DUCTILATER — A process-controlled Process for Magnesium-treatment of Cast Iron During Pouring

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Requirements to be met

For a long time already, there has been a need in foundries to mechanize and automate manufacturing processes as far as possible. At the same time, however, and in particular in jobbing foundries, highest flexibility regarding production rate and casting programme are required because of the small lot sizes involved.

In iron foundries, automatic induction-heated pouring furnaces such as the ABB PRESSPOUR® and MINIPOUR® in conjunction with advanced stopper-rod systems have stood up to the test in solving these problems[6].

Holding and automatic pouring of grey cast iron with the aid of such systems has meanwhile become state of the art: On the other hand, the holding and automatic pouring of magnesium-treated vermicular or nodular graphite cast iron imposes considerable additional requirements[9][4] on the pouring process with regard to maintenance, servicing and system monitoring.

In order to avoid such disadvantages in the future, the companies PECHINEY Electrométallurgie, Paris/F and ABB Industrietechnik AG, Dortmund/D in cooperation with the Belgium WTCM Foundry Centre, Gent/B have developed the DUCTILATER-process and applied it in series trial runs at the DOVRE foundry in Weelde/B.

After introduction of the treatment system, the operational results are presented which have been obtained in the making of nodular cast iron parts on a DISAMATIC moulding line.

Process description: Treating, inoculating and alloying by means of the DUCTILATER

The basic principle of this process consists in a controlled and dosed addition of fine-grain additives into the liquid iron stream. A schematic illustration (Fig. 1) shows how the DUCTILATER system is integrated between pouring furnace and mould[9].

The DUCTILATER system consists of a dosing unit with star feeder lock for the Mg-pre-alloy, the injector nozzle with feedline for the inert carrier gas, the treatment chamber with quick-changing device and the associated piston-operated cleaning rod as well as the control console with elements for process control and supervision.

In application of the system, an untreated base melt is introduced into the reaction chamber of the DUCTILATER from the upstream pouring furnace by means of stopper pouring. Dimensioning of the reaction chamber takes into consideration the pouring conditions to be
met, i.e. adapted to the maximum required pouring speed for practicable mould filling. A tangential feed orifice in the reaction chamber makes the iron stream rotate and form a defined vortex. The treatment agent is blown through the injector nozzle by means of a nitrogen carrier gas right into the centre of this vortex. Dosing of the treatment agent is performed by data signals from the stopper control on the pouring furnace. Here, the teach-in pouring curve of the mould memorized in the control computer is transmitted to the DUCTILATER control for adding the pre-alloy thus ensuring that dosing is a function of the pouring weight.

The reaction which starts immediately with the addition of the treatment agent takes place during the rotation of the iron stream in the reaction chamber so that treated iron is poured into the mould through the outlet opening provided in the bottom of the reaction chamber. Immediately after this pouring and treatment of the iron in the DUCTILATER, the outlet opening of the reaction chamber is cleaned and freed from particles by means of a piston-operated cleaning rod. Nevertheless, slight depositions of slag particles within the chamber can never be avoided, which means that after a certain production time the reaction chamber has to be replaced. This is done by means of an incorporated fast-changing device in which a second chamber is always ready for use. In order to avoid production delays, the changing process follows the pouring cycle. The replaced and cooled-down treatment chamber is then cleaned in an easy way and can be used again up to 10 times.

The making of vermicular and nodular graphite cast iron with the DUCTILATER

In the DUCTILATER process, vermicular and nodular graphite cast iron are made by adding a special FeSiMg pre-alloy with an increased portion of rare earth of the PECHINEY company. This pre-alloy called SIMAF (grain size 0.2 to 2mm) is a combination of inoculation and treatment agent which eliminates the need for an additional inoculation of the melt up to a casting wall thickness of 5mm. Smaller wall thicknesses can be produced carbide-free by an additional inoculation into the pouring stream using inoculant SPHERIX (increased portion of bismuth and other rare earth) of the PECHINEY company.

The Mg-yield is >70%, depending on the treatment temperature.

Combined with ABB pouring furnaces PRESSPOUR® and the stopper control system PROPOUR®, the DUCTILATER process, already tested in series trial runs, represents an ideal system for optimizing the treatment and pouring process.

Of course, the DUCTILATER process can be used also with other pouring systems and can be integrated to existing pouring systems with relatively low expenditure.

Untreated GGV/GGG base iron is kept ready in the pouring furnace which results in the following benefits for the furnace operation compared with the storing of treated base iron:

- No Mg based reaction products in the holding furnace
- Less slag
- Reduced expenditure for maintenance and supervision
- Less staff required
- Higher availability of the pouring system and thus increased production rate
- Longer furnace lining lives
The treatment for making GGV and GGG is then performed in the down-stream DUCTILATER process which, compared with other treatment process, offers the following advantages:
- Process-controlled and shotweight-dependent treatment (quick pattern change is possible)
- Mg-Yield > 70% with a very high reproducibility
- High flexibility in making different material qualities (e.g. GGG 40 - GGG 70 from one basic melt)
- Very little temperature losses of the iron due to the treatment process
  This results in a low tapping temperature in the pouring furnace and thus in a lower energy consumption for the holding operation
- Very low splash iron losses in the Mg treatment
- Little formation of flue gas which can be exhausted via the DUCTILATER exhaust and/or existing moulding line exhaust systems
- Treatment and inoculation process in the flask can be eliminated (higher flask utilisation possible)
- Combined shotweight dependent Mg treatment, alloying and inoculation is possible (which means a saving in additional inoculation/alloying equipment)

Application of the DUCTILATER in the DOVRE foundry in Weelde/Belgium

Producing grey iron castings, the DOVRE Foundry in Weelde/B is a successful manufacturer for a variety of end-users.

