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Efficiency of influence of a metal macroreinforcing phase on process of solidification of large-sized castings

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Summary. In a paper the question of manufacture of large castings by a casting method on Lost-foam process is considered. For the purpose of obtaining of castings with the guaranteed quality examined possibility of an intensification of process of solidification of preforms by introduction in polystyrene model a sample piece of a reinforcing metal phase. Conditions and regularities heat-weight transfer and hydrodynamics in systems "metal-sample piece-implantat-shape" and "metal – a reinforcing phase – the shape", and also interaction of new systems making these are defined. It is determined that lead of a macroreinforcing phase in polystyrene model sample piece or it is direct in a mould cavity allows to create new molten constructions which possess a complex of functional properties earlier not to inherent traditional cast alloys, namely: heightened strength properties of molten constructions, hardening of a surface layer of molten constructions or heightening of its special performances. It is fixed that presence of a macroreinforcing phase creates conditions for increase in a freezing rate of an alloy to its directly proportional mass and with its increase concerning metal volume in shape thus does not augment quantity indicators on ejection of harmful substances in atmosphere.

Key words: moulding on Lost-foam process (LFP), large castings, polystyrene sample piece macroreinforcing phases (RMP), the molten reinforced constructions (MRC), heat-weight transfer.

INTRODUCTION

In process of development of modern manufacture the increasing urgency is acquired by problems of working out and introduction a little - and techniques without waste. Speedup of the decision of this problem is considered as a strategic direction in each branch of a national economy, as a direction of rational use of natural resources and a ratio basic change to environment [16].

One of variants little-wastes, progressive and ecologically safe technique of castings obtaining is Lost-foam process (LFP). Application of process of moulding on evaporative sample pieces allows to eliminate power-intensive, labour-consuming, ecologically dangerous processes, such as preparation moulding and core sand mixtures, manufacture from them traditional mode of shapes and rods, knockout of castings and to reduce to a shake-out and deburring action of castings more than to 50 % [17].

The casting method on LFP has been licensed in 1958 by the American architect G. Shroer's and at once founders of many countries have shown to it heightened interest and have started to try in manufacture of castings. It has received such names in the different countries: Lost Foam Process, LMG-PROCESS «Policast», «Gamoliv» etc., is thus used as a filling agent dry sand with evacuation application, ferromagnetic loose materials with magnetic field creation, forming sandy-argillaceous, liquid self-hardening and non-clay moulding mixtures. Thus in mass and a long run method LFP is used basically for castings from ferrous and non-ferrous alloys in mass range up to 50 kgs., and only in singular manufacture up to 2000 kgs. [18].

MATERIALS AND METHODS

For manufacture of large and heavy castings on LFP in FTIMS NASU of Ukraine it is offered to one of variants to use as a filling agent liquid-movable self-hardening mixtures (LMHM), not demanding dynamic seal that is important because of low strength of a material (expanded polystyrene) and easy deformability of a sample piece under the influence of external loads which during moulding time usually should not exceed 1 kg/sm^2. Joint application LMHM and LFP complicates process of moulding by "superposition" of the factors peculiar to both techniques, creating series of especial circumstances which assume clearing up of regularities multifactorial interdependent making physico-chemical, gas - and hydrodynamic processes for the purpose of security of stable quality of received castings. At manufacture of castings in shapes with connecting own gas condition of the shape (be it hollow) it is supplemented with a powerful source of gas liberation (with mobile front) in the form of products of gasification of expanded polystyrene of a sample piece heat of filled in metal. And this additional source of gases can multiply exceed a flow of gases from moulding material [4].

RESULTS, DISCUSSION

In this connection, it is necessary to study as much as possible process of manufacture of large details on LFP in shapes from sand with vacuum application. A research objective is the intensification of process of solidification of large castings for deriving of qualitative preforms with high mechanical properties.

For increase in a freezing rate of large casting blocks disperse components-microrefrigerators which quickly remove initial overheating of a melt that promotes fine crushing of crystalline structure of cast metal [13, 15].are entered into volume of liquid metal.Processes of manufacture of reinforced castings by a moulding method in shapes in which takes place reinforcing elements of various geometry differ from the traditional.

At deriving of castings by their sheathing microimpalntants, located in a cavity of the molten shape or in polystyrene model's, there are new to the theory of foundry processes multicomponent systems: "metal-sample piece-implantat-shape" and "metal – a reinforcing phase – the shape" [9-12]. Schematically shaping of properties of the new molten reinforced constructions (CRC) can be presented as follows (Fig. 1).

