EFFECT OF RARE EARTH METALS ON THE PROPERTIES OF HEAT-RESISTANT NICKEL-CHROME ALLOY

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Great attention was devoted lately to research aimed at determining the effects of minor additions of rare-earth metals on the properties of steels and alloys.

It has been established that minor injections of rare-earth metals into stainless and heat-resistant alloys based on cobalt and nickel-chrome substantially increase their rupture strength and creep resistance at 700-900°. For example, a 1.6 kg per ton addition of misch metal to steel Kh25N20 produces a 25-% increase of tensile strength after a 100-hours test at 650° [1].

In a cobalt-based alloy (45-50% Co, 23-28% Cr, 9-12% Ni, 6-9% W) a 2% addition of misch metal causes the rupture strength to rise at 820-930°, but fails to improve the properties at room temperature.

It was demonstrated that the heat resistance of alloy EI437 improves on separate introduction of 0.025% Ce or La [3], and for austenitic steel 1Kh13N16B this effect may be achieved by adding 0.03% Ce [4]. Addition of 0.01% Ce heightens the creep resistance of alloy N36KhTYu [5].

In the majority of investigations the rare-earth metals were introduced into alloys in the form of misch metal (20-24% Nd + Pr + Sm, 1% Fe).

The present work was confined to a study of the influence produced by pure cerium, lanthanum, praseodymium, and neodymium upon the properties of heat-resistant alloy EI437 (0.03-0.05% C, 20-21% Cr, 2.5-28% Ti, 0.8-1.0% Al, 75-76% Ni). The separate calculated additions of these rare-earth metals amounted to 0.02, 0.06, 0.1, and 0.15%, respectively.

The heats were made in 30-kg capacity induction furnaces in crucibles with basic lining by the method of fusing together the charge materials. Rare-earth metals were injected into the well deoxidized bath after slag removal and 2 minutes before teeming. The 10-kg ingots were forged into 15-20-mm square section bars after heating to 1180°.

Rupture strength was determined at 700° under a 36-kg/mm^2 stress; the mechanical properties were registered in short-term tensile tests at 20 and 700°. Investigations were also carried out of the microstructure and the gas content of the experimental melts. The samples were held for 8 hours at 1080°, cooled in the air, and aged at 700° (16 hours).

The basic distinction between the rare-earth metals that were used consists in their different melting points. Cerium melts at 804°, lanthanum at 920°, praseodymium at 935°, and neodymium at 1024° [6].

Lanthanum, cerium, praseodymium, and neodymium are practically insoluble in solid nickel, and apparently also in nickel-based solid solutions. The above mentioned rare-earth metals form the same type of constitutional diagrams with nickel [7].

We were able to establish that addition of lanthanum, cerium, praseodymium, and neodymium in quantities up to 0.1% does not affect the ductility of alloy EI137. An increase of the addition up to 0.15% (calculated percentage) results in a decline of metal plasticity under hot deformation.

By method of chemical-spectral analysis (developed by N.N. Sorokina, N.G. Moreyn, Ye.A. Balasheva, and V. Golubeva) it was established that the actual contents of lanthanum and cerium in the metal amounts in most cases to 20-30% of the calculated addition.

In other words, lanthanum and cerium, and, probably, also neodymium and praseodymium burn out intensively in the process of melting. The added elements appear to be concentrating primarily along the grain boundaries of the primary crystals, and their contents in excess of 0.02% reduces the deformability of the metal.

Introduction of rare-earth metals does not affect the grain size; after 8-hours heating at 1080° the grain corresponded to size No. 2-4 of an 8-number scale.

The investigated additions of up to 0.1% produce no substantial effect on the mechanical properties of the alloy in the case of short-time tensile tests at room temperature. In all instances the tensile strength was equal to 110-118 kg/mm^2, with the elongation averaging 30-35%.

A considerable improvement of the plastic properties was registered in the alloy with rare-earth metal admixtures at 700° (Fig. 1). The curves manifest characteristic plasticity maxima corresponding to 0.01-0.02% contents of the said elements. An increase of cerium and lanthanum beyond the 0.02% level is accompanied by a sharp drop in the alloy ductility.

