SPECIAL ISSUE
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# NEW TECHNOLOGIES FOR DIE CASTING

## TECHNICAL ARTICLES & CASE STUDIES

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# CLEANING AND DROSSING GRANULATE FOR STRUCTURAL HIGH-PRESSURE DIE CAST ALUMINUM COMPONENTS

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This paper proves in detail and with the participation of industry (Magna Cosma) and science that under today's technological conditions the use of granulates in die casting is not only harmless but also economically and ecologically important.

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## INTRODUCTION

The use of chemical products has been the accepted standard for decades in sand, gravity die and low-pressure foundries casting aluminum alloys. Granulates are used for melt cleaning, grain refining, modification or drossing.

In the past, the addition of salt-based preparations such as powders or tablets was usually done manually. The disadvantages of this approach are uncontrolled addition rates and insufficient reaction in the aluminum melt, increasing the risk of salt inclusions in the casting. In many cases this would result in quality problems during welding (pore formation) and heat treatment (blister formation).

In high-pressure die casting (HPDC), the critical question therefore is to what extent chemical melt treatment is possible. In the case of weldable thin-walled Aluminum structural castings produced by high-pressure die casting, many foundries are reluctant to use chemical products such as granulates.

Automotive manufacturers as important end customers for such structural castings are also skeptical about the use of chemical products, despite the high economic benefits. Risks in series production and the lack of investigations and data, in many cases outweigh the known metallurgical and economic advantages of chemical treatment. However, with the introduction of the MTS 1500 process and continuous recipe optimization of the cleaning and drossing granulates, the technology has advanced significantly. Foseco took this as an opportunity to re-evaluate the application of granulates using the MTS 1500 process for structural castings. This study on the long-term testing of granulates in high-pressure die casting was planned and carried out in collaboration with the company Magna BDW technologies in Soest (Germany) and an expert in metal forming, materials science and welding processes from a University in Germany.

## THE MTS 1500 PROCESS

The MTS (Metal Treatment Station) process is an upgrade of the proven FDU (Foundry Degassing Unit) rotary degassing system and offers the possibility of a simultaneous addition of different melt treatment products into the melt. In this process, the treatment agent is added to the melt through a defined vortex. The vortex is carefully controlled during addition and allows highly effective mixing of the products with the melt. This results in many advantages: [Fig 1]

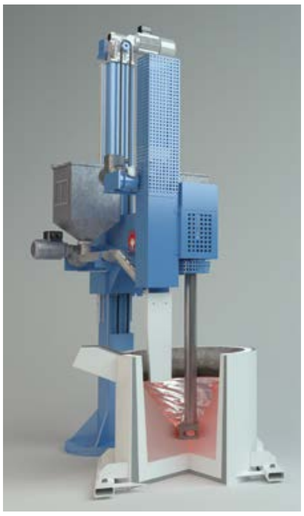

Figure 1: MTS Process

**Metallurgical advantages:**
- Consistent mechanical and physical properties
- Homogeneous microstructure and composition
- Low oxide content
- Controlled gas porosity

**Economic advantages:**
- Reduced treatment costs due to lower inert gas and granulate consumption
- Low metal dross formation
- Increased efficiency due to faster metal turnover
- Reproducible melt quality
- Increased reliability with reduced maintenance requirements

**Improved health and work safety:**
- Reduce particle and gas emissions by adding less granulate
- Vortex draws the granulate into the melt immediately after addition and mixes it intensively with the melt
- Granulate is reacted during treatment, there is no unwanted interaction on the melt surface
- Operator of the unit is not directly involved in the treatment process and is located outside a potential risk area

**Improved environmental protection:**
- Reduced use of consumables
- Reduced amount of dross
- Reduced emissions of $CO_2$
- Reduced temperature loss due to shorter treatment time (energy savings)

A complete overview of the MTS 1500 process is given in Foundry Practice article FP 247 (2007) „MTS 1500 - Automated Melt Treatment“

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# TASK DEFINITION AND EXPERIMENTAL PROCEDURE

The objective of this long-term test was to confirm  that no residues remain in the casting when the granulate is added by the MTS treatment and thus the process has no negative influence on the casting properties.

For the experiment, an FDU MTS 1500 rental unit from Foseco was provided to Magna Cosma together with the appropriate Foseco graphite consumables. The degassing parameters were taken from the existing production unit and times and rotor speed were evaluated for vortex formation. The amount of granulate added depends upon operational conditions such as the amount of scrap used, the alloy, the treatment temperature, and the ladle geometry.
The optimum addition quantity was determined in a preliminary test. For this purpose, different addition rates (0.02%, 0.04% and 0.06% of the metal weight) of the COVERAL ECO 2531 granulate were added in each of 3 trials using the MTS method. After treatment, density index, Vmet (Vesuvius metal cleanliness analysis) and dross samples were taken.

Based on these results, an addition rate of 0.06% Coveral ECO 2531 was determined as optimum for the long-term test, as this provided both the best metal quality and the most economical result.

**PARAMETERS**

**Shaft** FDU BKF 75/900.70
**Rotor** MTS FDR 190.70
**Baffle plate** I180 PL 04.500.2
**Alloy** AlSi10MgMnFe
**Transfer ladle** with 650 kg
(1,430 lbs) of melt
**Temperature** 730 °C (1,350 °F)

# ANALYTICAL METHODS AND THEIR SIGNIFICANCE FOR THE EXPERIMENT

## Density index

The density index (DI) is the quotient of the density of a sample solidified in vacuum compared to a sample solidified at athmospheric pressure and is an indirect measure of the hydrogen content in the melt. However, since gas is also preferentially precipitated on nuclei such as oxides in the vacuum density sample during solidification, a low-density index also means a very good and low-oxide melt quality. [1]

$$DI=(Rho_{atm}-Rho_{80mbar})/Rho_{atm}x100\%$$

Density index is by far the most widely used process parameter, which in practice is used as a quality control tool in production before the melt is poured. The measuring method is low-cost and easy to handle, even if it is not very selective. The density index describes the total hydrogen and oxides in the melt. Even if the density index itself does not initially allow any statement about the amount of hydrogen or oxides present, the density index is a  meaningful parameter for this long-term test. Constantly low DI values indicate a clean melt, and the high number of measurements provides a sufficiently high statistical confidence.

## Vmet Analyse

The Vmet analysis is a specially developed method used for the qualitative and quantitative characterization of the melt cleanliness. Here, the sample solidifies in a special mould and a defined section is used for further examination. An 1 cm$^2$ piece of the sample is prepared metallographically and scanned fully automatically using a scanning electron microscope. Defects are chemically analyzed by electron beam and their size is measured. The results are divided into 3 categories (pores, alumina, and oxides of alloying elements), and grouped into 4 size intervals (0.5-15 µm, 15-30 µm, 30-75 µm, >75 µm).

This method is more  precise due to the automated measurement process and will  detect any residues of salt in addition to assessing the melt cleanliness in terms of oxides. The effort and costs of VMet analysis limit the number of possible samples.

## Aluminum content in the dross

In this method, the aluminum content in the skimmed dross is measured after treatment with granulate. For this purpose, 750 g of the dross sample is mixed with 750 g of flux, heated to 800 °C for 8 hours and stirred several times. During this time, 2 phases form in the crucible. The aluminum phase collects at the bottom, and the oxide-containing salt phase settles above it. The crucible is then allowed to cool, and the phases are separated mechanically. [Fig. 2]

Special regulations for homogenization and sampling of the dross ensure that a representative  quantity is analyzed. This method is used, on the one hand, to calculate total process costs and, on the other hand, to check the correct amount of granulate is being added.

Figure 2: Metal phase and oxide-containing salt phase after dross analysis

### Scanning electron microscope (SEM) examination

The scanning electron microscope makes it possible to view the microstructure of a sample at very high magnification and to qualitatively determine the chemical composition of certain areas.

The expert used SEM to examine different density and fracture samples with and without granulate treatment for any anomalies. Two of the samples were additionally annealed at 540 °C for 1 hour, to visualize possible salt reactions on the fracture surface.

### X-ray fluorescence analysis

In energy-dispersive X-ray fluorescence analysis (XRF), atoms are excited to emit their characteristic X-ray fluorescence radiation using an X-ray tube. The radiation emitted by the sample is separated in the spectrometer, so that the intensities of individual spectral lines or spectral regions (wavelength-dispersive) can be measured. [Fig 3]

This method is used to detect salt residues in the dosing furnace lining.

## OBSERVATIONS FROM THE TRIALS

During the entire 8-week trial period, density index samples were regularly taken from each transport ladle - both using the standard process and the MTS process. Once a week, additional Vmet samples were collected from the transport ladle and the holding furnace and compared with the standard process. Residual aluminum analysis in the dross was performed three times throughout the test run. Analysis of the fracture samples was performed weekly, and examination of the furnace material was performed once.

During the trial period, cleanliness improved throughout the process. Employees repeatedly and independently reported that both the ladles and the holding furnaces were less dirty, and the cleaning process was significantly easier. As a result, the initial skepticism of the employees towards the new MTS technology with granulate was significantly reduced.

For a safe process, the ladle must always be placed centered under the degassing unit. Under trial or in-production conditions, this was not always the case, the granulate sometimes reacted at the melt surface, and there was occasionally slight smoke development during treatment. A workplace analysis was carried out by an authorized company to determine the hazard potential, in order to provide greater safety for all involved. During this measurement, inhalable dusts as well as fluoride emissions were determined. These values were used to determine whether the use of granulates could be hazardous to employees and the environment.

Results confirmed, Fluoride emissions were below the detection limit. The inhalable dust levels were in the lower quarter of the maximum workplace concentration. This confirms the MTS process using a granulate, does not present a risk to employees and or environment.

An additional finding from this long-term test is that the oxide content has a significant influence on the density index. As mentioned at the beginning of this article, the relative influence of hydrogen content and oxide content on the density index value cannot be determined. The consumables geometry - graphite rotor MTS FDR 190.70 – was the same for both processes – standard process and MTS process during the test. Thus, no change is to be expected with regard to the effectiveness of hydrogen removal. Based on more than 250 measured values, the process without granulate addition shows a density index below 4 %, the process with granulate addition always below 2 % density index. Through this test setup, we can conclude that the oxide content reduced by the granulate addition in this process contributes about 2 % in the density index.

In general, it can be concluded that the influence of the oxides in the density index is significantly higher than previously assumed.

Figure 3: Dosing furnace lining sample

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## RESULTS

### Melt treatment

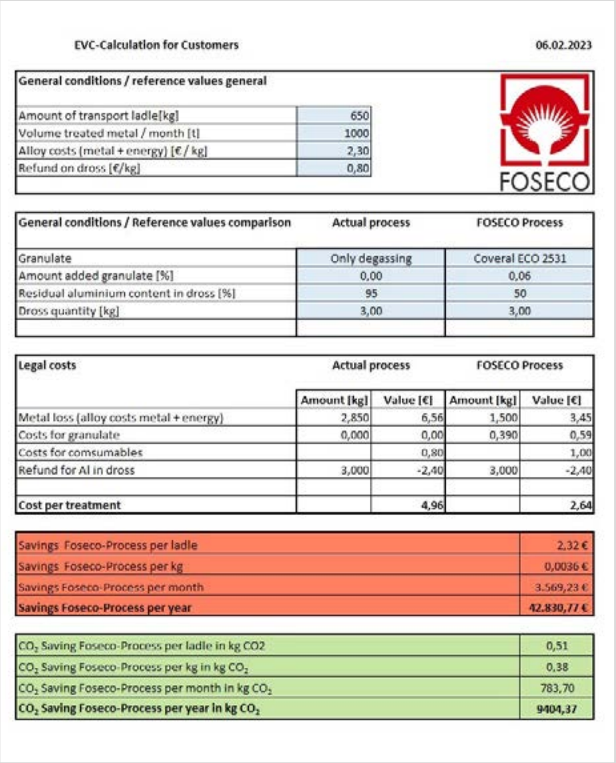
A significantly lower density index value after treatment with COVERAL ECO 2531 by means of MTS 1500 proves a better oxide removal. The Vmet analysis confirms this observation and shows an improved melt cleanliness by a factor of 6.

| | Density index | Vmet Analysis | Metal content in dross |
|---|---|---|---|
| Without COVERAL ECO 2531 | < 4 % | 460 defects | 95 % |
| With COVERAL ECO 2531 | < 2 % | 75 defects | 50 % |

Table 1: Results from melt samples

In addition to quality, the economic aspect must also be considered in any process optimization. The basis for this is an aluminum content measurement of the dross. This saved metal remains in the ladle and can be cast directly to produce additional castings. In this application, about 3 kg of dross per ladle are skimmed off and discharged. The use of COVERAL ECO 2531 saves 45 % aluminum in the dross, which corresponds to 1.35 kg.

The overview shows an example of a process cost evaluation (as of February 2023). Other favorable factors such as scrap reduction, reduced tool wear in machining and shorter cycles in furnace and ladle cleaning, are not considered in the cost assessment and provide additional benefits.



