RECOVERY OF MAGNESIUM IN A DUCTILE IRON PROCESS.

S.O.Olsen and C.Hartung

Elkem Foundry Products, Kristiansand, Norway

Abstract.

Residual magnesium and magnesium recovery have always been subjects for discussions amongst foundry people. This presentation summarises the most important factors that will influence the recovery and addition rate of magnesium in ladle treatment processes.

Factors influencing the Magnesium Recovery and Addition.

Sulphur and Oxygen in Base Iron.

In order to evaluate the basics of ductile iron production the growth mechanism of the graphite has to be considered. It is proposed that growth normally occur along the pole of the plane with the lowest interfacial energy in contact with the melt. This will be the plane with the highest packing density and this will have the highest growth rate. With surface-active elements like O and S present the prism plane will grow fastest, but these elements are neutralised the basal plan will again have the highest growth rate. The highest growth rate from the basal plane will result in ductile iron and from the prism plane in grey iron. Hence magnesium is added in order to neutralise surface-active elements such as sulphur and oxygen. This means that increased content of sulphur and oxygen in base iron require higher addition of magnesium. (Fig. 1.) An example showing the effect of higher sulphur level in the base iron without increasing the addition rate of MgFeSi is presented in figure 2.

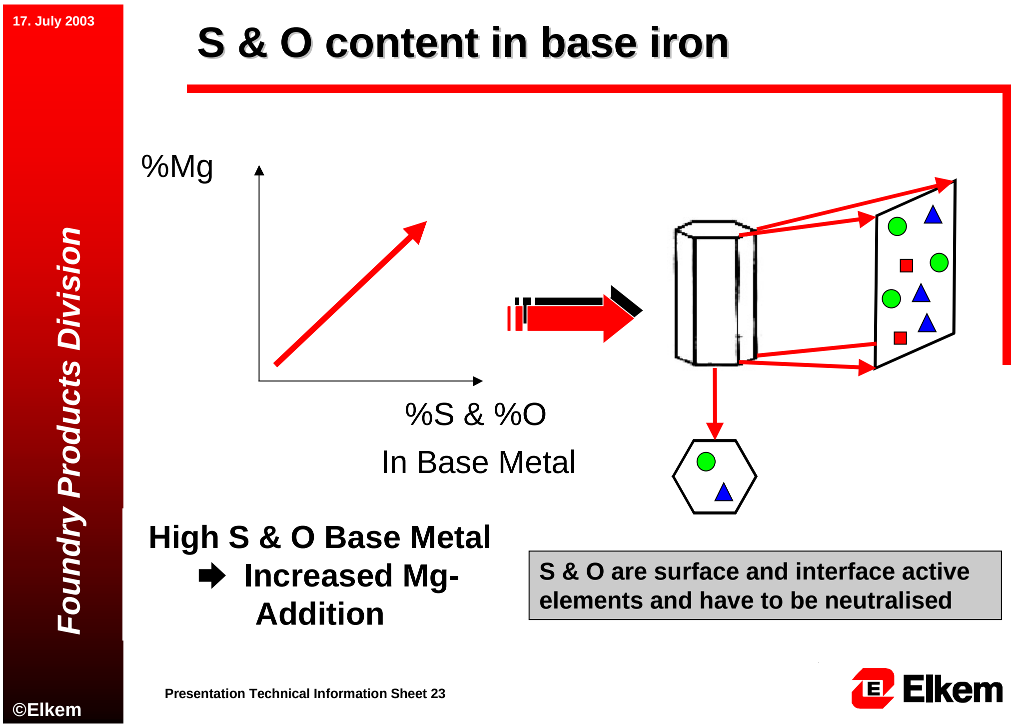

Figure 1: Increased content of sulphur and oxygen in base iron require higher addition of magnesium.

