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SOME ISSUES OF SURFACE CRACK PROPAGATION IN ALUMINUM ALLOYS

Abstract: The article describes cracks that can occur both during the crystallization of the alloy and after its complete solidification. Particular attention is paid to the fact that in the first case, cracks are called crystallization, or hot, in the second - cold.

Keywords: crack, raw materials, aluminum, alloy, temperature, construction.

Introduction

Hot cracks occur at temperatures exceeding the temperature of the real solidus of the alloy. Cold cracks are formed when ingots are cooled to relatively low temperatures, and their formation, as a rule, is accompanied by the ejection of the melt from the mold. Sometimes cold cracks are formed during the aging of ingots after casting and during heat treatment.

The occurrence of cracks during casting of ingots is associated with internal stresses due to the presence of a temperature gradient in the cross section and along the height of the ingot. The non-simultaneity of crystallization of the outer and inner volumes of the ingot and the difference in the rates of subsequent cooling inevitably lead to difficult shrinkage, first of the peripheral and then of the inner layers. The magnitude of the stresses in this case is determined by the elastic and plastic deformation that the considered volume of metal undergoes under the influence of neighboring layers, if they are currently cooled at a different rate.

Materials

The occurrence of cracks can be directly related to the process of deformation in various sections of the ingot and, bypassing the determination of the magnitude of stresses, to evaluate the resistance to cracks and the ability of the ingot to withstand tensile deformations. So, I. I. Novikov explained the occurrence of hot cracks by the low ductility of the alloy in the region of the solid-liquid state, and I.

L. Teitel established certain norms for the elongation of the alloy in the cast state as a criterion for the susceptibility of an ingot to cold cracks.

Central cracks can be both hot and cold, due to the fact that tensile stresses in the center of the ingot (along the diametral plane) develop from the moment of crystallization to complete cooling

ingot. The occurrence of cold central cracks is accompanied by the destruction of the ingot along the diametral plane. Hot cracks in ingots of ductile alloys develop in the central part and go along the entire length of the ingot.

In ingots of high-alloy alloys, hot central cracks, as a place of stress concentration, can cause the destruction of the remaining part of the section of the ingot at low temperatures: in this case, the destruction of the ingot occurs almost along the entire diameter and the crack will be mixed in type - hot in the middle part of the ingot and cold at periphery. The formation of central cracks can be prevented by lowering the casting speed, increasing the height of the mold, maintaining a uniform supply of water and the correct flow of the melt into the mold with a symmetrical direction of the liquid metal to the periphery of the ingot.

Results

Radial cracks develop in the direction from the periphery to the center with a sharp cooling of the peripheral layers and in the presence of a sufficiently strong and resistant to shrinkage of the outer layers of the core. Such cracks are formed when the bottom of the hole is above the zone of direct cooling of the ingot with water. The scheme of stress distribution and crack initiation in this case is the same as in case of hardening of massive products. Initially, the rate of cooling of the peripheral layers is much higher than the rate of cooling of the central ones, which leads to the appearance of deformations and stresses that are tensile at the periphery and compress in the center of the ingot. Then, in the process of cooling, the ratio of cooling rates and the signs of stresses change, and after cooling, the peripheral layers turn out to be compressed, while the inner ones become stretched.

Radial cracks appear only at the initial moment of water cooling of the ingot; upon subsequent cooling, they shrink tightly and are only detected by careful examination of the macrostructure. Radial cracks are usually hot, although they sometimes occur at temperatures below the solidus, similar to cracks that occur during quenching. Radial cracks usually do not propagate into the sprue as it solidifies in the mold. In the bottom part, such cracks are also not always found.

Therefore, they should be identified by the middle part of the cast ingot. The formation of radial cracks can be prevented by increasing the casting speed or by lowering the height of the mold.

Circular cracks appear in the bending zone of the transition region with a large difference in the cooling rates of the peripheral skin (from the walls of the mold) and the average volume of the ingot (from direct exposure to water). It is not possible to precisely separate these zones, but they still significantly affect the well profile. Circular cracks develop in a relatively narrow area. In the gating part of the ingot, they can have a significant length.

The propagation of cracks in this case corresponds to the direction of movement of the dimple inflection line. The occurrence of circular cracks is closely related to the structure of the ingot and the technology of melt preparation. These cracks are more often observed in ingots with a columnar structure. Of the technological parameters, the main influence on circular cracks is the height of the mold and the uniformity of cooling of the surface of the ingot. Cracks can be eliminated by using very low molds. To eliminate circular cracks in the gate part, the movement of the ingot should not be stopped after the metal supply is stopped. It is safe to stop the ingot when the gating surface is 60-70 mm above the water cooling zone.