**EVC-Calculation for Customers** 06.02.2023

| **General conditions / reference values general** | |
|---|---|
| Amount of transport ladle[kg] | 650 |
| Volume treated metal / month [t] | 1000 |
| Alloy costs (metal + energy) [€ / kg] | 2,30 |
| Refund on dross [€/kg] | 0,80 |

| **General conditions / Reference values comparison** | **Actual process** | **FOSECO Process** |
|---|---|---|
| Granulate | Only degassing | Coveral ECO 2531 |
| Amount added granulate [%] | 0,00 | 0,06 |
| Residual aluminium content in dross [%] | 95 | 50 |
| Dross quantity [kg] | 3,00 | 3,00 |
| | | |

| **Legal costs** | **Actual process** | | **FOSECO Process** | |
|---|---|---|---|---|
| | **Amount [kg]** | **Value [€]** | **Amount [kg]** | **Value [€]** |
| Metal loss (alloy costs metal + energy) | 2,850 | 6,56 | 1,500 | 3,45 |
| Costs for granulate | 0,000 | 0,00 | 0,390 | 0,59 |
| Costs for comsumables | | 0,80 | | 1,00 |
| Refund for Al in dross | 3,000 | -2,40 | 3,000 | -2,40 |
| | | | | |
| **Cost per treatment** | | 4,96 | | 2,64 |

| | |
|---|---|
| Savings Foseco-Process per ladle | 2,32 € |
| Savings Foseco-Process per kg | 0,0036 € |
| Savings Foseco-Process per month | 3.569,23 € |
| **Savings Foseco-Process per year** | **42.830,77 €** |

| | |
|---|---|
| $CO_2$ Saving Foseco-Process per ladle in kg CO2 | 0,51 |
| $CO_2$ Saving Foseco-Process per kg in kg $CO_2$ | 0,38 |
| $CO_2$ Saving Foseco-Process per month in kg $CO_2$ | 783,70 |
| **$CO_2$ Saving Foseco-Process per year in kg $CO_2$** | **9404,37** |

Table 2: Process cost comparison

### Examination for salt residues

A fracture area examination by scanning electron microscope shows no traces of any salt residues, neither in the original nor in the heat-treated condition. [Fig. 4]

Figure 4: Aluminum sample for SEM examination – after heat treatment

EDX (Energy Dispersive X-Ray) analysis of the furnace linings also shows no evidence of salt residues. [Fig. 5]

| Analysenparameter | Einheit | Ergebnis |
|---|---|---|
| **Elemente / Kationen** | | |
| Aluminium (Al) | % | 12.6 |
| Calcium (Ca) | % | 4.4 |
| Eisen (Fe) | % | 0.07 |
| Kalium (K) | % | 0.05 |
| Magnesium (Mg) | % | 0.05 |
| Natrium (Na) | % | 0.26 |
| Phosphor (P) | % | 0.11 |
| Silizium (Si) | % | 32.2 |

Figure 5: EDX-results from furnace lining examination

Our materials expert concludes after his research:

> Similarly, the results of the present investigation indicate no negative influence on the casting quality in terms of mechanical properties, weldability, heat treatment (blister formation, corrosion characteristics)."[2]

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## SUMMARY

The approach described in this article was intended to investigate whether the concern about negative consequences in the chemical treatment of melts for weldable high-pressure die casting is well-founded. With the aid of a high-quality and extensive test setup, it was finally proven that the use of granulates by means of the MTS process, can achieve better melt quality and make the process more economical and sustainable. In addition, it was clearly established that the correct use of Foseco's melt treatment agent COVERAL ECO 2531 has no negative impact on casting quality, weldability or corrosion resistance. These practical trials were accompanied and validated with the aid of the most up to date laboratories and test methods, with the involvement of independent partners from research and development.

This project conclusively demonstrates the advantages of using state-of-the-art melt treatment equipment combined with the use of technologically advanced granulates. Improved casting quality, financial savings including the return of investment of a new MTS unit of one year, as well as a significant $CO_2$ saving of 9 tons per year are reason enough to rethink and challenge existing processes.

## REFERENCES

[1] Gießerei Lexikon

[2] Final trial – Application of drossing and cleaning fluxes for structural components in HPDC – long term trials with COVERAL ECO 2531 (Magna, Foseco, Prof. Winkler)

## ABOUT THE AUTHORS

Kerstin has worked at Vesuvius GmbH since 2006 in melt treatment for non-ferrous metals. She developed Nucleant 1582, managed Germalux, and now oversees the Non Ferrous Metal Treatment product group as European Product Manager. She lives with her family near Borken, enjoys dancing, and is involved in charity work.

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Philip joined Vesuvius in 2015 in the non-ferrous sales team and today works as Technical Manager NF for Northern Europe. In this position he collaborates with our customers, partners and management to find optimal solutions for the foundry industry. In his free time, Philip enjoys traveling with his wife and two children.

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Ronny, with Foseco since 1998, managed multiple product areas in Europe's non-ferrous foundry sector and significantly influenced product strategy. Notably involved in MTS technology and chemical product development, he transferred to Cleveland, OH in 2021 as Technical Manager for NAFTA, exploring the new environment with his family.

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# SMARTT - defined hydrogen levels after aluminium rotary degassing

AUTHOR: Ronny Simon, Technical Manager Non-Ferrous

The production of Aluminium castings globally is dominated by the automotive industry. To ensure that the correct casting quality is achieved, a more effective and technically sound melt treatment is essential, followed by a well-designed and controlled pouring practice. Automotive industry requests process reproducibility and so any melt treatment adopted must be capable of achieving consistent levels of cleanliness and hydrogen control. Many quality management systems also require a 100 % record of production data, so again a sophisticated melt treatment with data storage capabilities becomes more attractive.

## Introduction

Process control in general refers to the way in which foundries maintain a tight control over the various components and steps involved in making castings. The importance of process control is derived from the way in which a strict adherence to process control helps a foundry avert potentially costly mistakes. Considering the fact, that process control requires a complete monitoring of the various parameters, any potential problem will be spotted early, before it becomes a significant problem later.

The intelligent use of process control technologies within the manufacturing process has beneficial effects far beyond the traditional aspects of quality assurance:

- Increase throughput from existing assets
- Increase automation and reduce human intervention
- Reduce rework, concessions and scrap
- Enhance production capability and take on more work.

## Parameters influencing rotary treatments

In rotary degassing we differentiate between factors that are almost constant over longer periods of time and variable factors. Alloy composition, vessel geometry and target melt quality are often well known and do not change remarkably. Usually several programs are set in the PLC, defining treatment time, rotor speed and gas flow rate. The operator selects a program following given instructions. The number of programs is limited, the programs need to be changed manually in case of process variations, and the operator might choose the wrong program.

Other factors such as ambient conditions and melt temperatures often vary in much wider ranges. The influence on degassing is usually underestimated or operators change parameters based on their experiences. Variations in these starting conditions may cause inconsistent results.

The hydrogen concentration in the melt during degassing for various ambient conditions and melt temperatures has been calculated using the Degassing Simulation for the following widely common set of parameters. Variations of the parameters illustrate the influence on the degassing result and the final hydrogen content in the melt after every single treatment.

Table 1: Model simulation parameters

| | |
|---|---|
| ATL 1000 with 850 kg melt | XSR 220 rotor |
| AlSi7Mg | 420 rpm |
| 750 °C melt temperature | 20 l/min inert gas |
| 50 % relative humidity | 20 l/min forming gas with 20 % hydrogen |
| 25 °C outside temperature | 0,30 ml $H_2$ / 100 g Al starting level |

## 1. Ambient conditions

The melt forms an equilibrium with the water in the surrounding atmosphere; a warm and humid climate results in a much higher hydrogen content in the melt than a dry and cold climate (picture 1).

During rotary degassing the melt is in interaction with the atmosphere. The degassing simulation shows the effect of different ambient conditions (diagram 1).

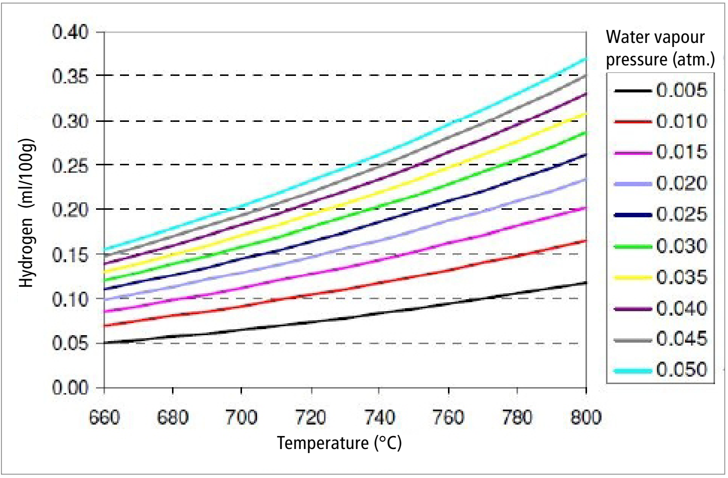
Likewise, the use of forming gas – a $N_2$-$H_2$ mixed gas - for upgassing procedures ends up with different hydrogen levels (diagram 2).

## 2. Melt temperature

The melt temperature influences the equilibrium with the atmosphere as well; melt at higher temperatures dissolves more hydrogen (diagram 3).

The variations in final results for use of forming gas are even higher at different melt temperatures (diagram 4).

A full description of the development work of "Batch Degassing Simulation" is given in Foundry Practice 256 (2011).



Picture 1: Influence of ambient conditions on hydrogen equilibrium (0,005 atm = 5 °C / 50 % rH; 0,050 atm = 35 °C / 90 % rH)

Diagram 1: Degassing curves for different ambient conditions

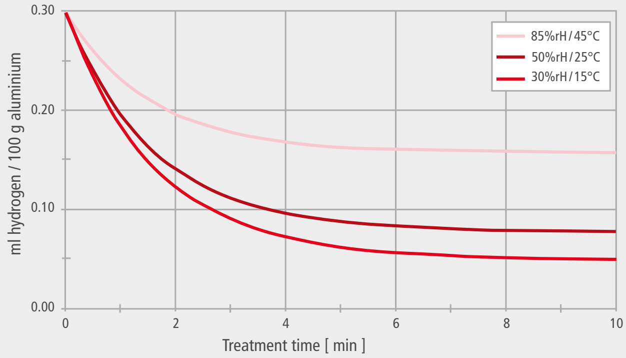


Diagram 2: Upgassing curves for different ambient conditions

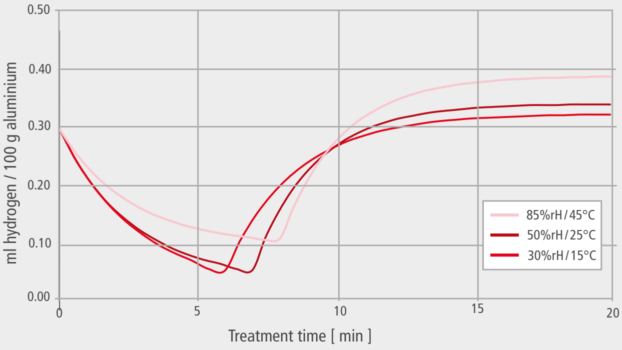


Diagram 3: Degassing curves for different melt temperatures

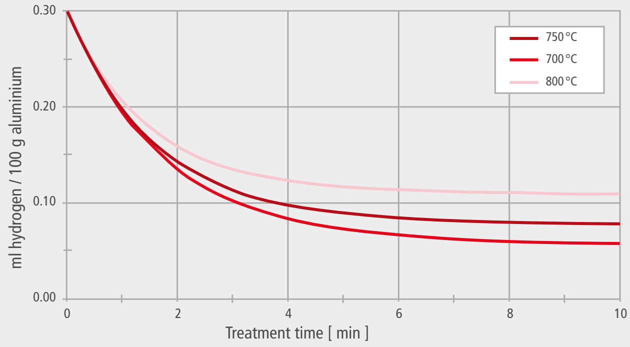
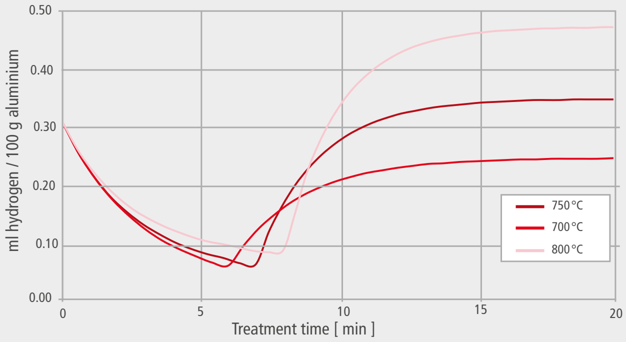


Diagram 4: Upgassing curves for different melt temperatures



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## SMARTT – an innovative process control

SMARTT is an acronym for *self-monitoring adaptive recalculation treatment* and an innovative process control that analyses all incoming parameters and calculates the treatment parameters for the rotary degassing process just before each treatment. The target for the optimization is a constant melt quality after each treatment.

The SMARTT software is installed on a Windows PC, input and output of data is carried out on a comfortable touch screen panel with a LAN connection to the SIEMENS PLC that finally controls the degassing unit.

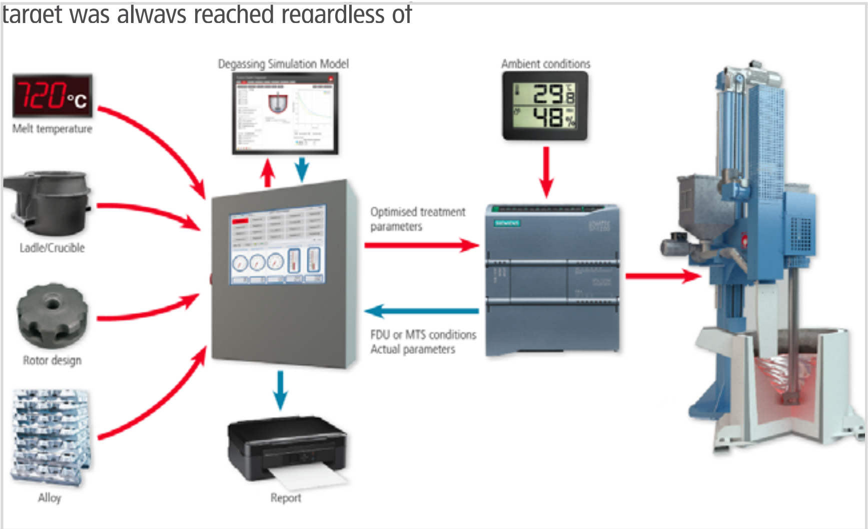
Relative humidity and outside temperature are measured by a standard humidity meter, mounted next to the control cabinet in the area where the treatment takes place. The actual readings are on-time transferred to SMARTT and recorded over time.

