UDC 621.744.3

Control of the solidification rate of castings from alloy AL9 due to zonal cooling during low-pressure casting

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Abstract
Purpose. To study the effect of zonal cooling, i.e. various cooling means, accelerating the heat sink to the rate of solidification in local thickenings.
Metodology. Applied standard methodology for determining zonal cooling, speed of solidification, the density of the metal.
Results. Determined the influence of zone cooling on the rate of solidification of the local thickening, determined by the density of the metal structure depending on the cooling with copper inserts and water.
Originality. A further development of representations about the effect of zonal cooling in the casting under low pressure, the decline of defect shrinkage in the thickenings of the casting and reducing the time of exposure of the metal under pressure.
Practical value. The use of zonal water-cooling in the casting under low-pressure parts "filter housing" in the mod. U95A has allowed to eliminate the shrinkage in local thickening and reduced the exposure time of the casting under pressure.
Key words: CASTING UNDER LOW PRESSURE, ZONAL COOLING, SOLIDIFICATION, HARDNESS.

Formulation of the problem. An increase in the productivity of low-pressure casting plants can be achieved by reducing the holding process of the casting in the chill mold until it solidifies completely.

Reduction of technological holding can be reached by controlling the solidification process of the casting, which is provided by a directional heat removal, which is achieved by cooling of one of the parts of the chill mold.

The work objective is to study the possibility of using zonal cooling in order to intensify the solidification process of local thickenings and to reduce the time for low-pressure holding of metal and to reduce the shrinkage porosity reject.

Statement of the main material of the study. For the experiment, new crucible pedestal and cover were developed for the existing equipment.

Fig. 1 shows a pedestal with two gating holes for the central supply of the cast metal. The height of the gating holes in the pedestal is 0.002 m. The diameter of the holes in the lower part is 0.005 m, in the upper part it is 0.006 m.

Figure 1. Pedestal with two gating holes

Figure 2. Equipment for filling a double-cavity mold of filter housing from two metal pipelines

The cover of the pouring device crucible with two windows made in it to allow passing and fixing of two metal wires is shown in Fig. 2.

The metal pipelines (Fig. 2) were sealed on the crucible cover with gaskets of asbestos sheet with the thickness of 0.004 m. The seal between the upper section of the metal pipeline and the pedestal was made with a special gasket, which consisted of 0.004 m thick asbestos sheet and of sheet steel 0.008 - 0.001 m thick. The thickness of the metal pipeline wall in the upper part was 0.004 - 0.006 m.

Alloy AL9 was used for the casting.

Melting was carried out in an induction crucible furnace with power frequency IST - 0.4.

Studies were carried out on the machine U95A which had been developed by OA "NIISLA" and up-gradated by the State Enterprise "Engineering Production and Research Center of high-pressure casting". The general arrangement of the low-pressure casting plant of U95A model is shown in Fig. 3.

After pouring, the special equipment takes out the casting from the chill mold cavity. The casting is cooled in air and afterwards it is subjected to heat treatment.

Local thickening of the casting was studied without cooling using copper inserts and water cooling.