Circular cracks are sometimes healed in the process of mother melt casting and are detected when examining the macrostructure for a specific network of low-melting intermetallic components. In this case, circular cracks cause slate in the ingots and in the peripheral layers of pressed bars.

Transverse cracks form in ingots of low-plastic alloys at relatively low temperatures. When casting ingots with a diameter of up to 500 mm, transverse cracks are sometimes observed in ingots of V95 and D16 alloys.

The larger the diameter of the ingot, the greater the likelihood of transverse cracks. They occur mainly in a certain range of casting speeds, at which the angle of inclination of the solidification surface to the horizon is close to 30°. It is difficult to reject ingots with transverse cracks using macrotemplates. It should be done using ultrasonic control.

Discussion

The listed types of cracks can also be found in ingots of a hollow section, but with some peculiarities. Central cracks in hollow ingots are found only when casting without water supply to the inner surface of the ingot.

In this case, the coefficient of linear shrinkage along the outer diameter of the ingot, as in the case of casting round ingots, increases with increasing casting speed and significantly exceeds the total thermal contraction in the solid state. Radial external cracks in hollow ingots rarely appear. Most often, when casting hollow ingots, radial internal cracks occur. According to the mechanism of occurrence, they are similar to external radial cracks. The only difference is that external cracks are formed from the "fitting" of the corresponding metal layer on the core of the ingot, and internal radial cracks - from "fitting" on the rod.

To prevent the formation of internal radial cracks, it is necessary to lower the level of water supplied to the inner surface of the ingot, increase the taper of the rod and eliminate the unevenness of the water supply. However, an increase in the taper of the rod leads to an increase in the segregation rim and, thereby, to metal losses; therefore, a cone that is too large should not be chosen. The difference in the upper and lower diameter of the rod, which is 7-10% of the inner diameter of the ingot, is quite sufficient. Circular cracks in hollow ingots occur: at the place of maximum deepening of the hole; when introducing metal with one jet; between injection points when metal is introduced by two jets. Circular cracks in hollow ingots are usually formed at a high level of water supply to the inner surface, when conditions are created for the occurrence of maximum stresses along the wall thickness of the hollow ingot. Equalizing the level of water supply from both surfaces is usually sufficient to eliminate circular cracks.

Transverse cracks are observed only in ingots of high-alloy alloys. Unlike transverse cracks in round ingots, they are not internal, but through, going through the entire thickness of the wall at a slight angle to the cross section of the ingots. These cracks are cold; they occur at low casting speeds, as do cold cracks in slabs. Transverse cracks can be eliminated by increasing the speed of casting or by using a rod without applying water to the inner surface of the ingot.

Hot and cold cracks in flat ingots are described by V. A. Livanov. The formation of hot cracks - mostly surface, running along wide edges and coinciding with the casting direction - is prevented by reducing the casting speed and eliminating the uneven supply of water to the ingot.

The elimination of cold cracks, as indicated, is achieved by using a sufficiently high casting speed and special protection of the bottom, gate and side surfaces. The bottom part is protected with liquid aluminum, the gating part is protected by stopping the cooling of the ingot before the moment of its complete solidification, the side surfaces are protected by a cutout on the narrow edges of the mold.

Conclusion

This brief review shows the complexity of the forms of manifestation of cracks and the variety of means for their elimination. All these means, based on the reduction of internal deformations and the stresses caused by them, have found wide application in industrial practice. There is, however, one general remedy that is applicable to the elimination of cracks of any form, and this is the increase in the resistance of alloys to deformations and thermal stresses. Reducing the tendency of alloys to hot and cold cracks is achieved by various means. The sensitivity to cold cracks is determined by the ductility of the alloy at low temperatures. According to I. J1. Teitel, cold cracks occur only in ingots with elongation less than 1.5%. This observation is consistent with the data on the linear shrinkage of round ingots, from which it follows that the excess of the actual shrinkage coefficient over the total thermal contraction, i.e., the value created by the plastic deformation of the ingot, can reach 1.5%. Ingots unable to withstand such deformation are destroyed.

The susceptibility of ingots to hot cracks is subject to more complex laws. Knowledge of the complex and varied dependence of the sensitivity to hot cracks on the composition of the alloy and the preparation of the melt for casting makes it possible to create additional possibilities for combating hot cracks in ingots.

At the present stage of research, it is possible to eliminate hot cracks in ingots of most alloys without deviating from the optimal casting conditions, by rational preparation of the melt and regulation of the composition of alloys by impurities.

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