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The use of zonal cooling to control the solidification rate of AK7ch alloy castings

The aim of the work was to study the effect of zonal cooling, i. e., various coolants that accelerate heat removal on the solidification rate in local thickenings (sockets). In the work, standard methods were used to determine zonal cooling, solidification rate, and metal density. For the experiments, equipment was developed that allows filling prototypes from two metal ducts. As the alloy under study, AK7ch was used, as the most common for low-pressure casting. Copper liners and steel water-cooled liners were used as coolants for local thickenings. The density control of the obtained castings was carried out according to the hardness measured by the Brinell method.

The dependences of the influence of zonal cooling on the hardening rate of local thickening, which is determined by the density of the metal structure depending on cooling by both copper inserts and water, are revealed.

Ideas about the influence of zonal water cooling in low-pressure casting, on reducing the shrinkage loosens in the thickening of the casting and reducing the holding time of the metal under pressure were further developed.

The research results showed that the use of zonal cooling of local thickenings of the casting at all studied thicknesses increases the hardness index. The creation of directional solidification and reduction of the holding time of castings in the chill mold increase productivity, which also plays an important role in foundry.

Use of zonal water cooling for low-pressure casting of the "filter housing" part on the mod installation U95A allowed to eliminate shrinkage looseness in the local thickening and reduce the holding time of the casting under pressure, which in turn allowed to increase the productivity of the installation.

Keywords: low pressure casting, zone cooling, hardening, hardness.

Casting under low pressure eliminates many of the shortcomings of casting in a chill mold and makes it possible to obtain sufficiently large castings that are difficult to obtain in other ways [1].

An increase in the productivity of low-pressure casting plants can be achieved by reducing the technological exposure of the casting in the chill mold to its full hardening [2].

Reducing the technological exposure can be achieved by controlling the solidification process of the casting, which is ensured by directional heat removal, which is achieved by cooling one of the parts of the chill mold [3].

The work objective is to study the possibility of using zonal cooling 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.

For the experiment, new crucible pedestal and cover were developed for the existing equipment [4, 5].

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.

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

The metal ducts (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 duct 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 duct wall in the upper part was 0.004–0.006 m.

Alloy AK7ch was used for the casting [6].

Melting was carried out in an induction crucible furnace with power frequency IST – 0.4 [7].

Studies were carried out on the machine U95A which had been developed by OA "NIISL" and upgraded 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.



Fig. 1. Pedestal with two gating holes



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



Fig. 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 $\delta = 0.02$ m, relatively dense casting is obtained with radii of local thick-

enings $R = 0.0075; 0.01; 0.015$ 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 $\delta = 0.02$ 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 $\delta = 0.015$ 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 $\delta = 0.01$ m, dense casting is obtained when the radii of the sockets of $R = 0.0075$ m.

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

a) when casting thickness of $\delta = 0.02$ m, only for $R = 0.02$ m;

b) when casting thickness of $\delta = 0.015$ m, only for $R = 0.015 - 0.02$ m;

c) when casting thickness of $\delta = 0.01$ 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.

Influence of zonal cooling on rate of casting solidifications

Thickness of studied casting, m	Radius of the local thickening, m	Hardness of the casting material (cross section average), HB	Hardness of the casting in local thickening without cooling, HB	Hardness of the casting in local thickening using copper inserts, HB	Hardness during water cooling, HB
0.02	0.02	96	54	114	104
0.015	0.02 0.015	101	52.4 62.5	97.7 110	89.7 97.5
0.01	0.020 0.015 0.01	92	Cavity 52 62	76 89 94	72 76 89

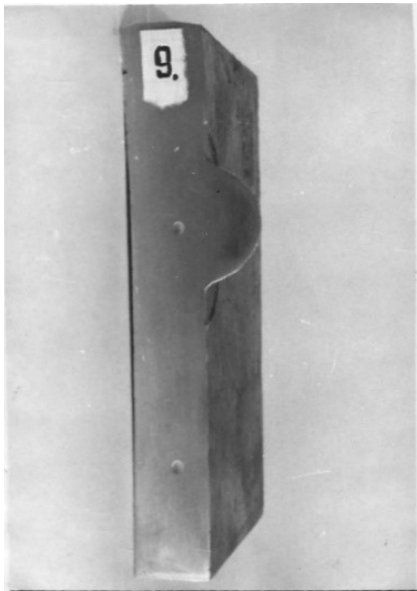


Fig. 4. Casting section $\delta = 0.02$ m, $R = 0.02$ m, when using of copper insert in local thickening

From Table, 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. 4): hardness when copper insert cooling is $HB = 114$ H/mm² and when using water cooling – $HB = 104$ H/mm², 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 AK7ch $HB = 70$ H/mm²).