A full report on SMARTT is given in Foundry Practice 264 (2015).

## Practice of degassing

For different ambient conditions SMARTT calculates treatment parameters to reach a target hydrogen content after each treatment. With increasing air temperature and relative humidity, rotor speed and inert gas flow rate increase to compensate the higher moisture content in atmosphere. The optimization always starts at minimum time, a time that allows sufficient oxide and inclusion removal as well. If flow rate and rotor speed are at its specific limit, the software starts prolonging the treatment time to reach the target (table 2, picture 2). A maximum treatment time limits temperature loss or melt shortage in the following casting step.

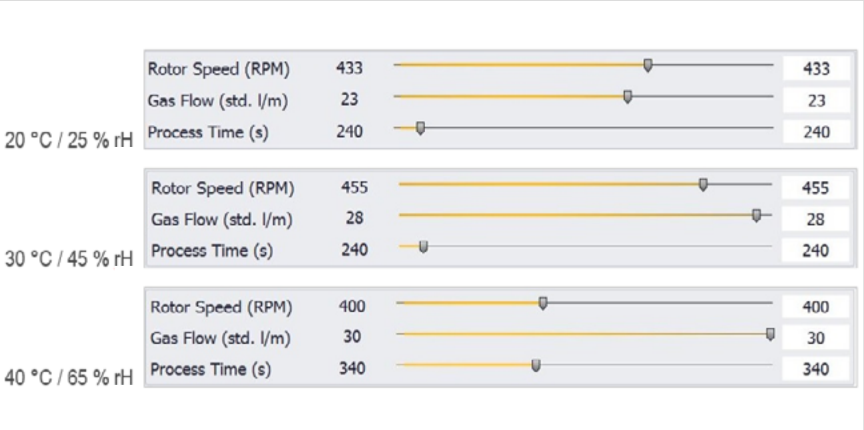
Variations in melt temperature before degassing are compensated by SMARTT in a similar way. Finally, every process is started with different rotor speed, inert gas flow rate and treatment time to achieve the same hydrogen content in the melt at the end of each treatment. Foundry trials have shown that the target was always reached regardless of



Picture 2: Schematic setting of SMARTT

| BU 600 with 530 kg melt | 0,06 ml $H_2$ / 100 g Al target |
|---|---|
| AlSi8Cu3 | Standard optimization |
| 750 °C melt temperature | 240 s minimum time |
| XSR 190 rotor | 500 s maximum time |

Table 2: Process parameters for SMARTT degassing



20 °C / 25 % rH
Rotor Speed (RPM) 433 433
Gas Flow (std. l/m) 23 23
Process Time (s) 240 240

30 °C / 45 % rH
Rotor Speed (RPM) 455 455
Gas Flow (std. l/m) 28 28
Process Time (s) 240 240

40 °C / 65 % rH
Rotor Speed (RPM) 400 400
Gas Flow (std. l/m) 30 30
Process Time (s) 340 340

Picture 3: Treatment parameters for different ambient conditions

## Practice of upgassing using forming gas

Some applications in foundries require a defined hydrogen content such as in the casting of wheels. It is common practice to run very short treatment times to avoid too much hydrogen removal; often oxide removal is not sufficient. The use of a $N_2$-$H_2$ mixed gas improves oxide removal due to longer treatment times but the variations in hydrogen at end of treatment are still high.

SMARTT now runs an inert gas treatment followed by a two stage upgassing. The 1st stage runs with $N_2$-$H_2$ mixed gas only reaching about 90 % of the target hydrogen; during stage 2 a mix between $N_2$-$H_2$ and inert gas provides a defined hydrogen content in treatment gas and ends in an equilibrium between treatment gas, aluminum melt and atmosphere.

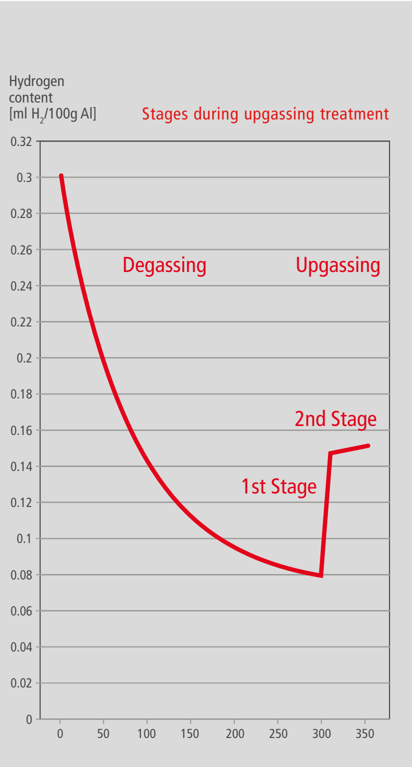


Diagram 5: Stages of an upgassing procedure

| | |
|---|---|
| ATL 1000 with 850 kg melt | 0,08 ml $H_2$ / 100 g Al target for degassing |
| AlSi7Mg | 0,15 ml $H_2$ / 100 g Al final target |
| 50 % relative humidity | 360 s minimum time |
| 25 °C outside temperature | 600 s maximum time |
| FDR 220 rotor | 45 s dwell time (2nd stage) |
| Standard optimization | 20 % hydrogen in $N_2$-$H_2$ mixed gas |

Table 3: Process parameters for SMARTT upgassing

| | | Rotor [rpm] | Inert gas [l/min] | $N_2$-$H_2$ [l/min] | Time [s] | Effective $H_2$ [%] |
|---|---|---|---|---|---|---|
| 720 °C | Degassing | 315 | 16 | 0 | 360 | 0 |
| | 1st Stage | 400 | 0 | 35 | 28 | 20 |
| | 2nd Stage | 400 | 26 | 9 | 45 | 5,3 |
| 740 °C | Degassing | 303 | 25 | 0 | 360 | 0 |
| | 1st Stage | 400 | 0 | 35 | 22 | 20 |
| | 2nd Stage | 400 | 28 | 7 | 45 | 3,8 |
| 760 °C | Degassing | 309 | 30 | 0 | 360 | 0 |
| | 1st Stage | 400 | 0 | 35 | 17 | 20 |
| | 2nd Stage | 400 | 30 | 5 | 45 | 2,8 |

Table 4: Treatment parameters for different temperatures for upgassing

Hydrogen transfer into melt becomes easier at higher temperatures which reduces 1st stage time. In this way 2nd stage is influenced as well; the effective hydrogen level in purge gas gets lower. This value is exactly the equilibrium between degassing the melt, hydrogen pickup at melt surface and upgassing by $N_2$-$H_2$ mixed gas. Under given conditions those parameters keep the final hydrogen content in the melt at constant level; a dwell time of 30 – 45 s is sufficient to get into that equilibrium.

The mass flow controller for inert gas and $N_2$-$H_2$ mixed gas blends the correct effective hydrogen content without operator involvement. The differences in effective hydrogen in purge gas and resulted treatment times illustrate the complexity of upgassing; it is obvious that a computer based simulation only can handle all variations in starting conditions (table 4).

The latest SMARTT version communicates with either an external temperature source or a handheld thermal couple. An external source can be a temperature reading that is already available from treatment crucible or ladle and sent by ethernet or analogue signal to the SMARTT software. Alternatively, the operator uses a handheld thermal couple which is connected directly to SMARTT and measures right before every rotary degassing; the reading is used for optimization.

A report system is part of the SMARTT software package. All treatment data are stored and available in Excel file format.

## Summary

SMARTT - innovative degassing control - offers a comfortable interface to program all necessary treatment steps, it reads or measures the starting conditions before every rotary degassing and predicts the best treatment parameters for different schemes. An integrated report system stores all data per treatment in Excel format and enables the melt shop manager to run further analysis on the process.

The use of SMARTT for degassing processes provides a melt on a constant hydrogen level independent from inconsistent starting conditions in a foundry. SMARTT enables the foundry to always reach this in a cost-effective way, there is no need for compensating these variations in overrunning the treatment which wastes time, inert gas and graphite consumables.

In upgassing – often used in wheel foundries – even small changes in environmental conditions or melt temperature have an enormous impact on the hydrogen content after the treatment. These complex relationships can only be managed by a mathematical model. SMARTT, based on the batch degasser software, is an intelligent solution to handle data for rotary degassing.

Find out
more about
our SMARTT
technology.

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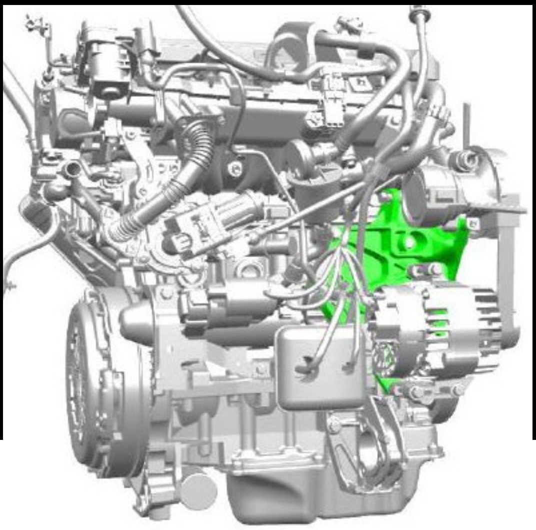
CASE STUDY

# ALTERNATOR AND POWER STEERING PUMP SUPPORT

NON FERROUS FOUNDRY
HPDC - MELT TREATMENT

# Stabilised and secured melt quality of weight reduction part through the use of SMARTT process control



KNOWLEDGE & PARTNERSHIP

## THE CHALLENGE

Sustainability and carbon emissions get more important for automotive industry. HPDC sector aims to reduce casting weight while maintaining mechanical properties. These studies cover many processes and metal quality is one of the most important topics. HPDC manufacturers need highly stable molten metal quality to achieve the high-quality requirements. Achieving stable molten metal quality is quite difficult because of many variable factors in the foundry and mainly factors that we couldn't influence like ambient condition.

### FOUNDRY:

Can Metal-HPDC is a company of the Yeşilova Holding Group and a leading manufacturer of high pressure die castings in Turkey, specialising in the automotive sector. Can Metal and has built a reputation for consistent quality, reliability and flexibility in serving the automotive industry. Their plant is equipped with a range of high pressure die casting machines, enabling efficient production of complex series and ensuring fast delivery of HPDC parts.

## PARAMETERS

**Alloy: AlSi9Cu3**
**Alloy weight: 1.9 kg / 1.2 kg**
**Alloy temperature: 710°C**
**Degassing time: 210 s**
**Flux amount: 240 g**

## FOSECO PRODUCTS

FDU MTS 1500
SMARTT process control
FDDR OX rotor / DSK OX shaft
COVERAL*2510 granular flux

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## OUR SOLUTION

SMARTT is a specially developed software for process control of aluminium degassing. It records and analyses all the initial variables and calculates the optimum parameters for each subsequent degassing and upgassing process. The aim of this optimisation is to achieve a consistent melt quality after each treatment, regardless of the initial conditions. SMARTT calculates the rotor speed and inert gas quantity and sends this data to the unit's control system at the start of treatment. Different optimisation modes (high-speed, low gas quantity, low wear, standard) offer the operator further options and work facilitation to achieve the required melt quality.

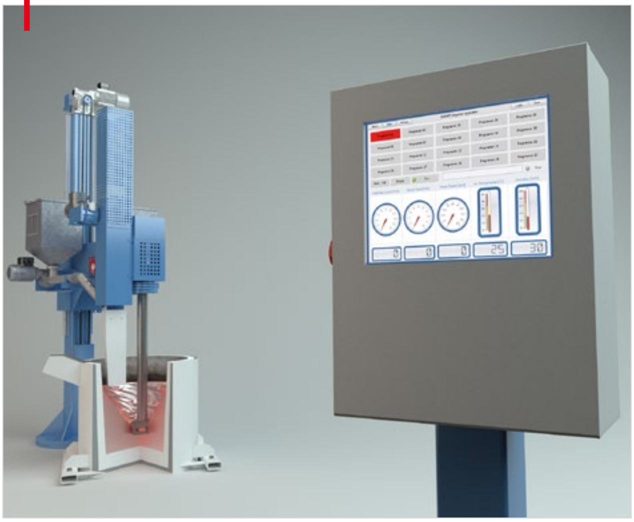
## KEY BENEFITS

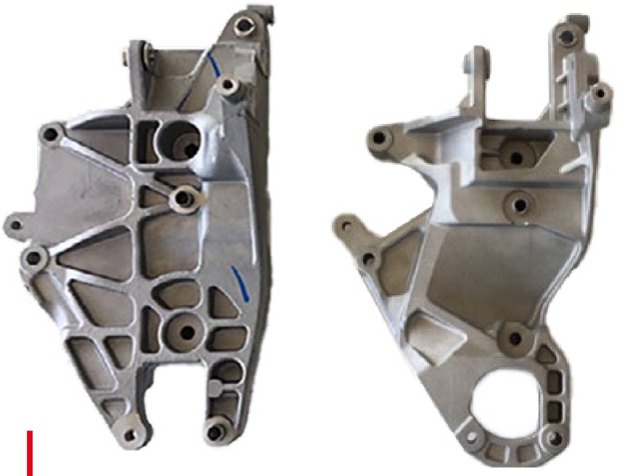
- **Recalculated specific parameters for each treatment**
- **High process reliability**
- **Decreased treatment times**
- **Lower oxide levels**

## THE OUTCOME

SMARTT and MTS technology integrated into the FDU unit ensured that molten aluminium was obtained with consistently stable quality. In this way, the sustainability of the mechanical properties of the weight-reduced cast parts is ensured.

