The use of metal treatment to control the quality of an aluminium casting produced by the High Pressure Diecasting process

Introduction

The High Pressure Diecasting process is very attractive to the casting buyer, offering fast production rates coupled to optimised production costs. Over the past 10 years there has been considerable growth in the HPDC process and now highly stressed castings are being manufactured . As castings become more complex and some wall sections become heavier, so the advantage of the very rapid cooling rate is reduced and casting defects more commonly seen in gravity diecasting and sand casting are now being experienced in High Pressure Die Castings. The need to heat treat and weld castings also means that casting quality levels must be improved. Safety critical castings are being inspected by X-ray and particular mechanical properties are required from the casting itself. There is therefore the need to produce alloys of a higher quality level and metal cleanliness has become vitally important.

A fresh approach to the treatment of the aluminium melt is therefore required in High Pressure Diecasting foundries.

It is well known that molten aluminium alloys have two inherent characteristics: the tendency to absorb hydrogen gas from the atmosphere, and the ability to readily oxidise. On melting, an alumina film is instantaneously formed and this will act as a protective layer as long as it is left in place. However, metal movement and breaking of the alumina film during metal treatment, transfer and pouring cause oxide films and inclusions to be formed and included within the melt. Over time there is also a tendency for oxide to form and build on refractory and crucible walls. These hard dense inclusions can break off after time, and result in hard spots in castings.

To help avoid excessive hydrogen pick up and oxide formation, protective chemical fluxes have long been used. These fluxes can be categorised depending upon their purpose.

- covering fluxes which form a molten layer to help protect the melt from oxidation and hydrogen pick-up
- drossing-off fluxes which react exothermically to allow free aluminium to flow back into the melt while also agglomerating the oxides, allowing easy removal from the surface of the melt. These are typically used immediately prior to transfer or pouring
- cleaning fluxes which remove non-metallics from the melt by encouraging the inclusions to float and then trapping them within the dross layer. These fluxes should be encouraged to move to the bottom of the melt so that they can treat the whole melt while they float back to the surface, bringing oxide and inclusions up with them. This action will also help to prevent harmful inclusions building up on crucible and refractory walls
- fluxes for the removal of oxide build-up from furnace walls. These can be used regularly to prevent such a build-up or can be used occasionally as part of a cleaning programme

Cleaning fluxes are traditionally added by hand and stirred into the melt but there is a limit with even the most conscientious of operators on the effectiveness of this treatment.

It is with this requirement in mind that a fully automated and efficient treatment process has been developed. This being the MTS 1500 process.

Figure 1. MTS metal treatment station showing flux hopper, dosing unit and moveable baffle plate

The MTS 1500 process is based upon the well proven FDU* rotary degassing technology but with the additional capability of the automised addition of a full range of metal treatment products. The addition of these treatment products uses a unique method, whereby the fluxes are fed from a dispensing unit into a vortex, which has been created in the melt by the spinning rotor, while the baffle plate is withdrawn.

The Metal Treatment Station MTS 1500 itself is a rotary degassing unit with the additional features of:

- one or two hoppers which feed a screw dosing unit
- a variable speed drive motor controlled by a plc
- a baffle which can be withdrawn and returned independently in to and out from the melt

Figure 2. The Vortex has been formed and the flux is dispensed deep into the melt

Figure 3. Flotation and degassing proceeds

The treatment begins, as with a standard FDU rotary degasser, with the rotor spinning while the baffle plate is within the melt. After a few seconds the rotation speed increases and the baffle plate rises out from the melt. The powerful rotation of the patented XSR pumping rotor encourages a vortex to be formed in the melt. Once the vortex is created the dosing unit introduces a controlled weight of a specially developed flux into the vortex.

This flux is taken to the bottom of the melt. The baffle plate then re-enters the melt and a controlled degassing and flotation treatment proceeds.

As the flux rises through the melt it reacts with oxide inclusions, reducing the surface tension around the inclusions and encourages them to float to the surface. This treatment is proving to be very efficient at removing oxides and dissolved hydrogen, creating levels of cleanliness seldom seen previously. The automated addition ensures a consistent treatment and by reducing the involvement of the operator encouraging safe working practice.

