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IN-MOULD INOCULATION OF GRAPHITIC CAST IRONS USING INOCULATION BODIES

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SUMMARY

The effects of inoculation with the aid of OPTIGRAN and GERMALLOY (SKW Trostberg) inoculation bodies placed on ceramic filters on hard-spot depth, structure and mechanical properties have been verified. It has been proved that this method of inoculation reduces chilling tendency in castings very effectively. It increases graphite dispersiveness and improves the plastic properties of ductile iron. The effect of inoculation is dependent on pouring time and sensitive to pouring temperature.

1. INTRODUCTION

In-mould inoculation of graphitic cast irons ranks among the progressive methods of affecting the crystallization of eutectic. Since the inoculation effect practically does not subside, substantially lower inoculant doses are sufficient compared with applying the inoculant in the pouring or transport ladle. Inoculation into a flow of metal is from this viewpoint of equal advantage, in which case, however, some metallurgical problems may arise. At a low pouring temperature the inoculant need not dissolve completely in the metal flow and non-dissolved inoculant particles may penetrate into the mould. Inoculant granules have a large specific surface and when injected into the metal flow they oxidize readily due to the contact with the atmosphere. This leads to the appearance of tiny slag particles, which are then borne by the metal flow into the mould.

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With inoculation by the In-mould method the inoculant can be used in the form of compact bodies of certain mass, placed in the pouring basin, in some part of the gating system or in a special chamber. An advantage of this method is particularly the fact that after pouring the metal the inoculant is not in contact with the atmosphere and thus it does not oxidize. Depending on the type of inoculant, the temperature of the metal and the flow conditions, the inoculant will gradually dissolve during pouring. This is actually where the main risk of the method lies – in the different dissolution intensity during pouring, the slow initial rise in the inoculation effect or, possibly, premature inoculant dissolution before the end of pouring. Manufacturers of inoculation bodies therefore recommend choosing the type of inoculation body in dependence on the mass cast, and keeping the pouring temperature and pouring time within relatively narrow limits.

Since in foundry practice the pouring temperatures usually vary over a wide range, and the pouring rates can also vary a lot, experiments were carried out to test the effect of inoculation bodies in dependence on the pouring rate and pouring temperature of the metal. The tests were performed on castings made of lamellar graphite iron and ductile iron.

2. VERIFYING THE INOCULATION EFFECT WHEN POURING LAMELLAR GRAPHITE IRON

Inoculation was performed with the aid of “Combi-filters”. These are pressed ceramic filters with straight holes (manufactured by KERAMTECH Zacler s.r.o.-CZ), in which inoculation bodies are placed. The inoculation bodies used (OPTIGRAN bodies manufactured by SKW Giessereitechnik GmbH) were recommended by the manufacturer for the inoculation of lamellar graphite iron. The pouring temperature recommended by the inoculant manufacturer is 1340 to 1380°C. The optimum pouring time was chosen in keeping with a graph published by the manufacturer, and in dependence on the mass of poured metal.

The metal poured in this experiment was iron with lamellar graphite, containing 3.1%C, 0.35%Mn, 2.1%Si, C_E = 3.8. A uniform charge was used for melting. Melting proceeded in an induction furnace of 40 kg capacity, the amount of metal poured was about 38 kg. The manufacturer recommends minimum inoculant dosing of 0.1%. For this reason, inoculation bodies marked K40 were chosen, whose mass was 45 g, which corresponds to 0.12% dosing. The location of the filter and inoculation body can be seen in Fig. 1.

The test mould was designed such that metal from different stages of pouring was separated and thus the inoculation effect could be compared in dependence on time. In the bottom part of the mould cavity there were 4 bodies, weighing 8.5 kg each, above which the distribution runner was led in the cope. In this way the first metal was captured in the nearest body and when this was filled, the metal flowed onto the second body and successively all the cavities were filled with metal, always ca ¼ of the poured metal per cavity. In the bottom part of each body a test piece was poured for testing the mechanical properties of cast iron in the respective block. At the end of each body a pattern was moulded whose shape was in compliance with the ISO chill test. On the face of the specimens the outer cast iron chills were placed. The mould is shown schematically in Fig. 1.

