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The authoritative magazine for foundry engineers

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METALLURGICAL AND POURING CONTROL

Theory and practice of grain refining for aluminium alloys - Utilizing COVERAL* MTS 1582

COATINGS, BINDERS, FILTRATION, METAL TREATMENT

Working together in partnership - Excellence in aluminium casting through cooperation

MELT SHOP REFRACTORIES

Dosing furnace lining with INSURAL* pre-cast shapes reduces downtime in foundries

FEEDING SYSTEMS

Brand-new innovation for the non-ferrous sector: The exothermic feeder FEEDEX* NF1

VESUVIUS

EDITORIAL

Dear Readers,
Welcome to our 268th edition of our in-house technical journal of Foundry Practice. The journal, now in its 87th year, is designed to inform foundrymen of Foseco's latest technologies and application techniques to ensure the ongoing advancement of our customer's foundry practice.

Non Ferrous is becoming more and more important in the daily world! Lighter applications, beautiful and perfect haptic solutions are very much in demand with the foundry's customers. Would you like to find out more about our latest developments? You will find answers in this book.

Theory and practice of grain refining for aluminium alloys - Utilizing COVERAL MTS 1582
Salt form grain refining offers improvements in grain refining of aluminum alloys. These improvements can be demonstrated via some industry standard techniques and then quantified for the technical and/or economic benefit to a casting and to the foundry that pours them.

Working together in partnership - Excellence in aluminium casting through cooperation
For the production of high quality castings it is essential that the best decisions are made at every step of the process from design and development of the component, the moulding practice, how the metal is prepared and finally the pouring and solidification of the casting. A cooperative approach ensures that a broad range of options can be considered and best practice is continually improved. This article details how this philosophy of partnership between supplier and customer contributes to the production of best-in-class aluminium castings.

Dosing furnace lining with INSURAL pre-cast shapes reduces downtime in foundries
A completely dry lining system using INSURAL pre-cast shapes eliminates time-consuming sintering during re-lining and the required aluminium melt density index is achieved immediately upon production start-up. Significant energy savings can be realized due to the highly insulating nature of the INSURAL lining system.

Brand-new innovation for the non-ferrous sector: the exothermic feeder FEEDEX NF1
FOSECO* launches the first exothermic feeder for NE applications. Quick, steady and long-lasting reaction, high strength and improved feeding effect characterize this recipe.

JENS OHM
Director Non-Ferrous EMEA

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CONTENTS

THEORY AND PRACTICE OF GRAIN REFINING FOR ALUMINIUM ALLOYS - UTILIZING COVERAL MTS 1582

Authors: Brian Began, Foseco USA & Pascaline Careil, Foseco Europe

The need for smaller grains is vital to achieving the required properties when pouring most cast aluminum alloys. Whether the desired results are high mechanical properties, leaker free castings, a cosmetic appearance or improved structural soundness, smaller grains are impactfully beneficial. Accordingly, there is a desire to improve both grain refining and the ability to quickly and effectively assess grain refinement effectiveness. This paper discusses both the need for smaller grains and the principle fundamentals of grain refining. Moreover, the paper reviews commercially-available grain refiner forms and currently available methods for assessing grain refinement. Finally, the paper introduces a new and improved flux form grain refiner (COVERAL MTS 1582) and documents two recently successful case studies where the COVERAL MTS 1582 was utilized to improve castings in both a low pressure wheel foundry and a high production sand moulding foundry, respectively.

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INTRODUCTION

Grain refining is an essential part of the aluminium casting process which aims at reducing the size of primary aluminium grains during the solidification phase. This process has many benefits for most hypo-eutectic aluminium alloys as it improves feeding, elongation and mechanical properties, increases resistance to fatigue, improves casting machinability, reduces hot tears, helps disperse micro-shrinkage, decreases the size of porosities and reduces thermal treatment cycles. Historically, grain refinement has been achieved using master alloys, with the most commonly used grain refiner mechanism involving the release of Titanium diboride into the melt. Grain refining is especially important in aluminium foundries using investment, sand, gravity die, or low pressure die casting processes due to the potential for delayed cooling and complex casting designs with varying section thickness.

In general, those castings with slower cooling rates and larger variation in casting thickness, require grain refinement more than other casting designs.

There are several casting segments where grain refining is critical including:

+ Wheel foundries where grain refinement and cleaning are crucial for achieving the required feeding and cosmetic surface finished of the casting.
+ Safety critical automotive castings such as suspension parts, turbochargers, and brake components which require good fatigue properties.
+ General automotive castings like cylinder heads, engine blocks, manifolds in gravity diecast where an intermediate level of grain refinement might suffice for the mechanical property requirements, but the improved feeding from grain refinement helps prevent leakers.
+ Aerospace and military castings requiring high mechanical properties for difficult applications, grain refining is highly beneficial.
+ Sand and investment castings where the long solidification times cause large grain growth and difficult feed paths without optimized grain refining.

GRAIN REFINEMENT MECHANISM IN ALUMINIUM ALLOYS

TARGET OF ALL MELT TREATMENT PROCEDURES IS AN IMPROVEMENT OF MECHANICAL PROPERTIES

Grain refinement affects the α-mixed crystal in the alloy. At decreasing temperature those α-mixed crystals grow. Grain size depends on cooling rate during solidification. The addition or formation of nuclei increases solidification speed and decreases the grain size.

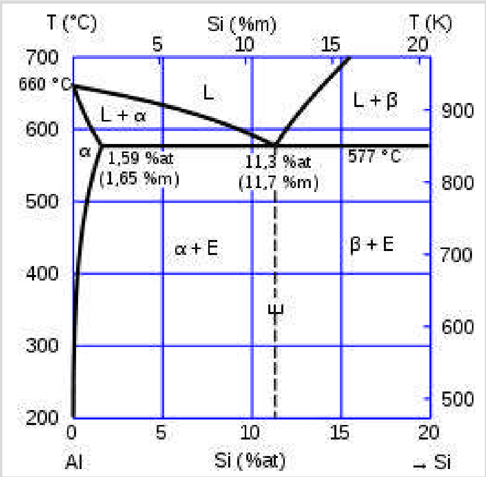

Figure 1: Al-Si phase diagram

Ceramic	Angle
TiB_2	60°
ZrB_2	106°
HfB_2	134°
TaB_2	125°
TiC	118°
ZrC	150°
SiC	135°
HfC	148°
NbC	136°
TaC	145°
TiN	135°
ZrN	167°
NbN	156°
AlN	138°

Table 1: Contact angle of different ceramic materials [1]

