

## GATING SYSTEM FOR IN-MOLD TECHNOLOGY

M. POKUSOVÁ<sup>1</sup>, M. MURGAŠ<sup>2</sup>

Faculty of Material Sciences and Technology STU, Paulínska 16, 917 24 Trnava, SR

### SUMMARY

The reaction chamber's shape is designed so to provide the homogeneous supply of the active elements from the master alloy at the different position of the casting towards the parting plane depending on the master alloy's melting speed, its granulometry and the melt's temperature. On the section including sprue–reaction chamber–slag skimmer the gating system is designed as the pressurized one with the control cross-section on the slag skimmer output.

*Keywords: ductile iron, In-mold process, master alloy, modification, inoculation, reaction chamber, gating system design*

### 1. INTRODUCTION

Now, many foundries use the in-mould technology to produce the ductile cast iron for its flexibility, low capitals, and the favourable environmental characteristic. This technology uses the complex master alloys containing the nodularising magnesium from 5 to 10 wt. % with the additional elements such as Ce, Ca, Ba, Sr etc., which control the graphitization process during solidification. The metallurgical processing of a melt takes place near the casting cavity in the foundry mould, in the special reaction chamber that is incorporated into the gating system. In spite of the common functions of gating systems like to transport, refine and distribute the melt metal into the castings, at the in-mold technology they have in addition to guarantee the accurate corresponding of the rates of a master alloy dissolution in the reaction chamber with the rate of the flowing melt.

<sup>1</sup>prof. Ing. CSc., marian.murgas@stuba.sk

<sup>2</sup>doc. Ing. CSc., marcela.pokusova@stuba.sk

## 2. REACTION OF MELT WITH COMPLEX MASTER ALLOY

The procedure shortens on minimum the time between the introduction of the master alloy into the melt and the beginning of casting's solidification. The high activity of the reactions' products immediately after their rising and the high efficiency of the introduction of the active elements into the melt can reduce the master alloy consumption of 0.7 to 1.0 % of processing melt mass. This is less than the half of the quantity than the processing of melt using the pour-over method in the ladle requires [1].

In the reaction chamber the kinetics of the interaction of the melt with the master alloy is different from common dissolving of the granules that are wet entirely by the melt. After the first contact of the melt with the granules the sintered interlayer is formed on their surface. During flowing of the melt this layer is gradually dissolved in it until the entire content of the chamber is consumed. The dissolving of the granules carries out nearly the constant rate that depends on the melt's temperature and the nodulariser's grain size, and on the melt's flowing rate it depends minimally [1]. The dependence of the dissolving rate for master alloy with the granulometries of 5 – 10 mm, 1 – 5 mm, and 0.5 – 1 mm without the dust fractions is documented in the Fig. 1. The dependence of the dissolving rate on the temperature for most often granulometry of 1 – 5 mm, and 5 – 10 mm is presented in Fig. 2.

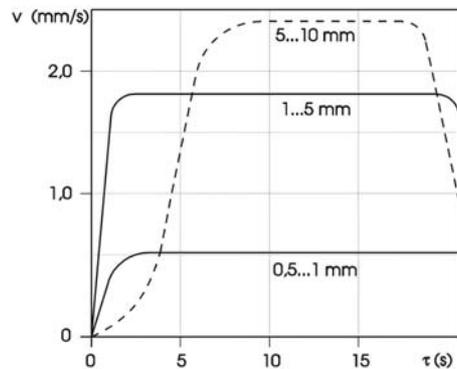


Fig. 1. Dependence of melting rate for different granulometry of complex master alloy