The addition rate of flux required by this style of treatment is also greatly reduced.

Such is the reactive nature of the flux that it will also exotherm to ensure that a dry powdery dross, low in free aluminium, is formed on the surface (Figures 4 and 5).

Figure 4. After the MTS 1500 treatment is complete a dry dross remains, significantly reducing the aluminium loss during treatment

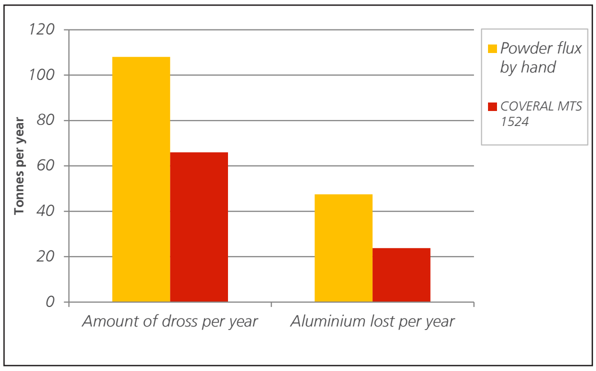

Figure 5. A comparison of dross creation with conventional powder flux added by hand with COVERAL* MTS 1524 granular flux added via the MTS 1500 process

Case Study 1

The Foundry: Foundry produces a range of castings in both high pressure and low pressure.

Foundry Practice: Foundry melts centrally and then transfers metal to the casting furnaces using a transfer ladle. Metal treatment was carried out in the transfer ladle using a rotary degassing unit and a manual addition of flux.

Achievements: Installation of the MTS 1500 process reduced treatment times from 9 minutes to 7 minutes due to the high efficiency of the MTS 1500 process ensuring that the same Density Index levels are achieved. The MTS 1500 process also offers significant cost savings in terms of less inert gas consumption, reduced flux usage and a reduction in metal loss in the dross.

The following annual savings are calculated:

		Conventional Flux	MTS 1500
Flux Type		Normal Powder Flux	COVERAL MTS 1565
Flux addition rate	gr	450 ± 50	212 ± 6
Treatment time	min	9	7
Yearly flux usage	Kg	8.100	3.816
Yearly flux saving	Euro		1.8000
Nitrogen consumption per treatment	Lt	450	154
Yearly nitrogen saving	Euro		15.984
Metal saving per treatment	gr		500
Yearly metal saving	Euro		14.400
Total yearly saving	Euro		32,184

Table 1.

Case Study 2

High Pressure diecasting foundry treating in 800 kg transfer ladle.

Problems:

- inconsistent density results
- leaking castings
- high reject level
- excessive cleaning

Introduction of a 3 minute MTS 1500 treatment with 400 grams COVERAL MTS 1524 flux

Improvements:

- reduction in dross creation
- increased refractory lifetime of the holding furnace due to the improved cleanliness
- reproducible density results (Figure 6)
- high quality castings guarantee for the customer
- increased productivity
- reduced tools maintenance (far less hard spots in the metal)

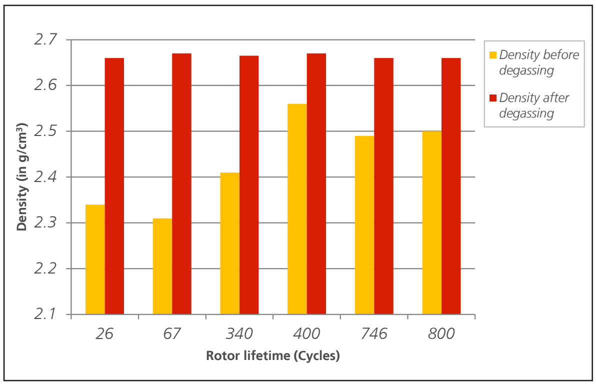

Figure 6. Density Index taken before and after treatment

It is clear from industrial experience, that the MTS 1500 process cleans the alloy of inclusions and hard spots as well as reducing the aluminium content of the dross. However, more HPDC foundries are seeing shrinkage and porosity in the more complex castings that are now being produced and the question being asked is, "could metal treatment be used to control porosity?"

