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TECHNICAL INFORMATION

PHASE ANALYSIS OF HEAT RESISTING CONSTRUCTIONAL STEELS

M. F. Alekseenko, N. F. Lashko, N. M. Popova
and G. N. Orekhov

We have studied the phase composition and mechanical properties of steels 30Kh2N2VA, 30Kh3VA (with different V content) and EI 415. The results of the mechanical tests are in the Table. Carbide analyses were made on cylinders 12 mm (.48 in) diam. and 60 mm (2.4 in) long, electrolyzed as anodes in a soln. of 1N KCl + 0.5% citric acid for 5 hours, at 0.2 amp/sq. cm (1.27 amps/sq. in), the solution being afterwards cooled to 0°C.

Steel	Tempered, Hours	TS kg/sq mm	0.2% YS kg/sq mm	El., %	RA, %	Impact Toughness KG.M/SQ CM	d, in mm
30Kh2N2VA	Quench 860°C (1580°F) in oil, Tempered at 600°C (1110°F)						
0.27-0.34% C, 0.30-0.60 Mn, 0.27-0.37 Si, 1.60-2.00 Cr, 1.40-1.80 Ni, 1.20-1.50 W	5 min	129	117	15	59	8	3.20
	0.5	129	119	14	59	8	3.18
	1	123	112	16	61	9	3.22
	4	120	107	14	61	10	3.33
	10	111	98	17	63	11	3.43
	25	113	101	15	64	12	3.42
	50	103	90	17	64	12	3.56
	100	98	88	17	63	12	3.60
	300	85	73	20	62	11	3.90
30Kh3VA	Oil Quench from 880°C (1615°F), Tempered at 600°C						
0.27-0.35% C, 0.30-0.60 Mn, 0.17-0.37 Si, 2.80-3.20 Cr, 0.80-1.10 W, max. .40 Ni.	5 min	131	120	15	59	8	3.12
	0.5	135	122	14	57	8	3.12
	1	126	113	14	60	9	3.22
	4	120	105	14	62	11	3.31
	10	112	97	15	63	13	3.42
	25	113	97	15	65	13	3.41
	50	95	81	18	69	20	3.69
	100	91	77	19	68	22	3.86
	300	81	65	20	70	20	3.98
EI415	Oil Quench from 1050°C, 2-Hour Tempering at 650°C (1200°F) + Prolonged Tempering at 500°C (930°F)						
Undisclosed Composition	2	96	86	11	64		
	10	86	83	12	62		
	50	87	82	11	66		
	100	83	80	11	67		
	300	81	77	10	66		

Fe, Cr, Mn, W, V and Mo were determined in the carbide residues obtained. For a separate determination of the elements in chromium carbides and cementite, the carbides were isolated by passivation of the chromium carbide in hydrogen peroxide, in whose presence they do not dissolve in hydrochloric acid, but cementite does. The carbide residues were boiled for one hour in a mixture of 25 ml of peroxide (concn. unstated) and 100 ml of 1:1 HCl, adding 5 ml of peroxide every 10-15 minutes. Iron and chromium were determined in the residue and filtrate. The results from the residue give the Fe and Cr contents of the chromium carbide, and those on the filtrate, the contents in the cementite.

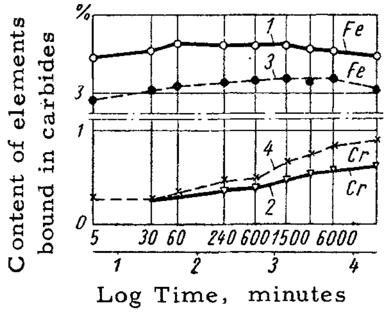

Figure 1.

Fig. 1. Effect of tempering time at 500°C (930°F) of steel 30Kh2N2VA (1 and 2) and 30Kh3VA (3 and 4) on the contents of elements, tied up as carbides.