The foundry is equipped with cold blast cupolas, rotary drum furnaces and a coreless induction melting system. Moulding is on three DISAMATIC lines which are equipped with ABB stopper-actuated automatic and induction-heated pouring systems.

DOVRE has decided to extend its production range to produce nodular graphite cast iron castings. The management has considered all of the available treatment methods and came to the conclusion that none of the processes presently available was able to fully meet the requirements – in particular, DOVRE was concerned regarding the holding of Mg-treated melts for the automatic pouring systems.

Contacts with the WTCM Foundry Centre/F, PECHINEY Electrométallurgie/F and ABB Industrietechnik AG/D made it possible to develop the DUCTILATER process up to industrial maturity.

The DUCTILATER unit is equipped with two reaction chambers. These consist of a casing of welded construction which is lined with refractory material and dimensionally adapted to the special pouring reference characteristics of the parts to be cast. An important aspect is that the outlet opening of the chamber is designed for maximum iron throughput during the pouring process. In series manufacture, chamber lives of approx. 1 hour were achieved.

In case of need, a second chamber can be properly positioned via a quick changing device without interrupting the production flow.

Experience in productional operation has shown that deposits of magnesium oxide/stag particles in the chamber outlet can never be avoided completely. Therefore, the reaction chamber is cleaned after each treatment or adding process using a piston actuated cleaning rod well known from operation of the ABB PRESSPOUR® furnaces.

For the pouring process, the base iron has been treated with 1.1% magnesium pre-alloy
SIMAF (approx. 6% Mg; 0.4% La and 0.5% Ca) of the PECHINEY company. The base iron had the following analysis:

C = 3.5 - 3.6%
Si = 1.7 - 1.8%
Mn = 0.05 - 0.07%
P = 0.03%
S = 0.012 - 0.016%

The residual magnesium contents in the casting produced varied between 0.045 and 0.050% which means an average magnesium yield of 71%.

The final analyses of the treated iron were:

C = 3.5 - 3.6%
Si = 2.5 - 2.6%
Mn = 0.05% - 0.07%

The metallographic evaluation shows a very good nodularity in a 3mm thick casting section. The castings were produced carbide-free in the as-cast condition using an additional inoculation in the outlet of the DUCTILATER reaction chamber with inoculant SPHERIX of the PECHINEY company. See Fig.2

Process requirements when using the DUCTILATER

In view of the production process when making Mg-treated iron by means of the DUCTILATER, the following aspects have to be observed:

The use of casting filters

Despite a purging of the treatment chamber with nitrogen gas – the reaction of the Mg-pre-alloy with the passing iron leads to some formation of slag, and therefore, casting filters have to be used in the mould in order to avoid slag particles being introduced. The use of such ceramic casting filters is imperative in the DUCTILATER process in order to avoid casting defects by slag inclusions.

Quality control and inspection of the castings

The process parameters once set, GGV and GGG can be made by means of the DUCTILATER with a very high reproducibility which is by far superior to other treatment systems. It should be noted that because of an individual Mg-treatment of each single mould, higher demands need to be met by the inspection process. As is the normal practice for safety critical castings, a 100% inspection has to be done which can be performed easily in an automated way by means of ultrasonics and/or sound frequency analysis. For inspection of the series production at DOVRE, a frequency analyzing apparatus of Messrs. LEMMENS in Leuven/B, called GrindoSonic, has been used. Here, the casting is made to vibrate by physical knocking and the natural frequency is then qualified by measuring. This testing method is today widely used in many foundries all over the world[9].

Summary
The special demands to be met by the maintenance and operating personnel in the automated pouring of magnesium-treated cast iron melts by means of pressurized pouring furnaces gave rise to the development of a magnesium treatment process which is performed in a reaction chamber positioned between stopper pouring basin of the pouring furnace and the mould, simultaneously with the pouring process proper. A magnesium pre-alloy is introduced by means of an inert carrier gas into the pouring stream flowing tangentially into the treatment chamber; with the aid of the process control via stopper actuation, the Mg-material flow is adjusted to suit the metal stream variation with time.

Practical experience made by the manufacturer of nodular graphite cast iron on a DISAMATIC moulding line showed that satisfactory nodularity can be reproducibly achieved with the DUCTILATER system at a magnesium yield of over 70%. Jointly developed by ABB Industrietechnik AG, PECHINEY Electrométallurgie and WTCM Foundry Centre, this process has reached a maturity which makes it suitable a large-scale industrial use.

Reference
Fig. 2 Castings with micrograph, made by the DUCTILATER process at DOVRE, Wealde/B