Lead of a macroreinforcing phase (RMP) in polystyrene a sample piece or it is direct in a mould cavity allows to create new molten constructions which possess a complex of functional properties earlier not to inherent traditional cast alloys (pig-iron, a steel, copper and aluminum) which are used for deriving of monocastings [1-3, 5], namely:

- Heightening of strength properties of molten constructions from traditional molten materials by sheathing of a body of an article by a reinforcing phase (filaments, spheres, rods, handsets, etc.) on strength Exceeding matrix alloy (pig-iron, a steel),

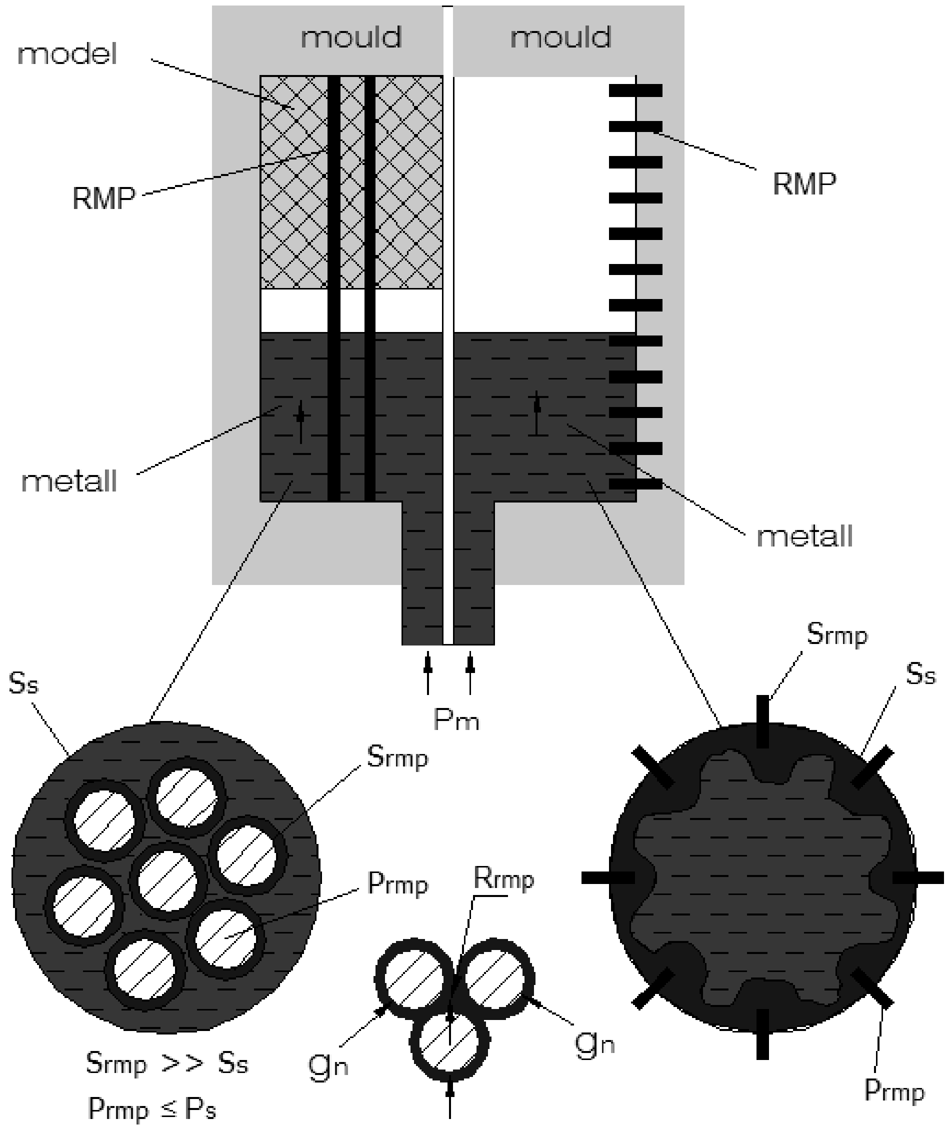

Fig.1. Circuits of shaping of surface and volume properties of molten constructions (RMP) with application macro (RMP) and a disperse reinforcing phase (DRP):
where: Sm, Srmp – a surface of the mould and RMP, Prmp, Pms - mass RMP and a matrix alloy, Pm – pressure upon a matrix alloy, R – radius of element RMP, g – width of a transitive stratum on boundary «RMP-MS»

- Preservation of high functional performances of a surface working stratum of molten constructions at preservation or heightening прочностных properties of a basic constructional stratum that is ensured by sheathing of a body of an article by a reinforcing phase (filaments, spheres, rods, handsets, etc.), on strength exceeding a matrix alloy (pig-iron, a steel),
- Hardening of a surface layer of molten constructions, or heightening of its special performances (tribotechnical, corrosion, wear-resistant, sealing hermetically properties) by lead of a reinforcing phase from metal and ceramic materials in a sample piece or shape surface layer.

Presence in styrofoam models pieces or in a cavity and a wall of shape RMP alters conditions gas-hydrodynamical moulding, intensity weight-heat exchange processes at solidification and refrigeration of molten articles that predetermines structurization and consumer performances of molten constructions [6-8, 15].