All investigated additions increase substantially the rupture strength of the alloy at 700°. The highest heat resistance characteristics were registered upon introduction of 0.1% (calculated) cerium, lanthanum, praseodymium, or neodymium (Fig. 2), corresponding to about

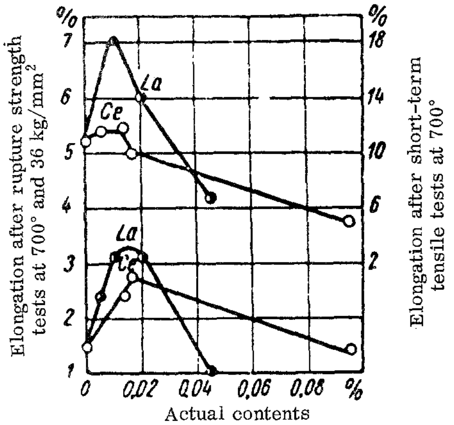

Fig. 1. The magnitude of elongation in short and long-time tensile tests at 700° depending on the actual contents of lanthanum and cerium in the alloy.

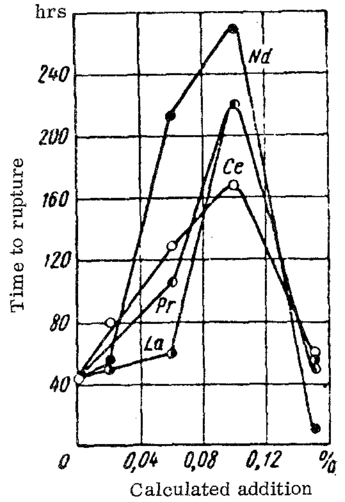

Fig. 2. Time to rupture at 700° and 36-kg/mm² load depending on the magnitude of the calculated addition of cerium, lanthanum, praseodymium, or neodymium to the alloy.

0.02% of actual cerium or lanthanum contents in the alloy (Fig. 3).

An increase of the actual rare-metal contents beyond the 0.02% value (calculated addition greater than 0.1%) leads to a sharp decline of the sample endurance and reduces the residual plasticity characteristics after stress-rupture tests (Figs. 2-4). By the effectiveness of their influence on rupture strength the rare-earth metals, when introduced in optimum quantities of 0.1%, range in the following order: cerium, lanthanum, praseodymium, and neodymium. This sequence corresponds to the ascending order of the melting-point temperatures. Introduction of 0.1% Nd increases the time to rupture at 700° and a load of 36 kg/mm² by a factor of 6, additions of lanthanum and praseodymim produce a fivefold, and cerium a fourfold increase.

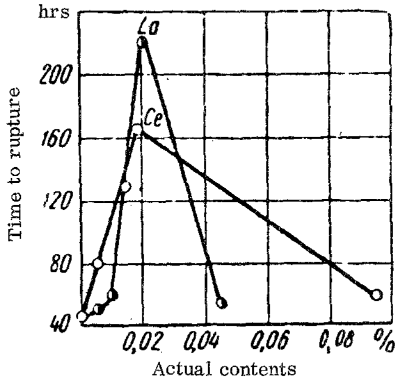

Fig. 3. Time to rupture at 700° and 36 kg/mm² load depending on the actual contents of cerium or lanthanum in the alloy.

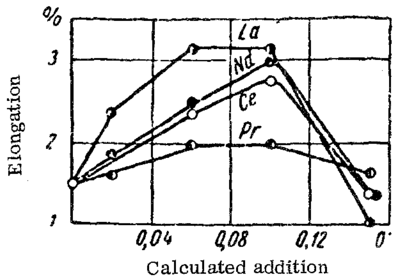

Fig. 4. Residual elongation after long-term tensile tests at 700° with a 36 km/mm² load depending on the magnitude of the calculated lanthanum, cerium, praseodymium, or neodymium addition to the alloy.