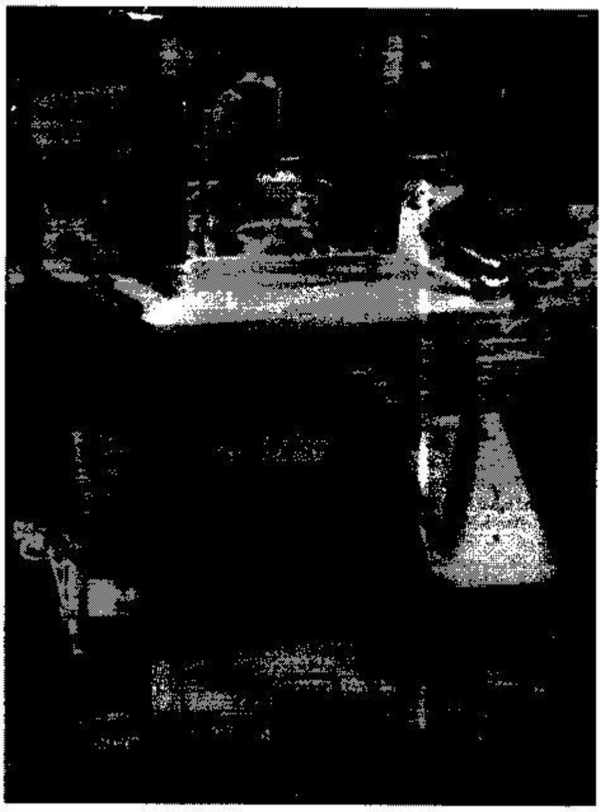

Figure 3. Low-pressure casting plant U95A model

Experiments on obtaining castings without zonal cooling established the following:

a) for the castings with wall thickness of δ = = 0.02 m, relatively dense casting is obtained with radii of local thickenings R = 0.0075; 0.01; 0.015 m. Hardness in places of thickening differs slightly from hardness in other places: that is, it has decreased that is allowed by technical condition for the given alloy.

b) for the castings with wall thickness of δ = = 0.02 m and local thickening radius of R = 0.02 m, hardness in local thickening in comparison with other places of casting decreases by 25 - 30 units and is 50-54 HB;

c) for the castings with wall thickness of δ = = 0.015 m, dense casting is obtained when the radii of the sockets of R = 0.0075; 0.01 m;

d) for the castings with wall thickness of δ = 0.01 m, dense casting is obtained when the radii of the sockets of R = 0.0075 m;

Therefore, on the basis of the experimental data obtained above, zonal cooling was applied:

a) when casting thickness of δ = 0.02 m, only for R = 0.02 m;

b) when casting thickness of δ = 0.015 m, only for R = 0.015 – 0.02 m;

c) when casting thickness of δ = 0.01 m, only for R = 0.01; 0.015; 0.02 m;

The results of the study of the influence of zonal cooling on the solidification rate of the local thickening determined from the density of the metal structure are given in Table. 1.

From Table. 1, it follows that at a casting thickness of 0.02 m using zonal cooling with copper inserts as well as zonal water cooling, a dense structure of the metal is obtained at the maximum radius of the local thickening R = 0.02 m (Fig. 1): hardness when copper insert cooling is HB = 1117 MPa and when using water cooling HB = 1019 MPa, i.e. when cooling is applied, the local thickening has a higher rate of solidification than the cross section of the casting without thickening, so that directional solidification is ensured, since the limiting feed section of the casting solidifies last.

With a casting thickness of 0.015 m and a local thickening radius R = 0.02 m, only cooling with a copper insert gives the hardness of the structure in the local thickening greater than the average hardness of the casting. With water cooling, the hardness in the local thickening is lower than the average, but in both cases, it is higher than the allowable according to the technical conditions (according to the technical conditions as per work for AL9 HB = 686 MPa).

In castings with wall thickness equals 0.01 m, at radii of local thickenings R = 0.02; 0,015 m; hardness in thickened even with the use of water cooling and cooling with copper inserts is below the average hardness of the casting.

Thus, according to the results of the studies, it can be concluded that zonal cooling at all the investigated thicknesses gives a hardness higher than the specified one in technical conditions.

