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FOSECO

FOUNDRY PRACTICE

The authoritative magazine for foundry engineers

- SINCE 1932 -

MELT SHOP REFRACTOIRES

ROTOCLENE PROCESS

Clean steel castings at ultralow pouring temperatures for high performance applications using the innovative ROTOCLENE process

NOZZLE TECHNOLOGY

Nozzle technologies for iron and steel foundries

FERROLAB V

Increasing the consistency of iron casting properties and reducing foundry rejects

EDITORIAL

Dear Readers,

Welcome to this edition of foundry practice which is focused on new developments for the foundry melt shop. As always FOSECO aim to provide new products and processes that can increase the quality of castings produced or to reduce their cost and both wherever possible.

In this issue we have significant focus on FOSECO's novel ROTOCLENE* process for treating ladles of molten steel. The process builds on our many years of offering rotary treatments to the aluminium industry but adapts and builds on this to generate benefits for Steel foundries. The major benefits of the process are to clean the steel, using tiny gas bubbles to float out inclusions and bifilms from the melt, and at the same time to use the powerful stirring action of a rotor to homogenise the temperature and composition within the ladle. The benefits of this are first of all to produce very clean steel, but also to allow casting at lower temperatures giving significant benefits in feeding properties. As you will read later, there are further additional processes and benefits that can be added optionally.

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We also have an article on FOSECO's offerings in the pouring nozzle market, in bottom pouring ladle applications for Steel, repetition pouring operations for cast iron and now for the production of metal powders. The article summarises our existing technologies that include multi-use nozzles and flow controlling 'Cross-Bore' products, but also highlights where we have new offerings in the market.

These are specifically our VAPEX* FOSFLOW nozzles whose diameter can be changed whilst ladles or pouring units are in service, and we also have speciality nozzles for use in the manufacture of 3D metal printing powders, at the cutting edge of new technology.

Finally we have a reminder of FOSAECO's FERROLAB* V equipment for thermal analysis and control of cast iron. This equipment, in conjunction with the consumables on offer from VESUVIUS's Sensor and probes division allows iron foundries to measure the physical inoculation state of iron before it poured, and to ensure that it is accurately inoculated which in conjunction with standard chemical analyses can avoid many common problems such as carbide formation and variable shrinkage behaviour.

We hope you enjoy the issue!

Colin Powell
International Marketing Manager –
Foundry Melt Shop

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WHITE PAPER

NEWS

CLEAN STEEL CASTINGS AT ULTRALOW POURING TEMPERATURES FOR HIGH PERFORMANCE APPLICATIONS USING THE INNOVATIVE ROTOCLENE PROCESS

Authors: David Hrabina & Colin Powell, Foseco // Co-Authors: Dalibor Čáp, Milan Turták, Jiří Kolár, UNEX

This article describes a new technique for improving the quality of Steel melts in the ladle prior to pouring.

The Process involves a rotary treatment process that stirs the metal in the ladle whilst passing a curtain of fine Argon bubbles through it. Together with flux and wire additions the process leads to effective inclusion removal, homogenized temperature, modification and desulfurization. The technique allows the steel to be cast at much lower temperatures even semi liquid, resulting in fine cast microstructures and reduced defects.

INTRODUCTION

Molten metal in the melting furnace will be clean but tapping into the pouring ladle significantly contaminates it. [1] The metal tapping process is not well controlled and splashed metal exposed to the atmosphere reacts with oxygen forming oxide films having melting temperature greater than temperature of the liquid metal in the ladle. Formed oxide films cannot dissolve or remelt in the ladle and floating up to the surface through their buoyancy would take excessive time due to their large surface area and negligible volume.

Injecting treatments and deoxidising alloys such as Al, SiCa, FeTi, and FeZr into the stream of tapped steel makes the situation even worse. Massive amounts of air entrained into the molten metal in the ladle (Fig 1a & 1b) immediately react with those high oxygen affinity elements forming even more non-metallic inclusions and oxide films.

Fig 1a: Water modeling of tapping process

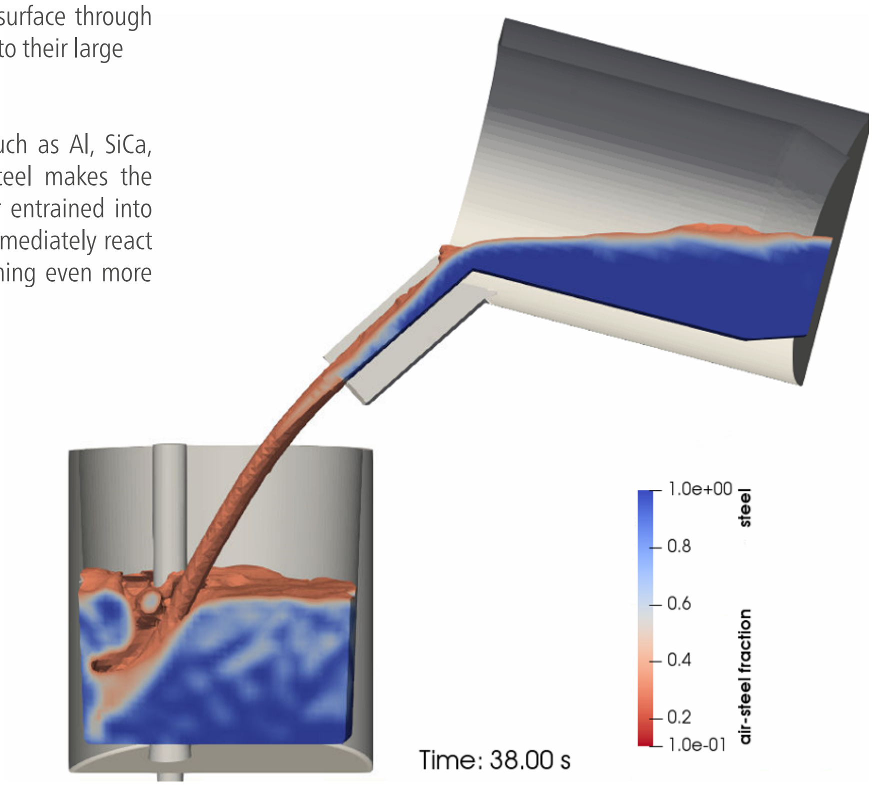

Fig 1b: CFD simulation of metal tapping

The metal temperature in the ladle may vary significantly in different locations due to the cooling effect of the refractory lining. The difference between the metal temperatures between the bottom and top of the ladle might be tens of degree before the pouring process starts. (Fig. 2a & 2b) Especially sensitive are smaller bottom pour ladles because of the cooling effect of stoppers and nozzles. The coldest metal sinks to the lowest area around the stopper nose and is the first metal to flow into the nozzle when the stopper is lifted up.

This metal cools even further as it passes through the unpreheated running system and leads to mis-runs and cold shut defects on the casting surface. The pouring temperature is measured by thermo probe at the top of the ladle before pouring starts but this is not representative of metal temperatures at other ladle locations.

