PROPERTIES OF CHROMIUM-NICKEL AUSTENITIC STEELS

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We studied the properties of unstabilized chromium-nickel austenitic steels designed for operation in steam superheaters. The chemical composition of the laboratory melts investigated is given in Table 1. The steel was melted in high-frequency basic furnaces and poured in ingots weighing 45 kg. The ingots were forged into bars 32 and 45 mm square.

The grain size of the steels after different heat treatments is given in Table 2. The steels with 0.09-0.11% C are more inclined to grain growth than the steels with 0.04-0.05% C. Nevertheless, melts 2, 3, and 5 (with higher carbon) had finer grains after quenching from 950°C. A banded structure was observed in these same melts. In the structure of melts 1 and 4 we observed δ ferrite in elongated arrays along the grains.

During aging at 620 and 650°C for periods up to 6,000 h $M_{23}C_6$ carbides are precipitated, the major quantity precipitating in the first thousand hours. After 1000 h of aging one observes an increased amount of δ ferrite in melts 1 and 4 and its appearance in melts 2, 3, and 5.

Metallographic and electron diffraction analyses did not reveal any σ phase in the grain boundaries after aging. The results of the carbide analysis of melts 1 and 5 after quenching and after aging at 620°C are shown in Fig. 1.

Heating up to 950°C does not lead to solution of the carbides in the steels with 0.09-0.11% C. Only at 1100°C are the carbides fairly completely dissolved except in the case of melt 5, in which the carbides are more stable because of the presence of molybdenum in the steel. Solution of the carbides in this steel requires heating to 1150°C.

Aging induces precipitation of carbides, although no essential difference was observed in carbide formation at 620 or 650°C. In steels with 0.09-0.11% C the amounts of carbides precipitated are considerably larger than in the steels with 0.04-0.05% C.

The mechanical properties of the steels in the original condition are given in Table 3.

Analysis of the data from testing at 20°C shows that increasing the quenching temperature from 950 to 1100°C reduces the yield point. In melts 2 and 3, containing ~0.1% C, the specific elongation and reduction in section increase. In all melts the impact strength is above 30 kgm/cm^2 after quenching from 1100°C.

At concentrations of 0.04-0.05% C we found no substantial difference in the ductility or impact strength after quenching from 950 or 1100°C, which indicates the low sensitivity of the properties of these steels to the quenching temperature. In melt 5 the ductility increases only after austenitizing at 1150°C, which is explained by the fact that the steel with 0.1% C was alloyed with molybdenum. Quenching other melts from this temperature reduces the specific elongation by comparison with quenching from 1100°C.

TABLE 1

Melt No.	Composition, %							
	C	Si	Mn	Cr	Ni	Mo	S	P
1	0.04	0.5	1.3	19.5	10.6	0.6	0.012	0.023
2	0.09	0.3	1.2	19.4	12.3	—	0.013	0.008
3	0.11	0.4	1.3	19.2	10.6	—	0.003	0.026
4	0.05	0.4	1.3	19.2	10.2	—	0.012	0.026
5	0.10	0.4	1.3	19.1	12.2	0.7	0.006	0.007

Eastern Branch of the All-Union Heat Engineering Institute. Translated from Metallovedenie i Termicheskaya Obrabotka Metallov, No. 8, pp. 42-46, August, 1967.

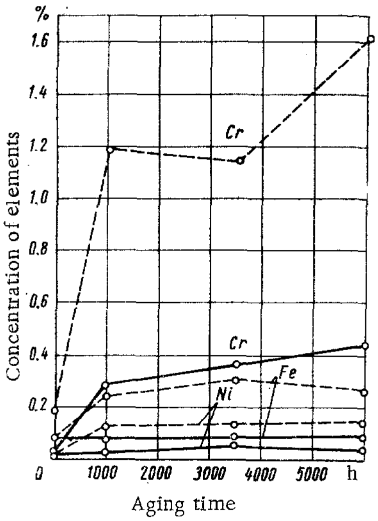

Fig. 1. Concentrations of chromium, nickel, and iron in electrolytic residues after quenching from 1100°C (soaked 30 min), cooling in water, and aging at 620°C. ——) Melt 1; - - - -) melt 5.

TABLE 2

Heat treatment	Grain size (grade)				
	melt 1	melt 2	melt 3	melt 4	melt 5
950° C 30 min water	6	8—7	8	6—7	8
1100° C 30 min water	5—4	5—6	5—6	5—6	6—7
1150° C 1 h water	4—5	1—3	Coarser than 1—3	2—3	2—3

With an increase of the testing temperature to 620 and 650°C the strength and ductility decrease; no essential difference in the properties was noted at these two temperatures.