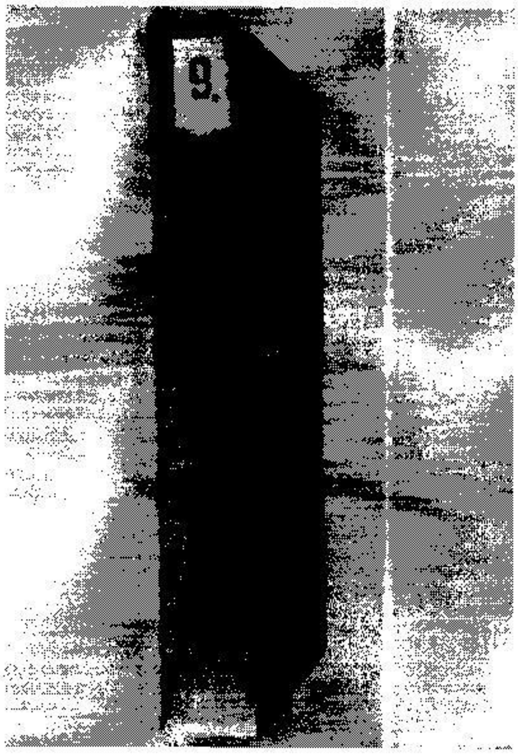

Figure. 4 Casting section δ = 0.02 m, R = 0.02 m, when using of copper insert in local thickening

Table 1. Influence of zonal cooling on rate of casting solidifications

Thickness of studied casting, m	Local thickening radius, m	Hardness of casting material (average for section), MPa	Hardness of casting in local thickening without cooling, MPa	Hardness of casting in local thickening using copper inserts, MPa	Hardness during water cooling, MPa
0.02	0.02	941	529	1117	1019
0.015	0.02	990	513	958	879
	0.015		612	1078	956
0.01	0.020	902	Blowhole	745	706
	0.015		510	872	745
	0.01		610	921	961

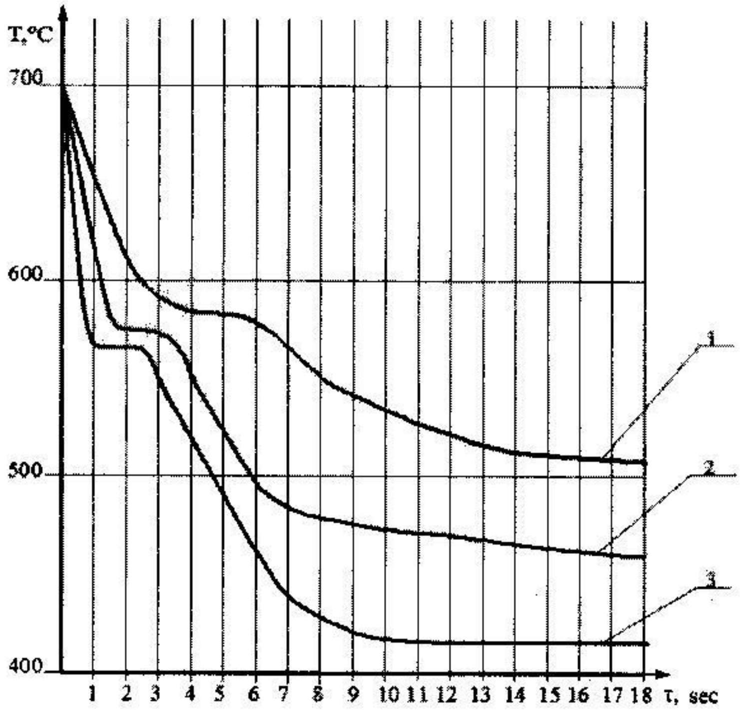

Figure. 5 Curves of hardening of an aluminum alloy under various conditions of hardening. 1 - without cooling; 2 - water cooling; 3 - cooling with copper inserts

These results are confirmed by solidification curves (Fig. 5). According to Fig. 5 and solidification curve 1, 2, 3, the rate of temperature drop in the crystallization interval $T_{liquidus}$ = 620°C, and $T_{solidus}$ = 577°C for cooling using:

- copper inserts is 43 °C/sec;
- water cooling is 22 °C/sec;
- without cooling is 16 °C/sec.

Conclusions:

1. Using zonal water cooling for low-pressure casting of filter housing part in the plant model U95A has allowed us to exclude shrinkage porosity in the local thickening and to reduce the holding time of the casting under pressure.

2. Zonal cooling in the form of copper inserts has been successfully used for low-pressure casting, as well as for directional crystallization.

3. The use of zonal cooling allows controlling the process of hardening of local thickenings and decreasing the time of aging of the metal under pressure (by 10 - 15%) and reducing the shrinkage porosity reject.

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