Aluminium low-pressure wheel production - end to end solutions

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There has been huge growth in the production of aluminium road wheels over the past decade, with the great majority being manufactured by the low-pressure diecasting process. The quality requirements of these safety critical castings are as high as any aluminium component made today and Foseco has developed a range of products aimed at improving the quality of the castings produced while also improving the profitability of the process.

This concept of an integrated solution package for a particular casting and process will be further developed in the future.

The application of aluminium wheels on light vehicles has become hugely popular over the past ten years. The reasons behind this are both technical as well as aesthetic as the castings are safety critical as well as pleasing to the eye. Aluminium wheels need to offer mechanical strength and lightness, toughness and rigidity, dimensional precision and style with a perfect aesthetic finish and so today aluminium wheels have become a technologically advanced product required to offer a high level of quality, reliability and safety.

The wheel is a safety critical component, which has a decisive effect on the performance of the vehicle and is responsible for propulsion, steering, supporting the vehicle, braking as well as suspension. Consequently it must possess characteristics of mechanical strength, plastic reserve and fatigue strength capable of resisting fracture during the full life cycle. In addition to this, roundness and balance must also be maintained over time.

Testing will include dimensional accuracy, alloy composition, hardness, grain size and eutectic structure, fatigue testing and die penetrant inspection after fatigue testing, x-ray inspection, pressure tightness, crash test, detailed visual inspection, radial load testing – all this means that aluminium wheels receive as much inspection as any other aluminium casting and more than most.

The process by which aluminium wheels are manufactured is almost always low-pressure diecasting and this process can be segmented into the following process steps:

• Alloy material selection
• Melting
• Holding
• Melt transfer by ladle
• Melt treatment in the ladle
• Transfer into the low-pressure furnace
• Die filling and solidification
• Removal and initial inspection
- X-ray inspection
- Heat treatment
- Machining
- Painting
- Pressure test and visual inspection

The Foseco approach is to develop a range of products and services which can add value to the foundry in all of these process steps.

**Alloy material selection**

To achieve the mechanical properties - particularly the elongation - it is essential that the iron content of the alloy is controlled and so commonly primary ingot is used along with foundry returns and the swarf and chippings from the machine line. Around 40 per cent of the as-cast wheel is removed during the process and so, although the swarf and chippings from machined wheels will have a very large surface area and be the potential source of oxide inclusions, it is commercially essential that this material is recycled and the value retained. A separate process to melt and clean this material is normally used and the use of a powerful cleaning flux, such as COVERAL* GR 6512, is an integral part of this process. Once cleaned to an acceptable quality level this material can be used, under control, as part of the alloy charge, either as cast ingot or in liquid form.

**Melting**

Melting in wheel foundries today tends to be by tower melter or reverberatory furnace and there are three key properties that are expected from the furnace itself - high melting rate, energy efficiency and the ability to avoid oxide formation.

In the melting and holding zone there is a strong need for a refractory material that is compatible with aluminium-silicon alloys, which has good mechanical strength and is non-wetted by aluminium alloys, resisting the growth of corundum. The lining material must also have a high resistance to mechanical damage in impact areas and have as long a service life as is practical.

ALUGARD* CE-S is a high alumina, low cement castable specifically designed for use with aluminium-silicon alloys and is well proven in aluminium tower and reverberatory melting furnaces. The ALUGARD CE-S lining will offer a long service life and good resistance to corundum growth and be easy to clean.

Within the range of refractory products there is also a lighter weight material for the furnace door, roof and upper walls, TRIAD* 45 AL and BLU-RAM* HS.

For general maintenance and repair DURAGUN* 66AL can be used for application by trowelling or gunning methods.

The same range of refractory materials can also be applied if the melting takes place in a reverberatory furnace.

Product selection is vitally important as is correct installation and Foseco can advise and sometimes supervise the installation of their refractory lining products.
In melting furnaces temperature measurement can also offer advantages if it is fast and accurate. Highly conductive ISO-PRIME or 3MSILICIUMNITRID thermocouple sheaths can both achieve these aims with the latter also offering longer service life. Correct refractory selection and fast response thermocouples can help to maintain the high quality standard of the aluminium alloy melt, the essential foundation of a sound foundry process.

