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NON-DENDRITIC CRYSTALLIZATION OF METALS – POSSIBLE CAUSES

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In experiments connected with the study of rheocasting methods for Al-Si alloy (A356) besides “classic dendrites” (Fig. 1, a) were found morphologies demonstrating more or less splitting of structure elements (Fig. 1, b – d).

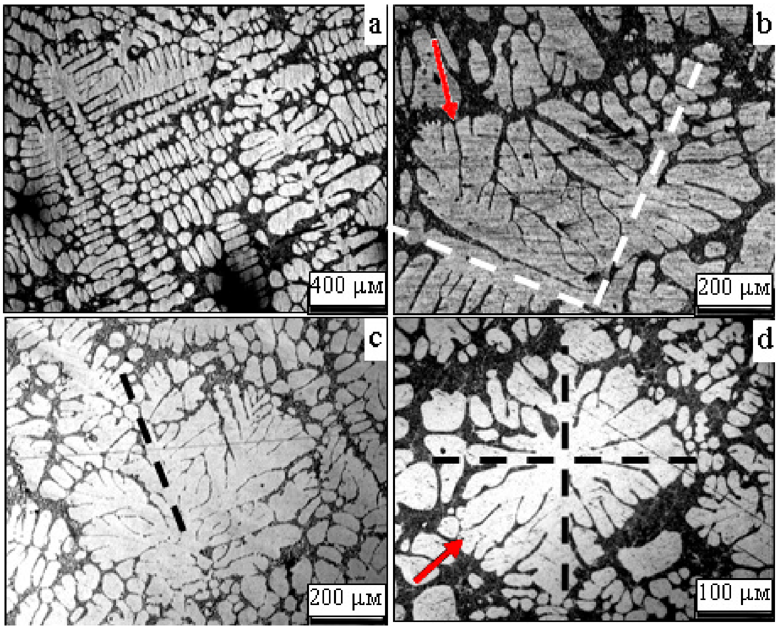

Fig.1. a – classic dendrite; b, c, d – splitting patterns. Dashed lines mark “dendrite stems”. Arrows on b) and d) indicate splitting elements for comparison with Fig. 6 d), h)

Such structure retains some “dendrite features”, therefore we entitled them as degenerate dendrites. Possible reasons for its appearance are discussed further.

It is known that regular dendrites form spontaneously by growth in a preferential direction (<100> for cubic symmetry), that reflects crystallographic anisotropy. For growth in other directions, anisotropy had to be “overcome” due to some circumstances. It seems that such circumstances can be reduction of anisotropy, transition processes and forced conditions.

Reduction of anisotropy. The formation of splitting patterns in the absence of anisotropy was demonstrated widely in numerical modelling. As concerns Al-based alloy [1] declares the possibility of splitting pattern formation as a consequence of alteration of preferential growth direction due to increase of Zn content for Al-Zn alloy. For verification of such ability for Al-Si alloy, the experiments on crystal growth in concentration gradient were performed. A complex cylindrical sample from two parts – pure Al and Al-Si eutectic was fabricated. The sample in the crucible was melted fully and then directional crystallization took place, so Al dendrites grow in the eutectic region, Fig. 2.

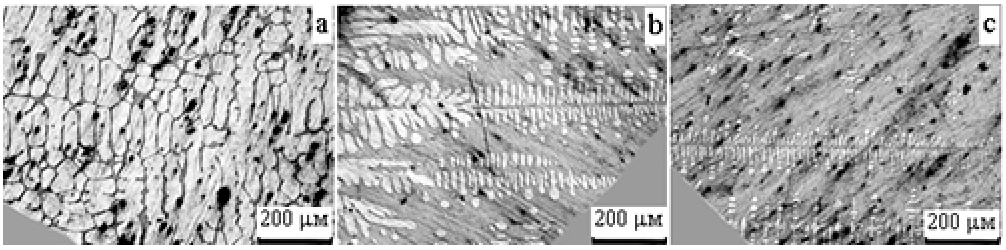

Fig. 2. Al-dendrites grow in eutectic region: a – Al region, b – transitory region, c – eutectic region

As it can be seen from the figure, dendrites continuously grow throughout the whole sample, and no changes of preferential growth direction or splitting were observed.