Therefore at probe of regularities heat-weight exchange and hydrodynamics in systems "metal-sample piece-implantat-shape" and "metal – a reinforcing phase – the shape" it was important to define conditions and regularities of influence of new systems making these, it is determined effecting each component of system and consequently to specify:

- Influence close-packed a macroreinforcing phase (RMP) in shape which organises own pores space with new to the shape hydraulic and heat-physically in performances, on hydrodynamic performances of moulding at a simultaneous variation in thermotime parametres of the shape, RMP and a matrix alloy,
- Regularities of influence RMP in the form of the solids which are not adjoining among themselves, located in the shape and oriented concerning a metal flow in it which predetermine new for Shapes hydraulic and heat-physycally parametres, on hydrodynamic performances of process of moulding at a simultaneous variation amount, geometry RMP and in thermotime parametres of a filled in alloy,
- Conditions of influence of an evaporating sample piece in the shape reinforcing phases, its geometries and amounts on hydrodynamics of moulding and warmly-weight-change in a liquid and solidifying alloy.

The decision of tasks in view as a whole presents special difficulties. Nevertheless, their decision is possible with sufficient for practical purposes exactitude with engaging of methods of physical and mathematical simulation [19, 20].

For these purposes were the known computer program "ProCast" which is used at probe of regularities of solidification of castings from iron-carbon alloys in shapes at presence in them RMP in the form of the oriented steel rods is adapted.

In that case applications of the adapted program "ProCast" has given the chance to evaluate conditions тепломассопереноса and solidifications in reinforced castings from iron-carbon alloys.

Originally regularities of solidification of the reinforced steel castings on molten samples from simple steel (the Steel 45 – 65GL) with a size (∅10,20,50) x200 mms. in the hollow sand mould and the reinforcing phase oriented in the sand mould in the form of rods (the Steel 20), occupying 50 % of the area of its section have been fixed∅.

In this case at solidification of a rod ∅of 10 mm from a steel (the Steel 65GL) in the hollow shape it is fixed that on a contact surface "metal – the shape" this alloy reaches liquidus temperatures of a matrix alloy (T_L) through 0,5 with (Fig. 2), and temperatures a solidus (T_s) - through 10,0 with. During the same period in a point equal to m of diameter of casting of this rod the alloy reaches temperatures T_L through 2,1 with (Fig. 2), and temperatures T_s- through 10,8 with. In the rod centre during the same period the alloy reaches temperatures T_L through 2,2 with (Fig. 2), and temperatures T_s- through 11,0 with then the solution phase in all sections of casting disappears.

At solidification of a rod ∅of 10 mm from a steel in the hollow shape with RMP making 1/2 of its section it is fixed that on a contact surface "metal – the shape" this alloy reaches temperatures T_L already through 0,4c (Fig. 3), and temperatures T_s- through 2,0 with. During the same period in a point equal to m of diameter of casting and on boundary "metal – RMP" the alloy reaches temperatures T_L through 0,2 with (Fig. 3), and temperatures T_s- through 2,3 with then the solution phase in all sections of casting disappears. It is necessary to mark that in these conditions centre RMP gets warm to temperature 980 $^{\circ}$C already through 0,5 with, and then is cooled with a rate 6-8 $^{\circ}$s/with (Fig. 3).

Important as to mark that rate of removal of overheating of a melt to T_L in all experiments differs from each other. So at rod solidification in the hollow shape this rate makes 260-70°C/s, and the smaller value treats to the central part of casting, and rate of refrigeration of last makes already 6,5-8,5 $^{\circ}$s/with where more value treats to the rod centre.

At rod solidification in shape where is RMP making 1/5 of its section, rate of reaching by melt T_L makes 325-640 $^{\circ}$s/with, and большее the value treats to a part of casting applying on boundary RMP, and rate of refrigeration of last makes already 21,0-25,0 $^{\circ}$s/with where more value treats to a contact area "metal-RMP". At rod solidification in shape where is RMP making 1/2 of its section, rate of reaching by melt T_L consist of reaching by melt T_L makes 260-430 $^{\circ}$s/with, and more value treats to a part of casting applying on boundary RMP, and rate of refrigeration of last makes already 19-21°C/s where большее the value treats to a contact area "metal-RMP".

At computer simulation of solidification of a rod ∅of 50 mm from the Steel 45L in the hollow shape it is fixed that on a contact surface "metal – the shape" this alloy reaches temperatures T_L through 8,9 with (Fig. 4), and temperatures T_s- through 165,0 with. During the same period in a point equal to m of diameter of casting of this rod the alloy reaches temperatures T_L through 14,2 with, and temperatures T_s- through 181,5 with. In the rod centre during the same period the alloy reaches temperatures T_L through 8,5 with (Fig. 4), and temperatures T_s- through 211,5 with then the solution phase in all sections of casting disappears.