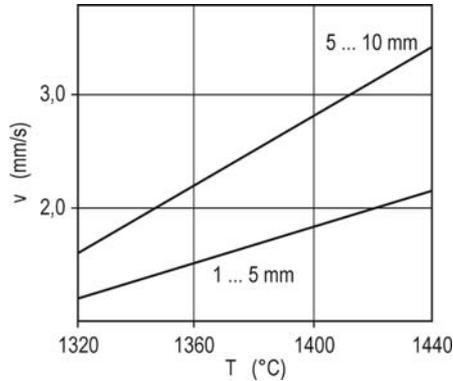


Fig. 2. Dependence of granulate dissolving rate on the melt's temperature

As it follows from Fig. 2, the deviation of the melt's temperature of  $\pm 40^\circ\text{C}$  from the nominal one can cause the deviation of the Mg content in the melt of  $\pm 0.007\%$  if the fraction of 1 – 5 mm is used, and  $\pm 0.0086\%$  for the fraction of 5 – 10 mm. If the granulometry from 1 to 5 mm suitable for the small castings is applied, after the elapse about one second, when the interlayer is formed the rate of the dissolution is nearly constant, ranged from 1.5 to  $2\text{ mm}\cdot\text{s}^{-1}$ , and depends on the melt's temperature only.

At the granulometry below 1 mm having the high portion of the dust component, virtually the entire volume of the chamber sinters and the small portion only dissolves. At the big granulometry, about 10 mm, the melt wets the bigger volume of the nodulariser that begins to dissolve with the delay of some seconds and forms the thinner interlayer that dissolves at the higher rate from 2 to 3 mm.s<sup>-1</sup>. This is proper for the production of the castings having the weight above 25 kg. Though the bigger volumes of the treated melt can eliminate the initial slowdown of dissolving, to use the granules of size above 10 mm is then problematic. The section, in which the width-length ratio is about 1:1.5 and the direction of the melt flowing along the chamber's length, allows to incorporate the reaction chamber with the gravity slag skimmer into one unit. The flowing rate of the melt in the chamber effects the rate of the dissolving negligibly and therefore, the supplied amount of the active elements into the melt per time unit has changed minimally.

The prismatic shape of the chamber (with the necessary drafts) is proper for the castings situated below the parting plane in bottom half of the mould because the near constant rate of the melt flowing is retained during their pouring. If the part of the casting is situated above the parting plane, as it is presented in Fig. 3, during its filling the melt flowing rate  $v$  gradually reduces on the height  $H_2$  resulting in the gradual increase of the Mg concentration ( $C_{Mg}$ ) in the melt. To assure the uniform supply of the nodularised elements denoted  $C_{Mg}$  during the full pouring time, it is necessary to compensate the drop of the rate on the height  $H_2$  by gradual reducing of the chamber's section. The size of the tapered part and angular one of the reaction chamber has to consider not only the changes of the rate but also the portion of the casting's mass below and above the parting plane. During the vents' filling, the significant drop of the rate does not affect the Mg concentration in the casting because in the vents the metal volume is generally smaller than the volume of a slag skimmer and the channels beyond it. When the risers are applied (Fig. 3c), during filling of the mould the rate of the melt decreases to the zero on the section  $H_2$  and  $H_3$ , and here, the chamber bottom part has the shape of quadrangular prism or wedge. If castings are only placed above the parting plane (Fig. 3d), in the cope the wedge-shaped chamber assures the uniform supply of nodularizing elements, and at the high thin-walled castings the pyramid shape of the chamber with square base is applied.

In the reaction chamber, the gradual dissolving of master alloy sustains the uniform supply of active elements such as Mg, Ce, Ca, Ba, Sr etc. and the formation of the high amount of the high-active products of the reactions between the melt and master alloy, which realize the modification and inoculation of the melt in one-step operation [1]. The nuclei of graphite do not only form in the reaction chamber, but also later in the slag skimmer and in the casting's microvolumes with the higher content of master alloy components. The formation of the high quantity of graphite nodules, and the nodules' growth from the melt entrance to the reaction chamber to the crystallization end reduce significantly the eutectic expansion, decrease the risk of chills and the volume of the shrinkage is half to compare with the other procedures.