MASTER ALLOY AND CHEMICAL PRODUCTS COMPARISON

Considerations when using master alloy grain refiners

- AlTi5B1 - AlTi3B1 - AlTi5B0,2 - AlTi10B1
- TiB_2 nuclei are pre-formed in an aluminium matrix
- Easy to apply
- Risk of oxides or impurities in the rod or waffle
- Moisture and oxides on rod surface contaminate melt

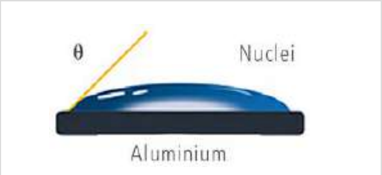

Figure 2: Nuclei needs a good wettability by melt

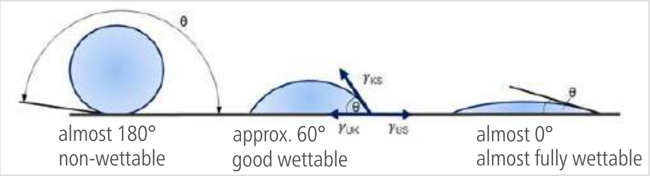

Figure 3: Heterogeneous nucleation as a function of wetting angle

$$\sigma_{\alpha F} = \sigma_{\beta F} + \sigma_{\alpha\beta} \cos(\theta)$$

$\sigma_{\alpha F}$ = melt surface energy
$\sigma_{\beta F}$ = surface energy of nuclei
$\sigma_{\alpha\beta}$ = interface energy between nuclei and melt

Figure 4: Young's equation

Benefits of chemical products are:

- Contain metallic titanium and boron salt or titanium and boron salt
- TiB_2 nuclei are in-situ formed in the melt – fresh surface – higher surface energy and lower θ angle
- No risk of impurities
- Additional cleaning effect

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REASONS FOR BETTER MECHANICAL STRENGTH WITH CHEMICAL PRODUCTS

We identified several reasons for archieving better mechanical strength with chemical products which are:

+ Chemical products and master alloys with pre-formed nuclei impact the contact angle θ differently
+ θ for TiB_2 = 60° is a theoretical value for an ideal nucleus
+ θ for TiB_2 from master alloys is significantly higher due to reduced surface energy
+ θ for TiB_2 from chemical products is close to 60° or even below due to fluxing effect from chemicals (fluorides)

COVERAL MTS 1582

FOSECO has developed a novel granulated flux COVERAL MTS 1582 that is capable of both grain refining and cleaning aluminium alloy melts. COVERAL MTS 1582 is highly concentrated in titanium and boron which form both titanium diboride and aluminum boride in situ leaving fresh nuclei within the aluminium melt. These finely dispersed species are highly efficient nuclei that promote a fine equiaxed grain growth during solidification.

In addition to strong grain refining, COVERAL MTS 1582 flux is also a very good cleaning product that will react to remove oxides and inclusions from the melt. No additional cleaning/drossing flux is required, resulting in lower overall process costs. COVERAL MTS 1582 is a sodium- and calcium-free granulated flux suitable for all types of aluminium alloys except hyper-eutectic alloys but including those alloys containing large amounts of magnesium.

APPLICATION OF COVERAL MTS 1582

COVERAL MTS 1582 is specially designed for use with FOSECOs MTS 1500 rotary degassing and melt treatment equipment, whereby controlled flux additions are made directly into a melt vortex and mixed vigorously. PLC controlled additions of the treatment flux are added into the vortex and mixed to complete reaction prior to the vortex breaker baffle board re-engaging the melt, effectively stopping the vortex. After the vortex has been stopped, the MTS completes a standard rotary degassing process and the treated metal in the ladle or crucible is used for transferring and/or casting.

For further information of the MTS 1500 process, readers are advised to review Foundry Practice Issue 247 (2007) or the Foundry Practice Special Edition for AFS CastExpo (2008).

Both issues feature excellent articles on the MTS 1500 technology [References 2 and 3].

MTS 1582 should be used with the melt at a temperature higher than 720 C. The reaction by-product from this treatment produces an extremely dry ash-like dross that is easily separated from the liquid metal with a coated skimmer or similar tool.

EVALUATING GRAIN REFINEMENT EFFECTIVENESS

Since grain refinement is critical to achieve the desired properties of aluminium castings, it is important that there are methods for assessing grain refinement effectiveness. The most common methods for evaluating grain refinement effectiveness are as follows:

+ Elemental spectroscopy
+ Thermal analysis
+ Microstructural evaluation

ELEMENTAL SPECTROSCOPY

Elemental spectroscopy is perhaps the most commonly employed method for assessing grain refinement, but it is also the least effective of the three methods listed. Spectroscopy only determines the total concentration of an element - however Titanium is usually present in other forms and phases in addition to TiB_2 and these other phases do not impact grain structure. Foundries will measure Ti into the alloy range (typically 0.10-0.25% by weight) and assume that because they are in range, they are achieving sufficient grain refinement. Consequently, given this issue, some foundries will also measure boron (typical range 5-25ppm) as an additional control. Tight controls of Ti and B do typically result in effective grain refining; however, more advanced methods like thermal analysis and microstructural analysis ensure higher probabilities of optimized grain refinement.

THERMAL ANALYSIS

Thermal Analysis is perhaps the fastest growing method for assessing grain refinement as it is quick and more accurate than elemental spectroscopy. The THERMATEST* 5000 NG III (pictured in Figure 5) is a widely used thermal analysis unit used to quickly and accurately assess grain refinement effectiveness in aluminium alloys. Thermal analysis involves collecting data of temperature versus time of a solidifying melt sample and comparing the curve to a set of known reference curves algorithmically. The THERMATEST 5000 NG III unit's algorithm analyzes the sample curve liquidus and computes a score on a scale from 1-9 for evaluating grain fineness (GF). A score of 1 references a curve that compares with curves exhibiting no grain refining.

In contrast, a GF score of 9 is achieved when the sample curve compares with those curves known to have produced "perfect" grain refining of melts with the same alloy composition. A pictorial representation of the THERMATEST 5000 NG III grain refinement levels is provided in Figure 7. Of note, THERMATEST 5000 NG III unit also provides the side benefit of helping to assess eutectic modification effectiveness in Al-Si alloys [References 4 and 5].