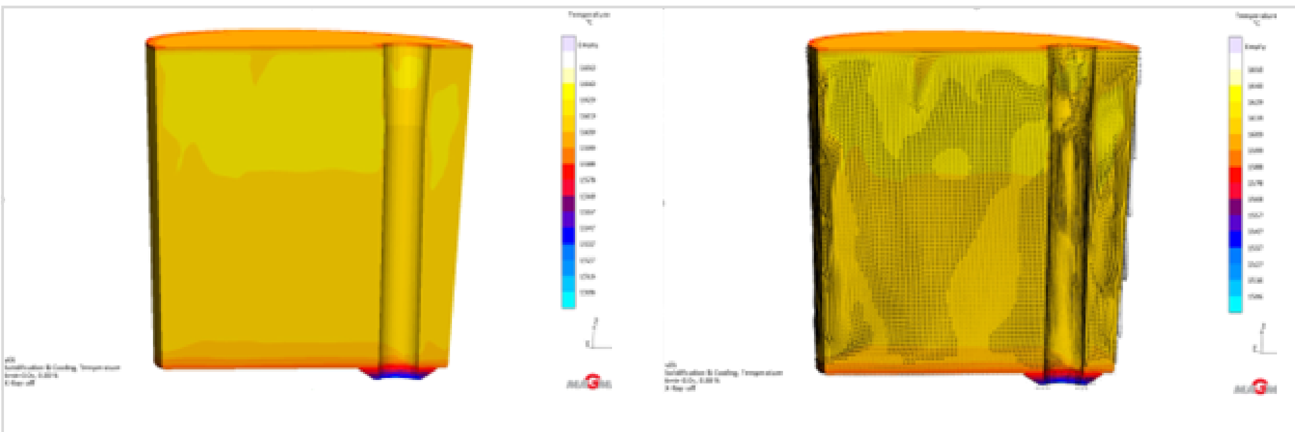

Fig 2: MAGMA simulation of metal temperature distribution at the ladle 6 min after tapping

The ROTOCLENE process has been developed to treat molten metal effectively in the ladle. For reducing hydrogen and nitrogen pick up we would ideally deoxidise the melt with cored wire before or during the rotary treatment rather than into the stream during metal tapping from either arc or induction melting furnace. A hollow ceramic rotor stirs the molten metal as argon is purged through it gets dispersed to form curtains of very fine bubbles. (Fig 3a) These float up slowly in a helical trajectory that extends their passage through the metal rotating around the vertical axis of the ladle. Slag particles inclusions and oxide films adhere to surface of the argon micro bubbles and float up into the slag layer at the top. The small size of the argon bubbles gives them a long residence time in the melt and together with the extended floating trajectory means that very effective metal purification is achieved (Fig 3b). The rotation of the melt also effectively homogenizes metal temperature and eliminates critical cold spots at the bottom (Fig 4a). Molten metal in the ladle keeps rotating through its moment of inertia even several minutes after the end of the rotary treatment. The metal temperature stays consistent at any ladle location without cold spots (Fig 4b) and pouring temperature can be significantly reduced compared to conventional practice.

Fig. 3a: Very fine Ar bubbles helically dispersed

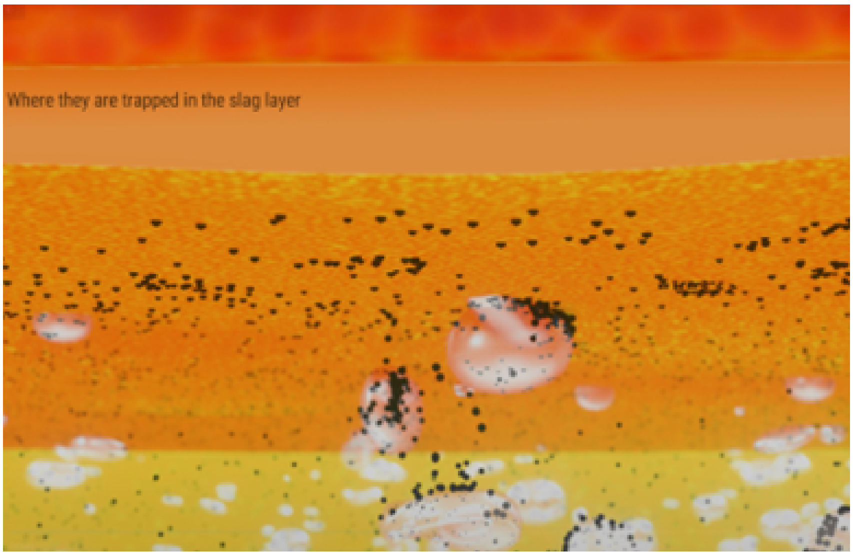

Fig. 3b: Effective bifilm and inclusions removal by Ar bubbles

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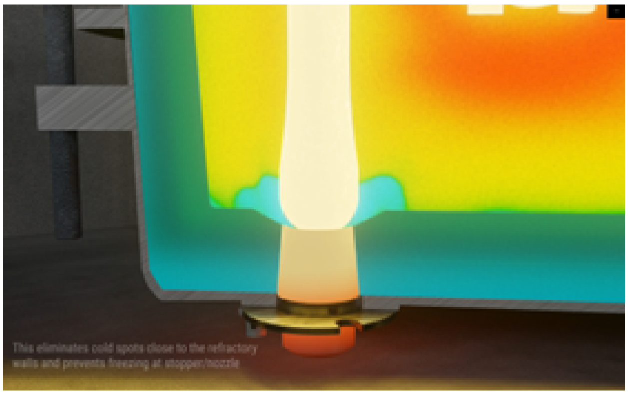

Fig. 4a: Cold spots of metal after the tapping

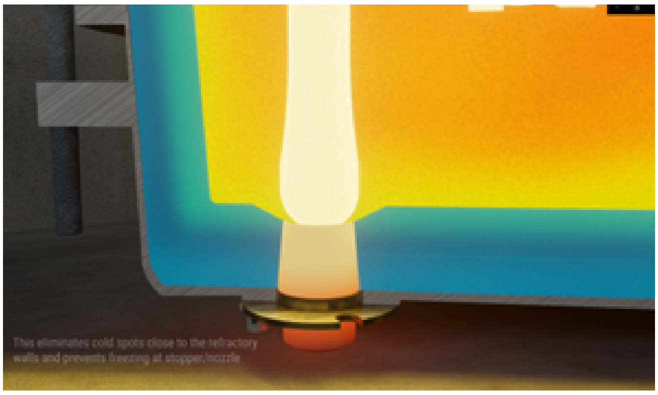

Fig. 4b: Metal temperature homogenization by ROTOCLENE - Rotary Treatment Process

WATCH ANIMATION

Our animation showcases all the features and benefits of the ROTOCLENE process, including its ability to clean up molten metal at the ladle and improve casting quality.

Synthetic slag can also be stirred into the molten metal to partially dissolve nonmetallic inclusions and perform deep desulfurization (Table 1) at the neutral or basic lining ladle similarly to a ladle furnace in secondary metallurgy [2]. The stirring action also allows a deeper deoxidation by extruded pure Ca wire to modify alumina inclusions (Fig. 5) to a more nodular shape more effectively than SiCa [3]. Pure Ca normally reacts too violently with steel and cannot be applied in foundry ladles, however, injecting the Ca into a moving stream dissolves it before it reaches the critical vapour concentration. Pure Ca also does not contribute to premature filter clogging in the way that SiCa typically does.

Test No	Time	C	Mn	Si	P	S	Cr	Mo	Ni	V	Cu	Al	Al soluble
1	12:40	0.67	0.85	0.18	0.016	0.017	0.30	0.20	0.22	0.01	0.05	*0.234	*0.220
2	13:08	0.31	0.16	0.00	0.002	0.012	0.09	0.27	0.20	0.00	0.05	*0.150	*0.143
3	13:45	0.40	0.42	0.42	0.006	0.007	0.89	0.26	0.19	0.01	0.05	0.027	0.023
final	14:37	0.45	0.82	0.52	0.008	0.002	1.13	0.26	0.19	0.01	0.05	0.033	0.031

Test No 1 – EAF just after smelting (6800 kg)

Test No 2 – EAF after oxidation

Test No 3 – EAF before tapping → 1% of synthetic slag SULFAMIN 70 into the pouring ladle within tapping

Test No 4 – Taken from the ladle after ROTOCLENE treatment at the end of pouring process. Sulfur level reduced from 70 to 20ppm.