SMARTT and MTS Technology for metal treatment





Original Part (Left) - Weight Reduced Part (Right)

CASE STUDY

# E-MOTOR HOUSING VW ID.3 / ID.4 / ID.5

NON FERROUS FOUNDRY
MELT TREATMENT

FOSECO

## Process stability and minimisation of rejects through the use of advanced metal treatment technology

KNOWLEDGE & PARTNERSHIP

## THE CHALLENGE

In order to achieve VW's high quality requirements and ambitious sustainability goals, high purity of the melt with high process reliability is required. In addition, tight density control, reduced environmental impact and labour savings were also key to the success of the project.

## PARAMETERS

**Alloy:** AlSi7Mg0,3
**Core production:** Cold-Box sand core
**Casting weight:** 7.5 kg
**Pouring temp.:** 740°C
**Casting time:** 12 s
**Moulding Process:** Gravity die casting

**FOUNDRY:**
The Volkswagen plant in Hannover is the headquarters of Volkswagen Commercial Vehicles, a division of Volkswagen AG.
The foundry mainly produces cylinder heads, intake manifolds and now also electric motor housings for the ID.3, ID.4 and ID.5.

## FOSECO PRODUCTS

FDU MTS 1500 degassing unit incl. rotors and shafts

SMARTT process control

NUCLEANT* 1582 grain refiner

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## OUR SOLUTION

SMARTT is a specially developed software for process control of aluminium degassing. It records and analyses all the initial variables and calculates the optimum parameters for each subsequent degassing and upgassing process. The aim of this optimisation is to achieve a consistent melt quality after each treatment, regardless of the initial conditions.

SMARTT calculates rotor speed and inert gas quantity and sends this data to the unit's control system at the start of treatment. Different optimisation modes (high-speed, low gas quantity, low wear, standard) offer the operator further options and work facilitation to achieve the required melt quality.

## KEY BENEFITS

- **Fully automatic process (oxide removal, grain refinement, upgassing)**
- **High process reliability**
- **Shorter treatment times; thus lower electricity and gas consumption**
- **Reduction of the reject rate by >10%**

> LET´S LEARN MORE

## THE OUTCOME

The combination of the MTS Melt Treatment Station with SMARTT degassing control and automated dosing of NUCLEANT 1582 grain refining fluxes delivered a 10% reduction in the scrap rate, thereby saving both labour and energy costs and reducing $CO_2$ emissions.

The automated melt treatment process delivered a consistent melt quality which adhered to the strict density tolerances required.

SMARTT process control for rotary degassing of molten aluminium

E-Motor housing

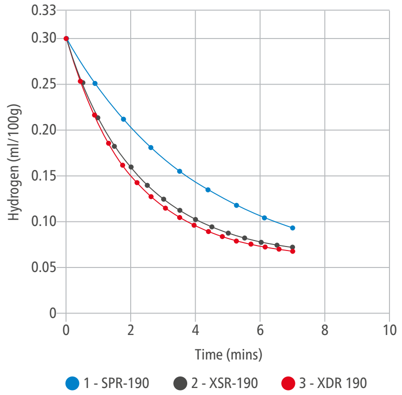
# HIGH PERFORMANCE ROTORS FOR OPTIMUM METAL TREATMENT

Improved performance and reduced costs

## XDR rotor

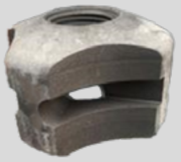
- + typically 250 - 400 rpm for degassing
- + typically 400 - 600 rpm for vortex
- + for all aluminium castings & applications
- + oxide removal using granular flux
- + available material: graphite
- + deeper rotors = stronger pumping and longer life (suitable for HPDC)

Stronger degassing power than XSR & SPR

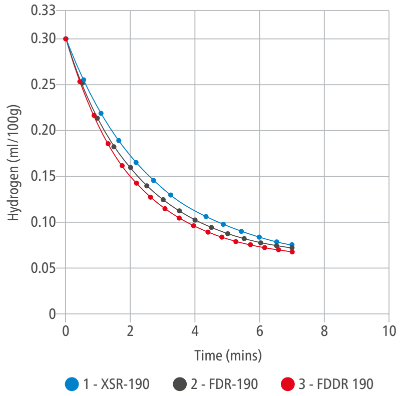


## FDDR rotor

- + typically 200 - 350 rpm for degassing
- + typically 350 - 550 rpm for vortex
- + for all aluminium castings & applications
- + oxide removal using granular flux
- + available material: graphite
- + deeper rotors = stronger pumping and longer life (suitable for HPDC)

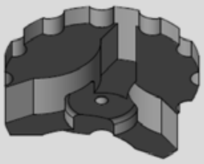


Stronger degassing than FDR & XSR

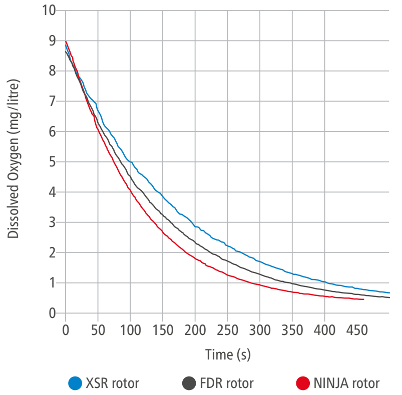


## DIAMANT NINJA rotor

- + typically 200 - 350 rpm for degassing
- + typically 350 - 550 rpm for vortex
- + for all aluminium castings & applications
- + oxide removal using granular flux
- + available material: DIAMANT ceramic
- + suitable for high-pressure die casting (HPDC)



Water modelling comparison of XSR - FDR - NINJA rotors



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ENERGY EFFICIENT

LONG LIFE

# ENHANCING CRUCIBLE PERFORMANCE IN NON-FERROUS APPLICATIONS

Author: Danièle Ung

Crucibles have an important role to play in improving the energy efficiency and environmental performance of non-ferrous casting operations. Recent technological advances have seen crucibles developed that increase thermal performance and improve the consistency and length of their operating life. Installation and operating practices are also critical to achieving consistent crucible performance however, and therefore careful attention to recommended procedures should be followed to ensure foundries get the most from their crucibles.

Figure 1: Foseco crucibles

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## INTRODUCTION

Crucibles have three overlapping functions within the non-ferrous foundry:

- Melting.
- Holding the melt at a specified temperature.
- Transferring the melt to the casting area.

These applications – and especially the first two – are particularly energy intensive functions. According to one estimate, melting and holding molten metal accounts for 60% of a typical foundry's energy consumption and 40% of its energy costs.[1] Improving the energy efficiency of these two processes thus carries significant advantages in terms of the cost and environmental footprint of casting production.

The job of improving a crucible's energy efficiency is not however an easy one, due in part to the competing demands posed by its role in melting and then in holding the molten metal at temperature. The first requires the crucible melt a defined quantity of alloy within a certain timeframe; any delay or decrease in performance can decrease the output and slow casting. Good heat conductivity through the crucible to the metal within is the major factor here. However, when holding that metal in molten form, the opposite is true.[2] Proper consideration of the thermo-mechanical properties of crucible design is thus essential.

In addition, crucibles should perform consistently, without excessive deterioration over time. This requires consideration of the materials and process used to manufacture the crucible, as well as the way in which they are handled. As one expert has noted, "customer practice across the industry is so variable that even correlating a furnace's efficiency to its own crucible becomes extremely difficult".[3] This reveals the importance of both proper training of operators and the application of best practices in the installation and handling of the crucible when it comes to achieving best performance.

Complicating the picture further still, crucibles are not a standard product, but are variable in size and capacity – including very large crucible sizes of more than 3 tonnes – as well as the metal being cast. This article will consider several technical innovations within the crucible space that have improved energy efficiency and operating life. It will conclude with a consideration of best practices in crucible care.

## TECHNICAL IMPROVEMENTS

Most crucibles for the non-ferrous casting sector are jiggered, rotationally moulded, or isostatically pressed from clay-bonded graphite or resin-bonded silicon carbide. These materials are suitable due to their refractoriness and their compatibility with non-ferrous alloys.

Technical improvements in the production of crucibles can however gain important benefits – e.g., improved energy efficiency, increased operating life, or improved resistance to oxidation. This includes:

- Adjusting the manufacturing process to improve physical properties such as density consistency and porosity .
- Adjusting the mix chemistry and material specifications to improve the mechanical strength, fracture toughness, thermal properties, or the electrical properties of the crucible, among others.
- Optimizing the external glaze or additional protective coating according to the needs of the foundry or application.

## IMPROVING ENERGY CONSUMPTION: ENERTEK* CRUCIBLES[4]

ENERTEK crucibles are a family of crucibles that are designed and manufactured to offer high thermal efficiency in both melting and holding furnace operations. The technology was originally developed for aluminium melting and holding applications, with a solution for zinc oxide production introduced in 2017 (ENERTEK ZnO, Fig 2) and more recently, a novel approach for aluminium transfer ladle applications (ENERTEK ATL).

Key benefits of the ENERTEK product line include:

- Reduced energy consumption during melting and holding due to:
  - The use of high-quality refractory materials, which are formulated to maximize thermal conductivity in any given casting application
  - Isostatic pressing in manufacture to maximize the density profile of the crucible.
- Minimal reduction in thermal conductivity over time due to refractories that are designed to withstand the effects of continuous use and aging.
- Maximized operating life and energy savings due to the proper balance in baseline thermal conductivity in conjunction with good refractory stability over time.
- Reduced carbon footprint due to improved energy efficiency and the resulting drop in energy consumption.

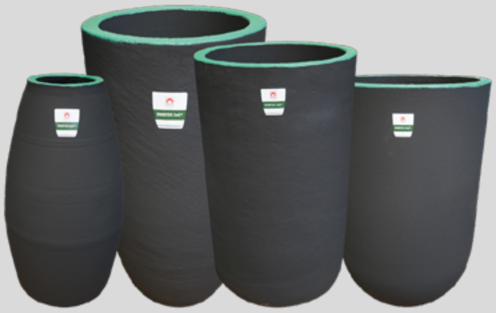

Figure 2: ENERTEK ZnO crucibles

In aluminium casting applications, standard ENERTEK crucibles can be applied to all standard designs of melting and holding furnaces; they are, however, particularly effective in electric resistance furnaces. Typical performance improvements over other crucible types include a 5 %-15 % energy saving and a significantly reduced temperature variation within the melt. In one example a foundry operating an electric resistance holding furnace with a target aluminium holding temperature of 677 °C observed a temperature delta of just 26 °C in the liquid metal with the ENERTEK crucible compared to a 42 deg° C variation with a conventional crucible over the same production period.

ENERTEK ZnO crucibles have been designed for use in the indirect or French process for zinc oxide manufacture, as well as the production of zinc dust. Temperatures here are significantly higher than in aluminium casting applications, reaching about 1000 °C in order to achieve vaporization of the zinc melt and consequently the energy demand in the process is significant and a major cost factor for the operation. ENERTEK ZnO crucibles are designed with high thermal conductivity and durability to ensure optimum thermal efficiency which in turn delivers energy savings by reducing the energy usage per tonne of zinc oxide output. Zinc oxide operations have also reported a higher zinc oxide output per shift due to the superior heat transfer of the ENERTEK ZnO crucibles.

ENERTEK ZnO crucibles are available in most standard shapes and capacities and can be fitted to the majority of crucible furnaces without any change to current practice.

In addition to the standard aluminium and zinc oxide ENERTEK solutions, the product line was updated in 2019 with the introduction of ENERTEK ISO crucibles for induction melting and continuous casting, and ENERTEK ATL for aluminium transfer.

ENERTEK ISO crucibles are insulating "duplex" crucibles that combine optimum physical properties, strength, and toughness with a highly insulating proprietary Vesuvius coating technology. A relatively thin layer (typically 12 mm ) of this proprietary coating significantly reduces thermal conductivity of a standard crucible from 25-30 W/mK to about < 2 W /mK.

The highly insulating nature of ENERTEK ISO crucibles delivers substantial performance benefits in induction furnace operations used for melting precious metals and in continuous copper production lines. Customers testing ENERTEK ISO crucibles in continuous copper wire production were able to reduce the furnace operating temperature "set point" by over 60 °deg C, with consequent benefits for crucible life due to reduced thermal stress. An increase in casting rates and reduced scrap levels have also been observed.

ENERTEK ATL crucibles offer an alternative technology for foundries using castable lined ladles or over-road hot charger transfer ladles for melt transfer. These crucibles also use the same proprietary Vesuvius insulating coating as ENERTEK ISO crucibles (Fig. 3) and provide several benefits in the transfer ladle application - notably reduced ladle preheat requirements – both on commissioning and daily use – as well as lowering melt temperature loss to 1.5 ° C per minute, compared to 2-3 °C per minute with standard refractory ladles. They also require very little maintenance or repair when in service, and deliver improved melt quality, lower oxide build-up, and no 'off-gas' during initial aluminium transfer cycles after installation.

Figure 3: ENERTEK ISO continuous casting crucible

## IMPROVING OPERATING LIFE: DURATEK* CRUCIBLES

Manufactured via a high-pressure isostatic pressing process, DURATEK crucibles are formulated to deliver longer operating life in harsh operating conditions. The range includes DURATEK PM and the recently developed DURATEK Supermelt crucibles.