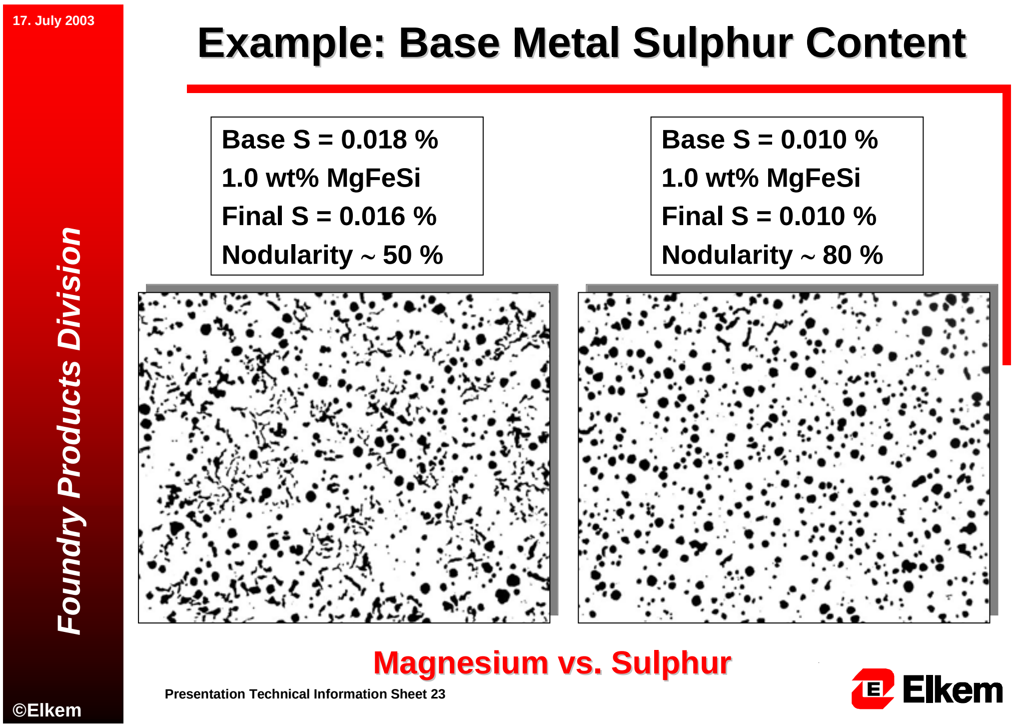

Figure 2: Shows an example of the effect of 2 different S contents in base iron at the same addition rate of MgFeSi-alloy. The 0,018% S gives 50 % nodularity while the 0,010 % S gives 80 % nodularity.

Figure 3 shows the relation between S in base iron and the minimum residual Mg that is required to give ductile iron.

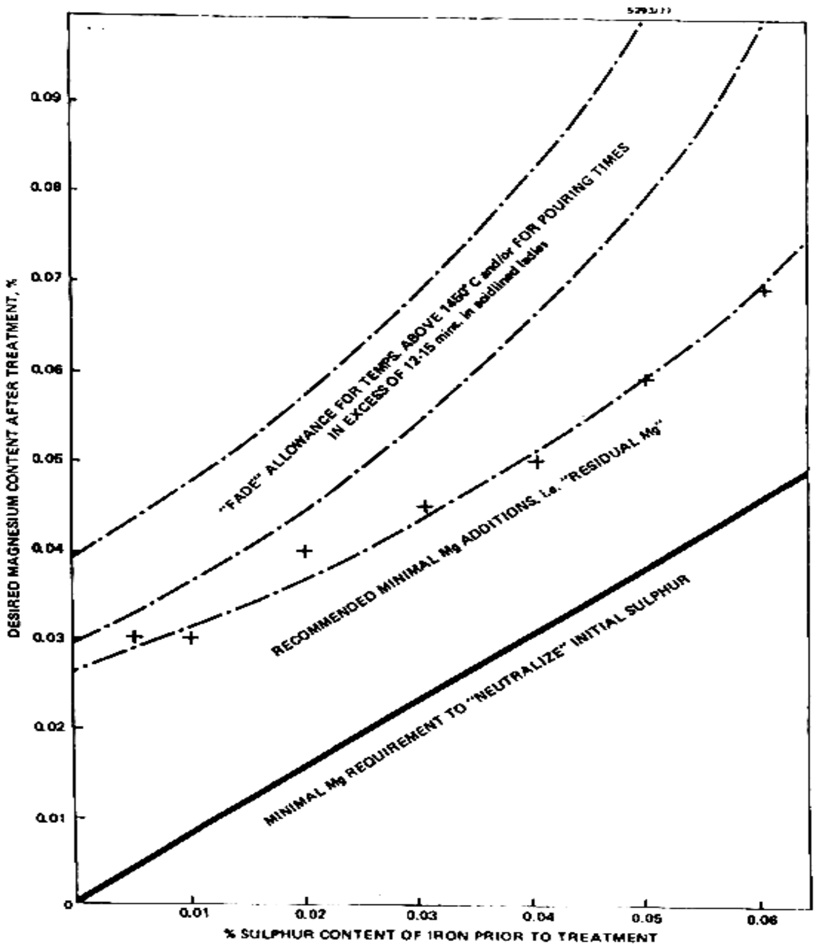

Figure 3. Schematic representation of the relation between base iron sulphur content and required residual magnesium to produce ductile iron.