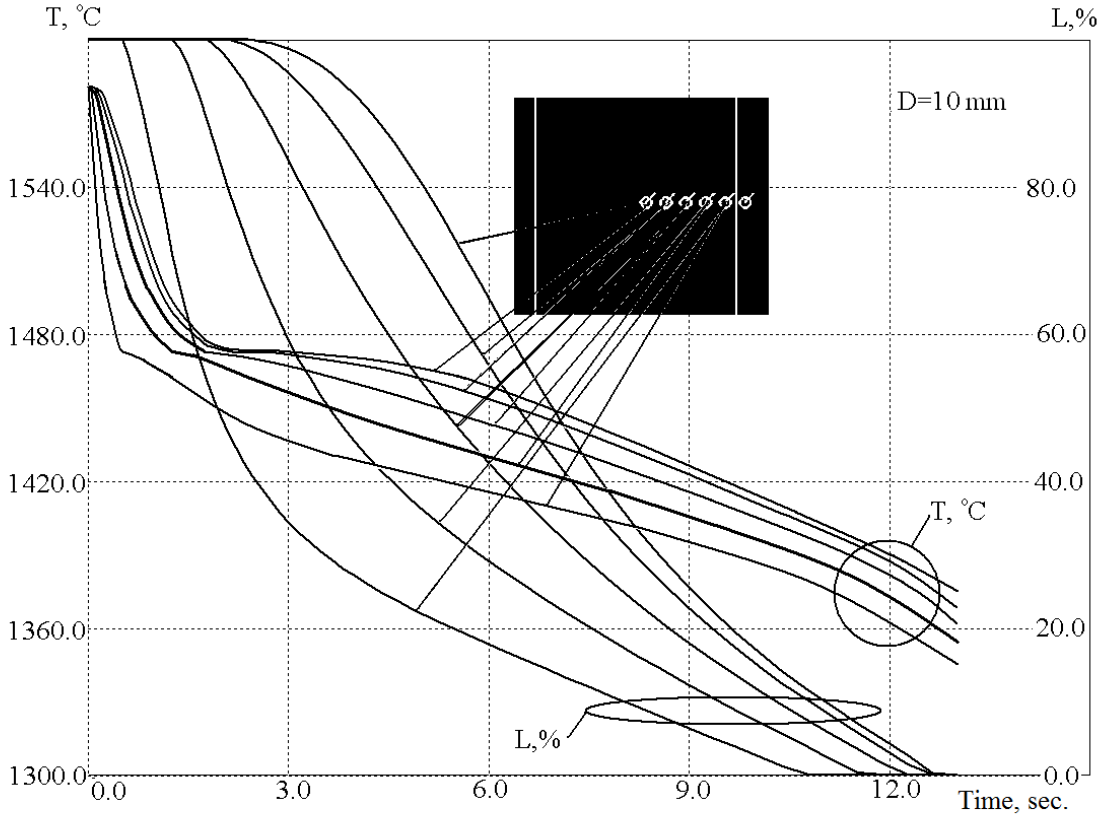

Fig. 2. Kinetics of solidification and casting crystallizaton (∅10x200mm) from the Steel 45L in the hollow shape:
L – amount of a solution phase in solidifying metal, %
T – temperature of solidifying metal, °C