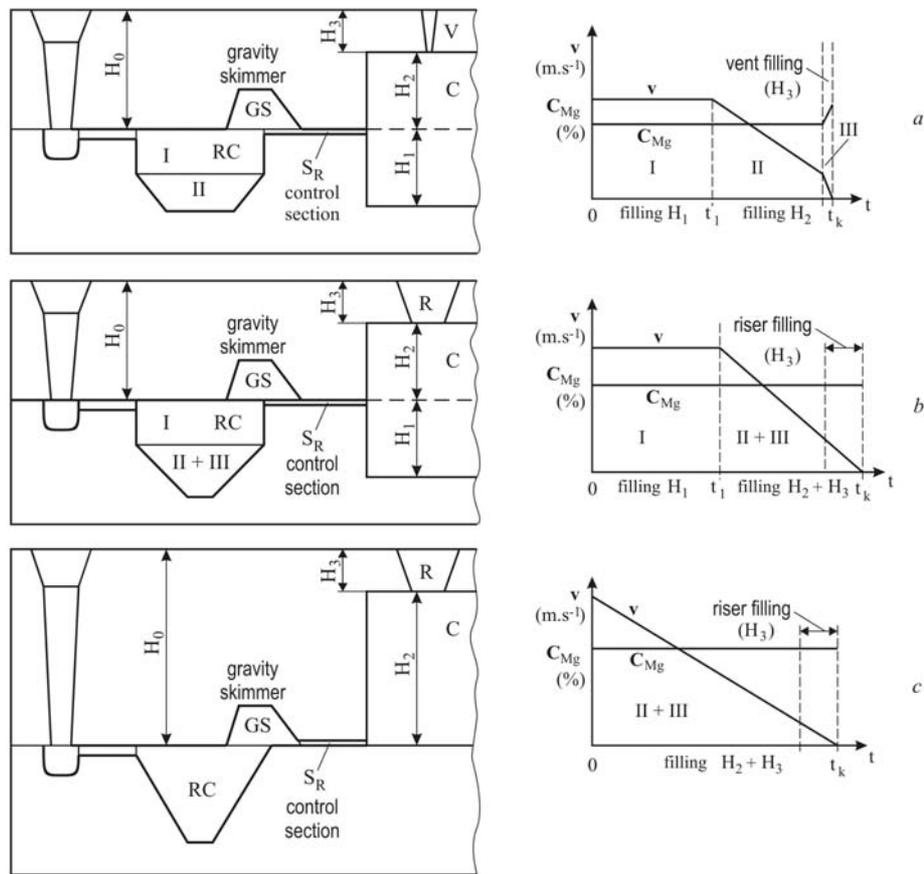


Fig. 3. Effect of a casting position in the mold on the reaction chamber's shape

The structure evaluation has shown that after the in-mould technology application the double count of the finer graphite nodules distributed in the matrix more uniformly, the higher portion of the ferrite, and the higher dispersity of the eutectic grains could be observed when compared with the pour-over method in the ladle. The tests of the mechanical properties of material on the samples of  $\varnothing 22$  mm have denoted the significant qualitative benefit of the in-mould technology. The typical values found out for the non-alloyed ductile iron were strength of 500 MPa, elongation of 13%, and the notch toughness of 75 J.cm<sup>-2</sup>. The identical cast iron processed by the pour-over method had the strength about 10% higher, of 550 MPa, but the worse plastic properties when the values of the elongation did not exceed of 7.5 % and the toughness of 35 J.cm<sup>-2</sup>. Besides the positive characteristics, the in-mould technology has also the negative ones. The metal volumes of the reaction chamber and the slag skimmer reduce the entire

utilization of the melt about 7 to 15%, and the method is sensitive to follow the technological discipline, especially the master alloy granulometry and the melt temperature, which could be in the range from 1380 to 1450°C.

### 3. DESIGN OF GATING SYSTEM FOR IN-MOULD TECHNOLOGY

Keeping the defined rate of the melt entering the reaction chamber it can be most simple done by the choke of the section at the suitable location of the gating system. The presented requirements meet best the pressurized gating system with the choke of the melt flowing using the tapered short channel behind the function unit that consists of the reaction chamber with the slag skimmer. From this tapered channel the melt enters either the mould cavity directly or the runner with the gates, when this part of gating system is desirable to design as the isobaric one. The positive pressure in the section from the sprue to the gating system control section  $F_R$  prevents the access of air and increases the efficiency of the gravity skimming the undesirable products of reactions. This type of gating system with the separate slag skimmer is presented in Fig. 4a where the direction of melt flowing and the location of the choke with the section  $F_R$  are marked.

