. High-temperature alloys of this type are multiphase and exhibit the occurrence of several types of different phases: Ni_3Al -base γ' -phase, carbide phases of the MC, M_{23}C_6 and M_6C type, TCP(topologically closed packed)-phases of σ - or μ -phases, and boride phases. The Cr-base M_{23}C_6 carbide forms during subsequent tempering at temperature below 1000°C . In order to determine time-temperature ranges of γ' -phase existence in the alloy, a phase diagram for temperature ranging from $750\text{-}1100^{\circ}\text{C}$ has been built (Fig.3). The γ' -phase formation at 800°C has been found after aging during 500 hours, the quantity of Cr and Mo bound in the second phases is growing substantially (Fig.4). γ' -phase forms more vigorously at 900°C and is found to occur after 50 hours of aging. γ' -phase is instable at temperatures over 950°C . Generally, the main phase reactions during long-term aging are carbide reaction $\text{MC} \rightarrow \text{M}_{23}\text{C}_6$ and γ' -phase formation. At 800°C the γ' -phase precipitation is initiated at the aging time interval of 500-1000 hours, while at 900°C the onset of γ' -phase precipitation falls within 30-50 hours.

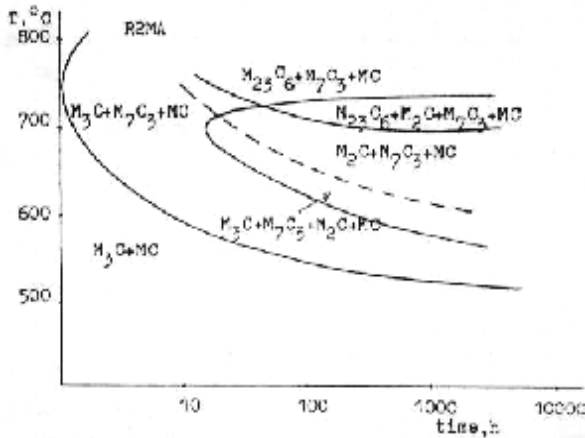


Fig. 1 Time- temperature carbide diagram for steel

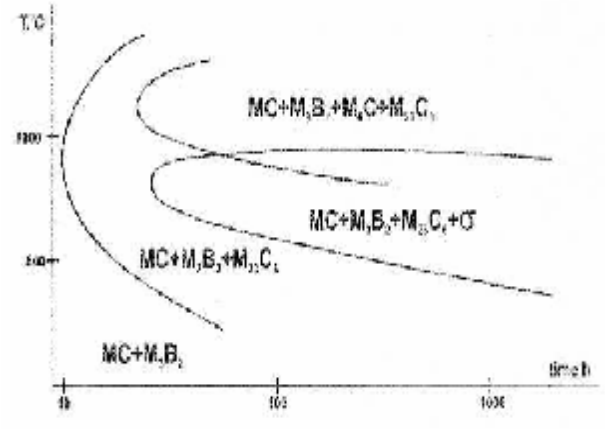


Fig. 3 Time- temperature phase diagram for Ni-base alloy.

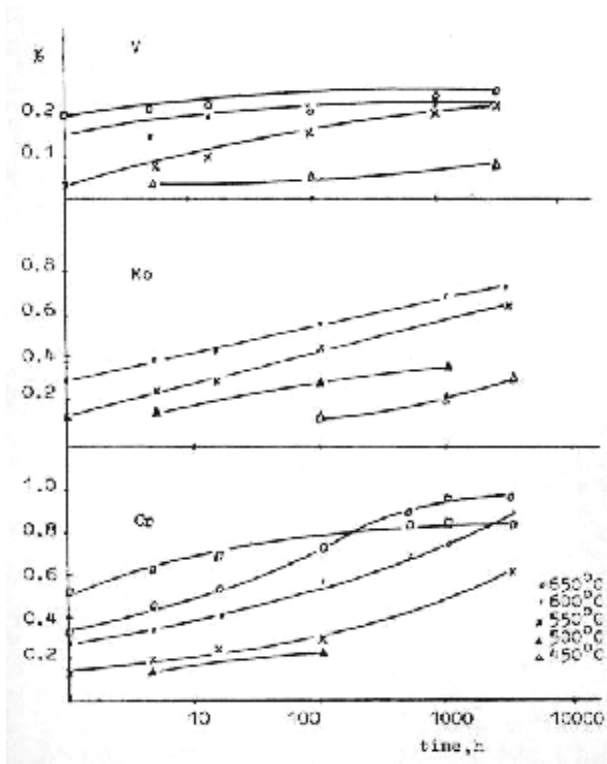


Fig. 2 Vanadium, molybdenum and chromium content in carbides during steel aging

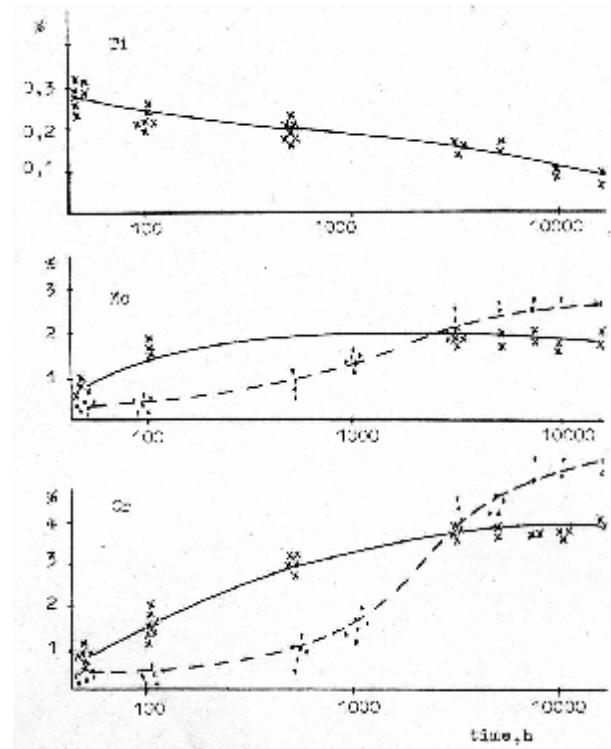


Fig. 4 Titanium, molybdenum and chromium content in second phases during aging at 800 (----) and 900°C (- - -)