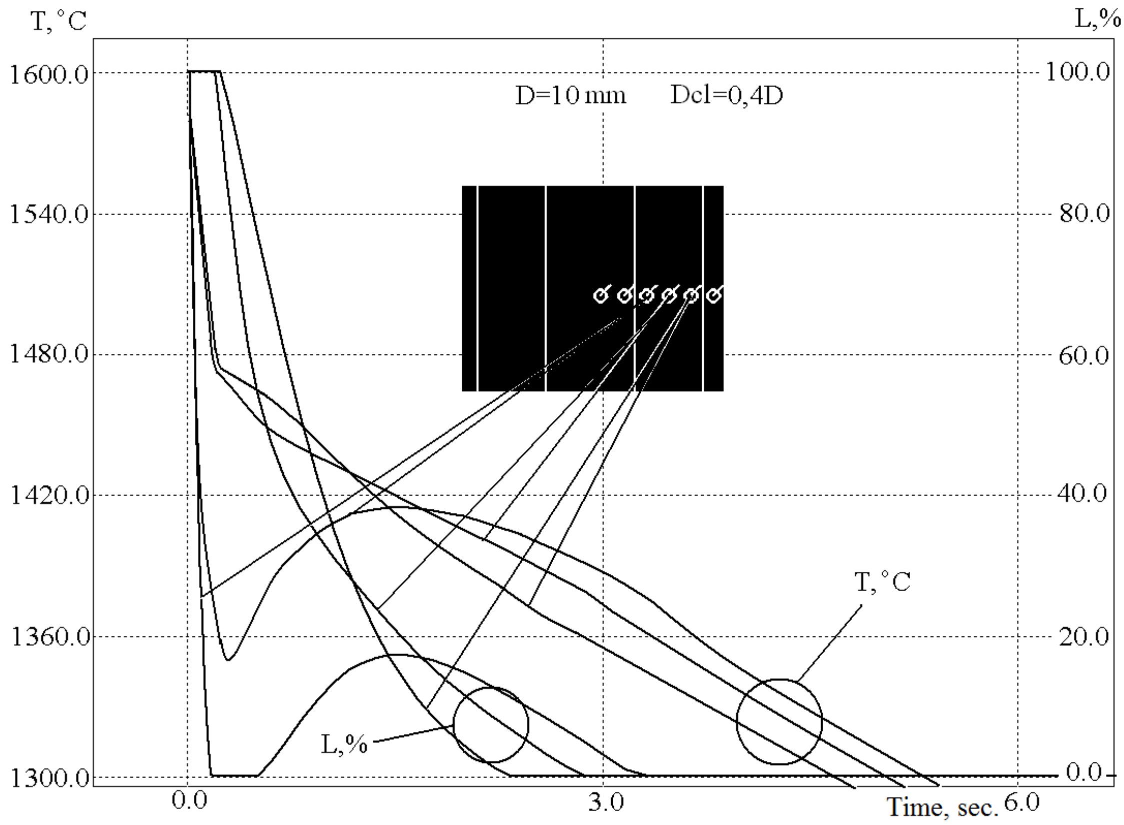

Fig. 3. Kinetics of solidification and casting refrigeration (∅10x200мм) from Stali45L in shape in the presence of RMP (0,5 Fcast.):
L – amount of a solution phase in solidifying metal, %
T – temperature of solidifying metal, °C

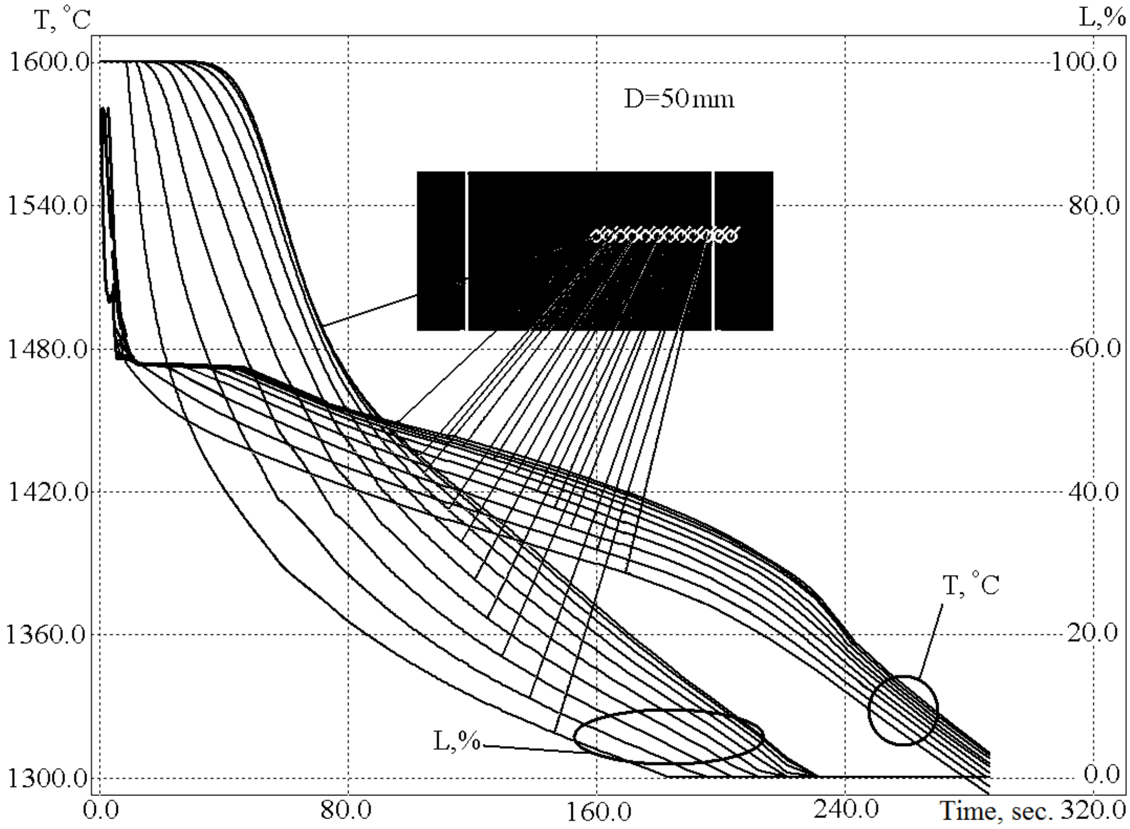

Fig 4. Kinetics of solidification and casting crystallization (Φ50x200mm) from the Steel 45L in the hollow shape:
L – amount of a solution phase in solidifying metal, %
T – temperature of solidifying metal, °C