The gating system was formed by a sprue of different diameters (which enabled changing the rate of pouring), a chamber to hold the filter with inoculant, and a distribution runner with a cross-section of 410 mm^2. The filter dimensions were 55x55 mm, thickness 20 mm, cross-section of opening 1186 mm^2. The metallostatic height was 200 mm.

The chill depth evaluation was performed on the fracture surface after the chill body had been separated and broken. The values give the overall depth of the chilled structure, inclusive of the transition zone. Mechanical tests were conducted on cylindrical rods of 10 mm in diameter. Tensile strenghts R_m, $R_{p0..2}$ and HB hardness were measured. The same mould lay-out and the same types of test specimens were also used when pouring ductile iron. In this case, ductility was also measured. On some castings, the possibility of applying thermal analysis in individual blocks was examined.

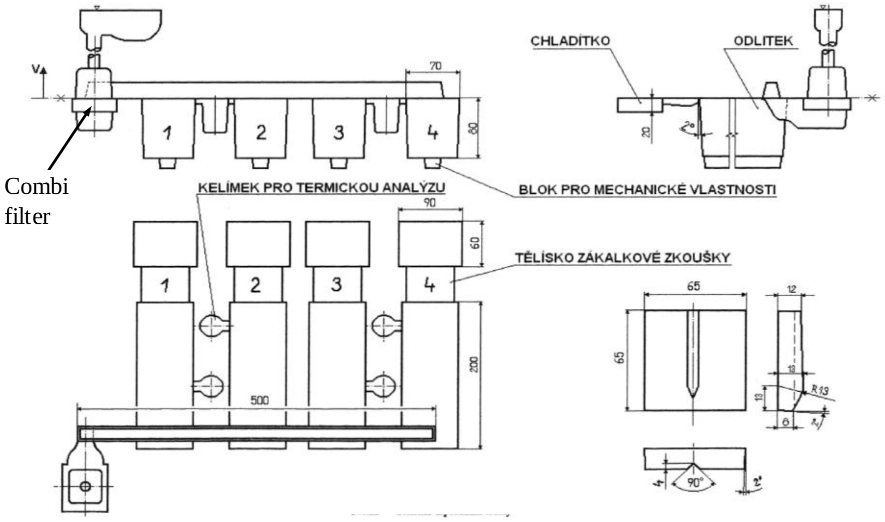
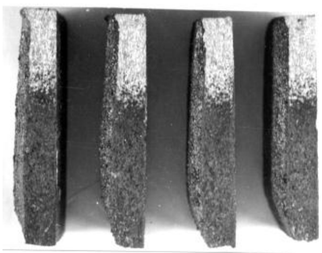


Fig. 1. Lay-out of experimental mould
Rys. 1. Układ wnęki formy eksperymentalnej

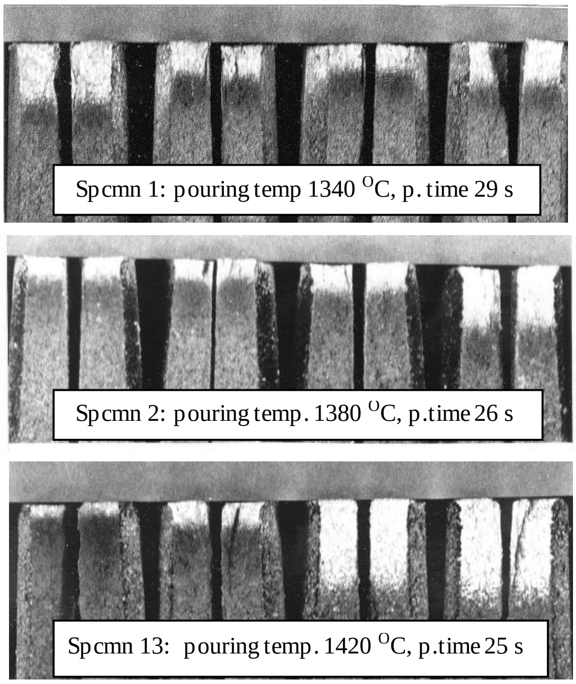
In the case of lamellar graphite iron the effect of pouring temperature ranging from 1340 to 1420°C was examined for pouring times ranging from 21 to 29 s. The recommended pouring time, which for this size of inoculation bodies is ca 10 s, was purposely exceeded in the tests in order to establish the inoculation effect during a longer pouring period.