It was decided to design a tool for High Pressure Diecasting production that had various sections which would be difficult to feed, and prone to shrinkage.
MAGMA Simulation was used to assist in the design of this tooling and Figure 7 shows the tool and Figure 8 the scale of porosity that is predicted to be formed on solidification.

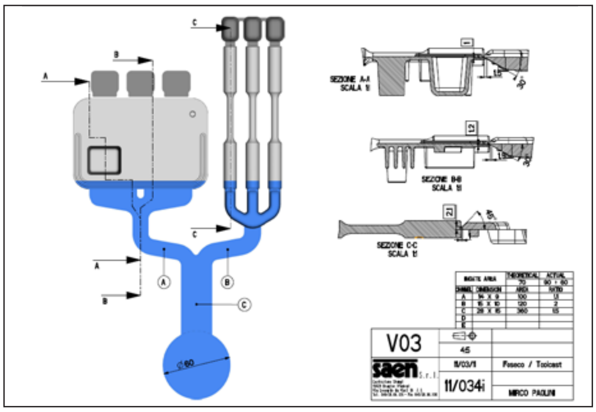

Figure 7. The tooling for manufacturing test pieces prone to shrinkage

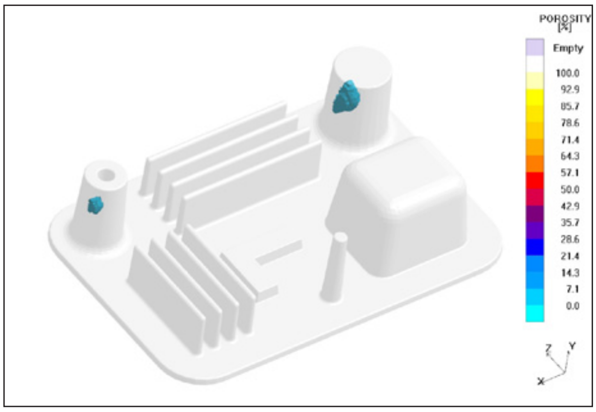

Figure 8. Simulation showing predicted porosity in thick sections

A 300 kg electric resistance holding furnace was used for melting, metal treatment and casting. The alloy selected was AlSi9Cu3Fe 46000 (A 380) and the charge was 100% returns. Castings were made in the as-cast condition before a rotary degassing treatment was carried out using a Foundry Degassing Unit (FDU) utilising a XSR pumping rotor. After further casting production, the furnace was charged with foundry returns and a MTS 1500 treatment was made using 0.15% COVERAL MTS 1524 flux.

In addition to the HPDC castings, a series of K-Mould samples were taken and these subjected to SEM and image analysis to measure the relative cleanliness of the melts.

The total number of pores and inclusions is reported (Figure 9) as well as the size range (Figure 10). This shows that inert gas alone, added through a pumping XSR rotor, will clean the melt, but the use of a specially designed flux added into the bottom of the melt in a vortex, will achieve even lower levels of inclusions and porosity.

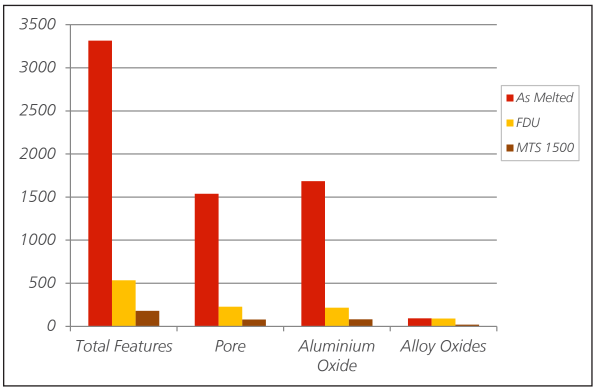

Figure 9. Cleanliness of the melt as-melted, after FDU inert gas treatment and after MTS 1500 treatment with COVERAL MTS 1524 flux