**Melt transfer**

Once melted the alloy is then poured into a transfer ladle in which the melt treatment is made prior to the ladle being moved to the low-pressure casting machines. This treatment of grain refinement, strontium modification, cleaning and hydrogen adjustment (degassing and sometimes regassing) can take around ten minutes and so temperature loss can be an issue. Good insulation and easy cleaning is therefore an essential characteristic of the lining material and Foseco has two options to offer. INSURAL* 140 is supplied as a pre-cast insert which has already been fired to over 700°C and when installed within the INSURAL 10 insulating backing will offer excellent insulation and non-wetting properties. When installed using the INSURAL 140 lining system the ladle will have a heat loss of less than 3°C per minute, depending upon the capacity, and will also be very easy to keep clean and free of oxide build-up.

If the service life of the ladle lining is of particular importance then INSURAL 270 offers good insulation and oxide resistance coupled with excellent erosion resistance. INSURAL 270 will therefore offer an extended service life.

**Melt treatment**

To achieve the required quality of melt it is necessary to carry out a controlled melt treatment in the transfer ladle.

To ensure the correct eutectic structure is achieved and that excellent elongation properties are assured, the alloy is modified with strontium. This can be done by using pre-modified ingot, which has already had a strontium addition, or by adding aluminium-strontium master alloy prior to degassing.

In addition to the strontium modification the alloy is also grain refined with titanium and boron to achieve optimum mechanical properties and to reduce the chances of shrinkage in thicker sections. In addition to an improvement in elongation and the consistency of mechanical properties, grain refinement also increases resistance to fatigue, improves machinability, reduces the tendency for hot tearing and helps to disperse micro-porosity.

This treatment is best carried out by chemical additions, which form fresh titanium diboride particles within the melt. A tablet addition with NUCLEANT* 70 SS or NUCLEANT 100 SP will have this effect but best of all a cleaning and grain refining flux, COVERAL MTS 1582 applied through a MTS 1500 metal treatment station, will give excellent grain refinement, remove oxides and inclusions while ensuring that a very dry dross is generated thereby reducing metal loss.
Melt cleaning and hydrogen control can best be done simultaneously and the traditional method is to add a granular flux COVERAL GR 6512 to the surface of the ladle and then to carry out rotary degassing with a pumping graphite FDU XSR rotor or a GBF rotor. The stirring action of the rotor will activate the COVERAL GR 6512 and create an exothermic reaction while the finely dispersed inert gas bubbles will help oxides to float to the surface to be collected in the dross. After several minutes of treatment the melt is cleaner and lower in hydrogen content.

A more modern version of this melt treatment is with MTS 1500 technology using a more powerful MTS FDR rotor. In the early stages of the rotary degassing treatment the baffle plate rises from the melt and a vortex is formed. A specially developed cleaning flux, COVERAL MTS 1565, is then added into the vortex. The flux is taken down to the lower parts of the ladle where it can react with the bulk of the melt and after less than 60 seconds the baffle plate moves back into the melt and the vortex disappears. Normal rotary degassing then continues but because the flux is low in the melt a much more effective cleaning process follows. The MTS 1500 process will therefore remove more oxides than FDU alone.

However for the most effective and automated treatment the COVERAL MTS 1565 flux can be replaced by COVERAL MTS 1582, which when added using the MTS 1500 unit, will offer hydrogen control, melt cleaning and grain refinement as well as generating a dry dross low in aluminium, as shown in fig.6, all in one automated treatment. To monitor the effectiveness of the modification and grain refinement treatments a cooling curve can be plotted using THERMATEST* equipment. As well as producing a cooling curve, where the undercooling of the liquidus and solidus can be observed, the software also calculates a eutectic structure index; where 5 is the maximum reading and a grain index, with 9 being the maximum reading. Thermal analysis is a very effective way of checking that each melt has been correctly treated.

As shrinkage is such a common issue in aluminium wheels it is sometimes advisable not to reduce the hydrogen content of the melt to the lowest possible level. The overall treatment time must be maintained because of the need to clean the alloy and so shortening the degassing is not an option. It is therefore beneficial to degas to a low level and then to reintroduce a small amount of hydrogen at the end of the treatment. To retain the advantage of automation and consistency it is possible to programme the FDU, GBF or MTS 1500 unit to make a late addition of Argon-H2 gas for just a few tens of seconds at the end of the treatment. This will adjust the hydrogen content to an acceptable level, which will not create porosity but will control the level of shrinkage found in the final casting.