EVALUATION OF GRAIN SIZE WITH THERMAL ANALYSIS

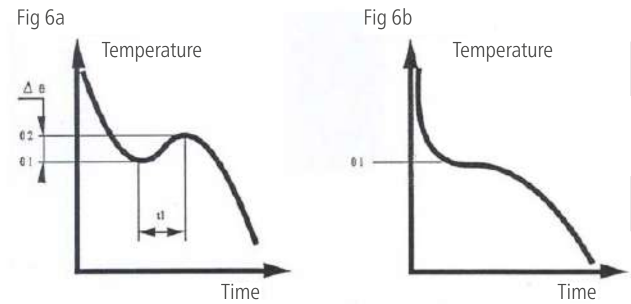
For a given cooling speed, the size of the grain depends on the amplitude and duration of the undercooling, which appears at the formation of primary aluminium crystals.

- When the undercooling is high and duration medium (Fig 6a), grain size is coarse.
- When there is no undercooling (Fig 6b), grain size is very fine.
- When undercooling is low but duration is high, the grain size is very coarse.

Figure 5: Photograph of a THERMATEST 5000 NG III unit

THERMATEST 5000 NG III measures the following Liquidus parameters:

- Temperature θ2 (°C)
- Undercooling Δθ (°C)
- The duration of undercooling t1 (in seconds)



θ1: Temperature at which the solidification begins
θ2: Maximum temperature reached at the end of undercooling
Δθ: Apparent undercooling equal to θ2-θ1
t1: Duration of undercooling

Figure 6a and b: Profiles of the cooling curve at the solidification of primary aluminium crystals in case of hypoeutectic alloy

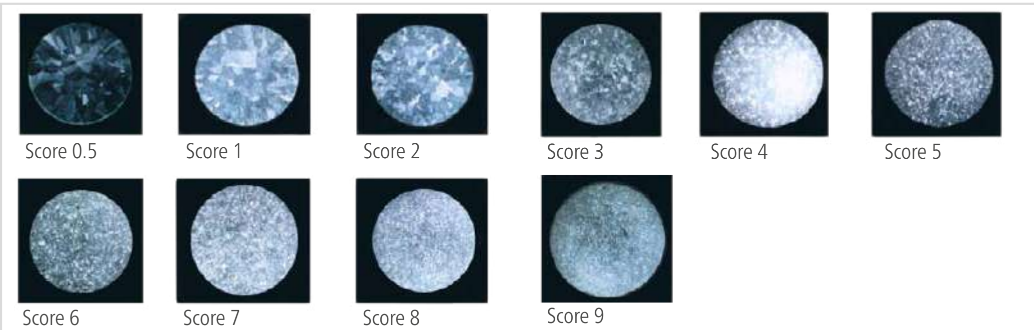


Figure 7: Test of grain refinement - Standard plate with Grain Fineness (GF)

Grain refinement is considered fully optimized when the undercooling is nil and grain size index is equal to 9. However, for certain alloys and thin shaped castings in permanent moulds, a lower grain size index (5 - 9) would be expected and is acceptable due to the higher cooling rate with permanent die casting.

We recommend setting a minimum grain size index for each casting, correlated with desired elongation of mechanical properties. For Al-Cu5%MgTi alloys, the absence of undercooling may not be sufficient to avoid hot tears. A stronger grain refinement is recommended to improve the alloy's performance.

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LIQUIDUS CURVES: COMPARISON OF TIB RODS WITH COVERAL MTS 1582

The lower the undercooling at Liquidus, the stronger the grain refinement. COVERAL MTS 1582, at much lower addition rate (0.11 % vs 0.2 % for AlTi5B1 rods), performs better compared to AlTi5B1 rods.

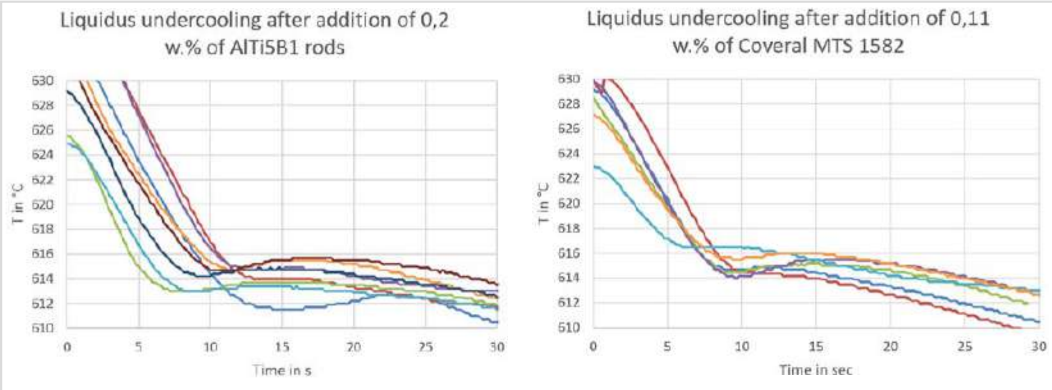


Figure 8: Thermal analysis curves

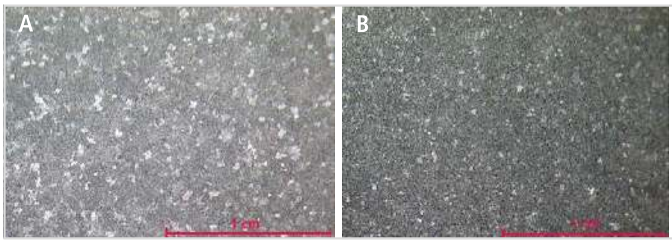
OPTICAL MICROSCOPY (BARKER TEST)

Optical microscopy is the final methodology employed by foundries to assess grain refinement. Optical microscopy is considered the most representative method for assessing grain refinement but is time-consuming and resource intensive. Optical microscopy involves grinding and polishing test specimens to microscopic levels to be evaluated for grain size under a microscope. One popular method for optical microscopy is the Barker test. The LectroPol-5 from Struers is used for electrolytic etching with Barker reagent consisting of a 5% tetrafluoroboric acid in distilled water. The sample to be tested acts as an anode in a galvanic cell, which removes material from the sample surface and an anodic layer can be formed. With the Barker method, under a polarized light, a colored representation of the grain structure of aluminum materials is achieved. It is possible to carry out microscopic testing with up to 1000x magnification.