Tapping Temperature.

Tapping or treatment temperature should be kept as low as possible in order to avoid excessive reaction violence. The higher the temperature, the more vaporisation and lower recovery of Mg. The boiling point of pure Mg is about 1110 °C and the normal treatment temperature in a foundry will be close to 1500 °C.

Nodulariser/MgFeSi addition to ladle.

The time between magnesium addition and tapping should be minimised to prevent preheating and oxidation of the alloy. At the same time there should be no liquid metal residual from previous treatments in the ladle as this may start to react with the alloy and lead to lower recovery of Mg.

Slag.

Slag carry over from melting and holding furnaces into the treatment ladle should be avoided. Slag that is transferred from furnace to the ladle will react with magnesium and reduce recovery. Proper separation procedures to minimise slag carry over need to be in place. Normally the furnace is properly skimmed before the first treatment, but the next treatments will suffer from slag contamination.

Ladle Design.

The ratio of internal Height : Diameter should be at least 2 : 1 and there should be an alloy pocket big enough to carry the alloy and covering material. The Mg recovery will increase with the height of the ladle because we increase the ferrostatic head before the reaction takes place.

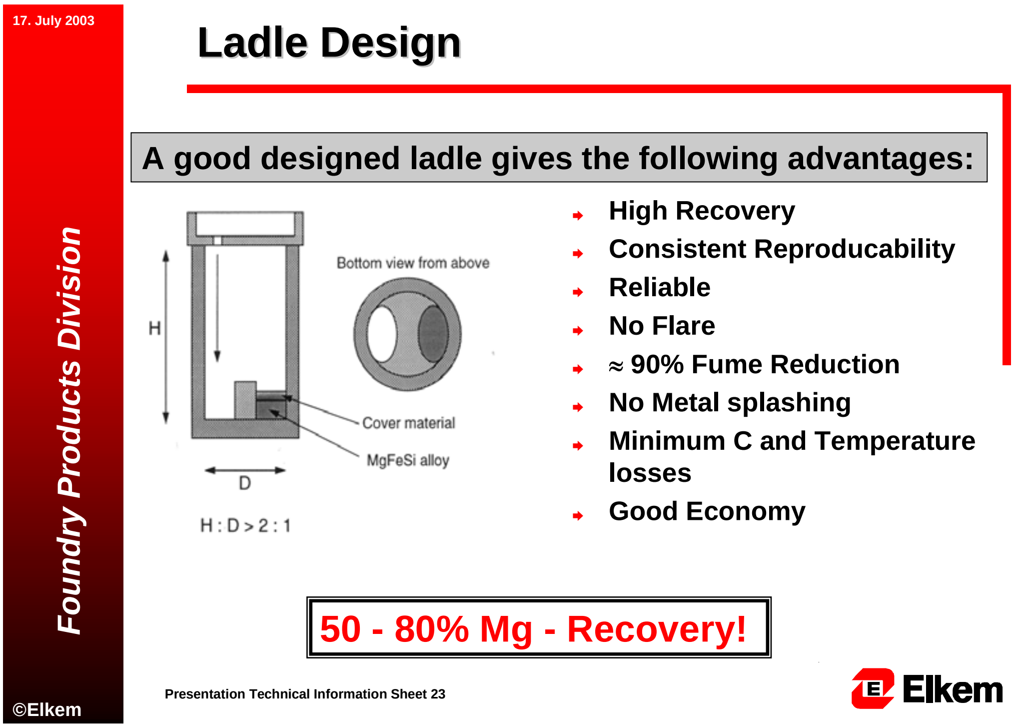

Figure 4: Ladle design criteria with the advantages of a good ladle design indicated.