Table 1: Desulfurization at the ladle by synthetic slag within ROTOCLENE treatment

Metal solidification is very complex process of transformation from liquid phase to solid involving the formation of dendrites and segregation of low solubility elements at the grain boundaries. Atoms are converted from liquid disordered phase to solid ordered phase releasing significant latent heat being accompanied by volumetric shrinkage. [4, 5, 6]. The liquidus point can be identified reliably by the initial chemical composition of the cast metal while the solidus point is varied by the actual metal composition being continuously saturated by segregating elements.

The temperature of the liquidus at any casting part is identical. However, the solidus temperature in thin sections of the same casting is higher than solidus temperature in thick sections. Extended solidification time in the thick casting sections allows dendrites to develop more and segregation at their grain boundaries changes their chemical composition due to the higher concentrations. This phenomenon results in the solidification range being narrower in thin sections and wider in thicker ones within the same casting. Solidification time highly influences the structure and therefore the final mechanical properties of steel castings. Longer solidification times allow dendrites to grow bigger and inter-dendritic segregation is higher (Fig 6, 7a, 7b, 7c, 8) [7, 8].

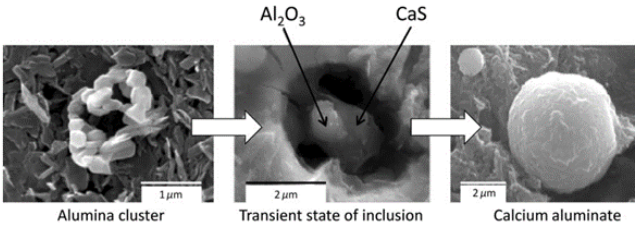

Fig. 5: Alumina inclusion modification by Ca to globular shape less harmful to low temperature notch toughness test and fatigue performance

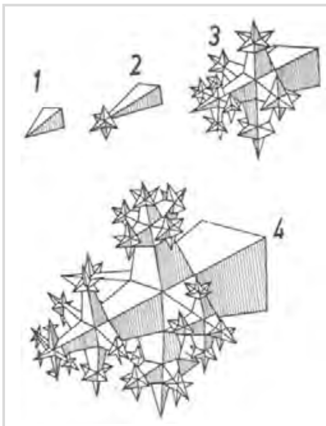

Fig. 6: Dendritic growth from primary, secondary, tertiary to quaternary dimensions according to solidification time by Robert Wlodawer [7]

Fig. 7a: Model of dendrite structure with primary, secondary, and tertiary axis [5]

Fig. 7b: Section through the structure of steel dendrite [6]

Fig. 7c: Dendrites growth at the shrinkage [6]

This impacts mechanical properties negatively. Solidification time depends on many parameters but most importantly on cast section modulus and pouring temperature. Modulus is mainly defined by castings geometry while pouring temperature depends on foundry practice. Superheat (the difference from pouring temperature to temperature of the liquidus) is applied to ensure the casting cavity is filled up before solidification starts. The mold absorbs superheat energy from the liquid steel and is heated up before molten metal temperature drops below the liquidus to start the solidification process. Higher pouring temperature leads to more energy absorption by the mold before solidification starts and lowers the capacity for the mold to absorb heat from the solidifying casting. (Fig. 9)

To maximise the reduction of pouring temperature and casting solidification time, the molten metal in the ladle is stirred by powerful ceramic rotor This prevents the embryonic crystals nucleating in the melt from agglomerating and limits the growth of dendrites and segregation when the temperature falls below the liquidus. Latent heat released by solid phase formation slows down metal cooling in the ladle and provides sufficient time to heat up the stoper, nozzle, and lining of the ladle very close to the molten metal temperature.

The requirement to superheat the steel for casting is eliminated and the ultralow pouring temperature, already in the range between liquidus and solidus, ensures that heat energy can be absorbed quickly by cold molds. This leads to immediate solidification achieving a very fine grain size and minimal segregation at the grain boundaries. Metal cast at an ultralow pouring temperature must be protected effectively from reoxidation and air entrainment ideally by a ceramic shroud. Semi-liquid metal is still sufficiently fluid to fill up the mold cavity but pouring time must be very short to avoid cold shuts and misrun defects. Oxide films and entrained air bubbles are not able to float up to the casting surface through semi liquid steel. It may not be possible to produce every casting at ultralow pouring temperature but massive, thick-walled castings which benefit from fast solidification process are exceptionally well suited to this technology. The limit to how far below the liquidus the molten metal stays fluid enough to be cast by gravity is determined by the chemical composition of the steel being cast. Carbon and high strength low alloy steels having a narrow solidification range and high heat conductivity are more sensitive to ultra-low pouring temperature than medium and high alloy steel having solidification ranges that are much wider and heat conductivity that is lower. The feasibility of casting at ultra-low pouring temperature will need to be considered based on the casting size and shape, and individual foundry experience.
Nevertheless any superheat reduction reduces primary grain size and segregation and consequently improves mechanical properties. Casting defects detected by ultrasonic, X-ray or magnetic particle inspection (MPI) are significantly reduced and castings achieve the higher grades of quality acceptance demanded by final customers.

More than one thousand steel melts in range from 3 to 20 tons have already been treated by the ROTOCLENE process. Overall casting results show significant improvement in terms of casting surface, internal homogeneity and metal cleanliness followed by higher mechanical properties compared to conventional technology. (Table 2. Fig 10a & 10b)

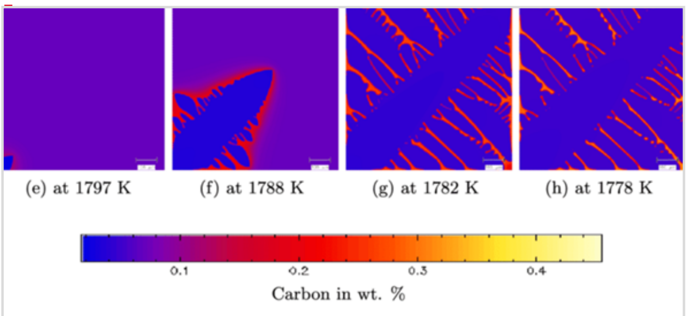

Fig. 8: Dendrite's growth and inter-dendritic segregation of carbon model [9]

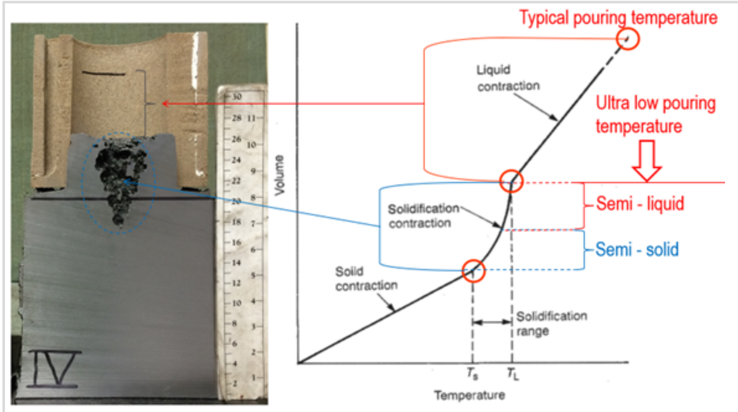

Fig. 9: Extended solidification time by superheating steel over the temperature of liquidus. Volumetric contraction starts from pouring temperature, but shrinkage cavity cannot be formed until temperature drops under the liquidus and solidification process starts

