molybdenum carbide which ties up about one half of the entire molybdenum indicates that the relation among the various alloy elements in this steel is rather ill-chosen.

**CONCLUSION**

1. Low carbon, Cr-Mo-V steels 12Kh1MF ("A") and 15Kh1MF ("B") air cooled from 970-1050°C are readily undercooled to the intermediate transformation temperatures and retain austenite in their structure.

2. During tempering, normalized steels pass through a series of metastable conditions which differ among themselves by the type and dispersion of the carbides and the degree of alloying of the ferrite.

**REFERENCES**


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**SIGMA-PHASE IN STEEL 1Kh20N14S2**

Dr. chem. sc., Prof. V.S. LYASHENKO, Cand. tech. sc., V.N. BYKOVO and Eng. V.A. RUDENKO

Steel 1Kh20N14S2 (1211 — to be called in the following "211" for brevity) has a combination of high mechanical properties in the initial condition [1] but tends to embrittle after aging at 500–700°C. The embrittlement is associated with a precipitation of carbides along the grain boundaries although a σ-phase was not detected.

The present work is devoted to problems related to the structural stabilization of such a steel containing 0.14 C, 20.2 Cr, 15.5 Ni, 2.44 Si and 1.14 Mn. Aging was conducted at 650°C/5000 hrs. The microstructure was studied on optical and electron microscopes as well as by means of X-rays.

Specimens of steel 211 first stabilized at 1000°C for one hr were held at 650°C for 50, 100, 500, 1000 and 5000 hrs. Etching for metallography was performed with a 20% H2O2 solution in concentrated hydrochloric acid. Two etching procedures were used: a weak one — to reveal the fine structure of the σ-phase and a normal one — to study the carbide phase distribution and the grain boundaries. Electron microscope observations were conducted on colloidal replicas shaded with chromium. The phase composition prior to and after aging was checked by X-rays on the basis of a polished surface and electrolytically extracted residues.

In its initial condition, this steel consists of large austenite grains and globular carbide formations of the Me23C6 type [5]. During the early aging period (50–100 hrs) a large amount of secondary carbide phases begins to precipitate from the austenite. The grain boundaries broaden considerably, and after holding for 500 hrs they represent a continuous carbide network, Fig. a and b. X-raygrams made on electrolytically extracted residues from specimens held for 50–500 hrs, showed only carbide Me23C6 lines.

After weak etching of a specimen aged for 1000 hrs, only occasional dark, and dispersed precipitation can be found on it, Fig. c. These are located along grain boundaries in areas of carbide concentration and almost always in contact with the carbides. The X-raygram of a residue of a particular specimen reveals a diffraction indicative of σ-phase. The structure of a specimen held for 1000 hrs reveals areas containing carbides in which one finds a zone with a "sponge-like" structure different from the matrix. Dark precipitates can be seen on the background of this zone, Fig. d. These areas apparently represent a metastable structure condition corresponding to σ-phase formation at an advantageous ratio of the components involved.

Soaking the specimens for 2000–5000 hrs results in an increasing number and size of the σ-phase precipitates, Fig. e, f; and also the appearance of a large number of acicular precipitates within the grain. The X-raygrams reveal only σ-phase and carbide Me23C6.

Hence, during the first period of isothermal holding of the steel at 650°C, the supersaturated austenite decomposes and separates out finely dispersed Me23C6-type carbides. We did not observe during this period (up to 600 hrs) any σ-phase precipitation. This is explained by the fact that steel 211 has a substantial carbon content (0.14%) and, as a result, does not contain in the initial condition (after stabilizing at 1000°C) any δ-ferrite, the decomposition of which may result in σ-formation [3].

Carbide formation causes a fall of the carbon and chromium concentrations in the solid solution, this resulting in conditions advantageous to the precipitation of an α-phase [4]. This is confirmed by the increased magnetic susceptibility. The formation of σ-phase is facilitated by the presence in the α-phase (alloyed ferrite) of components which increase the tendency towards σ-phase formation.

Along with formation of σ-phase from the unstable ferrite, a process of partial dissolution of carbide takes place.
Fig. Microstructure of steel 1Kh20N14S2 after aging at 650°C:

a - 500 hrs, 600 ×;  b - 500 hrs, 8000 ×;
c - 1000 hrs, 600 ×;  d - 1000 hrs, 8000 ×;
e - 5000 hrs, 600 ×;  f, g - 5000 hrs, 8000 ×;