Transition processes. Relatively transition processes it must be noted that in real casting growing crystal is surrounded with neighboring, so transition processes from one stationary growth state to another can be not completed and the structure of casting will fix just transition stage. Concerning the possibility of splitting morphology formation as the result of such processes, we take into account two moments.

At first, in [2] appearance of non-dendrite splitting patterns is associated with two-stage crystallization – formation of dendrites, which are partially melted, and the final structure is the result of loss of stability and further growth of fragments of different shares. To verify this hypothesis experiments with partial melting and further growth of camphene-10 wt.% salol alloy were carried out, Fig. 3

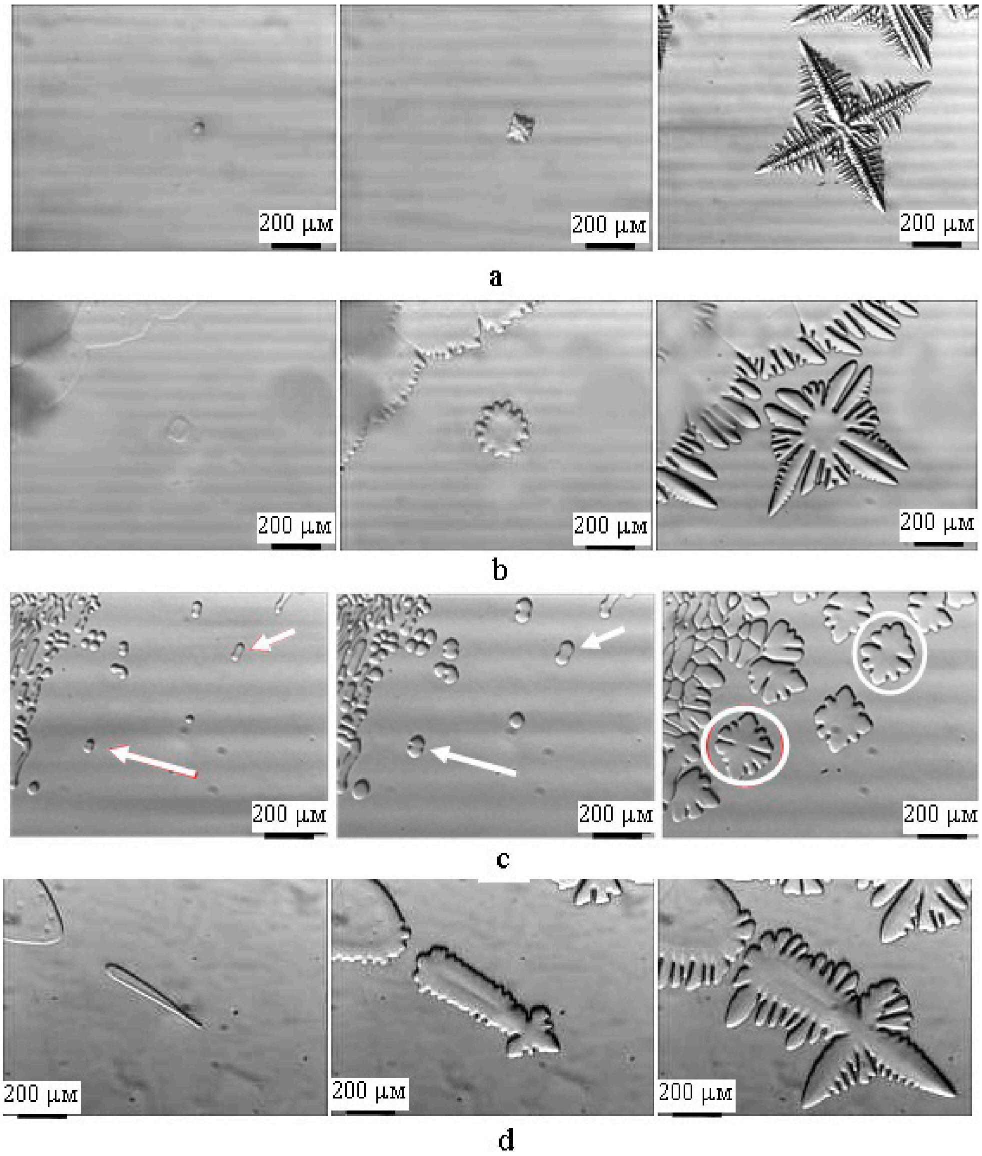

Fig. 3. Consequence stages of the growth of fragments: row a – seed crystal less than critical size; row b – rounded seed crystal a little more than critical size. See the duplex dendrite structure; row c – small elongated seed crystal. See dumbbell-like structure; row d) – large elongated seed crystal

During the melting of initial dendrite, different types of fragments were formed. Depending on the shape and size of fragments further growth formed different but regular dendrite structures.