Alloy: AlSi7Mg0,3
COVERAL MTS 1582
Addition rate: 0,1%

Figure 9a: Before treatment. Grain size dm [µm] = 984

Figure 9b: After treatment. Grain size dm [µm] = 206



A Alloy: AlSi7Mg0,3
Rods AlTi5B1
0.08 % addition rate
Grain size Ø = 422 µm

B COVERAL MTS 1582
0.05 % addition rate
Grain size Ø = 237 µm

Figure 10: Comparison of TiB rods with Coveral MTS 1582: grain size

CASE STUDIES

WITH COVERAL MTS 1582

1: European foundry
A European wheel foundry was interested in improving its melt treatment practices by utilizing COVERAL MTS 1582 with a FDU featuring MTS 1500 technology. This wheel foundry pours a standard AlSi7Mg alloy and historically performed grain refining by making manual additions of TiBor rod into a transfer ladle during degassing. It was the foundry's target to automate the grain refining process all while capturing the typical benefits (drier dross, lower spend, smaller grain) achieved when grain refining with COVERAL MTS 1582. The treatment parameters of the new process featuring COVERAL MTS 1582 can be found in Table 2.

After the new process grain refining with COVERAL MTS 1582 was implemented, pictures were taken of the ladle dross (Figure 11), thermal analysis curves (Figure 13) and microstructures (Figure 12).

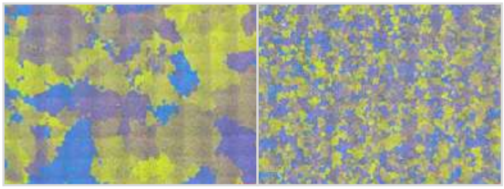


Figure 12: Microstructure before and after treatment with COVERAL MTS 1582.

Treatment parameters	
Ladle	INSURAL ATL 600 with 500 kg of AlSi7Mg
Temperature	730 - 760 °C
Addition rate	250 g COVERAL MTS 1582 (0.05 % of the melt weight)
Treatment time	6 minutes
Inert gas flow	20 l/min N_2
Rotor speed	450 rpm for MTS FDR 190.70

Table 2: European Wheel Foundry (EWF) treatment parameters.

Figure 11: Photograph of extremely dry dross in transfer ladle after treatment with COVERAL MTS 1582.

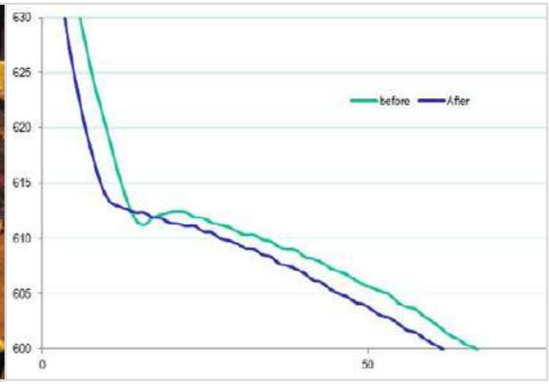


Figure 13: Thermal analysis curves

2: American foundry
Littlestown Foundry is a sand and low-pressure (LP) mould aluminium foundry in Littlestown, Pennsylvania in the USA. The main alloy poured by Littlestown Foundry is a standard 356 alloy (AlSi7Mg). In the sand foundry, Littlestown casts some difficult castings that are subjected to pressure testing with air to make sure they are leak free for application. After reducing scrap through improved grain refining in the LP foundry from 13.6% to 2.7% by converting from metallic TiBor (10%Ti, 1%B) to COVERAL MTS 1582, a similar project was undertaken in the sand foundry. The aim was that by improving the grain refining using COVERAL MTS 1582 - introduced via an MTS 1500 unit - in place of metallic TiBor rod, the sand foundry would see similar benefits in the form of reduced leakers and lower spend.

The first part of the project involved using a THERMATEST 5000 NG III unit to assess the incumbent procedure and then developing an optimized procedure using the MTS 1500 and COVERAL MTS 1582. The results of the THERMATEST 5000 NG III evaluation are presented in Table 3.

Sample #	Average Grain Fineness (GF)
Sample before treatments	5.8
Standard TiBor Additions	6.8
COVERAL MTS 1582	9.0

Table 3: Results of THERMATEST 5000 NG III evaluation with the COVERAL MTS 1582 grain refining flux.

The THERMATEST 5000 NG III evaluation confirmed that the metallic TiBor rod was successful in raising the Grain Fineness value from insufficient (5.8/9.0) to an improved and more acceptable level of grain refining (6.8/9.0). However, the THERMATEST 5000 NG III unit also confirmed that a huge improvement to a fully optimized level of perfect grain refinement (9.0/9.0) was possible with the COVERAL MTS 1582. Hence, mechanical test bars were poured and evaluated to assess any potential impact of the new process featuring the COVERAL MTS 1582.

The results of the mechanical testing evaluation are shown in Table 4. The results exhibited positive improvement in all three metrics evaluated, i.e., ultimate tensile strength (UTS), yield strength (YS) and % Elongation. Accordingly, the decision was made to convert to the new process to make a full assessment of the new process featuring COVERAL MTS 1582 and a FDU featuring MTS 1500 technology.

Test	Incumbent TiBor Process	New Process Featuring MTS 1500 & COVERAL MTS 1582
UTS in psi (MPa)	40,000 (276)	41,290 (285)
YS in psi (MPa)	34,500 (238)	35,100 (242)
Elongation (%)	4%	5%

Table 4: Results of mechanical testing of preceding treatment samples and samples collected after the implementation of a MTS 1500 with COVERAL MTS 1582.

Finally, after four months in production, the new process change was evaluated economically. The following economic benefits were achieved after implementation:

- Reduction in annual projected spend on grain refiners and cleaning flux by $276 per day, $1,380 per week, $5,750 per month or more than $69,000 per year.
- A ten-fold reduction in projected impregnation costs from a starting point that exceeds $1,500 per month to less than $150 per month.
- The calculated payback for the MTS 1500 unit when factoring in the lower grain refining spend, the lower flux cleaning flux spend and offsetting it with the slightly higher spend on filters is just over 6 months.

A full peer-reviewed paper (paper #19-015) on the Littlestown Case Study was published with the AFS 123rd Metalcasting Congress Proceedings in April 2019 and is available for a more extensive review.

SUMMARY & CONCLUSIONS

COVERAL MTS 1582 is a universal grain refining and cleaning flux for treating aluminium alloys. It forms in situ Aluminium boride and Titanium boride which are the most suitable nuclei, within aluminium melts. Creating TiB_2 nuclei in situ is more effective than releasing pre-made TiB_2 nuclei into a melt. Elemental spectroscopy, thermal analysis with a THERMATEST 5000 NG III and optical microscopy are three methods for assessing grain refinement effectiveness within a melt; the latter two methods being the most efficient. Experience in both a low pressure wheel foundry and high production greensand foundry has confirmed the benefits of superior casting mechanical properties and lower overall process costs when grain refining using COVERAL MTS 1582 through an MTS 1500 unit.

