Melt treatment of aluminium and aluminium alloys by MTS

In recent years aluminium and aluminium alloys have gained increasing importance as engineering materials in all areas of industry but particularly the automotive industry. As the applications for aluminium castings have expanded, the quality requirements have also increased. Melt quality has a major influence on the casting properties and therefore melt treatment practices have a major effect on the quality of the finished product (see figure 1).

Metal cleanliness

Until comparatively recently melt cleanliness was achieved by leaving the melt undisturbed so that dissolved hydrogen reached equilibrium and solid impurities rose to the melt surface or sank to the bottom of the furnace. The disadvantage was that it was a time consuming process with low efficiency.

Gas purging treatments were the next developments using inert gases like nitrogen and argon, sometimes mixed with chlorine. Originally lances were used to introduce the gases however, the large gas bubbles produced by this technique proved to be a disadvantage as they rose up too fast without reacting sufficiently within the melt. In addition, significant turbulence at the metal surface generated significant quantities of oxides.

The final breakthrough in the melt cleaning technology came with the introduction of the FDU spinning rotor treatment. This treatment involves the introduction of the inert gas into the melt through a rotating shaft and rotor. In this way the inert gas is broken down into cloud of small gas bubbles that are well distributed over the entire crucible volume and rise up very slowly through the melt giving a rapid and efficient removal of impurities. A detailed description of the FDU technology is given by JAUNICH (1).

Grain refinement

Depending on the type of alloy, a grain refinement may required to obtain optimum properties in the finished casting. This grain refinement is achieved through the introduction of foreign nuclei of TiB_2 and $TiAl_3$. These nuclei can be added in the form of AlTiB master alloys where the nucleating species already exist or as tablets containing a mixture of titanium and boron salts which form the nucleating species in the melt itself.

Modification

With AlSi alloys with a silicon content higher than 5% it is usually necessary to modify the AlSi eutectic to transform the normal lamella structure into a fine grained, modified structure. This treatment improves the properties of the casting significantly. Modification is usually carried out using sodium or strontium. Sodium is either added as metallic sodium or in the form of salts which react in the metal to release sodium. It is a very efficient modifier but the effect tends to fade relatively quickly. Strontium is added as a 5% or 10% master alloy and gives a modification that lasts for several hours.

Description of the MTS

For a long time cleaning and grain refinement/ modification were viewed as two separate steps in the treatment of aluminium. A first approach in combining these two processes was to fit a plunging cage to the FDU. The process involved placing grain refining and modifying tablets into the cage so that during the degassing treatment the tablets were introduced into the metal. Due to the intensive mixing caused by the rotor the reaction products were distributed homogeneously throughout the metal. In many foundries excellent results were achieved by this technique. However, a disadvantage of the immersion cage was the labour required in loading the cage with tablets and in cleaning the cage after the treatment.

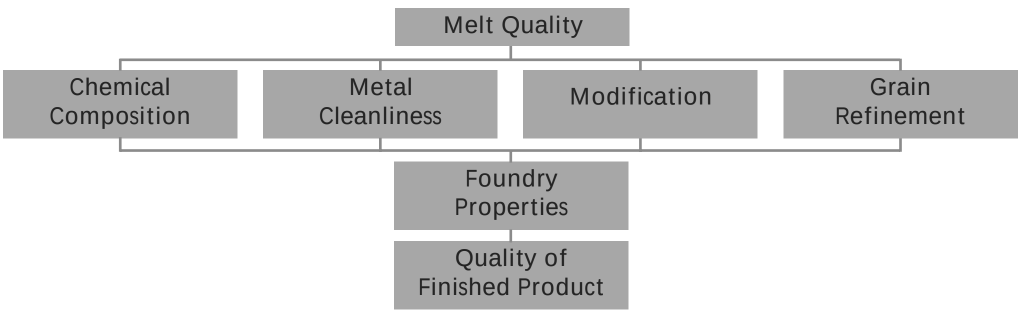

Figure 1: Factors influencing the quality of the casting.

The optimum solution for a combination of degassing and melt treatment with chemical agents is the MTS (Metal Treatment Station). The treatment agents in the form of granulates of a grain size of 1-5 mm are placed into a hopper located on the machine. Both the treatment gas and granulated flux are then introduced into the melt via the rotor and are homogeneously distributed through the entire crucible volume. The result is an efficient degassing and melt treatment. A general view of the MTS is shown in figure 2. For a combined modification and grain refinement treatment a twin injector is available to enable both types of granulated fluxes can be added independently (see figure 3)

The addition of the granulated flux is integrated into the treatment cycle of cleaning and degassing. A few seconds after immersing the rotor into the melt the dosing of the granulated flux starts. Addition quantities are adjustable from 100 to 500g/min and are accurately controlled using an advanced dosing technique to an accuracy of at least 95%. For example there is a deviation of less than 25g in an addition of 500g. After the required amount of flux has been added an additional few minutes treatment is recommended to homogenise the melt.
For the melt treatment three granulated fluxes series are available:

- Granulated cleaning/drossing flux
- Granulated grain refining flux
- Granulated modification flux

Since the granulated grain refining flux and the granulated modification flux have a marked cleaning effect no extra melt cleaning treatment is

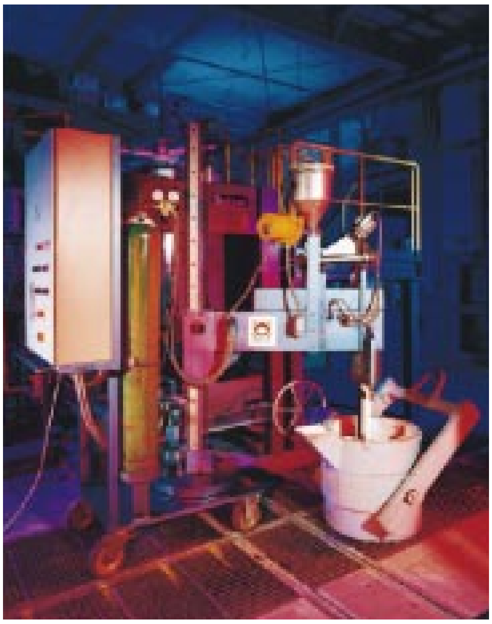

Figure 2: General view.

Figure 3: Dosing device of the twin injector.

required. In the following the different granulates and their effect will be described. In addition some trial results of practical tests are discussed.

Melt cleaning

For melt cleaning special granulated drossing and cleaning fluxes are used that capture aluminium oxides and other finely dispersed non metallic impurities in the melt and float them into the dross layer on the surface of the melt. This supports the effect of the cleaning gas. In addition the granulated flux reacts within the dross and reduces its metal content, resulting in a fine, dry dross which can be removed from the melt surface easily.

In a large wheel foundry trials were undertaken by using the MTS in combination with a 400 kg transport ladle. Within one minute, 140 g of COVERAL GRi 2450 were blown into the melt. The total treatment time was 4 to 6 minutes while the treatment temperature was 700 to 740 °C.

In the previously used technique 180 g of the cleaning granulate were placed on the metal surface and stirred by a skimming ladle. Sample bars for an AlSi7 alloy were cast, heat treated and

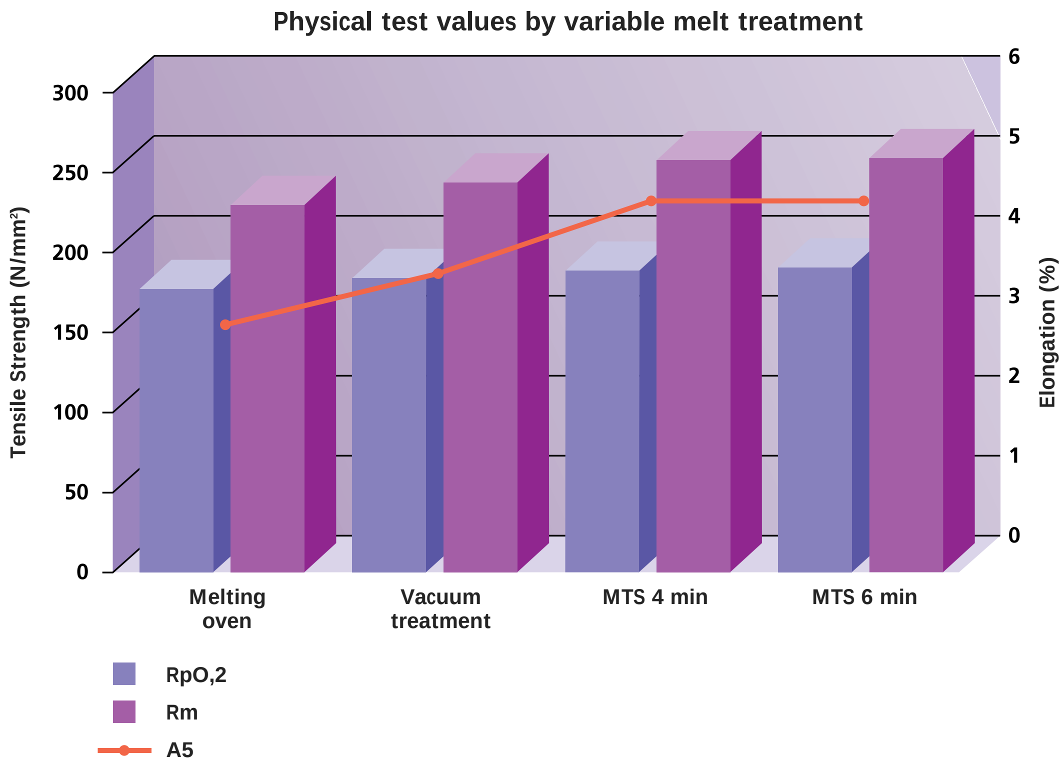

Figure 4: Mechanical properties of sample bars G-AlSi7 TE.

their mechanical properties determined (table 1; figure 4). The quality index QI was calculated according to the following equation:

$$QI=Rm+k.\log(A5),$$

with k representing a constant which depends on the alloy type (k = 150 for AlSi7).