	047 - Metal treated by Purging Plug at the ladle	092 - Metal treated by rotary treat-ment
Total Area Analyzed (mm^2)	116.64	116.64
Total Number of Classified Features	4709	2142
Total Area Analyzed Features without unclassified (micrometer^2)	49576	34942
Si>70	143	81
Al>70	208	107
70>Al>50	407	298
Mn>25 and S>10	2373	1426
Mg>25	1	0
Ca>50	2	7
50>Ca>10	1471	141
Rest	104	82

Table 2: Inclusion's removal and metal cleanliness comparison ROTOCLENE versus Purging Plug process. (Samples taken from the test block cast as connected to casting

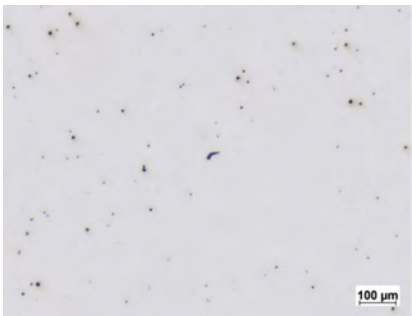

Figure 10a: PP treatment 20' metallography

Figure 10b: ROTOCLENE treatment 7'

Molten metal exposed to atmospheric oxygen forms oxide films at any time. (Fig. 11a & 11b). Super clean and temperature homogenous metal in the pouring ladle contaminated during the pouring process may still contribute to casting defects [9, 10, 11]. The HOLLOTEX* Shroud is highly recommended to protect cast steel from air entrainment and metal re-oxidation within the casting process, especially in combination with molten metal treated by ROTOCLENE in the pouring ladle.

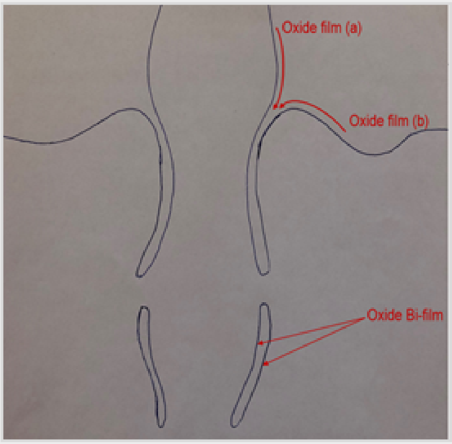

Fig. 11a: Air entrainment and bifilm formation principal

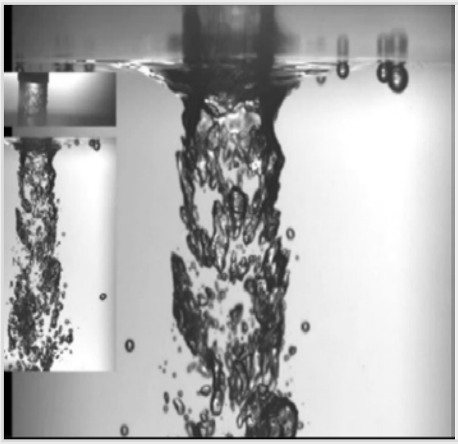

Fig. 11b: Air entrainment within pouring process

CASE STUDY: PISTON

This thick piston casting from carbon steel (GS-70) was produced regularly last 10 years and never passed inspection without excessive welding. It's shape is apparently simple (Fig. 12a) but solidifcation time of about 15 hours (Fig. 12b) leads to excessive dendrite growth and severe segregation complicates feeding within the last solidification stage.

Figure 12a: Shot blasted casting

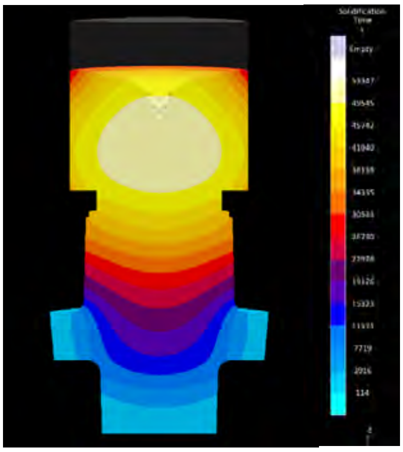

Figure 12b: Magma simulation of solidification time

Primary shrinkage has never been present, but ultrasonic echo was always lost within inspection of the bottom hub and upper part under the riser. Repeated heat treatment has been applied to try to refine the grain size and allow ultrasonic inspection but unsuccessfully. Defective parts from the drag (Fig. 13a) and under the riser (Fig. 13b) were machined out by carousel to a depth of 135mm until porosity detected by penetration was removed. Excavated diamater was 300mm in the drag and 400mm under the riser. Porosity detected by penetration test was finally much bigger than identified by ultrasonic test. Additional annealing heat treatment had to be applied after the welding.

Figure 13a: Porosity in bottom hub

Figure 13b: Porosity under the riser

The ROTOCLENE process has been applied to clean up the molten metal and reduce pouring temperature to liquidus level. 7400 kg of steel from EAF was treated in an 8,5 ton capacity ladle for 32 minutes until the temperuture dropped to 1495°C, then the ladle was transfered to the molding shop for pouring which took 7 minutes from the end of rotary treatment. Pouring temperature was 1480°C which was calculated as the liquidus temperature of this melt. Casting was through the HOLLOTEX Shroud to protect cast steel from reoxidation air entrainment and bifilm formation. The mold was filled within 44 seconds. Cast weight was 6400 kg and weight of the casting 3700 kg. There was no trace of molten metal freezing in the ladle. This casting passed ultrasonic inspection successfully without welding (Fig 15).

Operation of the ROTOCLENE process even under the liquidus temperature has been tried for other castings. The challenge is to measure metal temperature when it drops under 1500°C. Thermo probes for steel suffer from slag freezing on the metallic cup protecting the thermocouple and mostly does not record the temperature. Metal was treated until the temperature dropped under 1480°C before casting. There was some residual metal frozen in the ladle bottom but this could be cleaned up by oxygen lance when the ladle was emptied. One mold from the ladle can be cast from such ultra low pouring temperature significantly under the liquidus, but the casting must be thick and not sensitive to cold shuts or mis-runs. Pouring of more than one mold from the ladle might be problematic as metal may start to solidify at the nozzle to shroud connection.

Figure 14a: Defective part excavated up to 135mm

Figure 14b: Defects on the diameter are still present and needs to be further machined

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SUMMARY

ROTOCLENE – Rotary treatment of molten steel is an innovative technology allowing higher level of metal purification and temperature homogenization at the pouring ladle. Rotating molten steel heats up the ladle lining and stopper avoiding premature metal solidification at the ladle and stopper freezing risk. Treatment can be continued until metal temperature cools down to the desired pouring temperature regardless the metal holding time. Steel may be further desulfurized by synthetic slag stiring and alumina inclusions modified to less harmful globular shape by pure Ca. In combination with HOLLOTEX Shroud pouring temperature may be significantly reduced and cleaner castings achieved with finer grain size and higher levels of homogeneity.