The use of a programmable MTS 1500 treatment to clean, grain refine and control the hydrogen content of the melt gives the foundry excellent process control and repeatability.

**Melt transfer**

After treatment the melt is poured into the low-pressure furnace, ready for production. This is
another critical stage of the process as turbulent filling of the low-pressure furnace can result in oxide creation and an increase in hydrogen content. A specially designed INSURAL 140 pouring basin to suit the particular low-pressure furnace can help to control the filling process.

Low-pressure diecasting furnace
As these furnaces can be in service for up to seven years it is vital to select a refractory which will avoid oxide and corundum growth. ALUGARD A 95 has been used for several years in these types of furnace and will avoid many of the problems that can be experienced where furnaces run in production for long periods of time. When ALUGARD A 95 is installed in front of a highly insulating backing system then external steel shell temperatures can be as low as 65°C, reflecting a very energy efficient system.

As an alternative to casting the lining in the furnace body it is possible to install a pre-cast and pre-fired shape in INSURAL 270. This option offers a very fast reline and guarantees that all combined moisture has been removed before installation begins. A furnace relined with the INSURAL 270 system can therefore be put immediately into service after relining, without the need for additional drying and firing.

For the furnace roof, an insulating lining is appropriate and LITEWATE* 80 AL is an ideal material for this application.

The low-pressure furnace is heated by electric radiant glow-bars in the roof and their service life can be extended by covering them with a highly conductive protection tube. ISO-PRIME heater protection tubes ensure good heat transfer from electrical element to the furnace atmosphere while protecting the element from mechanical damage, metal splashing and chemical attack during general use or metal treatment and furnace cleaning. They will extend the life of the heater elements, reducing the running costs of the furnace.

For accurate temperature control, a thermocouple sheath with high conductivity is required and ISO-PRIME thermocouple sheaths are well proven in the specific application of a pressurised furnace. Again fast response will result in more accurate temperature control and less variation on casting temperatures.

To have accurate control of the filling process and to retain pressure for effective feeding during solidification a pressure tight LPS tube is essential.

Two materials are offered for this application - ZYAROCK* and ZYACAST - both based on fused silica and being well proven in these applications. These LPS tubes can be supplied with a SEDEX* or STELEX* ZR foam filter installed in the bottom to prevent oxide inclusions entering the tube from the furnace floor.

Casting
Above the LPS tube there is the opportunity to apply highly insulating ceramic inserts and INSURAL 140 is an ideal material for these applications. The use of these inserts allows the foundry to increase the amount of water cooling in the die, thus extracting heat from the casting while retaining heat in the feed areas. Casting quality is therefore improved while cycle time is
kept short to improve productivity.
To improve metal flow and trap oxide inclusions, a filter can be positioned in the upper bush.
Foam filters are the most effective at flow control and SIVEX® FC filters are lightweight and can be remelted from the carrot.
The die itself must be coated to control the thermal balance, ensuring good filling while also controlling heat loss during the feeding cycle. The aesthetic quality of the casting is also defined by the surface finish on the main face of the wheel and so a smooth coating is used on the front face, DYCOTE® 39. For an extended service life DYCOTE 3900 or DYCOTE 3950 can be used.
For the side and top cores a more insulating coating is required and this can be DYCOTE 34.
As service life of the coating is important to retain the insulating properties for a longer period, a primer coating - DYCOTE DR 87 - can first be applied to the die with the other DYCOTEs applied on top.
To ensure that the DYCOTE used is correctly prepared a special mixer - DYCOTE CARRY and MIX - is offered. This mixer will also maintain the quality of the coating during standing.

Conclusions
The important attributes of the low-pressure diecasting process are:
• Productivity
• Energy usage
• Metal yield
The important attributes of the casting itself are:
• Surface finish
• Mechanical properties
• Soundness
• Pressure tightness
• Freedom from oxides and porosity
• Machinability

The products listed above form a valuable group for the low-pressure wheel producer and when used together will have a positive impact on the quality and performance of the castings as well as the commercial success of the foundry. Research and development projects are now underway to add further elements to this range and to increase the end-to-end value offered to the industry.

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*COVERAL, ALUGARD, TRIAD, BLU-RAM, DURAGUN, ISO-PRIME, 3MSILICUMNITRID,
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