After quenching from 950°C the strength at room temperature, 620, and 650°C is higher in steels with 0.09-0.11% C than in the steels with 0.04-0.05% C. After quenching from 1100°C the steels with different carbon concentrations have similar yield points at 620 and 650°C.

The substantial advantage in specific elongation at 20°C for the low-carbon steels quenched from 950°C is reduced at testing temperatures of 620 and 650°C. After heat treatment at 1100°C the specific elongation is nearly the same for all melts except melt 5. The specific reduction and impact strength

TABLE 3

Heat treatment	Melt	Testing temperature, °C: 20						620					650				
		σ_b, kg/mm²	$\sigma_{0.2}$, kg/mm²	δ_5, %	ψ, %	a_n, kgm/cm²	HRB	σ_b, kg/mm²	$\sigma_{0.2}$, kg/mm²	δ_5, %	ψ, %	a_n, kgm/cm²	σ_b, kg/mm²	$\sigma_{0.2}$, kg/mm²	δ_5, %	ψ, %	a_n, kgm/cm²
Quenched from 950°C (30 min), water	1	64.3	33.2	71.1	78.9	>34.4	84	39.0	15.1	34 3	74.3	<34.7	40.7	15.7	43.9	69.7	36.1
	2	66.7	40.2	46 4	66 0	18.9	88	45.2	19.7	35.5	63.5	17.1	42.2	22.1	36.2	60.5	17.8
	3	70.5	38.0	50.0	66.0	16.5	90	43.5	22.1	35.0	64.1	16.7	41.1	20.8	34.2	56.0	15.9
	4	61.2	30.6	76.0	82.0	>35.5	82	41.5	16.0	40.4	79.5	33.2	34.6	16.3	40.0	66.4	33.6
	5	68.1	38.1	47.5	65.1	14.3	90	49.5	24.5	34.7	57.7	14.3	41.0	22.1	37.5	58.2	15.9
Quenched from 1100°C (30 min), water	1	53.8	24.5	76.1	78.0	>37.5	78	37 8	14.2	41.1	66.4	34.4	32 5	14.7	39.4	61.8	32.7
	2	64.6	28.8	72.7	74 6	30.5	80	43.2	14.8	39.4	56.0	26 6	37.9	15.6	39.6	54.2	31.7
	3	68.2	28.3	76.2	73.6	32.4	84	44.8	15.1	39 4	55.4	26.3	40.3	15.3	38.3	53.1	27.3
	4	60.8	28 4	72.7	79.7	>37.6	77	36.5	13.9	41.1	60.6	34.8	36.5	14.2	40.0	62.0	33.8
	5	69.4	33.1	48.9	61 8	32.1	85	45.6	17.1	38.4	56.4	24.5	41.2	13.9	37.6	58.3	28.6
Quenched from 1150°C (1 h) water	1	57.3	19.8	59.1	79.2	—	—	—	—	—	—	—	—	—	—	—	—
	2	56.0	23.9	57.1	70.8	—	—	—	—	—	—	—	—	—	—	—	—
	3	56.0	24.4	58.0	71.9	—	—	—	—	—	—	—	—	—	—	—	—
	4	57.3	21.3	59.1	79.2	—	—	—	—	—	—	—	—	—	—	—	—
	5	59.6	28.0	60.0	76.0	—	—	—	—	—	—	—	—	—	—	—	—

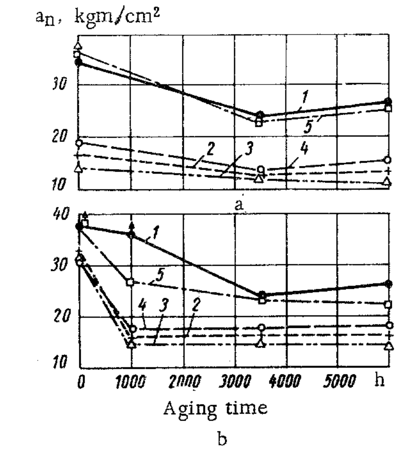

Fig. 2. Impact strength of the steel after aging at 650°C. a) Water-quenched from 950°C (30 min); b) water-quenched from 1100°C (30 min). Numbers on the curves are melt numbers.