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Want more info about grain refining with COVERAL?

WORKING TOGETHER IN PARTNERSHIP – EXCELLENCE IN ALUMINIUM CASTING THROUGH COOPERATION

Authors: Enrique Pardo & Luis Merchan, Foseco Iberia

Aluminum gravity casting production continues to grow, in many cases replacing ferrous materials, with increasing demand in industrial sectors such as energy, defense, medicine and transport. The reduction in the weight of the components is a very attractive point, and the latest technological advances, which have helped aluminum alloys to provide more mechanical strength, has opened up even more opportunities for cast aluminium components. The majority of these pieces for industrial applications require a very high level of quality control and quality assurance procedures.

To ensure sound castings it is essential that strict procedures are followed in the casting methods (feeding, filtration & simulation), manufacture and preparation of the moulds and cores and the pouring of molten metal, with its special treatments, to obtain final castings without inclusions, defects or shrinkage. Aluminium components produced by gravity casting are manufactured in medium or large series, where if a defect appears, it affects many parts and directly incurs an increase in manufacturing cost. Therefore, it is essential that within all parts of the process the correct raw material choices are made, and these decisions are critical to the successful and repeatable production of defect free castings and must be combined with the correctly applied application, technical and manufacturing process knowledge.

INTRODUCTION

Grupo Aluminio de Precision (GAP) is an aluminium foundry based in Burgos, Spain. It is a gravity, sand foundry and produces castings ranging from 0.2kg up to 300kg using either the greensand or no-bake moulding process. Production capacity is in the region of 12,500 tonnes per annum and castings are supplied to a diverse range of market sectors on a global basis.

To serve these demanding industries, GAP is providing their customers with a full supplier service, from casting design and development to production and delivery of fully machined, painted and tested cast components.

Throughout the design and implementation stage GAP works together with Foseco to optimise the casting methodology and subsequently utilizes the superior properties of Foseco consumable products to optimise casting quality, improve yield and reduce overall production costs.

This paper focuses on the partnership between Foseco and GAP throughout the development process and across several internal departments, and in doing so demonstrates the value created by undertaking such close cooperation.

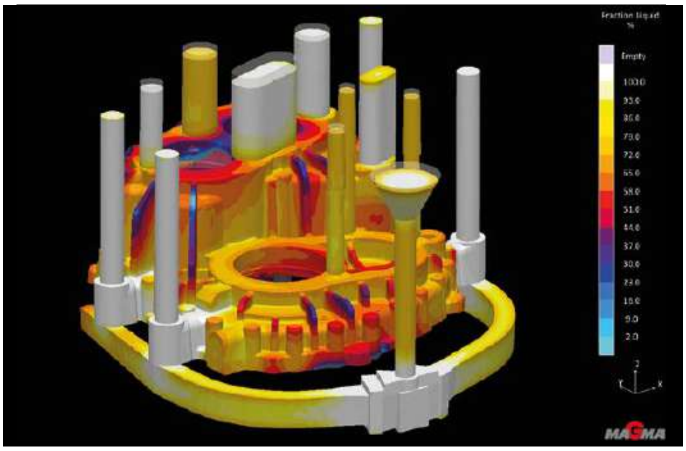

Figure 1: MAGMA simulation of casting

Fig. 2: Coreshop & cores coated with TENOTEC 7804A (inset) using the flow coating process

DESIGN & DEVELOPMENT

When a new casting is to be produced in the foundry the involvement of FOSECO starts in the design and development stage. The main criteria are how to produce a sound casting without defects and with optimum yield to ensure cost-effectiveness. Initial discussions focus on the method of producing the casting; how the metal will flow into the casting with minimal turbulence, where filters will be placed to reduce turbulence and eliminate inclusions and where to place feeders / feeding aids to ensure there is no shrinkage in the casting itself. There are many variables to consider including the orientation of the casting and the subsequent implications on moulding and core making.

Typically, there is more than one potential solution and by using metal flow and solidification modelling these solutions can be evaluated and optimised to focus in on the most cost-effective method of production, whilst delivering the customer's quality and integrity requirements. It is at this stage that many of the consumable products that enhance the casting process will be selected to optimise the casting process, such as:

- KALMIN* insulating sleeves – to prevent shrinkage defects
- SIVEX* foam filters – to remove inclusions and reduce turbulent metal flow

MOULDING & COREMAKING

After the design stage is complete the required designs are passed to the pattern workshop where skilled patternmakers will produce the pattern equipment to produce the moulds and the coreboxes for core production. The high-quality production of pattern tooling is essential to the casting process in that any discrepancies at this point will be reflected in the ease of production of the moulds and cores and subsequently in the dimensional accuracy of the final casting.

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For the production of cores GAP have a highly automated manufacturing line, which allows the mass production of cores without compromise of integrity or dimensional accuracy. The sand cores are bonded using a special polyurethane coldbox binder system supplied by FOSECO (POLITEC* AL320/420). The benefit of this system is that it requires very low addition rates to give high strength cores. The low binder addition rate minimizes the production of gases during thermal decomposition on pouring, thereby avoiding the potential for gas pinhole defects at the surface of the finished casting. To improve productivity the coreboxes are coated with a highly effective release agent (ACMOS* 118-63) that has superior release properties without the build-up of residues that need to be removed on a regular basis, taking the corebox out of service. Where cores are joined together a refractory putty (TAPA PLAST 41) is used to seal any gaps or small breakages. To further enhance the surface finish of the casting and to avoid sand adherences the cores are coated with a refractory coating from Foseco (TENOTEC* 7804A).

After casting the binder breaks down readily, allowing for the easy removal of the core material during the shake-out process, ensuring no damage to the casting. The casting surface finish is free from sand adherence, gas pin-hole defects or any other metal/mould reactions. GAP utilizes two modern moulding lines; the first utilizes a no-bake binder system based on polyurethane chemistry (POLISET* AL 6A & 6B), for high dimensionally accurate castings up to 300kg in weight.

Fig. 3: Assembly of POLISET bonded moulds and POLITEC bonded cores

Figure 4: Greensand line

The POLISET AL binder system has been specifically developed for the needs of aluminium sand foundries to reduce gas emissions, provide high production rates through reduced stripping times and easy core breakdown and shake-out after casting.