DURATEK PM crucibles are resin-bonded silicon carbide crucibles, suitable for use with a wide range of alloys, including aluminium, copper, and precious metals. Benefits include:

- High density and strength.
- High thermal conductivity.
- Low porosity.
- Excellent resistance to chemical attack (e.g., from fluxing practices).
- Excellent oxidation resistance leading to long service life.

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With chemical attack and erosion a particular feature of the aggressive conditions found in induction furnace applications and precious metal reclamation, refining and casting processes, DURATEK PM crucibles offer consistent performance over a longer period, for fewer planned changeovers and reduced downtime.

For example, in Miller gold refining process, extremely challenging conditions are created by the passing of chlorine gas through the melt to remove impurities. Both chorine gas and the chlorides created its reaction with impurities in the liquid metal are reactive at high temperatures with most crucible materials. However, this is not the case with DURATEK PM, which is formulated and processed to resist this harsh chemistry.

Meanwhile, in the Wohlwill process for gold refining, where high-purity gold cathodes are melted in an induction furnace to produce very pure ingots, the stability of DURATEK PM crucibles at very high temperatures – as well as their resistance to erosion and corrosion – means they do not require the usual wash-melts to achieve the finest quality gold.

DURATEK Supermelt has been developed specifically to provide aluminium melting departments with the possibility to maximize melting and holding capacity and reduce furnace downtime. The optimized chemistry of DURATEK Supermelt crucibles delivers superior critical mechanical properties - with increased fracture toughness and strength at high operating temperatures, and excellent resistance to oxidation.

For example, at Mahle, a Polish piston manufacturer, the foundry melts aluminium piston scrap on an almost-continuous basis. Before the introduction of DURATEK Supermelt, standard crucibles achieved 740 cycles on average. Following implementation, the DURATEK Supermelt crucible achieved 1284 cycles – an increase of more than 70%.  During the period of crucible operation the crucible experienced noticeably lower oxidation (Fig. 5) , thereby reducing the risk of oxidation inclusions.


Figure 4: Mahle and Foseco Teams after the unloading of the trial crucible.

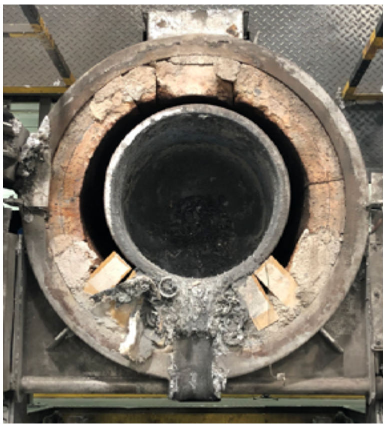
Figure 5: The DURATEK Supermelt after 1284 melt charges.

## CRUCIBLE CARE: BEST PRACTICES TO IMPROVE SAFETY AND SERVICE LIFE

In addition to the technical improvements discussed above, how the crucible is installed and operated all influence the operating life of a crucible. Best practices include:

- Inspection of the crucible upon receipt.
- Storage in a dry location.
- Proper handling of the crucible using a hand cart. Crucibles should not be rolled or shimmied.
- Using the correct stand, which should be made of the same material and be of the right size.
- Never wedging a crucible: let is expand and contract.
- Avoiding top smothering:
  - The furnace cover or lid should not rest on the crucible wall.
  - In electric resistance furnaces, the fibre blanket should not be compressed on top of the crucible.

- Maintenance of the furnace lining to keep it in good condition and in as concentric a position as possible. This prevents flame deflection or impingement in flame-fired furnaces, and will ensure proper melting in induction furnaces.
- Careful charging of the crucible to optimize capacity and avoid damage to the crucible.
- Using a slightly oxidizing flame, which should not directly contact the crucible. To ensure this, the centre line of the burner should be at the juncture of the crucible and the base block.
- Using properly fitting shanks that support the crucible bottom at all times.
- Correct use of fluxes as per the manufacturer’s instructions, which should be added to molten metal when possible.
- Keeping the crucible clean by removing the dross carefully when the crucible is hot.

## CONCLUSION

Solutions to improve the energy efficiency of the metal casting process are a win-win for foundries, as they simultaneously reduce costs and carbon emissions: two of the most pressing challenges currently facing the industry. Foundries that use less energy through lower operating temperatures and enhanced heat retention also experience fewer temperature fluctuations in the process, which ultimately results in fewer casting defects – another major win.

Crucibles have a crucial role to play in tackling these challenges. Recently technical improvements are enhancing both thermal behaviour and physical endurance. However, operating practices are also a significant factor. It is thus beneficial to work with a partner who understands not only the technology but can also guide foundries in the best practices of installation, operation, and maintenance.

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[1] K. Salonitis, B. Zeng, H.A. Mehrabi, M. Jolly, 'The challenges of energy efficiency casting processes', Procedia CIRP 40 (2016), pp. 24-29 (p.28).

[2] B. Pinto and W. Shi, 'Thermally-efficiency crucible technology: fundamentals, modelling, and applications for energy savings', Foundry Practice Issue 266, pp. 03-12 (p. 2).

[3] Ibid, p. 2.

[4] For more on ENERTEK crucibles see: Energy efficiency considerations for aluminium and zinc crucibles, Foseco whitepaper (2021), p. 5.

### ABOUT THE AUTHOR

Danièle Ung is with Foseco since 2020 as European Product Manager Crucibles for the Non-Ferrous market.
She enjoys travelling, discovering new cultures and gastronomy and is currently challenging herself to running a marathon.

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**DANIÈLE UNG**
European Product Manager
Crucibles

## ANIMATION

Experience energy-efficient performance with ENERTEK ISO and unmatched durability with DURATEK Supermelt.
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**ENERTEK ISO**

**DURATEK Supermelt**

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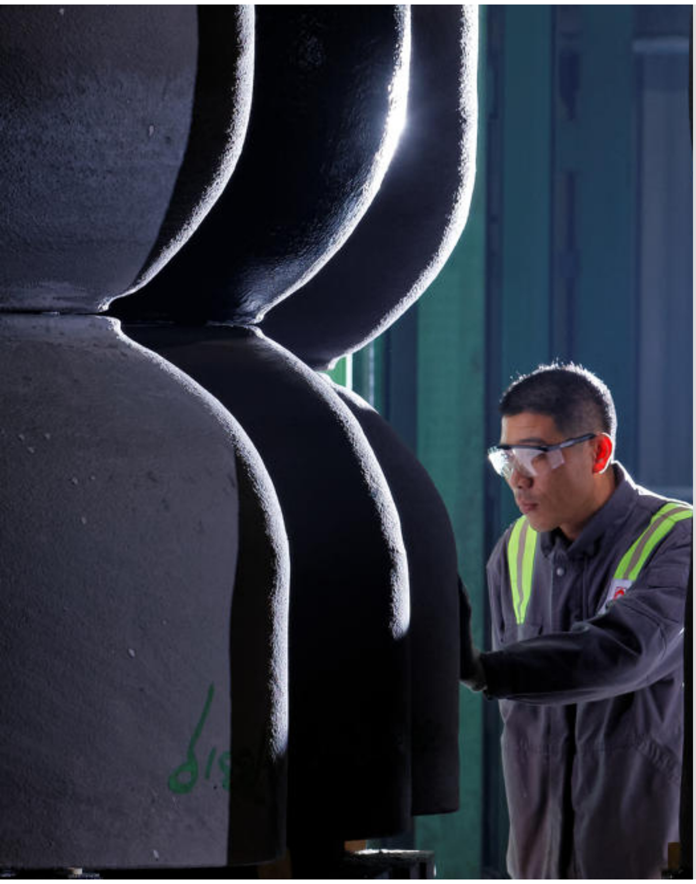

# ENERGY EFFICIENCY CONSIDERATIONS FOR ALUMINIUM AND ZINC CRUCIBLES

**Improving the energy efficiency of foundry operations reduces both energy costs and carbon emissions. It's a vital win-win for foundries under pressure to reduce their environmental impact, while staying cost competitive. Foundries should therefore consider switching to energy-efficiency crucibles, such as the ENERTEK crucible range from Foseco, even if this means challenging traditional price-based purchasing decision-making.**

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WHITE PAPER

**Energy efficiency considerations for aluminium and zinc crucibles**

10/2021

Non Ferrous Foundries

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# INNOVATIVE WASCO* WATER-SOLUBLE BINDER SYSTEMS FOR HPDC APPLICATIONS

Authors: Vincent Haanappel,
Thomas Linke

For HPDC applications, Foseco developed a new type of sand core using innovative WASCO water-soluble binder systems and optionally with adaptable coatings to avoid liquid metal penetration into the pores of the sand core.

This paper focuses first on some fundamental aspects on the development of such a water-soluble binder system, followed by 2 practical examples, one producing cores for explosion-proof instrument housings, and the other manufacturing sand cores for automotive applications. Irrespective of the high flexural strength of the sand cores, after the casting process the complete casting was immersed in cold water after which the binder showed excellent water-solubility. Due to the short cycle times resulting in a relatively low thermal impact, no issues occurred with the generation of volatile organic compounds (VOC's) as the organic binder thermally decomposes.

After washing-out core residue, a smooth, defect-free and sand-free casting surface was obtained, indicating that the sand cores with the WASCO water-soluble binder can be a promising candidate for structural castings.

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*WASCO is a trademark of the Vesuvius Group, registered in certain countries, used under licence.

## INTRODUCTION

In most casting processes, the molten metal is poured in a pre-formed mould, with the metal filling of the mould under gravity or low pressures resulting in the need for slightly higher metal temperatures to ensure a complete casting fill. When applicable the internal cavities needed in the castings are commonly defined by the use of disposable cores, which is typically an inorganic or organic resin-bonded sand core. Advantage of such a system is that due to the heat from the molten metal, the resin binder in the core starts to degrade resulting in an easy shaking out of the core residue. In die casting processes, such as Semi-Solid Casting [1-4] or High Pressure Die Casting (HPDC) [5-10], the metal is cooled very quickly, so the core itself will not be exposed anymore to high temperatures. Combined with the high core strengths needed to withstand these filling pressures, this results in difficulties to remove the sand core after the casting has solidified. Furthermore, the core will only be exposed for a short time to elevated temperatures up to 300 – 400 °C, which is insufficient to thermally decompose the binder.

This paper is focusing on the development of cores suitable for HPDC, consisting of a liquid polymer binder and a powder-like solid consisting of (various) minerals. This new and innovative WASCO water-soluble binder system is developed by Foseco.

Achieving high quality castings with the use of cores including the WASCO water-soluble binder system depends not only on the casting process itself and their processing parameters, but also on the quality of these cores. Use of cores with insufficient strength or with locally low compaction results in lower surface smoothness and can result in defects of the casting surface if not properly controlled. The main requirements to achieve high quality castings (from HPDC, Semi-solid processes) and received from the foundry industry are:

- High strength values
- Sufficient water solubility after the casting process
- No gas formation during the casting process
- Use of cost-effective and non-dangerous materials
- Easy to handle and able to be to mixed with various types of sand
- Sufficient bench life of the sand mixture
- Good flowability of the sand mixture
- High quality cores with sufficient compaction and surface smoothness
- Short cycle times = short core production times

Some fundamentals are highlighted on the manufacturing of cores based on sand and optionally with the presence of a coating. In more detail, flowability of the sand mixture, mechanical strength, surface smoothness, water solubility of the binder, and first casting results from HPDC processes will be presented.

## EXPERIMENTAL AND RESULTS

First step in the optimization of sand cores for HPDC applications was based on a 2-component liquid binder system and one additive. In this part, the ratio between both components were tested on flowability of the sand mixture, flexural strength and water solubility of non-treated sand cores and those treated for 2 hours at 140 °C and 200 °C (Table 1). These testing conditions were chosen to find out the optimum ratio for best performance on strength and water solubility.

Using the Powder Flow Tester Brookfield [11], the flowability of the various batches was determined and listed in Table 2. It was clear that the higher the contribution of component D, the higher the flowability; corresponding with the lowest consolidation stress.

Flexural strength was measured using standard-type transverse bars with dimensions of 22.4 x 22.4 x 180 mm. The flexure test (three-point measurement) measures the bending behavior of material subjected to simple beam loading. The flexural strength as a function of a 2-component liquid binder consisting of a liquid LB_A and a liquid LB_D is determined. The total addition rate of the liquid is kept constant at 5.0 wt%. Regarding the additive, a concentration of 2.0 wt% was chosen. All samples were manufactured with quartz sand H33 (Quarzwerke, Germany).

| Composition: | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 2-C Liquid Binder | 5.0 wt% | 5.0 wt% | 5.0 wt% | 5.0 wt% | 5.0 wt% | 5.0 wt% |
| Comp. D (wt%) | 0 | 20 | 40 | 60 | 80 | 100 |
| Comp. A (wt%) | 100 | 80 | 60 | 40 | 20 | 0 |
| Additive | 2.0 wt% | 2.0 wt% | 2.0 wt% | 2.0 wt% | 2.0 wt% | 2.0 wt% |
| Heat treatment – 0 | None | None | None | None | None | None |
| Heat treatment – 1 | 2h/140°C | 2h/140°C | 2h/140°C | 2h/140°C | 2h/140°C | 2h/140°C |
| Heat treatment – 2 | 2h/200°C | 2h/200°C | 2h/200°C | 2h/200°C | 2h/200°C | 2h/200°C |

Table 1: Composition of various batches with a 2-component liquid binder.

| Composition: | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 2-C Liquid Binder | 5.0 wt% | 5.0 wt% | 5.0 wt% | 5.0 wt% | 5.0 wt% | 5.0 wt% |
| Comp. D (wt%) | 0 | 20 | 40 | 60 | 80 | 100 |
| Comp. A (wt%) | 100 | 80 | 60 | 40 | 20 | 0 |
| Additive | 2.0 wt% | 2.0 wt% | 2.0 wt% | 2.0 wt% | 2.0 wt% | 2.0 wt% |
| Flowability - Consolidation stress (kPa) as function of the compressive strength | | | | | | |
| 0.60 kPa | 0.45 | 0.39 | 0.38 | 0.42 | 0.42 | 0.40 |
| 1.13 kPa | 0.63 | 0.58 | 0.56 | 0.56 | 0.57 | 0.56 |
| 2.19 kPa | 0.84 | 0.80 | 0.73 | 0.71 | 0.72 | 0.72 |
| 4.35 kPa | 1.11 | 1.02 | 0.92 | 0.86 | 0.87 | 0.89 |
| 8.70 kPa | 1.37 | 1.33 | 1.14 | 1.03 | 1.06 | 1.08 |

Table 2: Flowability (consolidation stress as a function of the compressive strength) of various sand mixtures with a 2-component liquid binder and as a function of the LB_A / LB_D ratio.