Fig. 2 gives the resultant chilled structure for different pouring temperatures and approximately the same pouring time of 26 s. To examine the chill depth of the basic cast iron, test moulds were cast without the inoculation body deployed. In these cases the chill depth reached of 17 – 19 mm.

Sequence of castings (from the ingate)	I	II	III	IV
Pouring time (circa)	0-7 s	7-13 s	13-20 s	20-26 s
Metal mass	8,5 kg	17 kg	25,5 kg	34 kg



Non-inoculated



Inoculated with the OPTIGRAN body–45 g

Fig. 2. Inoculation of lamellar graphite iron
Rys. 2. Modyfikacja żeliwa z grafitem płatkowym

The results are given in Table 1 and in graph 1.

Table 1. Chill depth values when casting at a pouring rate of ca 1.5 kg/s
Tablica 1. Głębokość zabielenia w odlewach zalewanych z prędkością 1.5kg/s

Pouring Temp.(^oC)	Pouring Rate (kg/s)	Pouring Time (s)	Chill depth (mm)			
			Block I	Block II	Block III	Block IV
1340	1,5	25 -29	12	6	5	8
1380			11	4,5	7	10
1420			2,5	4,5	15	18

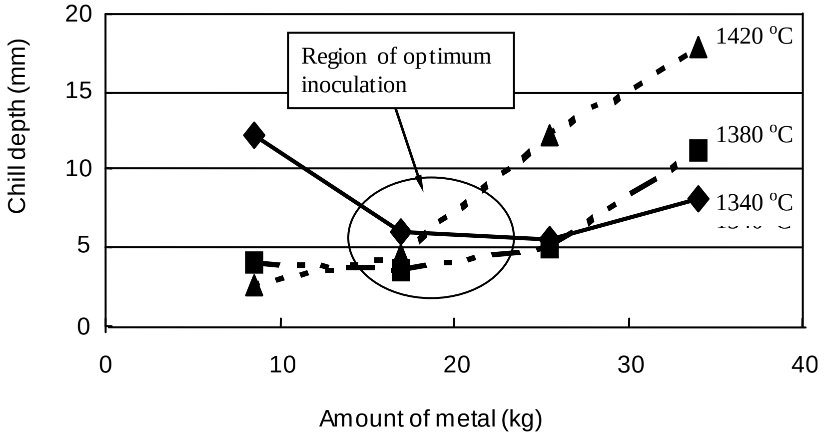


Fig. 3. Chill depth in dependence on the amount of metal flowed during pouring time of 26 s
Rys. 3. Głębokość zabielenia w zależności od ilości metalu przepływającego w czasie zalewania 26 s

It is obvious that the height of pouring temperature had a substantial effect on inoculation effectiveness. At a pouring temperature of 1340°C the metal was in the first body, i.e. in the amount of ca 8 kg, and for a pouring time of up to 7 s it was insufficiently inoculated. Good inoculation effect was in bodies II and III, and after pouring some 25 kg the effect got weaker, the inoculation body was probably almost dissolved.