At second, one of the possible reasons for formation of irregular splitting morphology can be the deceleration of the growth. Background for such suggestion are results of Trivedi [3]. It was pointed out that at least for directional solidification abrupt reduction of growth rate resulted in a transient process accompanied with the splitting of the pattern, see Fig. 4 b), c).

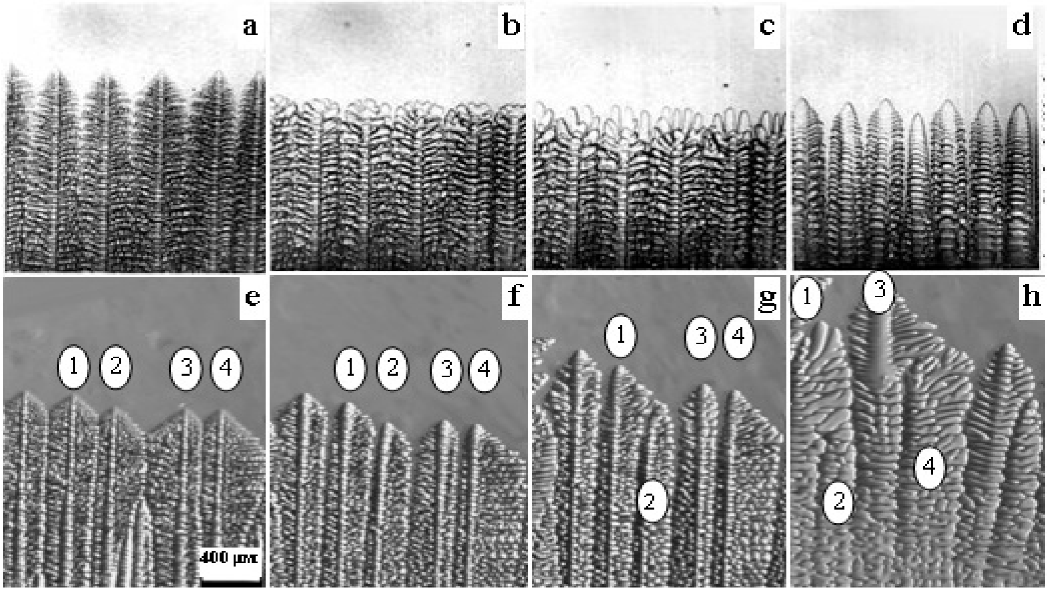

Fig. 4. Changes of growth morphology due to reduction of growth rate: a – d – data from [1]. Directional solidification of SCN-based alloy; e – h – reduction of supercooling from 2,2 ºC to 0,6 ºC. Camphene-based alloy

We made experiments with a reduction of growth rate by abrupt reduction of supercooling from 2,2 ºC to 0,6 ºC. As shown in Fig. 4 e) – h), no splitting took place during the transition. “Thickening” of dendrites took place by suppression of neighbors. Multiple dendrites are the result of the large size of the seed crystal, see Fig. 3, d.

Forced conditions. Relatively forced conditions, “constrains” crystal to grow in non preferential direction, growth of succinonitrile – 2 wt. acetone alloy was studied in a thin gap (20 μm) between parallel glass slides as well as its directional solidification with different orientations of seed crystal relatively direction of thermal gradient.

As shown in Fig. 5 c), d) as dendrite as splitting patterns can exist depending on the orientation of the seed crystal relatively to the plane of the slide. The last pattern looks like rather as a result of percolation than crystal growth.