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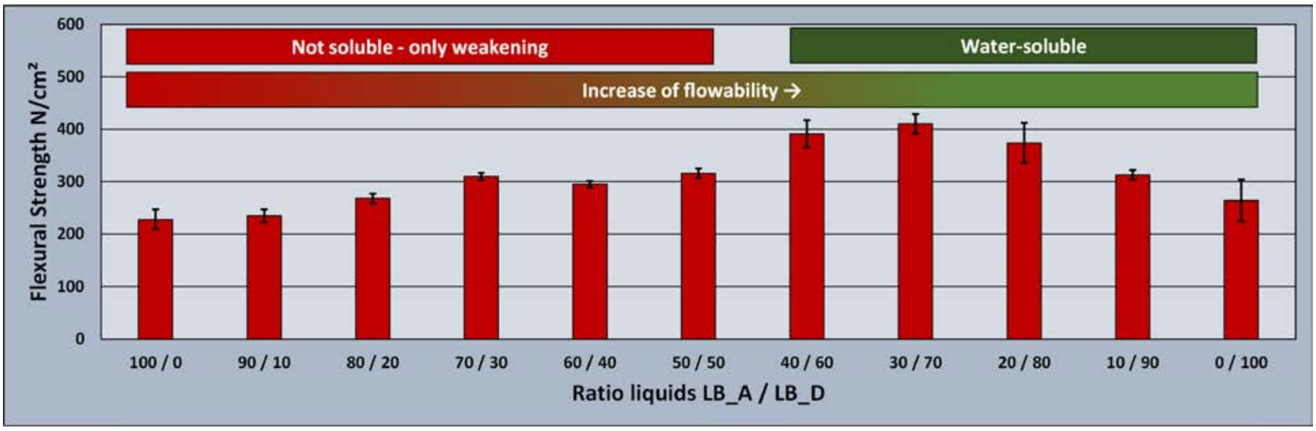

Figure 1: Flexural strength of sand cores (quartz sand H33) as a function of the type of liquid binder with various ratio's LB_A / LB_D.

From Figure 1 it is obvious that the flexural strength showed a maximum for the ratio 30 / 70, thus with 30 wt% LB_A and 70 wt% LB_D. Considering the potential applications of such types of sand cores, these cores should also meet other requirements, in particular water-solubility.

Solubility of the binder was determined by immersing cylinder-type cores in cold (20 °C) or hot (65 °C) tap water and with a rotation speed of 60 rpm (in cold water) and 150 rpm (in hot water); the first one related to moderate conditions and the other to more severe conditions. The outcome of the immersion test is shown in Table 3.

| Composition: | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 2-C Liquid Binder | 5.0 wt% | 5.0 wt% | 5.0 wt% | 5.0 wt% | 5.0 wt% | 5.0 wt% |
| Comp. D (wt%) | 0 | 20 | 40 | 60 | 80 | 100 |
| Comp. A (wt%) | 100 | 80 | 60 | 40 | 20 | 0 |
| Additive | 2.0 wt% | 2.0 wt% | 2.0 wt% | 2.0 wt% | 2.0 wt% | 2.0 wt% |
| Water-solubility | | | | | | |
| As-received | 5 – 10 s | 5 – 10 s | 5 – 10 s | 10 – 15 s | 20 – 25 s | 20 – 30 s |
| 2 h / 140 °C | 20 – 30 s | 10 – 15 s | 15 – 25 s | 5 – 10 s | 20 – 30 s | 20 – 25 s |
| 2 h / 200 °C | weakening | weakening | weakening | 50 – 60 s | 30 – 40 s | 30 – 40 s |

Table 3: Water solubility of various sand cores with a 2-component liquid binder and as a function of the LB_A / LB_D ratio and without or with a heat treatment.

Interesting to observe is that the as-received samples with the highest contribution of component A showed fast solubility, whereas those with a higher concentration of component D showed a slightly slower solubility rate. After the cores were exposed to heat for 2 h at 200 °C, those with a relatively high contribution of component A were not soluble, only weakening of the sand cores occurred. Since the application of these sand cores will be exposed to elevated temperatures during casting and cooling, those with the highest addition rate of component D is recommended.

In case of using these formulations for sand cores for HPDC high flexural strength is needed, this to avoid core breakage during the casting process. Figure 2 shows the flexural strength as a function of the grain size of the additive and the concentration. In case of an addition rate of 2.0 wt%, highest flexural strength was achieved with a grain size of 12 µm. This strength decreased to lower values with an increase of the grain size from 41 µm, 100 µm to 146 µm. From this figure it is clear that the smaller the average grain size of additive as well as the higher the addition rate, the higher the flexural strength of the sand cores. During HPDC process the liquid metal is fed under high pressure into the die and solidified to obtain the desired component. This process takes place in a fraction of seconds. The general description is that cores with 1000 N/cm² or higher are targeted [6-10].

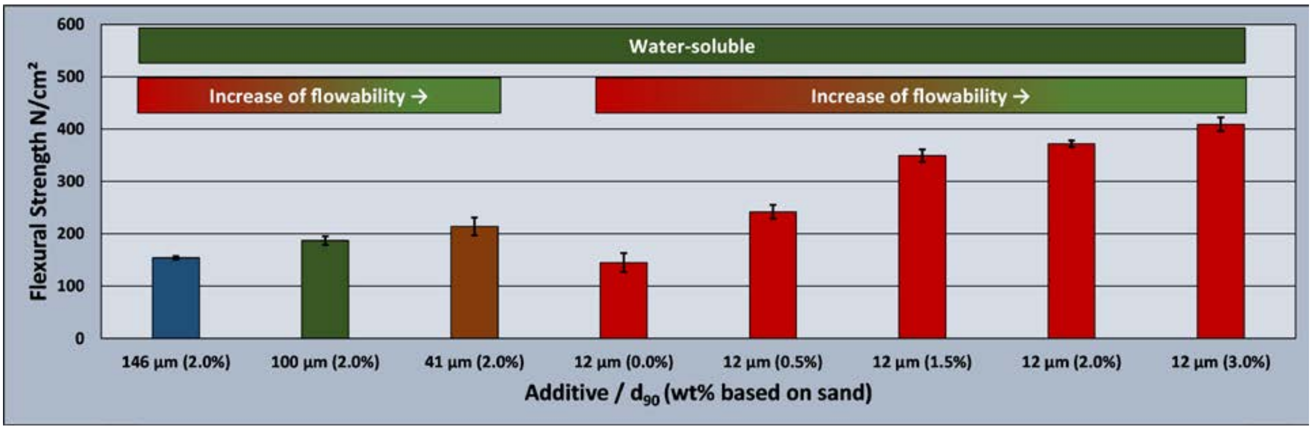

Figure 2: Flexural strength of sand cores (quartz sand H33) as a function of the grain size of the additive. The LB_A / LB_D ratio was set at 30 / 70 (5.0 wt%) and the additive concentration at 2.0 wt%.

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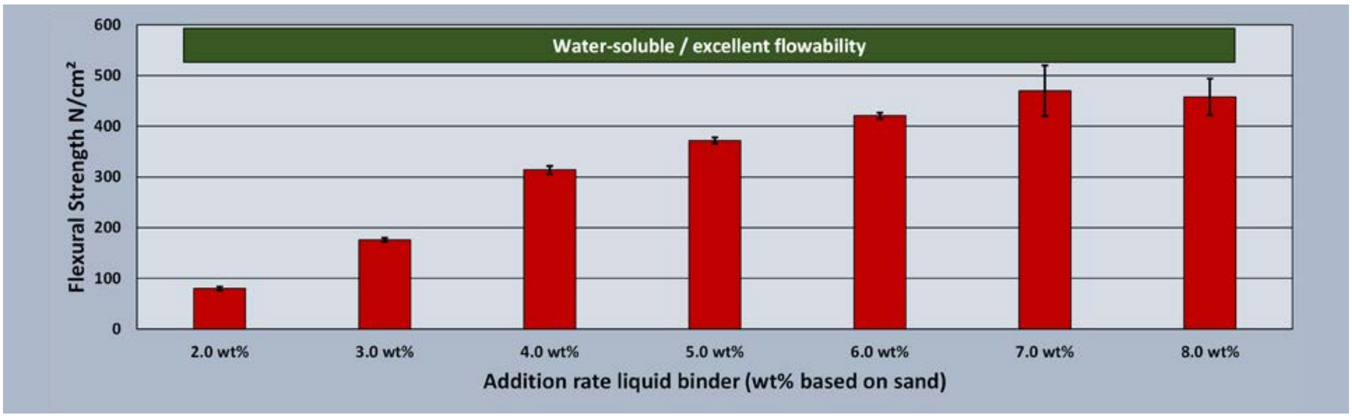

Figure 3: Flexural strength of sand cores (quartz sand H33) as a function of the addition rate of the liquid binder. the LB_A / LB_D ratio was set at 30 / 70 and the additive concentration at 2.0 wt%.

To improve further the mechanical properties, the flexural strength as a function of the addition rate of the liquid binder was investigated. Figure 3 shows the data of the flexural strength and in relation to the amount of liquid binder added to the sand mixture. In this case the concentration of the additive was set at 2.0 wt%. Interesting to observe is that the strength values increased with a higher addition rate of the liquid binder up to 7.0 wt%. More binder did not result anymore in higher strength values, this due to a certain over-saturation. This means that the highest flexural strength values were achieved with a combination of the individual liquids LB_A and LB_D and with an addition rate of 7.0 wt%.

Higher flexural strength values will now only be achieved when more attention is paid on the type and concentration of the additive(s). Since the usage of the additive resulted in flexural strength values up to about 500 N/cm², different types of other minerals or components were considered too.

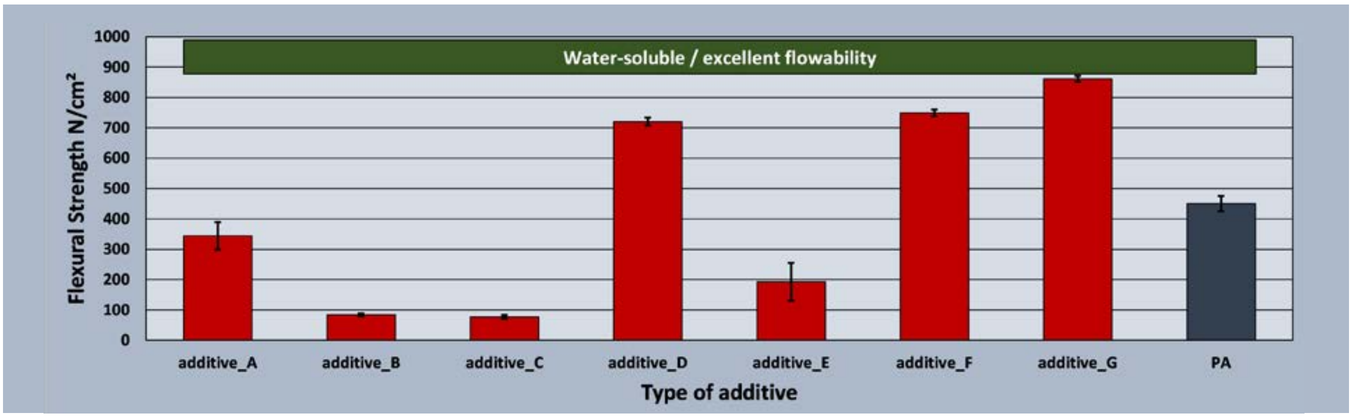

Figure 4: Flexural strength of sand cores (quartz sand H33) as a function of the type of additive. The liquid binder LB_A / LB_D ratio was set at 30 / 70 and at 4.0 wt% and the additive concentration was 4.0 wt%.

It is well-known [12,13] that in case of inorganic binder systems, other types of additives can achieve high strength values. Based on these documents, a selection was made of certain types of additives indicated as A – G. Figure 4 shows the flexural strength as a function of these various types of additives. Based on these values, also another type of additive was chosen indicated as type S. With this additive strength values could be achieved up to values higher than 1200 N/cm², as shown in Figure 5.