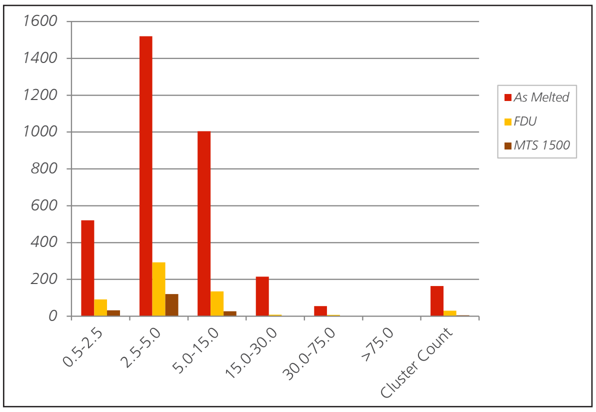

Figure 10. Size range in microns, of inclusions and pores as-melted, after FDU inert gas treatment and MTS 1500 treatment with COVERAL MTS 1524 flux

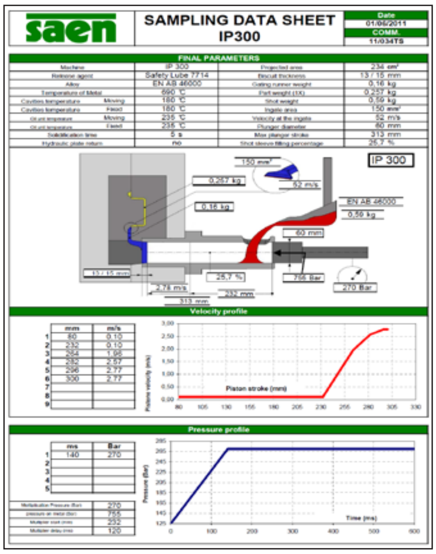

Figure 11. Machine parameters during the production trial

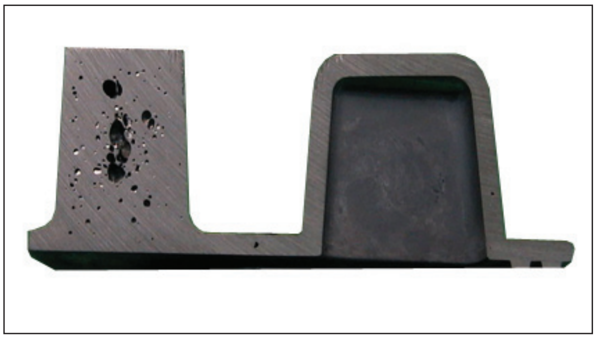

Figure 12. Casting in as-melted condition having had no metal treatment

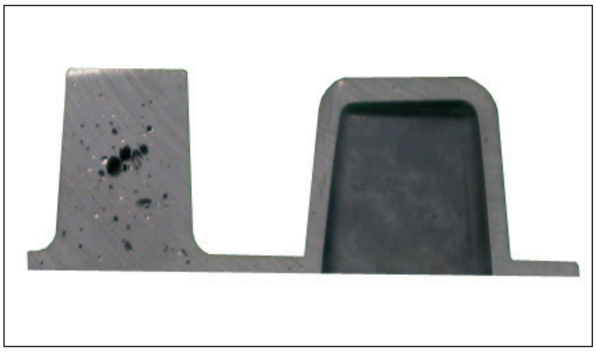

Figure 13. Casting produced from melt after 15 minutes FDU with 25 litres per minute nitrogen

Castings were made from alloy in the as-melted condition and then with the same machine parameters produced after FDU inert gas treatment.

Finally, a MTS 1500 treatment was carried out using COVERAL MTS 1525.