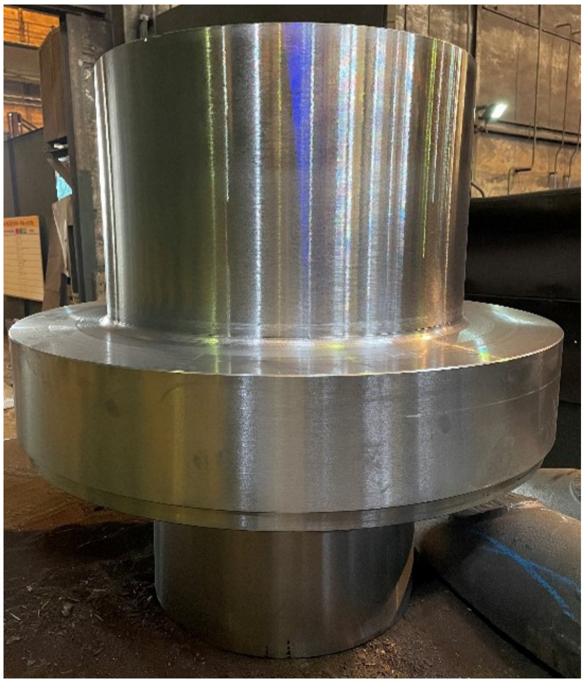

Figure 15: Sound casting

MAJOR BENEFITS OF THE ROTOCLENE INCLUDE:

- Molten metal temperature homogenization at any ladle position
- Inclusion and bi-film removal with metal purification
- Increased filtration capacity and reduced risk of filter clogging or breakage
- Desulfurization by synthetic slag
- Modification of inclusions by pure Ca
- Reduces risk of stopper freezing at the nozzle
- Pouring temperature reduction
- Reduced defect levels revealed on X-Ray and Magnetic Particle Investigation accepted without repair
- Improvement in mechanical properties

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ABOUT THE AUTHOR

David Hrabina is an International Project Manager at Foseco since 2005. His main tasks involve implementing innovative technologies into foundry processes to help them achieve new milestones. He enjoys developing new technologies and pushing the limits of abilities in terms of castings quality. In his free time, he likes to go trekking in remote places in the middle of nowhere.

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Colin Powell is the International Marketing Manager for Foundry Melt Shop at Foseco International Limited. He is responsible for marketing and management of all products used in the melting area and has worked for Foseco for 34 years. His favourite aspect of the job is helping customers get the most from their processes. In his free time he enjoys renovating his home.

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NOZZLE TECHNOLOGIES FOR IRON AND STEEL FOUNDRIES

Author: Rudi Bittniok

This article will give you an overview of actual nozzle technologies for iron autopour and steel bottom pour applications.

Looking at steel foundries in particular, lip pouring by Teapot ladles or when using bottom pour technologies, a one shot, low alumina nozzle are widespread technologies. Over the years, new long life or quick change solutions have been developed.

Cross-Bore and Multi Life nozzle solutions have been mentioned in previous articles (see below). We now also introduce our new VAPEX FosFlow nozzle system. Finally we include our newly developed Zirconia nozzles, which are used for the production of metal powders for additive manufacturing using 3D printers to create complex steel structures.

ONE SHOT NOZZLE APPLICATIONS

Those pressed nozzles (Figure 2) containing 38 % with or without 5% of Graphite or up to 80% alumina (no C) are mainly used as one shot application using a well block in a bottom pour ladle.

After the ladle is empty and the slag is removed, the nozzle is change manually which is not an easy job to do, especially when the ladle doesn´t has a well block.
We also recommend a L0 – L3 well block (Figure 1) when using standard nozzle 1A – 3A shape.

FOSECO can supply one shot nozzle systems out of their brand names VISO (Isopressed) and VAPEX (extruded).

The FOSECO range contains many pressed and cast nozzles but also different kind of nozzles that can be used more than one time. The following 4 products show you different possibilities for longer lifetime and/or better pouring

Figure 1. Wellblock L0 installed in the ladle bottom

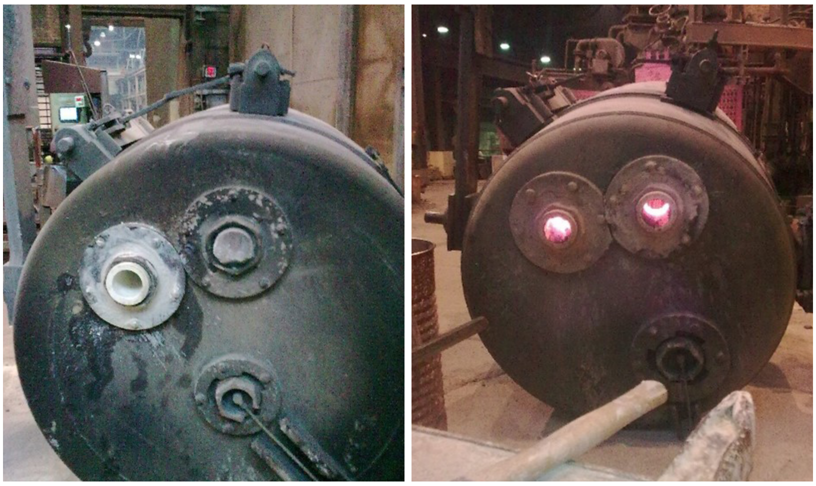

Figure 2: Typical one shot nozzle before use and after

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ZONED NOZZLES

Normally a steel foundry nozzle is a One-Shot product. As the market demands improvements, the new ZONED-NOZZLE (Figure 3) for multiple usage has been invented.

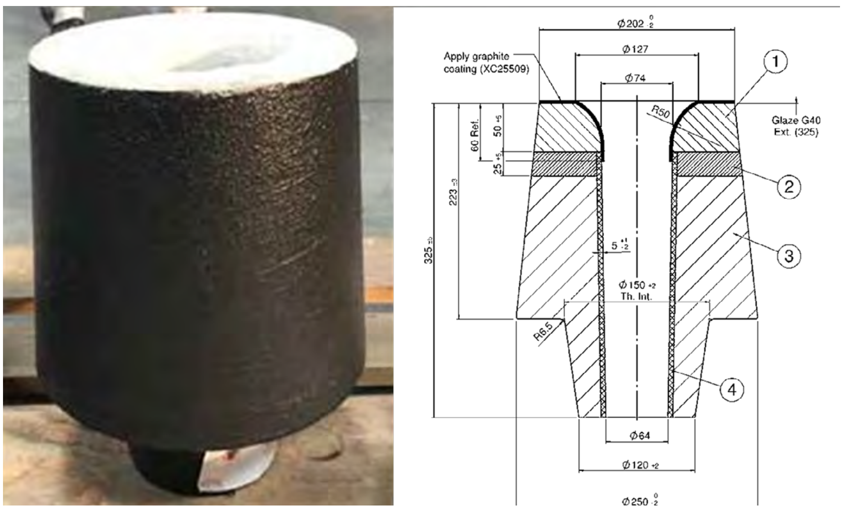


Figure 3. Zoned nozzle

FEATURES OF ZONED NOZZLES:

1. High quality refractory material at the top for improved erosion resistance
2. Transition layer to reduce thermal expansion
3. A main layer with good thermal shock resistance
4. Inner layer for insulation purposes

The nozzle also has a non-stick coating around the closing area.

CROSS-BORE NOZZLES

Invented nearly 12 years ago, the cross-bore nozzle technology has replaced the cheap standard one shot nozzle in many steel foundries giving the benefit of a compact and controlled pouring stream and double lifetime.

This is important in case of high speed pouring with large nozzle diameters, but even for small diameters, the cross-bore nozzle could be a benefit when the pouring cup is small and the operator wants to achieve maximum control of the casting process.

Fig. 4. Cross-bore nozzle installed

Fig 5. Cross-bore nozzle sectioned after 2 ladle journeys, showing minimum wear of the body material

VAPEX FOSFLOW NOZZLE TECHNOLOGY

FOSECO VAPEX FosFlow (Figure 4) is a new system that allows for changes in nozzle diameter, even in a full ladle. VAPEX FosFlow alumina graphite nozzles use both carbon and ceramic bond technology. The combination of the two bonding systems provide unique beneficial properties for steel foundry ladle applications.

The system contains a BASE NOZZLE which remains in the refractory bottom of the ladle and an interchangeable POURING NOZZLE with possible different inner diameters. This POURING NOZZLE can be replaced quickly even within a ladle cycle.