On the contrary, at a metal temperature of 1420°C the inoculation effect set in very early, it was very intensive but it decreased rapidly – already after pouring ca 17 kg and after ca 13 s the degree of inoculation was weak to negligible. In this case the dosing of inoculant in castings I and II corresponded to an amount of more than 0.2%. At a temperature of 1380°C uniform inoculation was found to proceed for a comparatively long period of ca 20 s.

It can be said in general that at temperatures of 1380 and 1420°C and at pouring times of 13 – 15 s, i.e. up to a metal amount of ca 20 kg, the inoculation effect was good; at lower temperatures, however, the inoculation effect was at the beginning insufficient.
At a reduced pouring rate, i.e. prolonged pouring time, the differences between the inoculation levels increased. Fig. 4 gives pictures of chilled structures for a pouring period of ca 35 s, i.e. a pouring rate of 1 kg/s, and for pouring temperatures of 1360 and 1420°C. It can be seen that at a temperature of 1360°C most of the inoculant dissolved only in the interval from 10 to 18 s; in the interval from 0 to 9 s the inoculation was insufficient. On the contrary, at a temperature of 1420°C the inoculation effect decreased.

Sequence of castigs	I	II	III	IV
Pouring time (circa):	0-9 s	10-18 s	19-27 s	28-36 s
Metal mass:	8,5 kg	17 kg	25,5 kg	34 kg

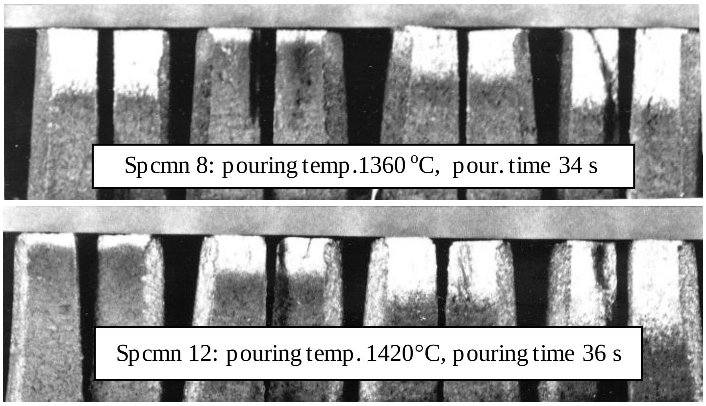


Fig. 4. Chill depth at a pouring rate of 1 kg/s
Rys. 4. Głębokość zabielenia przy prędkości zalewania 1kg/s

3. INOCULATION EFFECT WHEN POURING DUCTILE IRON

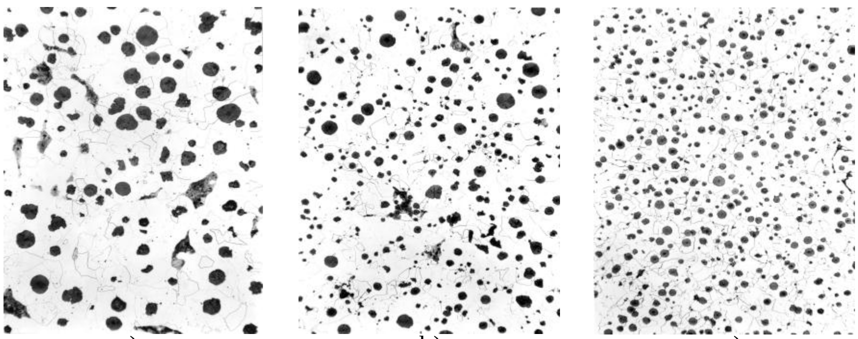
Tests similar to those of lamellar graphite iron were performed on ductile iron but on a smaller scale. The inoculation bodies used in this case, however, were bodies designed for inoculating ductile iron (trademark GERMALLOY). Chilling tests revealed similar dependence relations as in the case of lamellar graphite iron.