The castings were X-ray inspected before they were sectioned to observe the soundness of the different sections. (Figures 14 and 15)

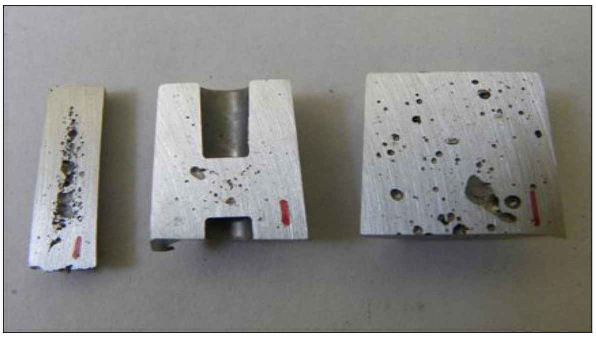

Figure 14. Three sectioned bosses from the casting without metal treatment

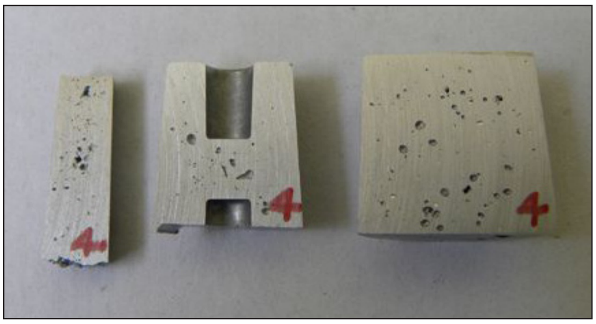

Figure 15. Three sectioned bosses from the casting made after MTS 1500 treatment with 0.015% COVERAL MTS 1524 flux

Finally X-Ray tomography was used to compare the porosity level of the castings (figure 16). The following results were found:

	As melted material	After MTS 1500 treatment
Number of Voids	68775	49476
Volume of voids	230.29 cubic mms	156.67 cubic mms

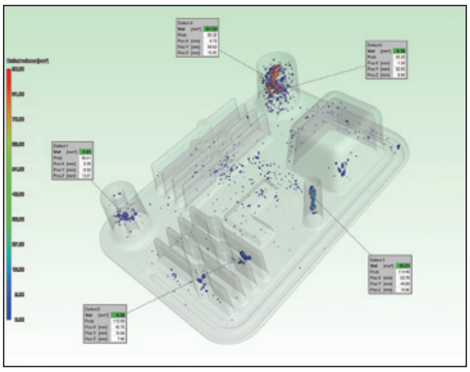

Figure 16. X Ray Tomography of a casting made in the as-melted condition showing Voids number 68775 and Voids volume 230.29 cu mm

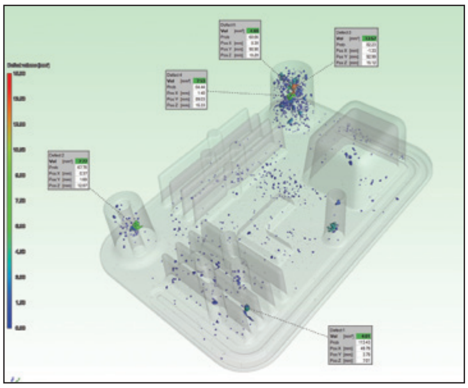

Figure 17. X Ray Tomography of a casting made after MTS 1500 metal treatment showing Voids number 49476 and Voids volume 156.67 cu mm

Conclusions

- the development in HPDC to produce castings of more varied section thickness is resulting in defects rarely seen before in High Pressure Die foundries
- porosity is now becoming a more common reason for casting rework and rejection in HPDC
- the use of rotary degassing and MTS 1500 rotary degassing vortex treatment along with a specially developed flux can:
    - reduce the amount of dross created and produce dross with a lower aluminium content, reducing metal loss and operating costs
    - shorten treatment times leading to higher productivity
    - consume less inert gas, again reducing operating costs
    - significantly clean the melt prior to casting resulting in better fluidity, die filling and extended feeding distances
- the use of this treatment can modify the size and position of porosity within a test casting
- further work will be carried out to optimise the metal treatment in line with specific casting requirements.

References

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