FOSECO provides 6 different VAPEX FOSFLOW series > 40 (mainly for iron autopour runners) 45, 65,65 extended, 100 and 100 extended for large ladles. The VAPEX FOSFLOW nozzle should be used in conjunction with VISO monobloc stopper technology that also allows multiple uses of the stopper (Figure 6 & 7).

Figure 6. Bottom Pour Ladle with VAPEX FosFlow

Figure 7. Base and Pouring Nozzles

BENEFITS

- Suitable for multiple use, mainly in steel foundry applications
- Pouring nozzle can be changed quickly
- Multi-use of the stopper & nozzle system resulting in labor cost reduction
- No cooldown of the ladle (energy savings, ladle lining performance)

As previously mentioned, VAPEX FosFlow can also be used in Iron Autopour applications. Here, the system offers a quick change of the pouring nozzle in the runner without losing time doing excessive refractory work. Especially on high speed molding such as DISAmatic, this system can be useful to minimise production downtim.

It is recommended to have spare runners to ensure an even easier and smoother change of the pouring nozzle in the maintenance area but for sure, the pouring nozzle can be changed easily on side and will be a quick help if the bore is blocked and a fast nozzle change within minutes is requested.

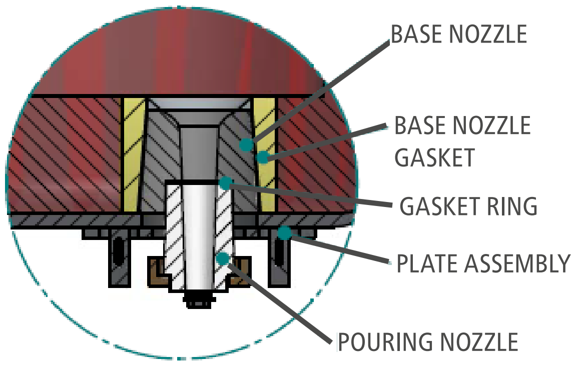


Figure 8. Installation Principle

Figure 9. VAPEX FosFlow system installed an ready to use

Figure 9. Conventional Nozzle in a runner of an Autopur Furnace, installed from the top

VESUVIUS ZIRCONIA NOZZLE OFFERINGS

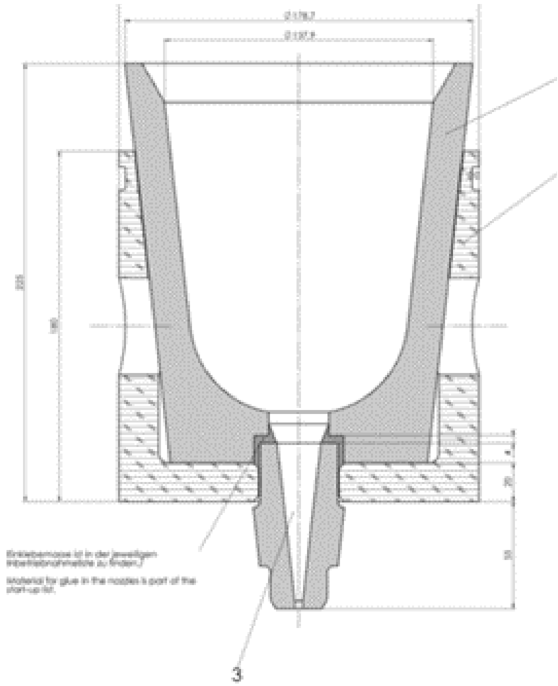
Additive manufacturing is a future production technology to create complex shapes by using 3D printing technology. For this product range, high purity metal powders are requested.

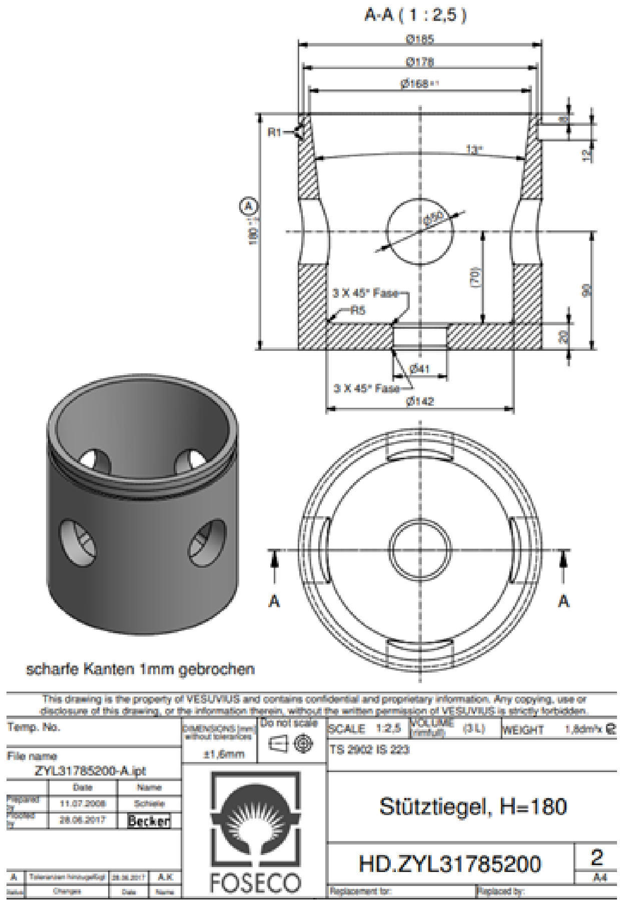
Those metal powders need to match pure quality properties to gain best production results and they are mostly produced under vacuum melting and then atomized to get a final powder structure with optimized grain size.

As a consequence of that, different furnace producers are offering different technologies to reach the best metal qualities. After the melting, the pouring stream should be as small as possible so small zirconia nozzle with diameters having 8-14 mm as inner bore are state of the art here. Furthermore, Zirconia nozzles will give you the best properties in terms of thermal stability.

VESUVIUS have invested in a fully automated production for Zirconia nozzles for steel casting applications in their flagship plant in Skawina (Poland). We also offer turnkey refractory solutions, starting in the master melting shop where we supply dry vibratory linings for the Coreless Induction Furnaces.

Those melting/casting machines are individual produced matching the customer demands. The picture below shows a scenario with pour cup, outer crucible and zirconia nozzle. FOSECO can supply this full set.





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THE FUTURE

Looking at continuous improvements in pouring technologies, time and safety will become more important in the future. The VAPEX FosFlow nozzle system will be the best solution to allow a fast and safe change of the pouring nozzle in steel bottom pour ladles as well as autopouring systems for mass iron foundries. FOSECO can also offer a full range of products serving the rapid growth in production of metal powders for 3D printing of complex shapes.

CONCLUSION

Over the last decades, the production of nozzles for bottom pouring processes have evolved simple chamotte products to a highly technical, pure material product that allow better lifetimes and high tech products that satisfy demands that did not exist 5 years ago. With a significant investment to create a fully automated Zirconia nozzle production line, VESUVIUS will play an important role in this market in the future.

ABOUT THE AUTHOR

Rudi Bittniok is an International Marketing Manager for Flow Control Foundry. With 34 years of experience in the foundry industry and 26 years with the company, Rudi provides technical and commercial support to local teams worldwide in implementing Flow Control products into Iron and Steel Foundries. He enjoys the diversity of the products and applications in each foundry and values the learning experience every time he visits a customer. Additionally, Rudi appreciates the internal foundry network. In his free time, Rudi enjoys spending time with his family, listening to vinyl records, going to concerts, playing table tennis twice a week, and jogging and walking when time allows.