The second line is for smaller casting up to 80kg in weight and is based around a greensand system. To avoid sticking of the greensand to the pattern plates, small amounts of a highly effective release agent (PARTISAL* 421) are sprayed on to the pattern at regular intervals. PARTISAL is an environmentally friendly product without aromatic solvents.

MELTSHOP

The quality of the molten aluminium alloy is paramount to producing consistent castings to the correct metallurgical specification and free from defects such as inclusions and gas porosity. GAP uses a Foseco Degassing Unit (FDU) melt treatment system for the degassing and cleaning of the aluminium alloys. The FDU rotary degassing units utilize patented rotor designs to ensure rapid and efficient distribution of nitrogen or argon as finely dispersed bubbles to ensure effective degassing in short treatment cycles. Advantages are:

+ Reproducible results
+ Short treatment time
+ Reduced gas porosity and hard inclusions in castings
+ Reduced machining costs
+ Consistent mechanical and physical properties
+ Environmentally friendly

Figure 5: Effective degassing process using a Foseco Degassing Unit (left) and the patented impeller rotor (right)

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The benefits of best practice in terms of melting, melt treatment and pouring of the molten aluminium are observed in the non-destructive testing laboratory with the cast materials having optimum metallurgical structures and soundness. Foseco supply testing equipment and consumables that support the quality assurance procedure such as GASTEC PRO and DENSITEC devices for measuring density. GASTEC PRO allows for the creation of a partial vacuum (up to 10 mBar) under one glass bell, in order to highlight the presence or absence of dissolved hydrogen which has a negative influence on the tightness and mechanical characteristics of aluminum castings. DENSITEC provides a direct measurement of density, a ticket can be printed, or values are recorded to a computer for traceability.

Figure 6: GASTEC PRO (left) and DENSITEC (right) density measuring equipment

GAP is also using Thermatest 5000 NG III thermal analysis equipment. These units are designed to predict and control the structure of aluminium alloys before casting, including the grain refinement and the type of eutectic structure that will be formed. Within only a few minutes, it assesses the melt quality, allowing for specific additions to be made to the melt before casting, therefore avoiding costly scrap due to shrinkage, leakage, porosity, and hot tears.

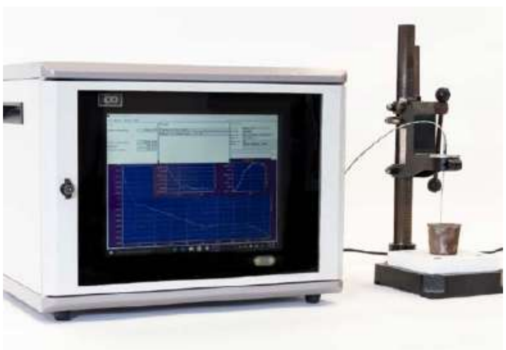

Figure 7: Thermatest 5000 NG III thermal analysis unit

CONCLUSION

FOSECO offers the aluminium foundry a full range of equipment and consumables that support the production of quality castings. In the sand foundry binders, coatings and moulding materials supplied by Foseco ensure the integrity of the moulding process and enable complex castings to be manufactured with superior surface finish. The preparation and transfer to the mould of the liquid aluminium is equally important and again Foseco products are used to improve metal cleanliness and metallurgical structure, with product performance ensuring energy costs are minimized and casting quality is maximized.
The benefits of this focus on process and consumable technology is observed in the high quality, defect free castings produced, with Foseco developed test methods providing the end user with quality assurance data.
Above all the benefits of the products themselves, it is the relationship with foundries such as GAP that elevates performance to a higher level. By working in partnership to deliver best in class solutions and creating value for the end-user a sustainable relationship is developed that ensures future success for all parties.

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DOSING FURNACE LINING WITH INSURAL PRE-CAST SHAPES REDUCES DOWNTIME IN FOUNDRIES

Author: Dirk Schmeisser, Foseco Europe

By using INSURAL pre-cast shapes for furnace relining, sintering can be dispensed with and a constant density index can be achieved. The use of high-quality insulating materials in the lining process enables significant energy savings and thus a reduction in CO_2 emissions.

INTRODUCTION

The relining of a dosing furnace in aluminium foundries is always labour-intensive and particularly time-consuming. In the case of a monolithic lining, the sintering phase in particular extends the downtime of the furnace. A market analysis among relevant customers shows that there is a need for optimisation in the area of furnace lining and cleaning of dosing furnaces in connection with corundum formation.

The solution for your dosing furnace in pressure and low-pressure die casting foundries: A completely dry lining with INSURAL pre-cast components combined with high-quality insulation materials.

THE FORMATION OF CORUNDUM

There are basically two types of corundum formation: external and internal corundum generation.

External corundum formation occurs on the bath surface by oxidation of liquid aluminium with oxygen from the furnace atmosphere. Aluminium is sucked upwards through pores and oxides on the metal surface and forms corundum-lumps. This process is accelerated by a high proportion of oxygen, the presence of certain alloying elements and high temperatures.

In addition, there is internal corundum formation, also called penetration. In the contact area of the refractory lining with the liquid aluminium, a substitution reaction occurs due to the higher affinity of oxygen to the aluminium in the molten melt and the free oxygen from the SiO_2 in the refractory lining. This reaction takes place within the refractory structure and below the melt surface. A dense black zone is formed. This is accelerated by a high bath temperature and an increase in the pre-baking temperature, which burns out non-wetting additives.

In order to solve this problem, extensive tests were carried out with various INSURAL recipes. Suitable compositions were then determined and new formulations developed. FOSECO offers a completely dry lining with INSURAL pre-shaped parts for all common dosing and low-pressure furnaces, which is not only economically attractive but also offers the following further advantages:

- Direct installation on site possible
- No time-consuming sintering required
- Stable density index after relining is achieved in a much shorter time
- Corundum formation is reduced to a minimum
- Easy cleaning, thus alloy change with little effort possible
- Larger filling volume for some furnace types due to optimized design
- Energy saving during operation
- Reduction of CO_2 emissions

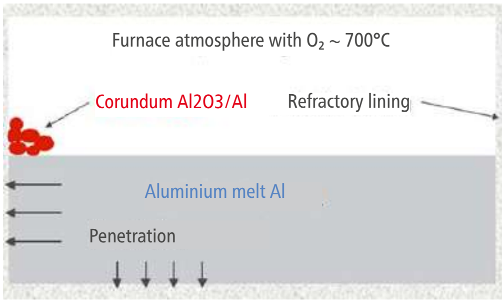

Figure 1: Schematic of corundum formation

THE INSTALLATION

The new lining consists of INSURAL pre-cast parts, which are assembled according to a modular principle. The time required for a furnace installation using a clean and empty steel shell is between two and four days, depending on the furnace type. In addition to the INSURAL pre-cast parts, high-quality insulation materials are used. The insulation materials are mounted between the INSURAL parts and the steel shell. After insulating the bottom area and the side walls, the main liner is inserted. The gap between the bassin and the insulation is then filled and the heating and ceiling blocks are placed on top. The remaining insulation work is then carried out and the holes for the thermocouple and the compressed air supply are drilled. The last step is closing the furnace with the lid.