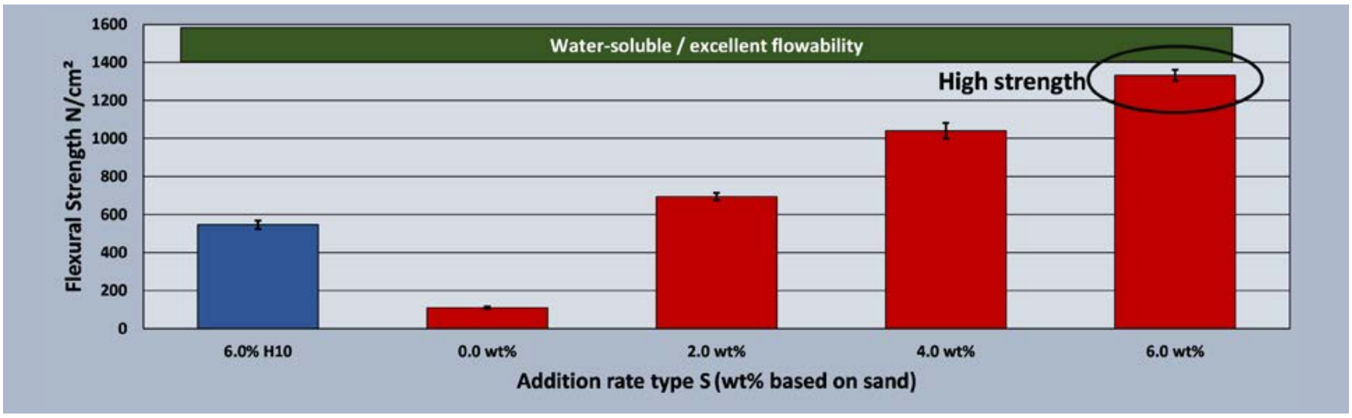

Figure 5: Flexural strength of sand cores (quartz sand H33) as a function of the addition rate of the additive S. The liquid binder (6.0 wt%) LB_A / LB_D ratio was set at 30 / 70.

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Since this type of additive, here type S showed very promising results, also flowability of the modified sand mixture has to be determined again. More information about measuring and improving flowability of sand mixtures can be found in reference [14].

The fastest indirect method to obtain information about flowability of the sand mixtures is related to the core or sample weight after curing. In relation to Figure 5, showing the bending strength values as a function of the addition rate of type S, Figure 6 shows the corresponding sample weight as a function of the amount of type S added to the sand mixture. In case no additive was added, the sample weight was about 670 g (5 samples), but with an increase of the amount of the additive, the sample weight also increased up to values of around 740 g (with 6.0 wt%). Worth to mention is that the additive particles are completely spherical which induced higher flowability of the sand mixture. On the contrary, irregular shaped particles resulted generally in lower flowability. The type of sand can also be a parameter to affect flowability. The most important structural parameters influencing the flowability of the sand mixture are the average grain size and grain size distribution and the shape (angular or well-rounded and with low sphericity or high sphericity). Foundries generally will use the sand that is available from a local quarry near the production site, this to reduce transport costs. This means that flexibility in the type of sand is very limited which means that the type is generally a given parameter hardly to be replaced by another type of sand.

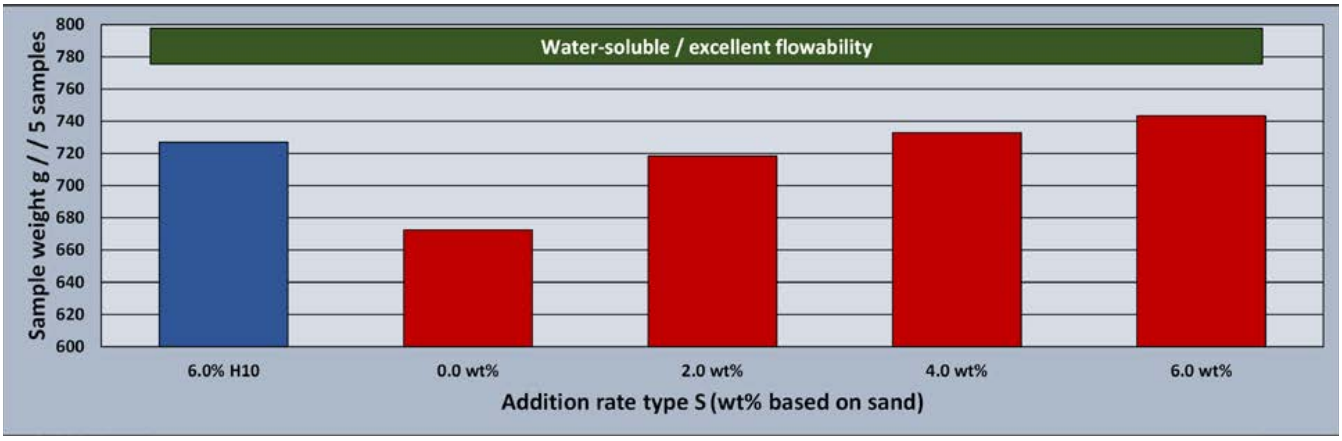

Figure 6: Sample weight of sand cores (quartz sand H33) as a function of the addition rate of the additive S. The liquid binder (6.0 wt%) LB_A / LB_D ratio was set at 30 / 70.

One main component of a sand mixture with a water-soluble binder system is the liquid part of the binder. As already reported, this liquid binder is a 2-component polymer system based on one liquid type LB_A and one on type LB_D and with addition of a small amount of water and with a special type of surface-active agent. In case the viscosity of the liquid binder is high, it will have a detrimental impact on flowability and therefore on the quality of the sand cores. With a water-based polymer solution, a lower viscosity can be achieved in case the chain length of the polymer is shorter, thus with a lower n-value. The viscosity of a polymer can be expressed by the Mark-Houwink equation:

$$\boldsymbol{\eta = K.M\alpha}$$

whereas $\eta$ = viscosity of the polymer, K and $\alpha$ depend on the specific polymer, and M = molecular weight.

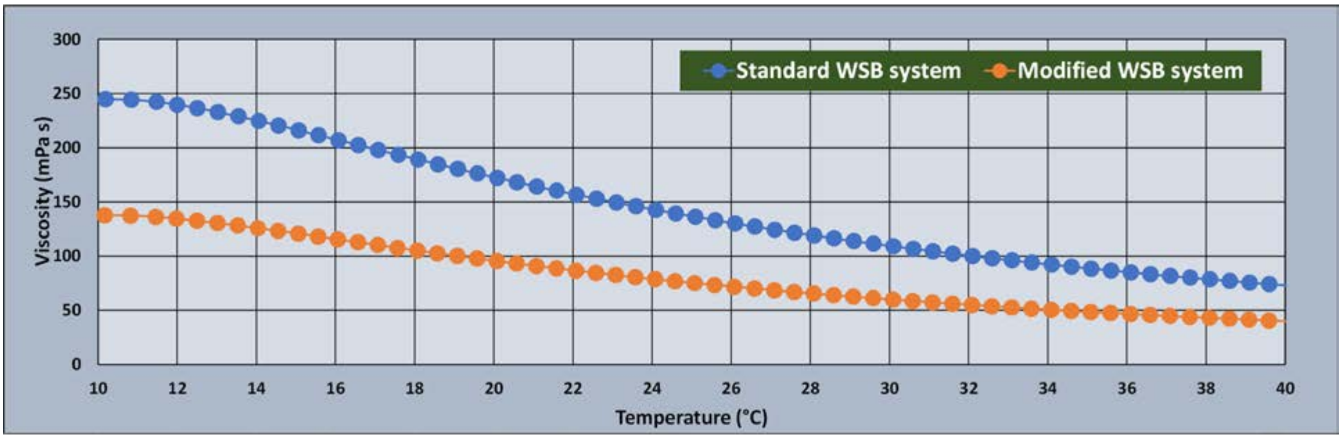

Figure 7: Viscosity of the standard WASCO system (blue) and the modified WASCO system (orange) as a function of the temperature.

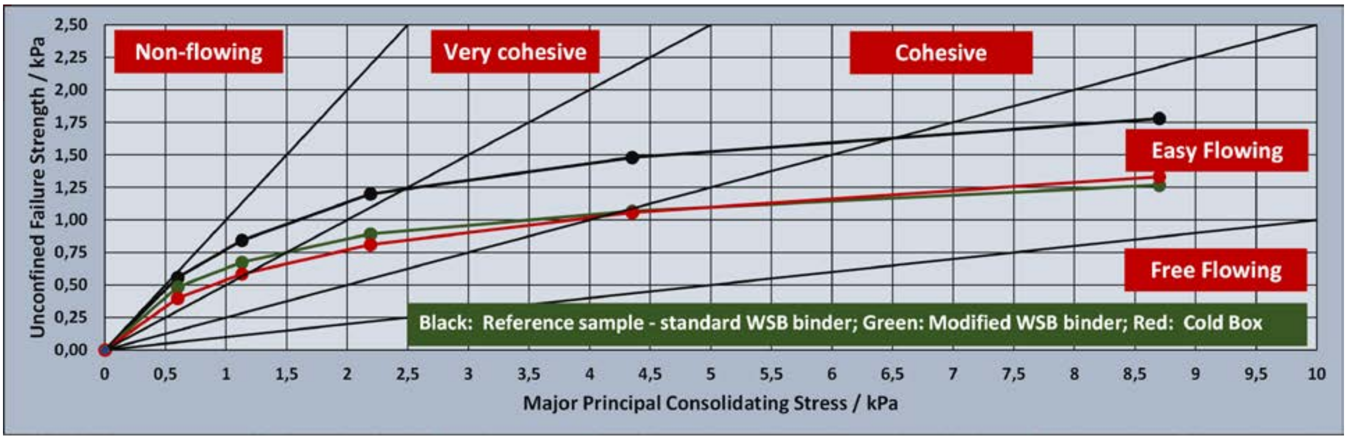

Figure 8: Unconfined failure strength versus major principal consolidating stress for three various sand mixtures: black: standard-type of the WASCO water-soluble binder system; green: modified WASCO water-soluble binder system with shorter chain length; red: PU cold box system.

2 types of the WASCO water-soluble binders were considered, one the standard-type and the other with a shorter chain length of the polymer. The viscosity of both WASCO water-soluble binder systems was measured between 10 °C and 40 °C and results are depicted in Figure 7. From this plot, it can be concluded that between the above given temperature range, the viscosity of the modified WASCO water-soluble binder system is always significantly lower than that of the standard WASCO water-soluble binder system. Figure 8 shows the flowability curves, one corresponds with the reference sample prepared with the standard-type of organic-based water-soluble binder system (black curve), the second one with the modified organic binder including a shorter chain length (green curve), and the third with the standard cold box system. Clear is that the flowability of the sand mixture with the modified organic-based water-soluble binder is significantly higher.

The influence of the modified WASCO water-soluble binder system was further investigated with a series of core manufacturing, in this case transverse bars. The shooting parameters with the L1 Laempe core shooter were 4 bar shooting pressure and 0.4 s shooting time. The prepared sand mixture was first stored under various temperatures, here between 10 °C and 25 °C and with steps of 5 °C. Results from these tests are visualized in Figure 9. With the standard WASCO water-soluble binder system and under relatively cold conditions, no complete sand cores could be produced. Due to the high viscosity of the liquid binder, in particular at 10 °C and 15 °C, flowability is too low to completely fill the cavities of the core box. Only at higher temperatures, here 20 °C or 25 °C, complete cores could be produced. In case of the modified WASCO water-soluble binder system, characterized by a significantly lower viscosity, even at 10 °C, complete sand cores could be produced, even at the lowest test temperature. Generally, a lower viscosity will result in defect-free sand cores with high compaction.

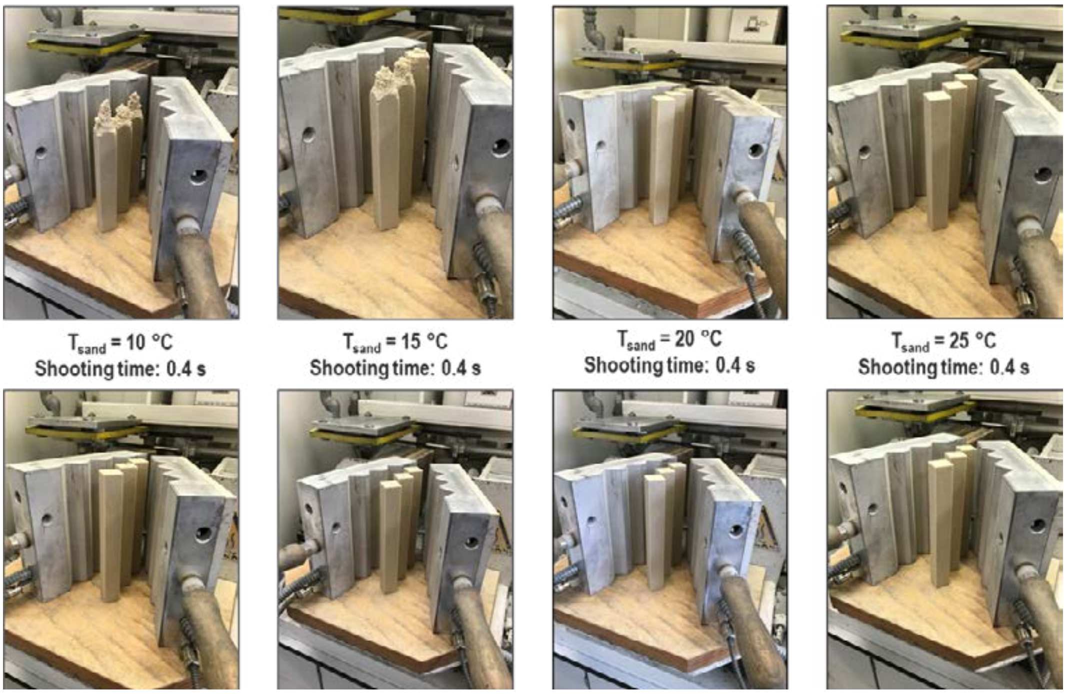

Figure 9:
Core manufacturing (transverse bars) with the standard-type WASCO water-soluble binder system (upper pictures) and with the modified WASCO water-soluble binder system (bottom pictures). In all cases, the shooting time was set at 0.4 s. The addition rate of the liquid binder was set at 6.0 wt% and of the additive at 4.0 wt%.