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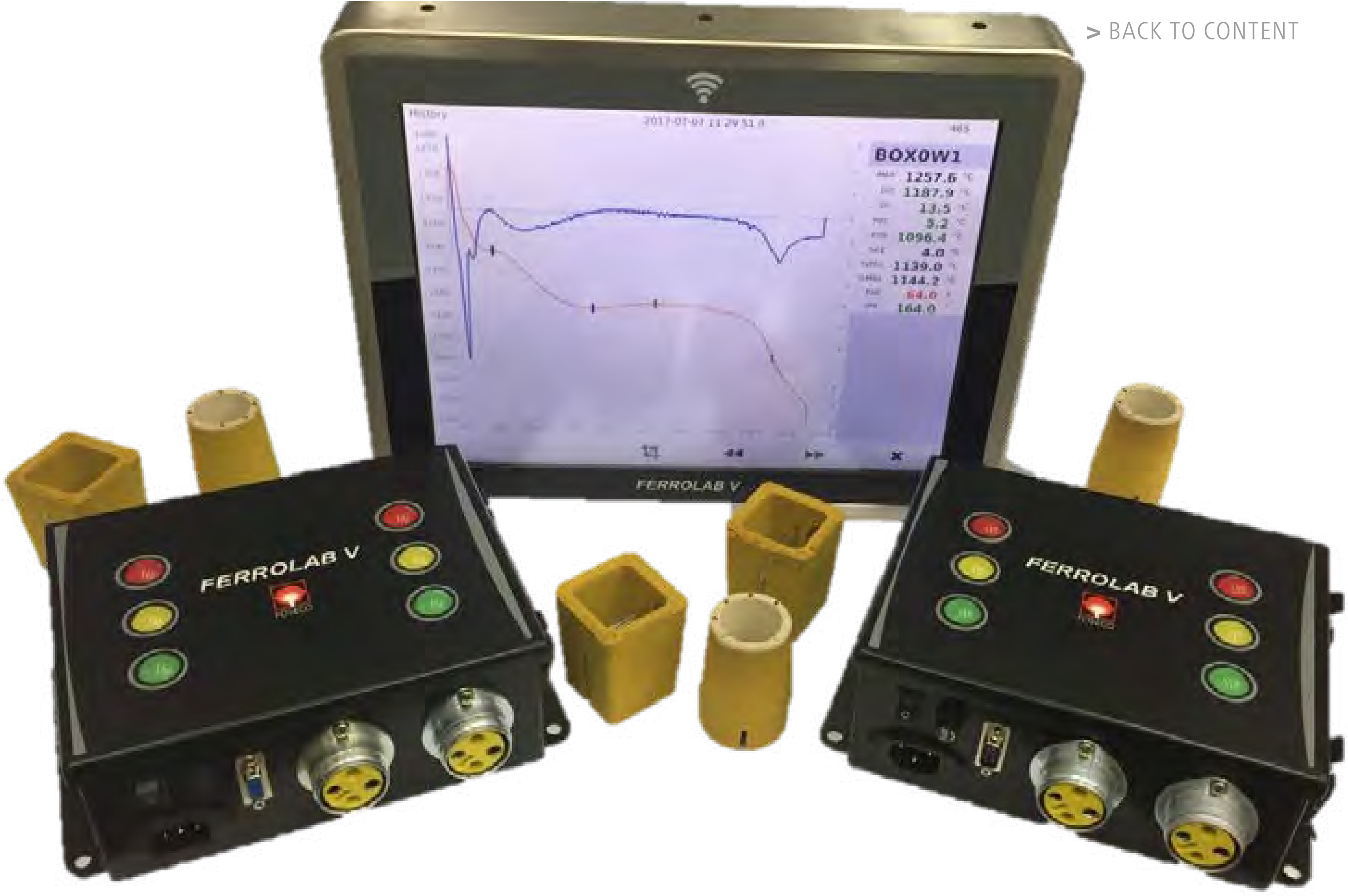

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INCREASING THE CONSISTENCY OF IRON CASTING PROPERTIES AND REDUCING FOUNDRY REJECTS BY THE USE OF FERROLAB* V THERMAL ANALYSIS EQUIPMENT

FOSECO

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Author: Colin Powell

Producing high quality iron castings requires high quality, consistent liquid iron.

The quality of the liquid iron depends not only on its chemistry, but also its inoculation state – the ease of forming the physical iron structure on cooling.

Thermal analysis provides a fast and cost-effective way to assess the inoculation state of liquid iron, ensuring that it can be made consistently from one batch to the next.

This article describes the simple and robust device – Foseco's FERROLAB V Thermal Analysis Equipment. It further shows how it can be used by Romi foundry in Brazil to check, adjust and record the thermal fingerprint of each batch of iron.

INTRODUCTION

To make a high quality casting it is obvious that the liquid metal used to make it must be of high quality.

Firstly, the chemistry of the iron must be correct. This usually means monitoring Carbon using a CE meter or combustion analyser, and other elements using a spectrometer and keeping them within accepted ranges.

However, having the correct chemistry of the iron is only part of the story, we also need to know that the inoculation of the iron is correct.

The number of sites available for the deposition of the first solids forming as the iron cools has a tremendous effect on the structure of the solidified iron. Though the chemical composition of the iron hardly changes, the addition of a good quality inoculant such as Foseco's INOCULIN* to a poorly inoculated iron can totally change its properties.

Inoculation affects the amounts of carbides, how much shrinkage occurs and the strength and ductility of the castings it produces.

The best way to know how a casting will solidify is to take a sample of the liquid iron and record its solidification. We can do this using FERROLAB V (five) equipment supplied by FOSECO.

The sample is poured into the INOCUP test cups and in around 300 seconds we have a clear presentation of the parameters most important for controlling the iron.

The parameters can be used initially to categorise the iron and assist in determining the correct type and amount of inoculant. The foundry can then set its own specification for ranges of the parameters acceptable when in general production.

The unit can then be employed as a quality control tool, to make sure the iron is within specification and to highlight cases when adjustment may be required.

FERROLAB V

Calculations are performed in an industrial pc that is robust enough to be used in the foundry environment, but can be located in a control cabin. The computer connects wirelessly to the FERROBOX data acquisition unit located near to the sampling station.

A simple set of traffic lights on the FERROBOX lets the operator know that the sampling cup is correctly placed and ready to use.

THE KEY TO FERROLAB V IS ITS SIMPLICITY

The FERROBOX can be placed on the melt deck and can sample two cups. Two FERROBOXES can be connected wirelessly to each computer. This allows a range of possibilities for sample taking.

For example, stable analysis of solidification parameters for up to four furnaces, or alternatively configurations for metastable analysis using tellurium containing cups or for checking inoculation after ladle treatments or immediately before pouring.

The results of the test appear colour coded. As would be expected, green is good, yellow is borderline acceptable (requires checking) and red is out of specification. General parameters are preset, but obviously these can be adjusted to the foundry's preferences.

The colour coding means that for QC purposes, operators do not need to be trained in thermal analysis, but rather can call a supervisor if the results are borderline or out of specification.

As well as critical parameters, the system displays the cooling curve and the first differential, so experienced TA users can immediately identify the characteristics of the iron.

All of the data from tests is stored and recorded, so can be used as part of the quality control record.

Previous results can be retrieved and displayed. The system allows the comparison of multiple cooling curves and derivative curves for investigative purposes.

Of course it's not just the iron in the furnace, FERROLAB allows you to look at ductile iron after the nodularising treatment, and inoculated iron right up to the moment it is poured.

The equipment is robust, and because two acquisition boxes can be connected wirelessly to one computer, you can analyse up to four cups in two different locations

The system is provided free of charge to Foseco customers that buy our inoculants, nodularisers and sampling cups. And we work together with them to ensure that they can consistently produce the highest quality iron possible.