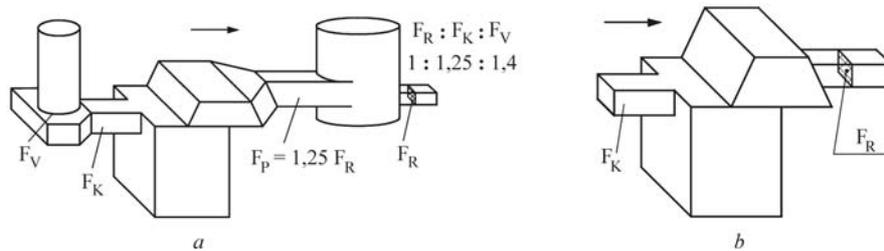


Fig. 4. Reaction chamber with a whirl skimmer (a) and with gravity one (b);  $F_R$ - control section

In Fig. 4b, the spatial arrangement of a reaction chamber incorporated into the common unit with the gravity slag skimmer is plotted. This system, in spite of its simplicity and small volume of a skimmer, has the sufficient refining effect and it has proved for the complex castings with a mass up to 25 kg. However, the reproducibility of the results depends on the gating system's design quality from the viewpoint of its configuration, shape and the size of particular parts. Regarding the difficult calculations, now its design can be solved by using the suitable software that can directly specify the shape and size of the gating system with the reaction chamber from the given data about the casting, master alloy and the melt [3]. The paper's authors use their software [3] that besides the proper basic calculations takes into account also the most important dependencies and virtually eliminates the risk of the unsuccessful design. During the whole computation the software algorithm allows the user not only to input data but also to interfere the notion of gating system, when the possible variants are controlled

by this software. The software considers the mass and the section thickness of the casting, whereon the necessary residual content of magnesium depends, next, the sulphur content in the base iron, the magnesium content in the master alloy, the temperature and the time of pouring. It allows to select the type of slag skimmer that can be gravity, separate or mechanical, or combined one with the higher level of melt refining.

#### 4. CONCLUSION

As followed from the characteristics of presented technology, this technology does not require the serious technical and investment equipments and therefore, it is especially capable for the small foundries with the wide brand of the casting's material with the small portion of ductile iron. Up to now, the big barrier was the computing difficult design of the gating systems with too high risk of errors, and in practice the experimental test of the designed running system can only face to this. The computer-aided design of gating systems virtually entire eliminates the risk of its wrong design, adjusts the time serious routine calculations, and so gives more space for the creative activity of a foundry engineer. The uniformity of the active elements' supply into the melt, or contrary, its difference can be adjusted by re-correcting of the computed chamber shape in the horizontal plane and both vertical ones according to the particular casting's shape, and the prevailing wall thickness in the different distances from the parting plane.

#### REFERENCES

- [1] LEKACH, S.N., BESTUŽEV, N.I.: *Vnepečnaja obrabotka vysokokačestvennyh čugunov v mašinostrojeniji*. Navuka i tehnika, Minska, 1992.
- [2] MURGAŠ, M.: *Slévárenství*, 1994, roč. 42, č. 5, s314.
- [3] MURGAŠ, M.: *Acta Metallurgica Slovaca*, 1997, roč. 3, č. 1/2, s. 249.

*The paper was supported by the project VEGA No. č. 1/2114/05.*

#### SYSTEM WYPEŁNIENIA ODLEWNICZEJ FORMY W TECHNOLOGII IN-MOLD

#### STRESZCZENIE

Kształt komory reakcji technologii In-mold dla żeliwa sferoidalnego jest zaprojektowany tak aby zabezpieczyć jednorodną podaż aktywnych elementów stopowych w różnych położeniach odlewu do płaszczyzny podziału zależnie od prędkości topnienia stopu, jego ziarnistości i temperatury topnienia.

Recenzował: Prof. Augustin Sladek