Fig. 1 shows the percentages of elements tied up in carbides and isolated from steels 30Kh2N2VA and 30Kh3VA. Tempering of these steels proceeded qualitatively in the same manner. According to X-ray powder analysis figures (Co-Kα radiation) the anode residue from a steel, tempered at 500°C (930°F) is cementite, whose iron content is practically independent of the tempering time (5 minutes to 300 hours). In the initial stages of tempering at 600°C (1110°F) (Figs. 2 and 3) cementite precipitates, and after about one hour's tempering the Me_7C_3 phase appears, when the chromium content in the cementite is 10-12%. Increase in the amount of this type of carbide decreases the amount of cementite. Both

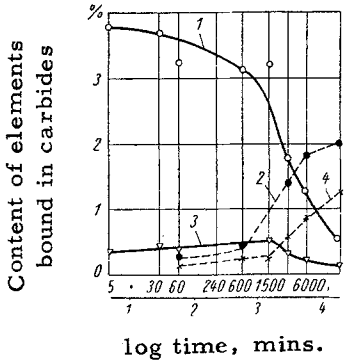

Fig. 2. Effect of tempering time at 600°C (1110°F) of steel 30Kh2N2VA on the contents of Cr and Fe, in cementite and trigonal Cr carbide.

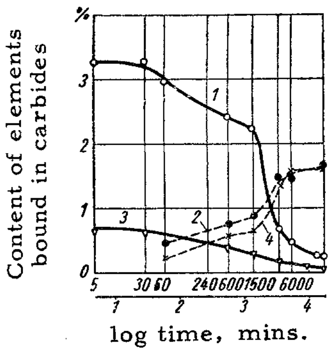

Fig. 3. Effect of tempering time at 600°C of steel 30Kh3VA on the contents of Cr and Fe in cementite and trigonal Cr carbide.

1 = Fe, and 3 = Cr, in $(Cr,Fe)_3C$;
2 = Fe, and 4 = Cr, in $(Cr,Fe)_7C_3$.

processes reach a maximum after 50 hrs (Fig. 3); the rate of decrease of cementite is greater than the rate of increase of Me_7C_3. After about 10 hours tempering at 600°C, practically all carbon has been converted to carbide, showing that Me_7C_3 can be formed by dissolution of Me_3C; its formation directly in Me_3C by lattice rearrangement is less probable.

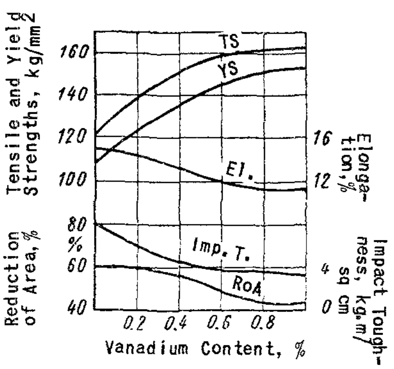

Fig. 4. Effect of vanadium on the mechanical properties of steel 30Kh2N2VA, quenched from 1020°C (1870°F) in oil and tempered for one hour at 600°C (1110°F).

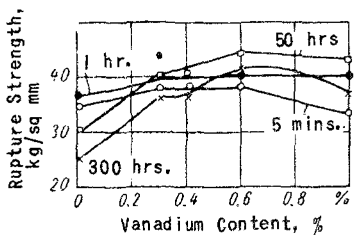

Fig. 5. Effect of vanadium on the 100 hour rupture strength of steel 30Kh2N2VA at 550°C (1020°F). Quenched from 1020°C, tempered at 500°C.

Figs. 4 and 5 show the mechanical properties of steel 30Kh2N2VA after various heat treatments, plotted against vanadium content. In tempering at 500°C (930°F) only carbide separates from supersaturated solid solution of the steels containing up to 0.4% V, this carbide being metastable cementite, in which the chromium, manganese, and tungsten contents continuously increase while the iron content decreases. The degree of metastability increases with the vanadium content.

Even after a short period at 500°C, practically all the carbon has been converted to carbide so that VC is formed by solution of the cementite.

An analysis of the phase composition of steels 30Kh2N2VA with different vanadium contents (EI659, EI415, etc.) explains their behavior in rupture testing at 550°C (1020°F). The magnitude of the rupture strength is determined by the strengthening of the solid solution, its thermal stability and its interaction with precipitated phases. The hardening action of the latter depends on their particle size and tendency to diffuse into the solid solution; the lower the rates of formation and growth of nuclei, the more pronounced the strengthening action. In steel EI415 after tempering at 650°C (1200°F), the carbide has only partly combined with Cr, W, Mo and V. The alloying elements remain in solid solution, retard diffusion and harden the solid solution. After one hour's tempering at 650°C, 2.2% Cr, 6.6% V, 0.2% Mo and 0.4% W remain in solid solution; further tempering for 10 & 300 hrs. at 500°C hardly affects the distribution of elements between solid solution and carbides. This alloying of solid solution distinguishes steel EI415 from other steels of similar composition.

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