# 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.

## 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]

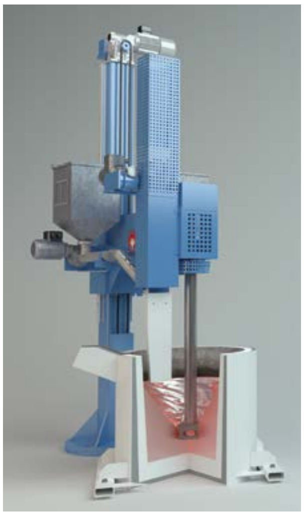

Figure 1: MTS Process

**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"

## 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

## 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]

## 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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