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 thick-

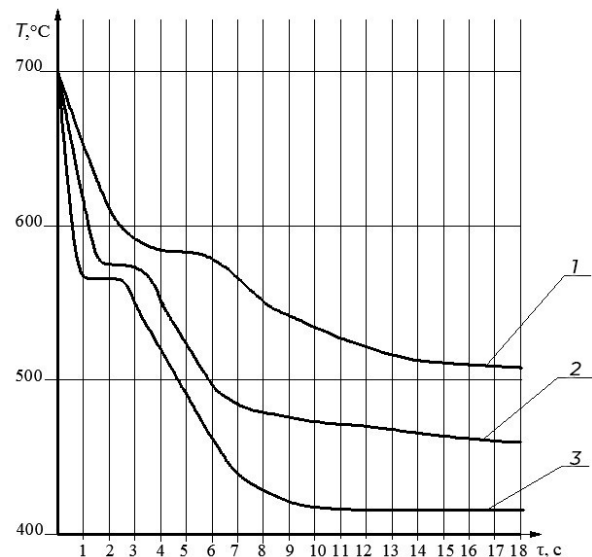


Fig. 5. Curves of hardening of an aluminum alloy under various conditions of hardening: 1 – without cooling; 2 – water cooling; 3 – cooling with copper inserts

nesses gives hardness higher than the specified one in technical conditions.

These results are confirmed by solidification curves (Fig. 5).

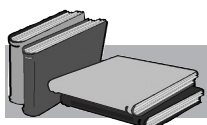
According to Fig. 5 and solidification curves 1, 2, 3, the rate of temperature drops in the crystallization interval $T_{\text{liquidus}} = 620$ °C, and $T_{\text{solidus}} = 577$ °C for cooling using:
– copper inserts is 43 °C/sec;
– water cooling is 22 °C/sec;
– without cooling is 16 °C/sec.

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.

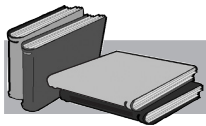


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Використання зонального охолодження для управління швидкістю затвердіння виливків зі сплаву АК7ч

Метою роботи було вивчення впливу зонального охолодження, тобто різних охолоджувальних засобів, що прискорюють тепловідвід, на швидкість затвердіння в місцевих потовщеннях (бобишках). У роботі були застосовані стандартні методики визначення зонального охолодження, швидкості затвердіння, щільності металу. Для проведення експериментів було розроблено оснащення, що дозволяє заповнювати дослідні зразки з двох металопроводів. В якості до-

сліджуваного сплаву використовувався АК7ч, як найбільш поширений для лиття під низьким тиском. В якості охолоджуючих засобів місцевих потовщень використовувалися вкладиші з міді, а також сталеві водоохолоджувані вкладиші. Контроль щільності одержуваних виливків здійснювався за твердістю, яка вимірюється методом Брінелля.

Виявлено залежності впливу зонального охолодження на швидкість затвердіння місцевого потовщення, яка визначається за щільністю структури металу в залежності від охолодження як мідними вставками, так і водою.

Отримали подальший розвиток уявлення про вплив зонального водяного охолодження при литті під низьким тиском на зниження усадочних дефектів в потовщеннях виливка і зменшенні часу витримки металу під тиском.

Результати досліджень показали, що використання зонального охолодження місцевих потовщень виливка на всіх досліджуваних товщинах сприяє збільшенню твердості. Створення спрямованого затвердіння і зменшення часу витримки виливків у кокілі сприяють збільшенню продуктивності, що так само відіграє важливу роль у ливарному виробництві.

Використання зонального водяного охолодження при литті під низьким тиском деталі «корпус фільтра» на установці мод. У95А дозволило виключити усадкові рихлоти в місцевому потовщенні і зменшити час витримки виливка під тиском, що в свою чергу дозволило збільшити продуктивність установки.

Ключові слова

Лиття під низьким тиском, зональне охолодження, затвердіння, твердість.