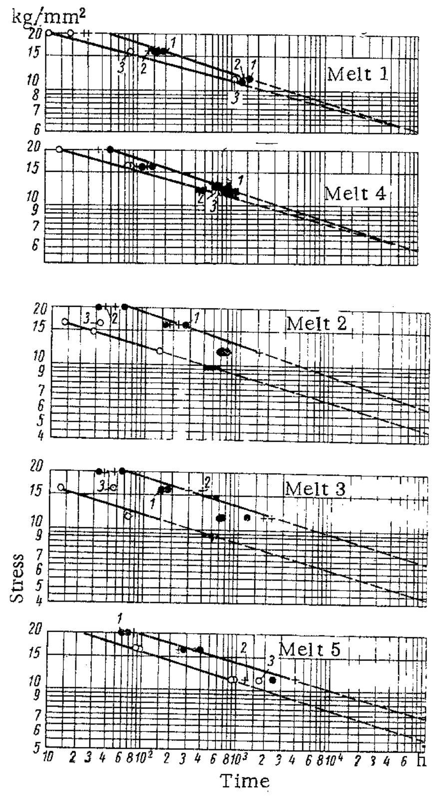

Fig. 3. Long-term strength of steels at 650°C after different heat treatments. 1) Water-quenched from 950°C (30 min); 2) water-quenched from 1100°C (30 min); 3) water-quenched from 1150°C (1 h).

TABLE 4

Melt No.	σ_{long}, kg/mm², at testing temperature, °C	
	620	650
1	2/6.2	5.4/5.4
2	6.6/7.5	—/6.0
3	6.2/7.2	5.4/6.5
4	—/6.5	5.4/5.4
5	6.2/7.2	5.4/6.5

Note: The numerators indicate melts water-quenched from 950°C (30 min), the denominators melts water-quenched from 1100°C (30 min).

at 20, 620, and 650°C are higher in the low-carbon steels than in melts 2, 3, and 5, particularly after quenching from 950°C.

After aging up to 6000 h at 620 and 650°C the ultimate strength and yield point change little and the specific elongation decreases, although remaining above 35% and, for melts 1 and 4, above 50%. After quenching from 1100°C the specific elongation stabilizes after aging 1000 h; the reduction in section remains essentially unchanged.

The impact strength of all the steels decreases but remains at least 22 kgm/cm² in the low-carbon steels and 11 kgm/cm² in the steels with 0.09-0.11% C (Fig. 2). The impact strength stabilizes after aging 1000 h.

After aging 6000 h at 620 and 650°C the hardness of the steels investigated differs no more than 4 HRB units from the hardness after quenching.

In Table 4 are given the values of the long-term strength for 100,000 h obtained by extrapolating from the average values of the experimental points (but disregarding the results from testing less than 100 h). The long-term strength is shown in Fig. 3.

These results are somewhat lower than the corresponding values for steel 1Kh18N12T treated under optimum conditions. However, for other than optimum conditions the long-term strength of 1Kh18N12T steel for 100,000 h at 650°C may be 3-4.4 kg/mm² lower (Fig. 3).

Apart from long-term strength, a major factor in evaluating the steels is the long-term ductility (Table 5). The steels with 0.04-0.05% C (melts 1 and 4) have the highest long-term ductility. The long-term ductility of steels with 0.09-0.11% C is considerably lower, the lowest values occurring for quenching from 1150°C.

TABLE 5

Heat treatment	Long-term ductility†, % of melts									
	1		2		3		4		5	
	δ_{10}	ψ	δ_{10}	ψ	δ_{10}	ψ	δ_{10}	ψ	δ_{10}	ψ
Quenched from 950°C (30 min), water	27—55 / —	30—51 / —	6—70 † / 10—62*	12—46 / 11—39	8—20 / 11—35	14—39 / 14—46	34—49 / 28—57	21—58 / 30—49	11—28 / 9—16	14—36 / 16—34
Quenched from 1100°C (30 min), water	27—47 / 17—37	35—49 / 27—51	6—16 / 2—7	8—25 / 7—11	7—19 / 9—12	12—36 / 8—24	20—48 / 14—44	24—53 / 20—47	8—19 / 6—20	14—31 / 7—31
Quenched from 1150°C (30 min), water	17—50 / —	21—49 / —	2—5* / —	4—12 / —	3—7* / —	5—14 / —	17—20 / —	16—26 / —	3—4* / —	2—10 / —

* δ_5.

† The numerators indicate testing at 650°C, the denominators at 620°C.

Thus, austenitic chromium-nickel steel of the 18/9 and 18/12 types without titanium and niobium have highly stable properties under long-term heating conditions (1000 h). The properties of the steels with 0.04-0.05% C depend little on austenitizing temperatures of 950-1150°C, and therefore the steel is more suitable for steam superheaters than 1Kh18N12T steel if the heat treatment deviates from the optimum.

LITERATURE CITED

1. V. N. Gulyaev and Yu. P. Bulanov, Teploénergetika, No. 11 (1964).