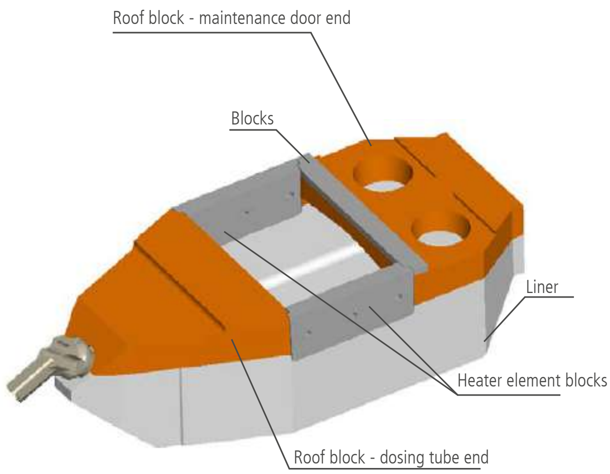

Figure 2: INSURAL precast components

Figure 3: Empty steel shell

Figure 4: Insulating materials for floor and side walls

Figure 5: Installation of the liner into the steel shell

Figure 6: Installation of heating and roof blocks

ADVANTAGES

After complete assembly, the furnace can be put into operation immediately and is ready for operation once the desired furnace chamber temperature has been reached. A sintering program as with a conventional installation is not necessary. As can be seen from Diagram 1, this step saves a great amount of time.

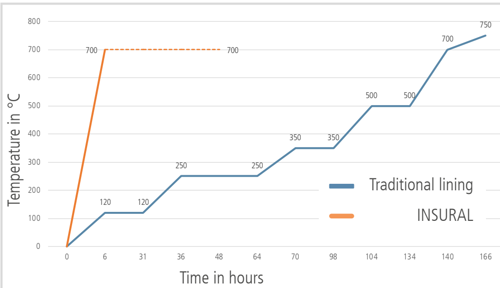

Diagram 1: Comparison of preheating curves

Depending on the casting process and quality requirements, the density index plays an important role in the availability of the dosing furnace. After reaching the furnace chamber temperature, a constant low density index value can be measured after only two days (Diagram 2). The availability of the system by lining it with INSURAL pre-cast parts has clear advantages over conventional lining. With conventional installations, the sintering process takes seven days. If INSURAL prefabricated parts are used, this part is completely obsolete.

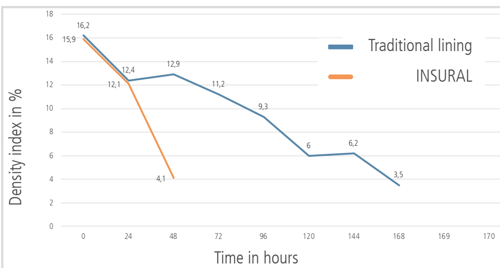

Diagram 2: Density Index

In addition, a constant density index is achieved much faster with an INSURAL lining. As a result, the furnace can return to the production process faster due to the shortened integration time.

The use of INSURAL prefabricated parts minimizes corundum formation and facilitates furnace cleaning. For this purpose, the method of corundum formation will be discussed once again. Parameters that can influence the formation of corundum are:

- High proportion of O_2
- Pores
- SiO_2 ratio in refractory material
- Temperature
- Wetting properties

Based on these points, the INSURAL 270 recipe was developed in 2015, which has a small amount of SiO_2, low porosity and good non-wettability with liquid aluminium. With the INSURAL 270 recipe, dry lining with pre-cast parts for dosing furnaces has been successfully introduced to the market in recent years and excellent results have been achieved with a large number of customers.

INSURAL 270 has a SiO_2 content of 22 %, a porosity of about 17 %, a cold compressive strength of 50 N/mm^2 and excellent non-wetting properties compared to liquid aluminium. In order to meet the growing demands of the market, another INSURAL formulation has been developed, which has extended the product range since April 2019. The INSURAL 290 recipe has a SiO_2 content of less than 10 % only, a porosity of around 16 % and a higher cold compressive strength of 100 N/mm^2. The non-wetting properties remain excellent.

Another important point is the temperature in the furnace, which is a decisive factor for the formation of corundum. The compensation of temperature loss in dosing furnaces is controlled by the heaters and can be readjusted depending on the insulation. Since the heating takes place via radiant heat, the heating elements become significantly hotter than the melt bath temperature. This is a major reason why the formation of corundum accelerates and good insulation therefore has a positive influence on corundum avoidance.

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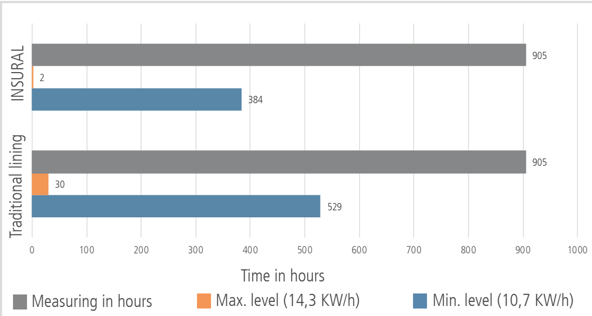

Diagram 3: Power consumption


Figure 7: Condition of furnace after 3.5 years

FOSECOs insulation concept can counteract corundum formation and also save energy costs (Diagram 3). The power consumption measurements carried out in a foundry using a 650 kg dosing furnace show a lower energy requirement compared to conventional lining. The heating power remains at the lowest level for almost 98% of the time, which avoids overheating and effectively prevents corundum formation. Operation at low heating output levels also has an influence on the peak shutdown in the foundry's energy management and reduces weekly average consumption.