The obtained data are in good agreement with the results recorded in the previously mentioned papers. It was shown, for example, that metallic lanthanum produces a stronger effect on the heat-resistance properties of alloy EI437 than metallic cerium [3]. Some investigators [8] recommend the use of lanthanum-rich misch metals (45-50% Ce, >30% La, 20-24% Y and other elements), since lanthanum has a higher boiling point (1800°) than cerium (1400°).

Additions of cerium, lanthanum, and praseodymium reduce considerably the total amount of gases in the metal, mainly at the expense of oxygen contents (which show a 3 to 4-fold reduction). Introduction of 0.05-0.15% Ce or Pr causes the total contents of gases in the alloy to drop to a 3-3.5 times lower level (Fig. 5).

It should be noted that the effect of rare-metal additions on the plasticity and strength characteristics of the alloy is most pronounced at high test temperatures, when the mechanical properties depend on the condition of the grain boundaries.

Addition of rare-earth metals augments the intercrystalline strength of the metal, mainly due to a supplemental reduction and the combining of the harmful low-melting admixtures into high-melting compounds [3].

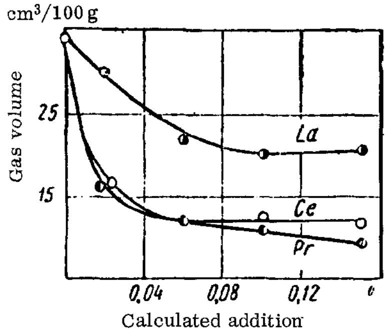

Fig. 5. The gas saturation of the alloy depending on the magnitude of the lanthanum, cerium, or praseodymium addition.

It is also possible that a certain proportion of the rare-earth metals, while dissolving in the boundary crystallite zones, strengthen the grain boundaries and inhibit the diffusion processes.

CONCLUSIONS

1. Separate additions of cerium, lanthanum, neodymium, and praseodymium to alloy EI437 produce a substantial increase in the strength and plasticity of metal in long- and short-time tensile tests at 700°, and also reduce the total contents of gases in the metal.

2. The maximum effect of rare-earth metals is observable when the residual amount of the injected addition does not exceed 0.02%.

3. By the effectiveness of their influence on the rupture strength of alloy EI437 the investigated elements range in the order corresponding to their progressively increasing melting points.

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EFFECT OF Ti, W, Mo, AND Si ADDITIONS ON THE PROPERTIES OF CHROMIUM STEEL

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In studying the corrosion resistence of the material for cold-rolled heat-exchange piping (19 x 1.5 - 38 x 3.5 mm) an investigation was carried out (with the participation of Z. A. Abramova) of the properties of four experimental chromium steel melts. (Table 1).

The investigation was conducted with 40-mm diameter rods produced by forging of 35-kg ingots. The rods were then cooled in air to assure a hardness value of HB 340-390.

The critical points for the steels (see Table 1) were determined by dilatometric method during heating and cooling at a rate of 4 deg/min, and by the method of test hardening (Ac_1 and Ac_3). The critical point values defined by both methods showed a good agreement.

Dilatometric investigation revealed that transformation occurs in the intermediate range (285-315°) if steels Kh8 and Kh8SM are being cooled slowly. Introduction of titanium, which combines with carbon, intensifies pearlite transformation. As a result of this point Ar_3 (for steels Kh8T and Kh8VT) rises and the critical cooling range becomes narrower.

Heat-exchange pipes are being used at relatively small stresses and moderately elevated temperatures (up to 350-450°). The main requirement to be met by the pipes (in addition to high resistance to corrosion) is that they should respond well to rolling. Therefore, the pipe material in the finished state must exhibit high plasticity and impact toughness values. (For example, according to the Standard Specification No. 2968-51 for ferrous metals steel Kh5M heat-exchange pipes must satisfy the following standards on delivery: $\sigma_b \geqslant 40$ kg/mm², $\sigma_s \geqslant 17$ kg/mm², $\sigma_5 \geqslant 24\%$, $\psi \geqslant 50\%$, $\alpha_k \geqslant 10$ kg. ⁻m/cm², HB ≤ 170).