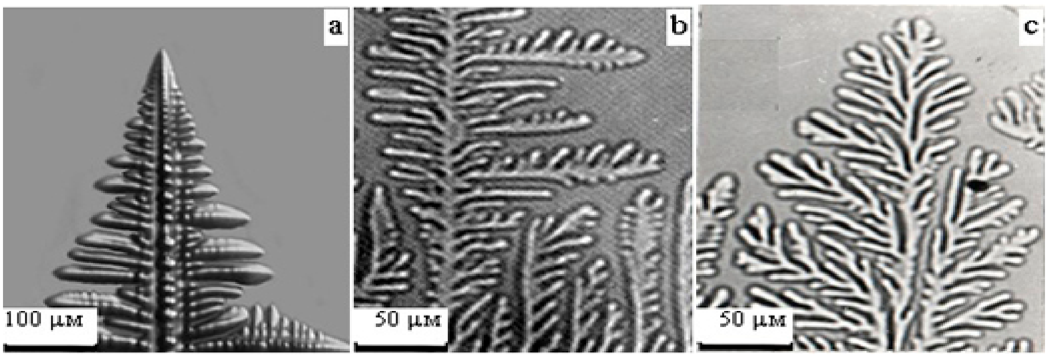

Fig. 5. Various morphologies: a – unconstrained dendrite growth, b – dendrite pattern in the gap, c – splitting pattern in the gap

For growing of crystals in non preferential direction installation for directional solidification was used, which permits to rotate cuvette with seed crystal relatively direction of the imposed thermal gradient, which was 40 °C/sm. It was found that for rate 6 µm/s, Fig. 6, e) – h), structure elements (dendrites) were growing in preferential direction <100> independently from orientation of seed crystal, while for rate 3 µm/s structure elements tilted to thermal gradient direction and formed splitting patterns similar to those for degenerate dendrites (compare marked with red arrows structures on Fig. 6, c, d and Fig. 1, b, d.

So analogy in morphologies put forward the question relatively analogy of "forced conditions" in both cases. Back to the rheocasting process (producing degenerate dendrites), it must be noted that its essential feature is the intensive shearing of the melt. Thereby it seems that flow incoming on solid-liquid interface generates some gradient. Due to this locally crystal is growing along this gradient (not in a preferential direction) and some "directional solidification" takes place.

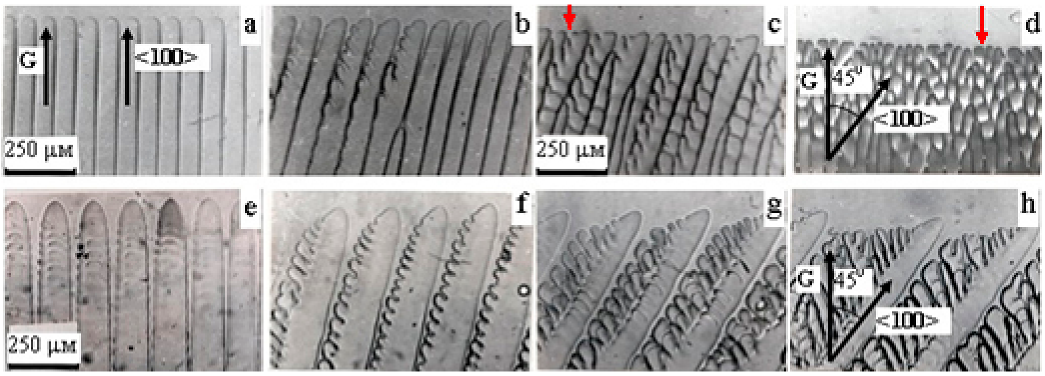

Fig. 6. Directional solidification. G – direction of thermal gradient. Angle between G and <100> direction is 0° for a), e); 15° for b), f); 30° for c), g) and 45° for d), h). Rate of growth is 3 µm/s for a) – d) and 6 µm/s for e) – h). Arrows on c) and d) indicates splitting element to compare with Fig. 1.

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DISSOLUTION OF NITROGEN IN AUSTENITE STEEL 10Cr14NMn15

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It is necessary to control and calculate the nitrogen content in the metal during the production of nitrogen-containing steel in order to determine in advance the conditions for obtaining a given grade of steel. For this, a thermodynamic calculation should be used, which describes the solubility based on the parameters of the interaction of nitrogen with alloying elements in iron.

There are different approximations of the calculation, which include the interaction parameters of the first, second, second and first order and their various combinations and temperature dependences. A comparison was made of various methods of calculating the solubility of nitrogen in 10Cr14NMn15 steel, in particular, the Wagner method, the Chipman and Corrigan method, the calculations of V.I. Lakomskyi with co-authors, analytical and experimental material by J. Pitkälä with co-authors and others.

Chromium-manganese steels have high plasticity in a wide range of temperatures and can be used in cryogenic technology. Manganese is an austenizer of steel, it stabilizes