The ladle should also be properly insulated to minimise heat losses and consequently the required treatment temperature. A tundish cover lid is also highly recommended for magnesium and temperature yield reasons.

Alloy Cover.

An alloy cover (sandwich cover) in the ladle will delay the reaction start and give better absorption of magnesium into the liquid iron. As cover a fine sized FeSi are often used, but also steel plates or dry cast iron turnings could be used. The important thing is to use a cover and not so much what type of cover is used.

Filling Time.

Filling rate should be high in order to achieve a high ferrostatic head in the ladle before the reaction starts. A short filling time will also lead to reduced temperature loss and evaporation.

Chemical Composition of Nodulizer.

High magnesium content in the alloy will give a more violent reaction and reduced recovery. High calcium content will reduce the reactivity and increase the magnesium recovery, but it will also increase the tendency to slag formation. The rare earth metals (cerium) will assist in giving a better recovery because it allows for working at lower magnesium in the alloy and lower residual magnesium in the iron. Aluminium should be kept low in the alloy in order to reduce tendency to slag and dross formation.

Alloy Sizing.

A wide alloy sizing gives dense bulk packing in the ladle chamber. The alloy will then fuse and react slowly in a controlled manner with a minimum of pieces escaping. Pieces floating and burning on the surface are a waste. However grain segregation should be avoided since this can cause inconsistency in the production. Recommended sizing for small ladles is 1 – 10 millimetres and for bigger treatments 4 – 32 millimetres.

Pouring Time.

Long pouring times require higher initial residual magnesium in order to compensate for fading losses during time. This means increased alloy addition and again reduced magnesium recovery. Higher addition in general will give lower recovery.

Inoculation.

With a good inoculation less residual magnesium is required to give good nodularity, and as a result a lower alloy addition can be used and thereby a better alloy recovery can be achieved. In many cases poor nodularity or degeneration of graphite nodules is incorrectly attributed to low residual Mg-levels when the cause is really insufficient inoculation.

Slag in Ladle and Alloy Pocket.

Slag building up in the ladle and alloy pocket leads to reduced magnesium recovery, probably due to reactions between the slag and magnesium. Overspill of alloy will occur if pocket is allowed to fill with slag and this can lead to floatation of alloy. Ladles should be kept tilted when empty to avoid slag clogging the alloy pocket and ladle walls.

Storage of Foundry Alloys.

All foundry alloys will contain a certain level of reactive elements. These reactive elements are necessary in order to give the wanted effect. This means that foundry alloys will oxidise if exposed to moisture. Oxidised alloys will give a lower recovery than fresh materials and heavy oxidation can result in up to 50 % reduction in the magnesium recovery. Containers of alloy should be stored in a dry place and not be opened until required at the treatment station. Large changes in temperature should also be avoided in order to minimise risk of condensation and transportation should be done in closed and watertight units.

Examples of how different Factors can influence the MgFeSi Addition.