At solidification of a rod ∅of 50 mm from the Steel 45 in shape RMP wich makes 1/2 its diameters, it is fixed that on a contact surface "metal – the shape" this alloy reaches temperatures T_L already through 5,3 with (Fig. 5), and temperatures T_s- through 42,0 with During the same period in a point equal to m of diameter of casting and on boundary "metal – RMP" the alloy reaches temperatures T_L through 8,8 with (fig. 5), and temperatures T_s- through 124,0 with, and on contact of a melt with MAΦ the alloy reaches temperatures T_L through 1,8 with (Fig. 5), and temperatures T_s- through 80,0 with then the solution phase in all sections of casting disappears.

It is necessary to mark that in these conditions the surface and centre RMP gets warm to the maximum temperature 1410 °C already through 5,0 with, and then is cooled with a rate 1,5–2,0 s/with (Fig. 6).

It is important to mark also that rate of removal of overheating of a melt to T_L in all experiments differs from each other. So at solidification of the sample in the hollow shape this rate makes 8,5–14,0 °s/with, and the smaller value treats to the central part of casting, and rate of refrigeration of last makes already 4.0–5,0 °s/with where more value treats to a rod surface.

At solidification of a rod to the shape where rate of reaching is with melt T_L RMP making 1/2 of its diameter makes 15,0–70,0 °C/sec.

And большее the value treats to a part of casting applying on boundary MAΦ, and rate of refrigeration of last makes 2,0–3,0 °s/with where большее the value treats to a contact area "metal – MAΦ".

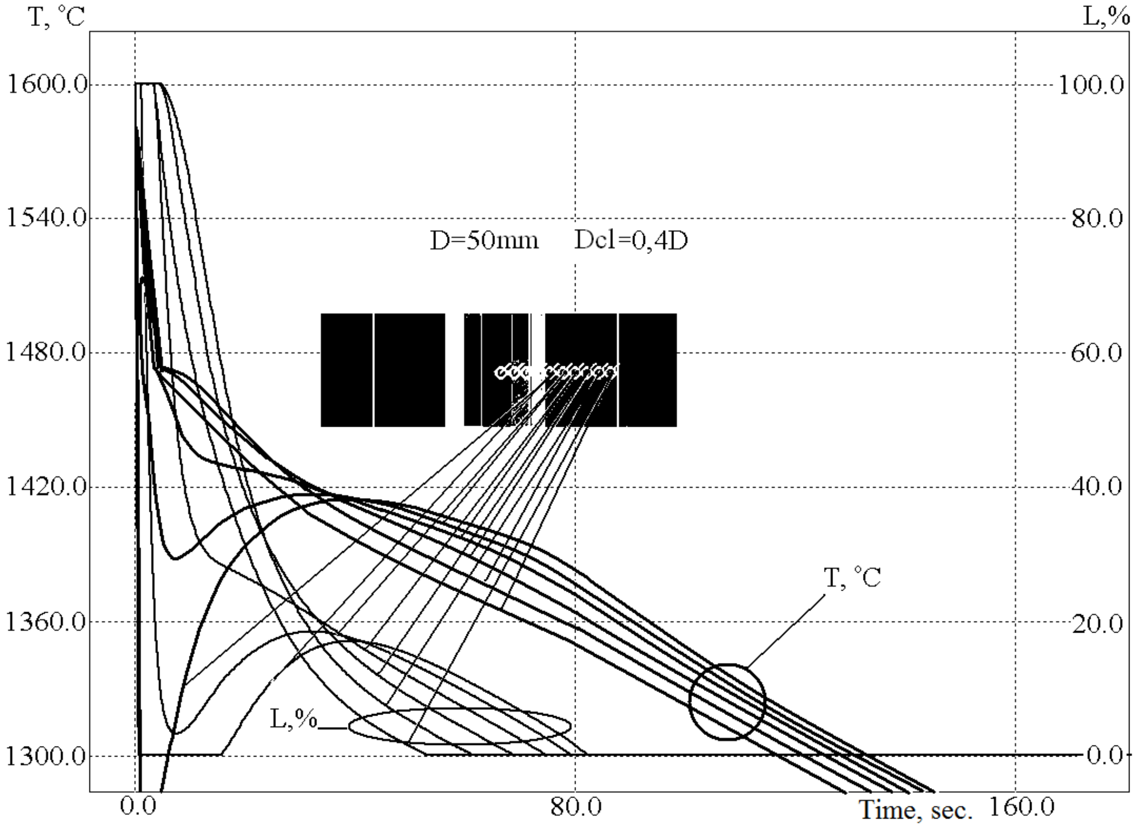

Fig. 5. Kinetics of solidification and casting crystallization (Φ50x200mm) from a steel 45L in shape in the presence of RRMP (0,5DF$_{cast.}$)

