PERITECTIC TRANSFORMATIONS IN CRYSTALLIZATION OF ALLOYS OF THE Al─Cr SYSTEM. I

A. V. Kuznetsov and V. I. Psarev

Established laws of the nonequilibrium crystallization of aluminum—chromium alloys permit the conclusion that each peritectic horizontal on the diagram of the Al—Cr system (at 725, 930, and 1000°C) corresponds to a region of structural transformation to a liquid extending from aluminum is the vertical of an intermediate compound. Retention of the stability of the high-temperature structural state of the liquid during its cooling predetermines the possibility of a delay in the peritectic transformation, crystallization according to metastable diagrams and, in individual cases, the formation of supersaturated solid solutions based on aluminum.

Present concepts of an incongruent saturated solution — "a liquid solution which may at a given pressure be found in equilibrium in two or more solid phases, one of which is dissolved when heat is removed from the system and the other of which is precipitated" [1] — to a considerable extent do not reflect the substance of accumulated experimental facts on peritectic transformations in different alloy systems, particularly in the case of their nonequilibrium crystallization. This also applies to phenomena of the formation of highly supersaturated solid solutions, metastable phases, alloys with an amorphous structure, and other effects the physical significance of which, in our opinion, could be explored with regard for changes in the internal structure of the crystallizing liquid. The same view has been expressed by other authors (see, e.g., [2, 3]) although no systematic empirical studies have been conducted in this area.

The present work was devoted mainly to explaining, according to characteristic signs of the nonequilibrium crystallization of aluminum—chromium alloys, changes in the internal structure of the liquid during a peritectic transformation of the melt. The Al—Cr system is most favorable in this sense, since its phase diagram contains a whole series of peritectic horizontals.

To experimentally study aluminum AVOCO and chromium of spectral purity, we prepared alloys containing 5, 10, 15, and 26 wt. % Cr.

Specimens made of these materials were subjected to nonequilibrium crystallization on a unit that permitted drops of the melt to spread in the form of a thin film between two cooling copper disks brought into contact with each other (see [4]), with the simultaneous recording of cooling curves by means of oscillograph SN-700. The cooling rates thus achieved had values ranging from $10^2$ to $10^5$ deg/sec, depending on the film thickness. The thin films crystallized at different temperatures corresponding to regions of single-phase liquid and two-phase liquid + crystals were subjected to metallographic, x-ray phase, x-ray diffraction, and thermogravimetric analyses. The crystal structure of the phases was judged from data from interpretation of diffraction patterns taken of the surface of the films on a Dron-2.0 unit. The chromium content of the aluminum solid solution was determined by means of the formula [5]

$$\alpha(\text{Cr}) = 4.0496 - 4.16 \times 10^{-3} \sec (\text{wt. } \% \text{ Cr}),$$

where $\alpha$ is the lattice parameter of $\alpha$-Al.

The cooling curves corresponding to Al alloys containing 10 and 15% Cr are shown in Fig. 1. The cooling rate of the melt, determined from the slope of the descending section of the curves (at the moment of spreading of the drops pressed between the copper disks) was $4-5 \times 10^4$ deg/sec. Features of the nonequilibrium crystallization of the alloys will be analyzed here with allowance for the structure of the equilibrium phase diagram of the Al—Cr system, a section of which is shown in Fig. 2. In cooling of the melt from 1000°C...
Fig. 1. Cooling curves in the nonequilibrium crystallization of Al–Cr alloys: 90% Al, 10% Cr: 1) from 1000°C; 2) from 920°C; 3) from 855°C; 4) from 710°C; 85% Al, 15% Cr; 5) from 1050°C; 6) from 860°C.

Fig. 2. Section of phase diagram of Al–Cr system [6]. Symbols: \(\times\) solid solution of aluminum; \(\theta\)–Al\(_2\)Cr; \(\eta\)–Al\(_{11}\)Cr\(_2\); \(\varepsilon\)–Al\(_4\)Cr; L(a), L(b), L(c) regions of the liquid state with different internal structures.

Fig. 3. Profiles of interference maximums of diffraction pattern (Fe-radiation) of \(\chi\)-Al crystallographic plane (311) in nonequilibrium-crystallized AlCr alloys: 90% Al, 10% Cr: a) from 1000°C; b) from 855°C; 85% Al, 15% Cr: c) from 860°C.

Fig. 4. Microstructure of nonequilibrium-crystallized aluminum–chromium alloys: a) 90% Al, 10% Cr, from 920°C, \(v = 2-4 \times 10^2\) deg/sec; b) 74% Al, 26% Cr, from 950°C, \(v = 10^3\) deg/sec. × 250.

(curve 1; superheating \(\Delta T = 120-130\)°C) the Al\(_2\)Cr crystallization process begins after the melt reaches 720°C. An aluminum solid solution is achieved at 660°C. These phases are retained down to room temperature, and can easily be detected by means of metallographic and x-ray phase analysis. Individual interference maximums corresponding to the crystalline lattice of \(\chi\)-Al on the film diffraction patterns are split (Fig. 3a), which is indicative of the inhomogeneity of the aluminum-base solid solution. A solid solution with a larger lattice parameter \(a = 4.0451\) Å and a lower chromium content \(c = 1.08\%\), see Table 1) arises as a result of crystallization of the alloy according to the metastable diagram of Al–Al\(_2\)Cr. The presence of a small quantity of highly supersaturated solid solution \(a = 4.0233\) Å and \(c = 5.60\%\) Cr in the film should be attributed to partial recrystallization of the melt according to the diagram of Al–Al\(_{11}\)Cr\(_2\). The latter is represented in Fig. 2 by a continuation of the dashed liquidus line of the \(\eta + L(b)\)-region.

With less superheating (curve 2; \(\Delta T = 50\)°C), the melt begins to recrystallize at 769°C and precipitates mainly Al\(_{11}\)Cr\(_2\) crystals, with precipitation of a negligible quantity of Al\(_4\)Cr. At 660°C, two solid solutions once again crystallize: one slightly supersaturated at the boundary with the \(\varepsilon\)-phase, and one highly super-