Figure 1. FERROBOX data acquisition unit

PRACTICAL APPLICATION OF FERROLAB V AT ROMI FOUNDRY BRAZIL.

FERROLAB V equipment was installed at Romi, a medium sized foundry in Brazil producing Ductile Iron castings. The equipment was installed with one channel acting as a standard CE meter, and another performing stable analysis to give information of the casting structure.

Use of the equipment is still in the early phases, but already the foundry has started to modify the treatment process to make best use of combinations of inoculants and nodularisers on offer.
From figure 3 we can see that the standard material treated with 1.3% FSM (5% Mg) and standard inoculation is of relatively good quality, but it may still be possible to improve on this.

Figure 4 shows how the iron has been improved, firstly because its composition has been moved closer to eutectic, meaning a shorter freezing range. Secondly a preconditioning treatment and late stream inoculation have been added. These reduce the amount of undercooling before solidification and recalescence during solidification having the overall effect of moderating the solidification process and giving a better structure.

SG iron preconditioned with INOCULIN* 390 in furnace. 1.5% NODULANT* FSM, 0.3% INOCULIN 320 inoculation + 0.2% post inoculation with INOCULIN 920 (simulated with addition in cup). Comments: Nearer eutectic but higher TeMin and PAE and lower VPS than without post inoculation.

Further trials will allow Romi to further optimise their inoculation and nodularisation practices.

From this point Romi will be looking for castings that lie at the limits of their specifications and using FERROLAB V will create systems allowing them to move the quality even closer to their target.

Figure 2. Romi Foundry, Brazil

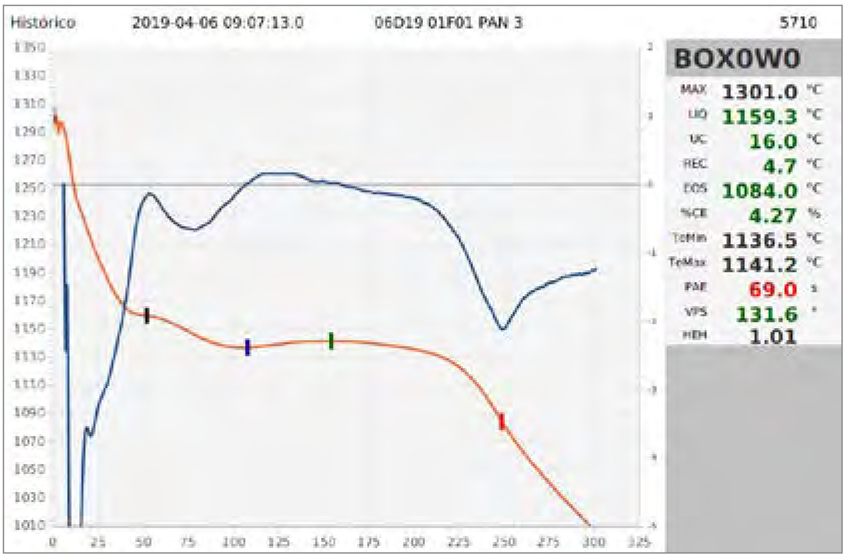

Figure 3.

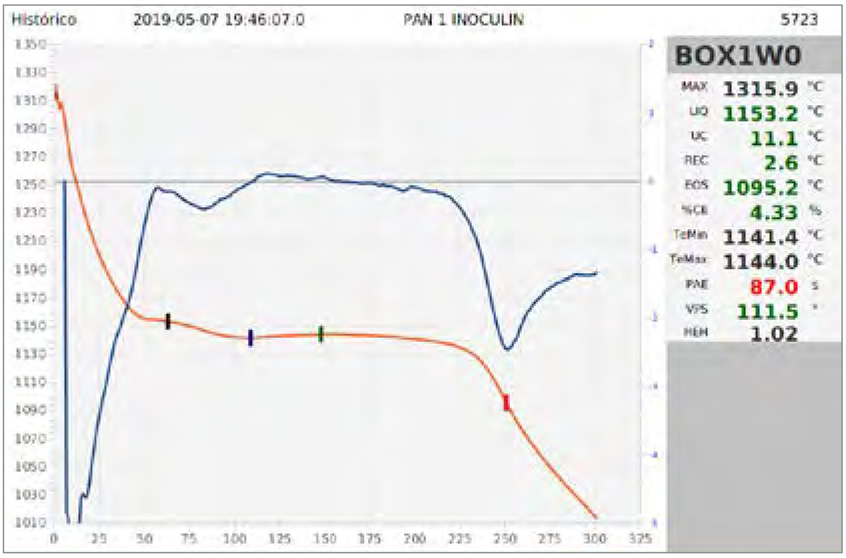

Figure 4.

SUMMARY

FERROLAB V is a simple and highly cost effective route to increasing quality and reducing the number of defective castings by the use of Thermal Analysis.

ACKNOWLEDGEMENT

Foseco would like to thank the management and staff of Romi Foundry for their cooperation in preparing this article and for giving permission to use their data.

ABOUT THE AUTHOR

Colin Powell is the International Marketing Manager for Foundry Melt Shop at Foseco International Limited. He is responsible for marketing and management of all products used in the melting area and has worked for Foseco for 34 years. His favourite aspect of the job is helping customers get the most from their processes. In his free time he enjoys renovating his home.

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COLIN POWELL
International Marketing Manager
Foundry Melt Shop

WATCH VIDEO

CASTING CLEAN STEEL: TODAY'S SOLUTIONS AND OPPORTUNITIES

Improving as-cast quality offers a range of benefits to steel foundries – from improved yield and lower production costs per piece, to reduced lead times and lower carbon emissions. Cleaner casting is not however something achieved by a single solution or process improvement. Casting defects have a range of causes and can occur at a number of points along the casting process. Minimising defects therefore requires the adoption of a range of solutions from melt to mould.

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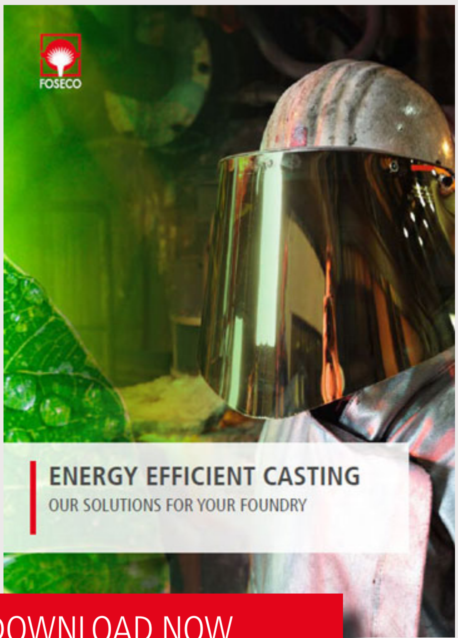

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ESCALATING COSTS OF ELECTRICITY AND GAS REQUIRE NEW SOLUTIONS FOR FOUNDRIES

It is more important than ever for foundries to control and minimise their energy consumption costs in order to remain competitive. The war in Ukraine has led to a drastic increase in energy costs. Energy-intensive industries, such as the foundry industry, are particularly impacted by this cost explosion.

While the industry has long contributed to sustainability in some areas, notably through the recycling of iron, steel and aluminium scrap, there is still much room for improvement in other areas, such as increasing energy efficiency.

Therefore, technologies and solutions that reduce energy consumption are becoming increasingly important. The good news is that today there are many ways to achieve this through the use of modern foundry consumables.

In our e-book "Energy efficient casting - Our solutions for foundries", we show you how our solutions for iron, steel and aluminium foundries help to save energy and reduce CO_2 emissions in the various areas of the foundry.

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