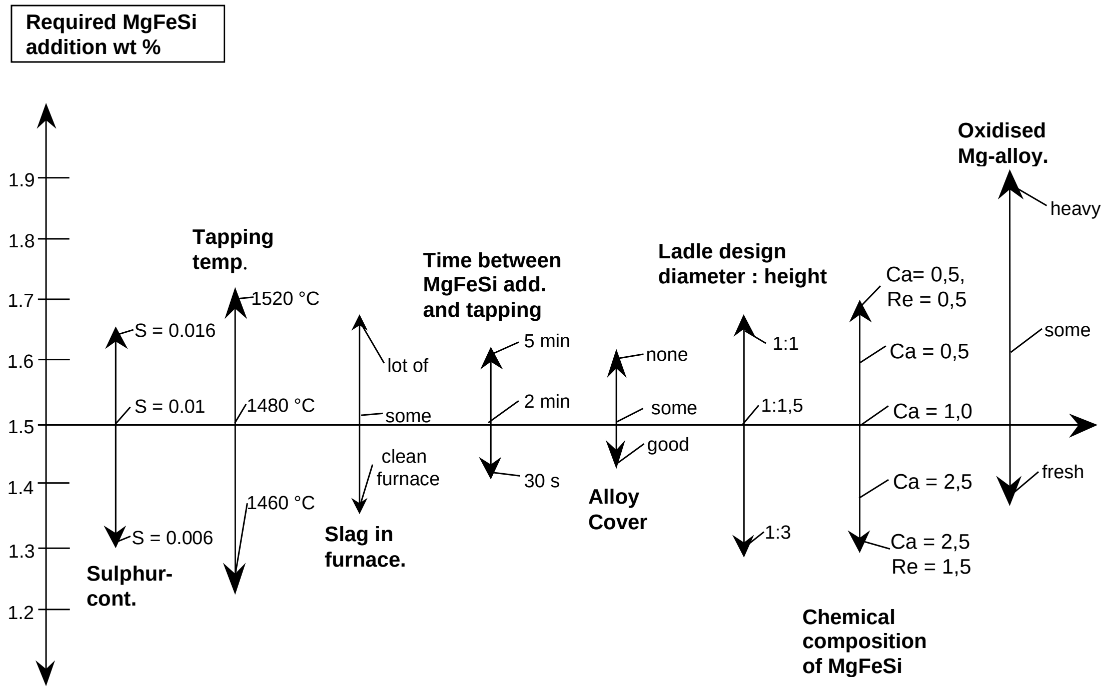

Figure 5: The diagram shows some examples how different factors can influence the MgFeSi addition in a ductile iron ladle treatment process.

Residual Magnesium and Fading.

The total analytical or residual magnesium content of liquid iron immediately after treatment is comprised of:

- Dissolved magnesium
- Micro inclusions of magnesium compounds
- Larger magnesium containing slag particles

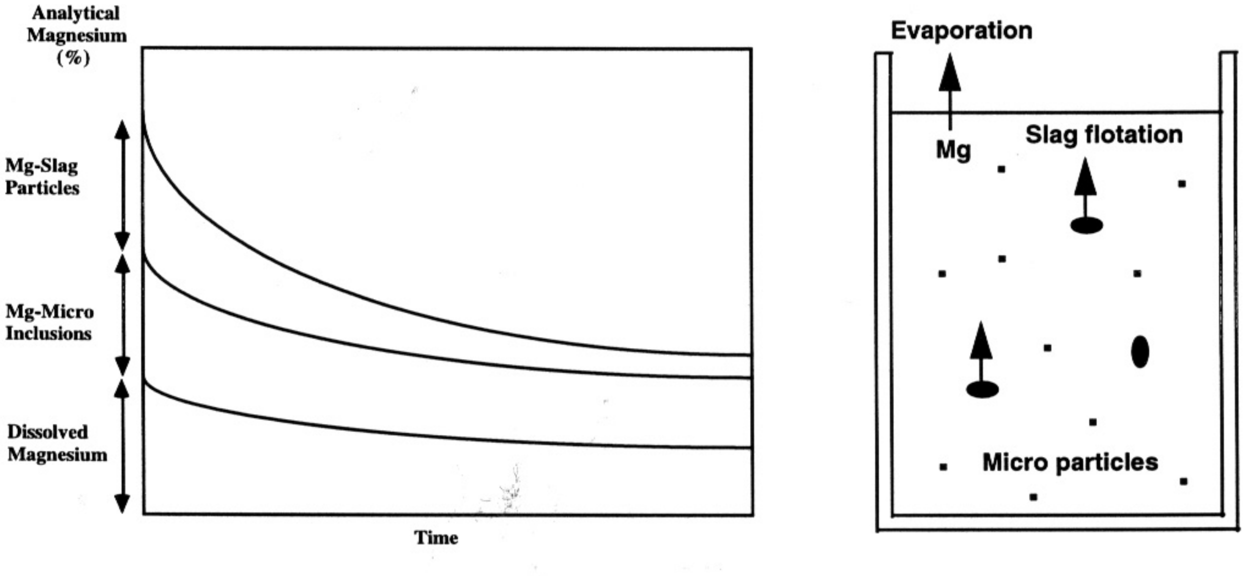

Figure 6: Fading of magnesium during holding of treated ductile iron (left), and schematic representation of magnesium losses from a treatment ladle (right).

These contributions to total (residual) magnesium will react in different ways during subsequent holding of the iron. The slag particles will float according to Stokes Law and move to the surface. Analytically we will see this effect as a fading of residual magnesium. In order to use residual magnesium as criteria for acceptance there should be a very strict sampling procedure. Only if samples are taken the same way every time will it be possible to compare the results.

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