With ductile iron, however, we considered the effect of inoculation on the structure and mechanical properties more significant than the effect on the chilling tendency. To examine this effect, specimens of Y2 test blocks were poured from the basic cast iron and inoculated with the aid of Combi-filters with GERMALLOY inoculation bodies.

The pouring basin with the Combi-filter was placed on the open mould of the test block. This method of pouring is a type of the in-mould inoculation method.

Charge material: 36 kg pig iron, 2.5 kg steel scrap
Sandwich modification: 0.8 kg FeSiMg5, 0.4 kg FeSi75,
modification temperature 1530°C
Chemical composition after modification:
3.7%C, 2.2%Si, 0.06%Mn, 0.047%P, 0.02%Cr, 0.03%Cu, 0.039%Mg_{res}
Mass of metal poured through the filter: 12 kg
Mass of the GERMALLOY inoculation bodies: 20 or 40 g

Structural analysis and mechanical tests confirmed the pronounced effect of inoculation on the properties of cast iron. It can be seen that there was a marked refinement of graphite and a reduction (in this case up to complete removal) of pearlite in the structure. Mechanical tests revealed increased plastic properties of cast irons inoculated in this way. Table 2 gives the mechanical properties of the basic modified metal and after inoculation with an inoculation body of 40 g per 12 kg mass block. Fig. 5 shows the structure of specimens of basic cast iron after etching and after inoculation with inoculation bodies of 20 and 40 g, which corresponds to a dosing of ca 0.15 and 0.3% of inoculant.



a) b) c)

Fig. 5: Ductile iron structures: a) basic iron, b) inoculated with 0.15% of OPTIGRAN, c) inoculated with 0.3% of OPTIGRAN

Rys. 5. Struktura żeliwa sferoidalnego: a) żeliwo wyjściowe, b) modyfikowane 0.15% OPTIGRAN'em, c) modyfikowane 0.3% OPTIGRAN'em

Table 2. Mechanical properties of ductile iron after in-mould inoculation
Tabela 2. Własności mechaniczne żeliwa sferoidalnego po modyfikacji in-mold

	Rm (Mpa)	Rp0,2 (Mpa)	A (%)	Z (%)
Basic ductile iron as modified	427	258	18,4	21,0
Inoculated with 0,3% of OPTIGRAN	418	294	25,9	26,7

4. CONCLUSION

The above tests of inoculating with OPTIGRAN and GERMALLOY inoculation bodies by the in-mould method have proved a pronounced effect on the structure of cast irons. For lamellar graphite iron it is in particular the intensive effect on chilling tendency reduction, for ductile iron it is in particular the effect of this type of inoculation on increased graphite dispersiveness, reduced pearlite proportion and improved plastic characteristics of cast iron.

When inoculating with the aid of inoculation bodies it is necessary to maintain the pouring temperatures within the narrowest range possible. Pouring times must be comparatively short (which in some cases is hard to realize) and in keeping with the manufacturer's recommendation. With high pouring temperatures and pouring times exceeding the recommended value it is necessary to reckon with non-uniform inoculation effect. Unless the metal gets homogenized right in the casting, it may be reasonable to provide for the homogenization of a larger amount of cast iron by inoculating with these inoculation bodies in the pouring basin.

MODYFIKACJA IN-MOLD ŻELIWA SZAREGO Z UŻYCIEM ZAPRAW MODYFIKUJĄCYCH

SUMMARY

Zweryfikowano wpływ modyfikacji przy zastosowaniu zapraw modyfikujących OPTIGRAN i GERMALLOY (SKW Trostberg) umieszczanych na filtrach ceramicznych, na głębokość warstwy utwardzonej, strukturę i własności mechaniczne. Zostało udowodnione, że przedstawiona metoda modyfikacji bardzo efektywnie redukuje skłonność do zabieleń. Zwiększa rozdrobnienie grafitu i własności plastyczne żeliwa sferoidalnego. Efekt modyfikacji zależy od czasu zalewania i temperatury zalewania.

Recenzował Prof. Przemysław Wasilewski