CERTAIN FEATURES OF THE STRUCTURE AND ANISOTROPY IN Ni₃Al SINGLE CRYSTALS

A. S. Verin

UDC 669.245.620.186.5

The structure of single crystals of an intermetallic, the composition of which is close to stoichiometric, was investigated. It was shown that it is sensitive to microadditions of rare-earth metals within limits of 0.05-0.3% and crystallization rate of 10-210 mm/min.

It is quite difficult to obtain castings of Ni₃Al single crystals with uniform distribution of the primary axes of the dendrites in the height in directed crystallization furnaces used at present. The structure of such castings consists of primary γ (Ni₃Al)-phase (matrix) and particles of γ-phase (disordered solid solution of Al in Ni) distributed in its volume in the form of dendritic combinations [1]. Such a structure may be obtained only by the combined Bridgeman method with zone remelting [1]. This process is very complex and is practically unused in industry. However, production of castings with such a structure in directed crystallization production equipment used for casting of nickel high-temperature strength alloy parts is possible with more accurate temperature control in combination with microalloying of the intermetallic with up to 1% of various elements. Such elements as Cr, Nb, Ta, W, Mo, Co, Si, Ce, B, Zr, and La were used for microalloying. On the basis of the investigation results, an optimum composition based on compositions close to stoichiometric was developed: Ni – 12% Al – 0.28% Ce – 0.5% Co. The structure of a casting of such a composition corresponded to that given above and with a small increase had a textured form (compositelike) (Fig. 1).

It is known that material containing 12-13.5% Al has a high degree of short- and long-range order and after single-step cold deformation becomes stronger and harder. This is characteristic of practically all structural modifications starting from equiaxial castings to single-crystal ones. The difference is only in the absolute values of strength and hardness. Practically all metals and alloys are subject to strain hardening. It should be pointed out that in the compound Ni₃Al this process probably has a more complex character. In practically all metals and alloys strain hardening is eliminated in hardening to 400-500°C, while in the compound Ni₃Al it not only does not disappear in heating to 760-800°C but continues to increase.

It is known [2] that strain hardening of this compound is determined by the interaction of two slip systems, the octahedral {111} (011) and the cubic {001} (011). During development of etching methods for the macrostructure it was observed that on single-crystal castings with a [001] direction of crystal growth after long etching in FeCl₃ solution the plane which was identified by x-ray analysis as {001} was corroded. It was of interest to roll such castings at room temperature with reduction perpendicular to this plane. In addition, in this direction the crystalline structure is characterized by two types of alternating planes consisting only of nickel or aluminum atoms.

In this work, all of the castings were produced in semiproduction directed crystallization equipment in which in place of a water-cooled mold there is a tank with molten tin in which the heated mold is immersed. The temperature of the molten material before immersion was 280-300°C and the rate of immersion 4-210 mm/min.

The shape and dimensions of the castings in the casting block (Fig. 2) were selected taking into consideration obtaining of a single crystalline structure at any crystallization rate in the given range. At the same time, with variation of the crystallization rate, the crystallographic direction of crystal growth was changed without use of inoculants. With a crystallization rate of 10-40 mm/min single crystals with an [001] direction of growth are always formed. With a crystallization rate of \( v_c = 10 \) mm/min the minimum angle of disorientation was 15-20° and with \( v_c = 20 \) mm/min 3-5°. With \( v_c > 20 \) mm/min the angle of disorientation again starts to increase and with \( v_c = 40 \) mm/min it reaches 15-20° and more. With rates from 40 to 80
mm/min crystallization occurs in the [110] direction and with rates of 180-210 mm/min in the [111] direction. The rule of change in disorientation with a change in crystallization rate in obtaining of the [011] and [111] directions is approximately the same as in the case of the [001] direction. In this case only two directions, [001] and [111], were of interest. The deviation from these directions within limits of 0-5° was determined visually from etching figures in the plane perpendicular to the direction of crystal growth under a binocular microscope at a magnification of 20-50×. The characteristic dendritic structure in the [001] and [111] directions of crystal growth is shown in Fig. 3. Such a form of dendrites was observed in the cutting plane formed by a corundum cutting wheel after etching for 5-10 min in a 4:1 HCl + H₂O₂ solution. Specimens taken with minimum deviation from the selection direction with a diameter of 3 and a length of 120-130 mm were placed in an FeCl₃ solution and held for 1-3 days. On specimens with an [001] crystal growth direction after a 1-day etching the above plane was formed on the whole length (Fig. 4) and on some specimens even two symmetrically located planes. Specimens with [001] and [111] crystal growth directions were rolled under the same conditions except that the specimens with the [111] direction were not oriented in relation to the rolling axis. On the ends of the specimens with an [001] direction an entry area with a length of 10 mm up to a thickness