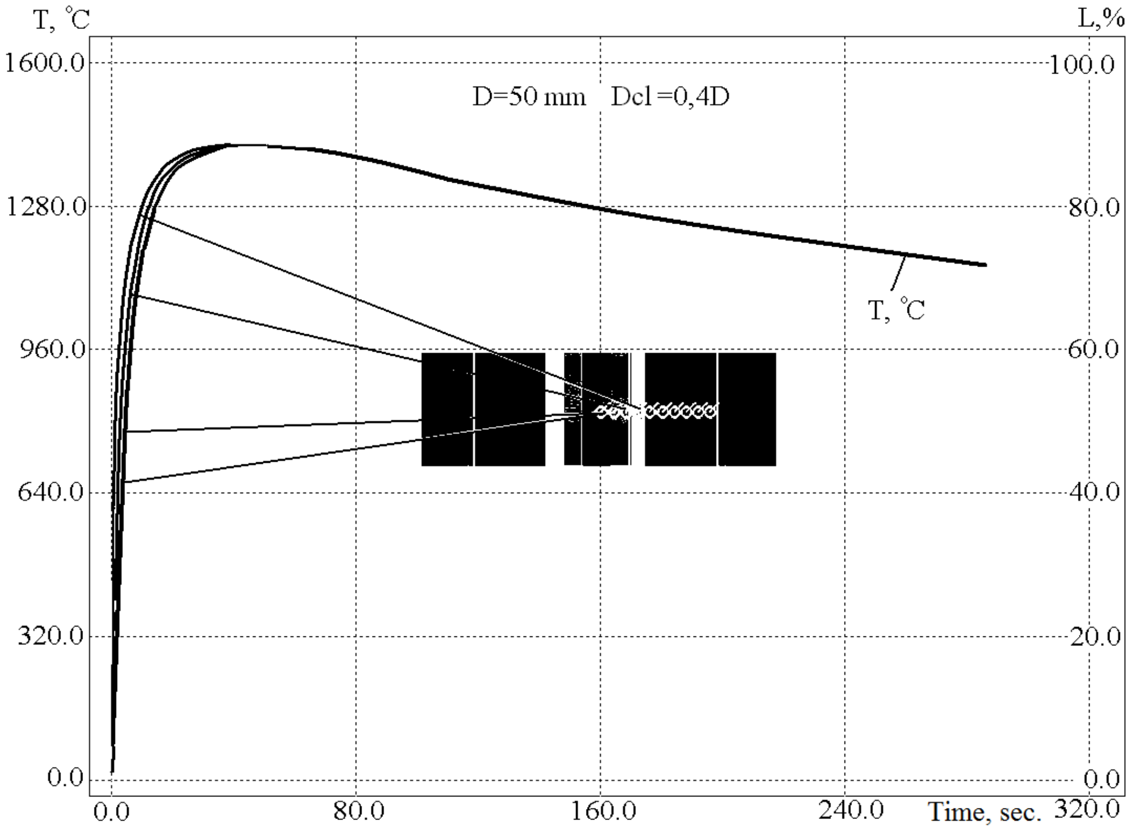

Fig. 6. Kinetics a heat and cooling RMP (0,5 D$_{cast}$):
T – a preheating temperature, coolong RMP, °C

CONCLUSIONS

Probes heat-weight transfer in new systems with use of the macroreinforcing phase oriented in shape in the form of discrete elements of various geometry, have allowed to fix qualitative and quantitative performances of thermal interaction between RMP and a matrix alloy, namely:

1. Presence RMP creates conditions for increase in a freezing rate of an alloy to its directly proportional mass and with its increase concerning metal volume in shape at what essential influence of presence RMP in shape renders on removal of overheating to temperature T_L which exceeds similar at casting solidification in the hollow shape of all in 1,4-2,0 times.

2. Presence RMP in shape as influences refrigeration of casting, but already in a smaller measure, the ratio between rate of refrigeration of a rod in the hollow shape and in the presence of RMP makes only 1 / (1,15-8,0).

3. On a contact area "RMP – metal" solidification process goes initially with fast formation of a solid phase (uppercooling), then is organised in this stratum to 15 %-20 % of a solid phase. Definitive shaping of firm metal around RMP occurs, when the previous stratums already crystallized.

4. It is important to mark that presence in polystyrene-model RMP does not augment quantity indicators on ejection of harmful substances in atmosphere, and at the expense of abbreviation of rate of refrigeration – duration of ejection of harmful substances is diminished at a casting and casting solidification.