# TESTING TRIALS-ON-SITE I

This chapter is dealing with a project aiming to manufacture explosion-proof instrument housings. Figure 10 shows a schematic view of this housings with the designed sand core. First step in this was to start with a non-coated or unsealed sand core, this to investigate in more detail the surface quality of the castings.

After the casting process all castings were immersed in cold water. Within a very short time, all sand cores could easily be removed due to the high solubility of the binder.

Figure 11 shows the inner surface of the casting in case a non-coated sand core was used. The surface shows high roughness with severe sand adhesion, this due to metal penetration into the pores of the sand core. Even with a Kärcher pressure washer, the adhered sand grains could not be removed.

To avoid metal penetration finally resulting in severe sand adhesion, a special type of waterborne coating was developed. Such a coating could be applied by the dipping process, followed by furnace drying at 120 °C. Figure 12 shows 3 sand cores with the waterborne coating, after dipping and after furnace drying at 120 °C for 1 h.

With the application of a coating to avoid metal penetration a smooth and sand-free casting surface was achieved. Figure 13 shows the final product fulfilling the following main requirements: good flowability of the sand mixture resulting in defect-free sand cores, high mechanical strength, easy to apply a waterborne coating, fast solubility of the binder after the casting process, smooth and sand-free casting surface.

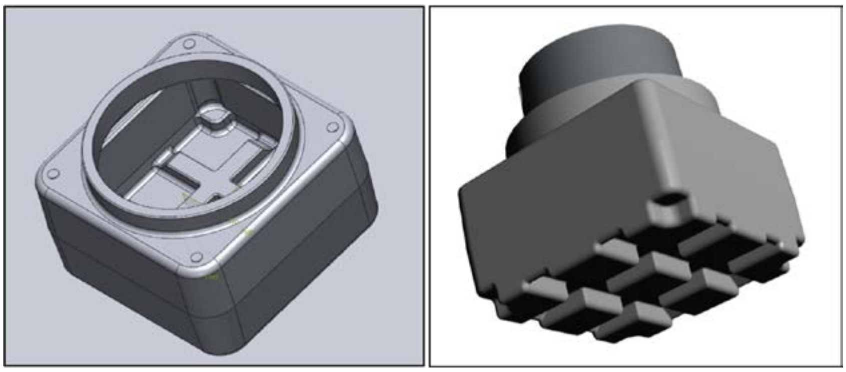

Figure 10: left: schematic view of an explosion-proof instrument housings; right: drawing of the developed core (courtesy Limatherm S.A. Poland)

Figure 11: Left: non-coated sand core; middle and right: inner casting surface with significant sand adhesion.

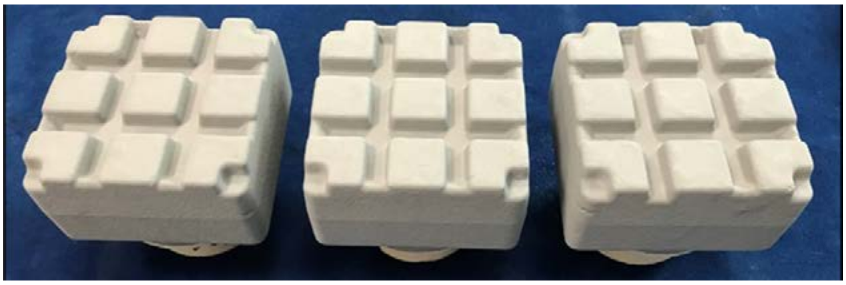

Figure 12: Sand cores with a coating applied by dipping. The coating was furnace dried at 120 °C for 1 h.

Figure 13: Inner surface of the casting (explosion-proof instrument housing) after removing the coated sand core (courtesy Limatherm S.A. Poland).

# TESTING TRIALS-ON-SITE II

The second series of sand cores manufactured with the WASCO water-soluble binder system is dealing with an example of potential automotive applications for HPDC. In particular the production of light-weight hollow parts is key in this project.

As already mentioned, the presence of a coating is needed, this to avoid metal penetration and sand adhesion. Sand cores could be dipped or the coating could be applied by spraying. In both cases, a dense and compact coating layer was applied (see Figure 14). After solidification, the castings were ejected from the mould and directly immersed in a water bath. All castings were collected followed by a further cleaning of the inner surface.

After cross sectioning the castings, it was obvious that the use of sand cores without a coating resulted in severe sand adhesion, as can be observed from Figure 15.

With the presence of a coating, no sand adhesion occurred and the inner casting surface showed an acceptable surface quality (see Figure 16).

In some specific complex regions of the core surface, a secondary process using a Kärcher pressure jet wash enabled a completely sand-free casting surface.

Figure 16 shows the casting on the left and on the right part of the inner surface.

Surface roughness of both casting pieces, non-coated and coated, was also determined by a 3D image of the surface, measured with the Keyence surface profilometer (Figure 17). Clear is the high smoothness of the surface in case a coated sand core was used.

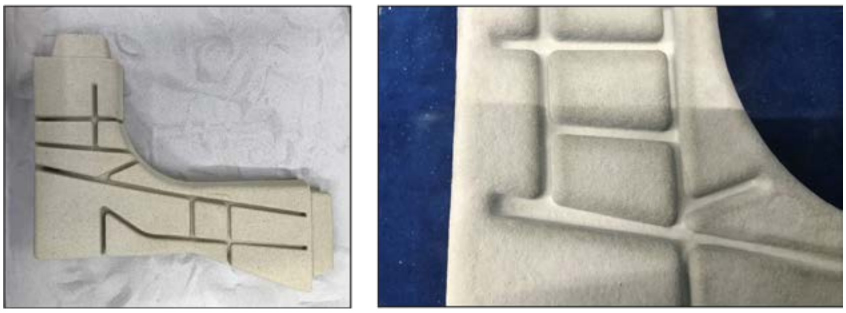

Figure 14: Left: uncoated sand core; Right: higher magnification of the surface with an applied water-borne coating

Figure 15: Inner casting surface after cross sectioning of the castings. Left: after removing a non-coated sand core; right: after removing a coated sand core

Figure 16: Sand cores with a coating applied by dipping. The coating was furnace dried at 120 °C for 1 h.

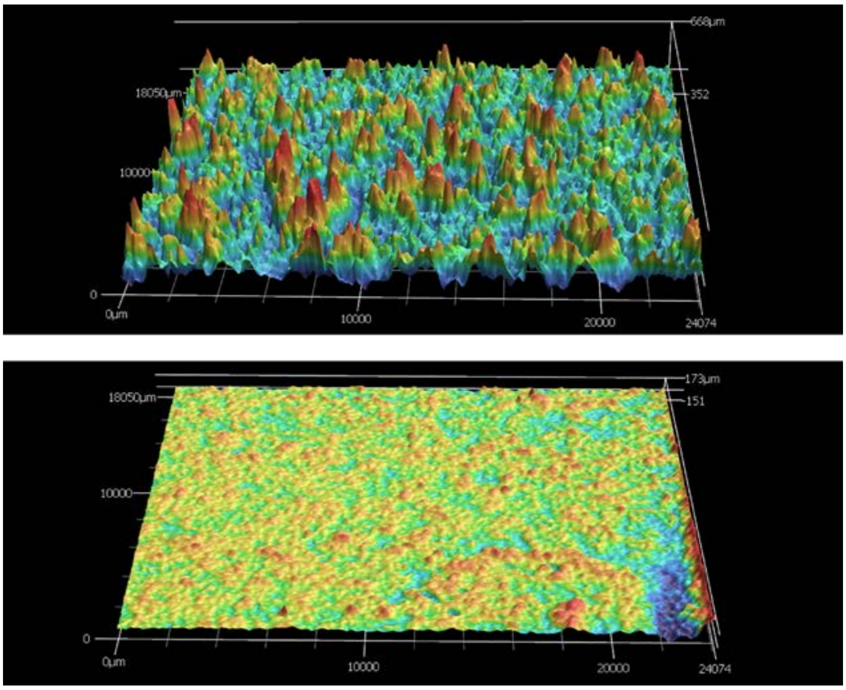

Figure 17: Inner surface of the casting (explosion-proof instrument housing) after removing the coated sand core.

## CONCLUSIONS

The new and innovative WASCO water-soluble binder system developed by the Foseco has demonstrated their high strength in severe processing conditions, such as HPDC. With the use of an appropriate and compatible coating, these innovative sand cores can withstand high pressures and temperatures whilst facilitating easy core removal from internal cavities by flushing water, leaving a smooth and sand-free surface.

This WASCO system demonstrated the strong potential and can meet a wide range of customer requirements, showing very promising results not only for liquid HPDC, but also for Semi-solid processes.

Main advantages of the new WASCO system are:

a) Strength values exceeding 1000 N/cm$^2$ are achievable.
b) Core residue is easy to remove and without use of mechanical force.
c) Use of cost-effective materials.
d) High flexibility in the use of additives.
b) Core manufacturing uses only standard hot box core shooters with hot air purge

### ABOUT THE AUTHORS

Vincent joined Foseco in 2011. He is currently R&D Manager for Binders at our Global R&D Centre, where he leads development of our innovative and environmentally-friendly inorganic binders. Outside work, Vincent enjoys spending time with his family, cycling, playing the organ and piano, cooking, and learning languages.

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CASE STUDY

**SUN ROOF PARTS**
ALUMINIUM HPDC FOUNDRY
MELT TREATMENT

FOSECO

# How Foseco's granulate and rotor system can boost your aluminium HPDC foundry

KNOWLEDGE & PARTNERSHI

## THE CHALLENGE

The HPDC foundry industry is facing increasing pressure to reduce production costs and improve quality. At the same time they are challenged to improve sustainability and respect the environment.

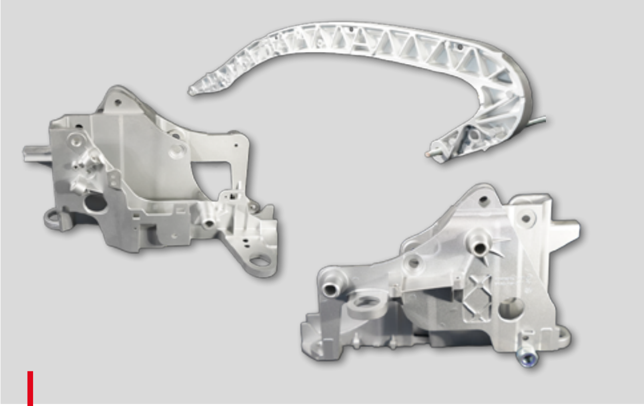
HPDC foundries need to reduce metal losses, avoid oxide formation and optimise treatment time while ensuring dry and clean dross. A leading HPDC foundry in Europe, producing automotive parts for a wide range of customers and applications was looking for a solution to meet these challenges.

### FOUNDRY:

Tugçelik Alüminyum & Metal Mamülleri San. ve Tic. A.S. is a leading high pressure die casting parts manufacturer in Turkey, specialising in the automotive, home appliances/white goods, and electrical and mechanical industries. Their plant is equipped with a range of high pressure die casting machines, making them a competent partner for die cast aluminum components.

## PARAMETERS

**Alloy:** AlSi12Cu1
**Alloy weight:** 350 kg
**Alloy temperature:** 750°C
**Degassing time:** 210 s
**Flux amount:** 240 g



Sun roof components

## FOSECO PRODUCTS

COVERAL* 2510 granular fluxes
DIAMANT* FDR rotor system

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## OUR SOLUTION

The foundry adopted COVERAL 2510 granular fluxes and DIAMANT FDR rotor system which gave superior results to the alternative highly exothermic fluxes that they were using. COVERAL 2510 fluxes and DIAMANT FDR rotor system delivered a dry dross without the need for an exothermic reaction, better oxide removal and longer lifetime. They also produce less fume and are more environmentally friendly than conventional fluxes.

## KEY BENEFITS

- **55% less aluminium in dross**
- **28% less oxide content**
- **Increased casting quality**
- **Lower metal treatment costs**
- **Lower fume**

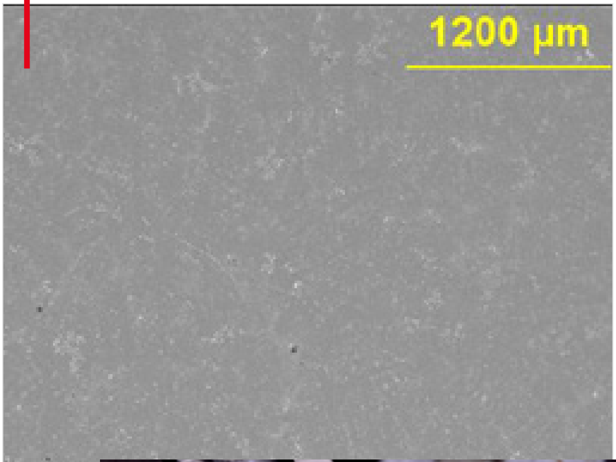
> LET´S LEARN MORE

**THINK BEYOND.** SHAPE THE FUTURE.

## THE OUTCOME

Vmet and Dross tests were conducted before and after the process change and the samples were sent for analysis. The results clearly showed that the combination of COVERAL 2510 and DIAMANT FDR rotor system significantly reduced the aluminium content in the dross by 65% and the oxide level at VMet analysis by 28%. This led to an improvement in casting quality due to less oxide and lower metal treatment costs for the foundry.

Vmet Results



Degassing process

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## CRUCIBLE INSTALLATION

Empower your foundry with a seamless installation! Watch our video now to unlock the potential of a crucible and elevate your metalworking capabilities. Enhance efficiency, reduce downtime, and achieve outstanding results with our easy-to-follow installation guide.

## HPDC PROCESS WITH WASCO

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