With respect to the untreated melt the mechanical properties of the MTS treated melt were improved by 20 percent. Also the elongation at rupture, an important parameter in wheel casting, was increased. To characterise the dross, trials were carried out by using a 800 kg crucible. The dross was analysed for its metal content. By applying a granulated cleaning agent with the help of a MTS the metal content was reduced by 15 percent compared to the traditional dross treatment.

The application of the granulated cleaning agent COVERAL GRi 2450 via a MTS shows the following advantages:

- Improvement of mechanical properties
- Reduction of metal content in dross
- More efficient application of granulated cleaning flux

Grain refinement

The MTS also offers the opportunity of dosing grain refining granulates to a melt. This means grain refinement and melt cleaning are taking place simultaneously, reducing the process duration and the manpower required.

	Rp0,2 [N/mm²]	Rm [N/mm²]	A5 [%]	Q1
Melting Furnace	172,7	224,6	2,9	294,0
Casting Machine (after vaccum treatment)	179,5	239,0	3,6	322,4
Casting Machine (MTS treatment 4 min)	183,7	251,8	4,5	349,8
Casting Machine (MTS treatment 6 min)	185,6	253,8	4,5	351,8

Table 1: Mechanical properties of sample bars G-AlSi7 TE (TE: artificially aged).

Figure 5a: Pure aluminium 99,7; unrefined.

Figure 5b: Grain refinement by addition of 0,05 % NUCLEANT GRi 2850.

Figure 5c: Grain refinement by addition of 0,08 % NUCLEANT GRi 2850.

For grain refinement NUCLEANT GRi 2850 is available. This material was used to carry out trials in different foundries. After treatment a sample of the melt was poured into a water cooled copper die. These samples were sawn, polished and immersed in etching solution in order to visualise the macro structure. The results obtained with different addition levels are shown in figure 5.

The grain refinement by NUCLEANT GRi 2850 applied by an MTS unit shows the following advantages:

- Exact dosing and adjustment of the desired grain refinement state
- A grain refinement with a minimum of fume and dust
- Simultaneous grain refinement and melt cleaning of the melt
- Formation of a dry dross with a low metal content

Modification

The MTS can also be used to modify aluminium alloys by the addition of sodium bearing fluxes. Trials were undertaken in foundries using the granulated modification flux SIMODAL GRi 2750. The melt treatment temperature varied in a range from 690 to 820 °C. However, the reactivity of the granulated flux did not depend upon the treatment temperature. The addition levels and the sodium pick up are shown in table 2.

The effect of the modification can be shown with the help of thermal analysis. Depending upon the casting an under cooling between 5 and 10 Kelvin of the eutectic solidification temperature is required. Figure 6 shows the typical profile of a thermal analysis of a G-AlSi10Mg alloy after modification with SIMODAL GRi 2750.

Sodium Content	
Addition level: 0,15 % of metal weight	50 - 55 ppm
Addition level: 0,20 % of metal weight	70 - 75 ppm

Table 2: Modification with SIMODAL GRi 2750.

Even when the sodium burns off under the influence of the atmospheric oxygen long term modifications of at least 60 minutes can be obtained by the application of SIMODAL GRi 2750. During this time no secondary treatment to maintain sodium levels is necessary.

As with grain refinement, the treatment time can be reduced as the SIMODAL GRi 2750 also serves as a powerful cleaning agent.

The advantages of a modification with SIMODAL GRi 2750 with an MTS are:

- More accurate adjustment of the desired modification

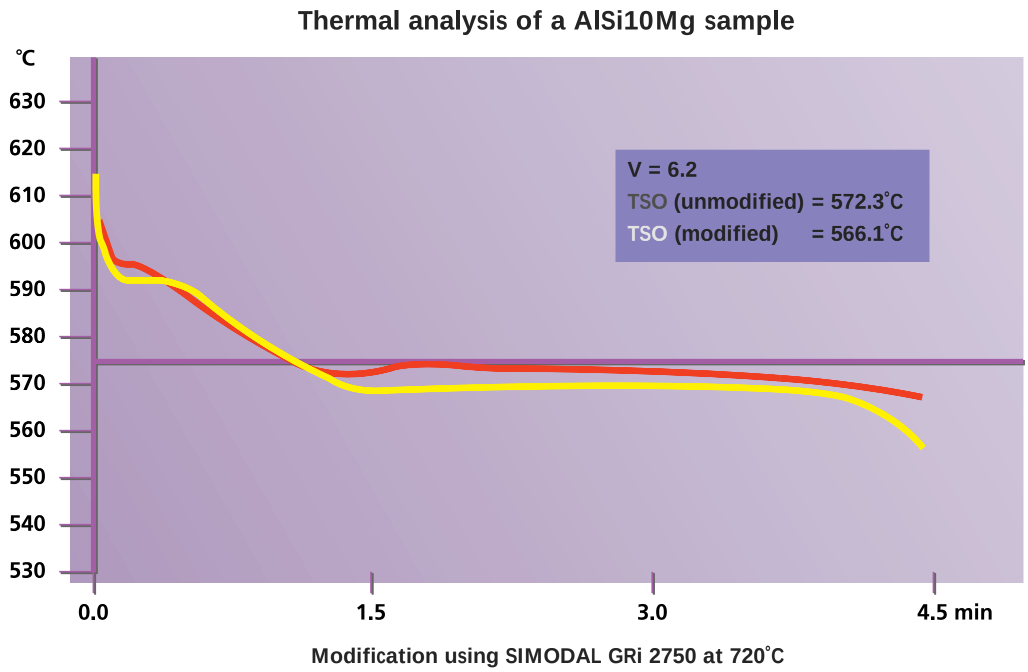

Figure 6: Thermal analysis after modification with SIMODAL GRi 2750.

- Temperature independent sodium transition in to the melt
- Dust and fume reduced modification
- The modification is combined with the melt cleaning
- Formation of a fine powdery dross with low metal content

Correction of the chemical composition

In terms of their chemical composition all alloys must meet particular specifications. The MTS offers the opportunity to adjust the alloy composition via the addition or removal of certain elements.

Additions of silicon and magnesium can be dosed very accurately and due to the strong mixing effect of the rotor can be distributed in the melt homogeneously. This offers the opportunity of producing aluminium silicon alloys or compensating for magnesium burn off. Chemical agents can also be fed to the melt via the MTS which can be used to reduce the calcium and sodium content of alloys sensitive to these elements.

Summary

The MTS process represents a combination of traditional melt treatment methods by using chemical agents and the cleaning/degassing of a melt via a rotor. Both process steps are vital for an aluminium melt to meet high requirements necessary to produce castings of highest quality. The main advantages of the MTS is the combination of different treatment steps within one system. Joining together previously separate treatment steps gives the opportunity of automation which can significantly reduce total treatment times (see figure 7).
A more automated treatment saves manpower, reduces the processing time of the aluminium melt and improves the efficiency of the foundry. Equipping the MTS system with a programmable controller enables a flexible application of the system. In addition to this it also gives the opportunity to monitor the process of melt treatment which is of large interest in terms of quality control.

References

(1) JAUNICH, H. (1998): Entgasen und Reinigen von Aluminiumschmelzen in Gießereien, Steel & Metals Magazine, 5.

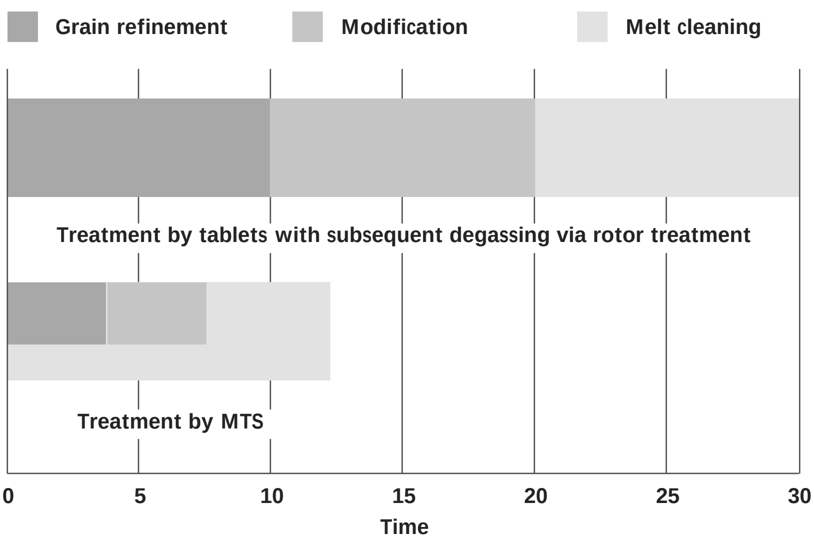

Figure 7: Comparison of treatment duration.