REFERENCES

1. **Balandyn G., 1979.** Bases of the casting theory formation.:// Machine building P.1, 328, & 2. (in Russian).
2. **Cybrik A., 1977.** Physico-chemical processes in contact zone metal-mould. K.: Science mind. 211. (in Russian).
3. **Doroshenko S., Drobyazko V., Vaschenko K., 1978.:** Receiving of castings free of burn-in in sand-moulds. M. Machine building. 208. (in Russian).
4. **Doroshenko V., Chichkan I., 2008.** Gas regime controlling of mould made of LSHM under obtaining large castings by Lost-foam process// Metal & Casting of Ukraine. K., № 11-12. 35-38. (in Russian).
5. **Efimov V., Eldrkhanov A., 1998.:** Modern technologies of pouring and crystallization of alloys. M.: Machine building. 359. (in Russian).
6. **Efimov V., 1976.** Pouring and crystallization of steel. M.: Metallurgy. 552. (in Russian).
7. **Gorenko V., Yanover Y., 1981.** Heat-insulating materials in foundry production. – K.: Technique. (in Russian).
8. **Gulyaev B., 1976.** Theory of casting processes. L.: Machine building. 214. (in Russian).
9. **Karnozhicky V., 1978.** Contact heat-transfer in casting processes. K.: Science mind. 300. (in Russian).
10. **Kutateladze S., 1979.** Basis of heat-transfer theory. M.: Atomizdat. 415. (in Russian).
11. **Malevich Y., Samoilovich Y., 1989.** Heat-physical basis of castings and ingots crystallization. Minsk.: High school. 203. (in Russian).
12. **Mamyshev V., Shinsky O., Sokolovskaya L., 2008.** About heat-physical influence of ingot with mold and casting in the cast structure formation // Casting and Metallurgy. № 3, (special edition). M. 307-309. (in Russian).
13. **Mamyshev V., Shinsky O., Sokolovskaya L., 2010.** System analysis of crystallization process of crystallization of cast raw pieces of different weights and purpose // Casing processes. K., № 1. 20-24. (in Russian)
14. **Prymak I., Brechko A., 1976.** Castings' production for energy-machine building. L.: Machine building. (in Russian).
15. **Ryabicheva L., Tsirkin A., Usatyuk D**., **2010.** Warm deformation of copper porous powder billets. TEKA. Edition of Lublin University of technology. Vol. XB, Lublin.
16. **Shalevskaya I., 2015.** Reducing harmful influence of foundry production on environment by the mean of progressive technologies // Russian Foundryman. M., №1. 37-39. (in Russian).
17. **Shalevskaya I., Bogdan A., Shinsky V., 2015.** Ecological monitoring harmful wastes development in th Lost-foam foundry// Metal & Casting of Ukraine. K., №2. 32-36. (in Russian).
18. **Shulyak V., 2007.** Lost-foam casting. StPbg.: NPO «Professional». M. 200. (in Russian).
19. **Veinyk A., 1960.** Theory of casting's crystallization. M.:: Mashgiz. 435. (in Russian).
20. **Zhizhkina N., Budagyants N., Gutko Y**., **2010.** The refining of rolls metal of non-metallic inclusions during centrifugal casting. TEKA. Edition of Lublin University of technology. Vol. XD, Lublin.

ЭФФЕКТИВНОСТЬ ВЛИЯНИЯ МЕТАЛЛИЧЕСКОЙ МАКРОАРМИРУЮЩЕЙ ФАЗЫ НА ПРОЦЕСС ЗАТВЕРДЕВАНИЯ КРУПНОГАБАРИТНЫХ ОТЛИВОК

И. Шинский, И. Шалевская, Д. Мусбах

Аннотация. В статье рассмотрен вопрос изготовления массивных отливок способом литья по газифицированным моделям. С целью получения отливок с гарантированным качеством исследовали возможность интенсификации процесса затвердевания заготовок путем введения в пенополистироловую модель армирующей металлической фазы. Определены условия и закономерности тепломассобмена и гидродинамики в системах "металл–модель–имплантат–форма" и "металл – армирующая фаза – форма", а также взаимодействие составляющих этих новых систем. Выявлено, что ввод макроармирующей фазы в пенополистироловую модель или непосредственно в полость формы позволяет создать новые литые конструкции, которые обладают комплексом функциональных свойств ранее не присущим традиционным литейным сплавам, а именно: повышенными прочностными характеристиками литых конструкций, упрочнением поверхностного слоя литых конструкций или повышением его специальных характеристик. Установлено, что наличие макроармирующей фазы создает условия для увеличения скорости затвердевания сплава прямо пропорционально ее массе и с увеличением ее относительно объема металла в форме при этом не увеличивает количественные показатели по выбросу вредных веществ в атмосферу.

Ключевые слова: литье по газифицируемым моделям (ЛГМ), массивные отливки, пенополистироловая модель, макроармирующая фазы (МАФ), литые армированные конструкции (ЛАК), тепломассообмен.