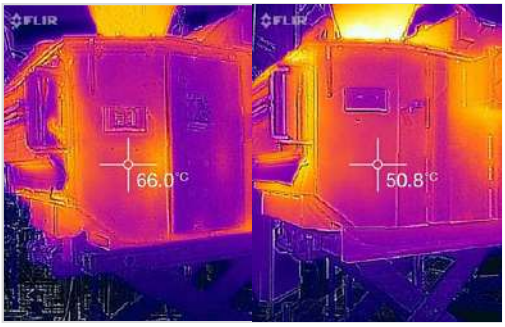

Figure. 8: Furnace surface temperature (left: conventional lining, right INSURAL 270)

CONCLUSION

Furnace lining with INSURAL pre-cast parts offers a number of advantages over conventional lining. On the one hand, the actual lining process requires considerably less time, and on the other hand, time-consuming sintering is no longer necessary. Furthermore, the dry lining avoids the absorption of hydrogen by the melt in the first days after commissioning. The formation of corundum is minimized and furnace cleaning is simplified. Furnace cleaning remains important, so a weekly cleaning interval is recommended. Depending on the insulation concept selected, energy and CO_2 output can be significantly reduced. The current electricity mix in Germany indicates that for 1 kWh an average of 511.2 grams CO_2 are released to atmosphere. With a furnace that saves 48,000 kWh per year, the foundry achieves a reduction of 24.5 tons of climate-damaging CO_2.

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BRAND-NEW INNOVATION FOR THE NON FERROUS SECTOR: THE EXOTHERMIC FEEDER FEEDEX NF1

Author: Arndt Fröscher, Foseco Germany

In aluminium foundries, the use of insulating sleeves in a wide variety of materials has been common practice for many years. FOSECO is now launching an exothermic sleeve material for aluminium casting applications for the first time. The new recipe FEEDEX NF1 was specially developed for the aluminium sector and adapted to the existing requirements there. It ignites quickly, the exothermic reaction takes place slowly and steadily and ensures a considerable improvement in the feeding effect. This results in only low emissions. FEEDEX NF1 feeders are available in numerous different versions and eliminate the need for manual addition of exothermic powders.

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INTRODUCTION

The use of insulating feeders is common practice in aluminium foundries. In this segment, many different products are available. In most cases, the products are made of fibres or spheres. In both cases, organic or inorganic binders are being used.

THE CHALLENGE

If the insulating property is not sufficient or if the size of the sleeve is limited, very often so called exothermic powders are applied. These powders start an exothermic reaction when in touch with liquid aluminium and provide their energy to the melt in the feeder to slow down the solidification. Also this technology is common practice.
However, this process contains a number of disadvantages:
First of all, the application of the powder has to be done manually, therefore the amount is often unstable. At big castings with a number of feeders, it is difficult for the operator to apply the powder to all feeders in an acceptable time frame. The exothermic reaction of the powder creates smoke, which (although it is not harmful) should be extracted. As the surface of the feeder must be open to apply the powder, users face limitation during the moulding process.

THE SOLUTION

With the new product line FEEDEX NF1, FOSECO now provides for the first time exothermic feeders for aluminium applications. These products are made of a new developed exothermic recipe and make the application of exothermic powders obsolete. When in contact with liquid aluminium, ignition starts within 30 seconds.
This exothermic reaction goes on slowly and steadily and provides a significantly delayed solidification of the metal in the sleeve and therefore a long lasting feeding performance.
The module extension factor which is between 1.3 and 1.5 for insulating sleeves is between 1.55 and 1.65 for FEDEX NF1.
These facts lead to a number of benefits: First of all, the manual application of exothermic powder becomes obsolete. In addition it is now possible to mould the feeders completely, which leads to reduced emissions. But also at open FEEDEX NF1 sleeves, reduced emissions can be observed. Due to the better feeding performance, sleeve dimensions can be reduced which leads to reduced re-melting costs. Figure 1 shows a typical cooling curve of a FEEDEX NF1 sleeve. The exothermic reaction is clearly visible. The released energy leads to a strongly delayed solidification. FEEDEX NF1 sleeves are available in all common dimensions. In all cases, the combination with a breaker core is possible. The use of breaker cores provides an easy knock-off of the sleeves from the casting and therefore reduces the costs.

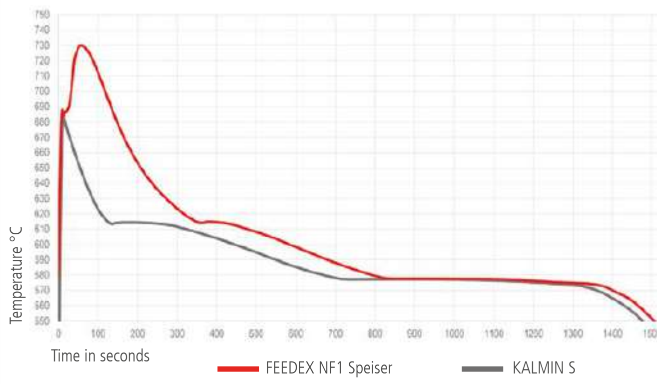
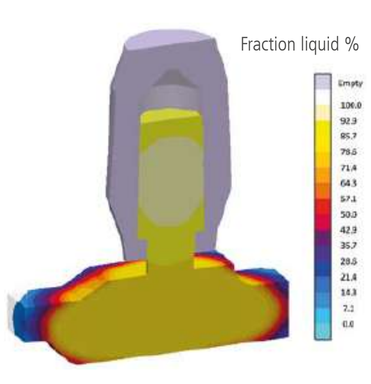


Figure 1: Comparison between cooling curve of an exothermic feeder sleeve FEEDEX NF1 and insulating feeder sleeve KALMIN* S



MAGMA simulation - Fraction liquid in %

Figure 2 shows the risers in the core box. Due to the high strength of the FEEDEX NF1 recipe it is possible to use the feeders on automated moulding lines without any problems. On the opposite, feeders with lower strength can break or deform during the moulding process.
Figure 3 shows the FEEDEX NF1 risers during casting. The exothermic reaction is clearly visible in contrast to the insulating risers. The reaction starts only a few seconds after filling with the melt and continues slowly and evenly. This makes the addition of exothermic powders such as FEEDOL* obsolete.

Figure 3: Clearly visible exothermic reaction of the FEEDEX NF1 riser

Figure 4. Constant burn-off of the FEEDEX NF1 feeder

CONCLUSION

FEEDEX NF1 is a new recipe for the non- errous sector. The fast, steady and lasting reaction makes it an excellent alternative to conventional insulating feeders. The high strength of the risers makes them suitable for use on automated moulding lines. The improved feeding effect can lead to a reduction of the feeder size and thus to a saving of recycled material. The manual addition of blowhole powders is no longer necessary, which increases process stability.

Figure. 2: Exothermic and insulating risers positioned in the moulding box

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