METAL TREATMENT

Two different aspects of metal treatment, by calcium and by magnesium, dealt with in the following articles.

A sandwich process using pure magnesium

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Introduction
The most popular of the methods of adding magnesium in spheroidal graphite (SG) or ductile iron production is an overpour technique, usually with a sandwich of steel scrap. This process requires the minimum of special plant and is simple and versatile to use. It is often refined by building a pocket or recess in the bottom of the ladle, or by some other simple modification. However, the essential advantage of simplicity is always retained.

Until now, it has not been possible to use pure magnesium in these processes because of its very low density and violent, even explosive, reaction. Expensive and complicated plant is needed for the conventional pure magnesium processes. The need for equipment such as the Fischer Converter or plunging apparatus has restricted pure magnesium methods to a relatively small number of large foundries.

The usual alloys for the sandwich process are NiMg and MgFeSi. The NiMg (or the less common CuMg) alloys have the disadvantages of high cost and the introduction of elements which might not be wanted. FeSiMg can have the following disadvantages:

1. Large quantities of silicon are introduced, limiting the amount of return scrap which can be remelted.
For example, a typical addition of 1.8% FeSiMg (5%) introduces 0.8% Si to the iron. Post inoculation could provide another 0-4-0.8% Si. Because of this and the constraint of 2.8% silicon content in the castings, it is common for foundries to control the silicon content by mixing NiMg with MgFeSi. This is particularly the case when the sulphur content of the base iron increases, necessitating a greater Mg addition which would increase the silicon content still further if MgFeSi alone were used.

2. From time-to-time, excess aluminium may be introduced by the MgFeSi, which can cause hydrogen pinholing.

3. MgFeSi has a significant de-siliconising tendency.

The importance of silicon control

The normal range of silicon contents in S.G. irons is about 2.2-2.8%. This range is imposed by the criteria of the properties, which are related to—

1. The matrix microstructure.
2. The silicon content of the matrix.
   - This effect must be considered along with the other elements which are alloyed in the matrix.
3. The presence of carbides.
   - In austenitic ferritic S.G. iron the silicon content is increased to prevent the formation of carbides, but it will also promote ferrite and embrittle the pearlitic matrix. In pearlitic irons, silicon is controlled with these factors in mind.
   - In normal amounts, silicon increases hardness by making the pearlite finer.

In the mainly ferritic S.G. irons, silicon will strengthen and harden the matrix, until above about 4% when the ferrite becomes embrittled. The silicon content required to produce a given proportion of ferrite is related to the purity of the metal, and in relatively impure irons raising the silicon sufficiently to overcome pearlitic-predominating trace elements might embrittle both pearlite and ferrite.

Perhaps the most important factor controlling silicon content is its effect on impact properties. The ductile-brittle transition temperature ranges to ambient temperatures when the silicon content exceeds 2.8%, and this is the main reason why this value is generally accepted as the upper constraint on silicon content.

Other processing factors influence the final silicon content and the following tendencies apply:

- When greater amounts of ferrite are required or carbides might occur (e.g. in thin sections) higher silicon levels are used.
- If charge materials are impure, higher silicon levels are required. Heat treatments to ferritize or remove carbides would allow a lower silicon level to be used.

In heavy section castings, lower silicon contents can be used because the tendency to carbide formation is less, and lower carbon equivalent values are required to avoid graphite flotation. All of these influence the usual silicon range of 2-2-2.8%.

In production, the silicon content is affected by the magnesium treatment process, the inoculation used and the charge materials. Normally about 40-60% returns will be available as charge materials and it is desirable for economy reasons to use all of these.

Good inoculation techniques, including the use of a late inoculation (although late inoculation is normally used in addition to ladle inoculation) can reduce the silicon introduced here, but MgFeSi treatment can easily introduce 0.8-1.0% Si. Thus to accommodate the silicon additions from the MgFeSi and the inoculant, it is necessary to have a base charge silicon of less than 1.3% if the final analysis is to be contained within the desired maximum 2-8% level.

Achieving this low base charge silicon places constraints on the amount of high silicon return scrap which can be used, often to the point where this valuable low sulphur charge material can only be sold at nominal scrap prices.

In addition, melting of low silicon charges in electric furnaces tends to reduce lining life by extracting silicon from the refractory. These reasons all suggest that use of a pure magnesium nodulariser, which is free from silicon is desirable.

Nodulant

Nodulant is a pure magnesium product for manufacture of ductile iron by the sandwich process. It comes in a tablet form, these tablets being produced in a press under very high pressures. They consist of a pure iron powder, pure magnesium and a small amount of CaSi. Rare earths can be included if required. By using iron powder as the binder for
the magnesium, a density in excess of 4.6 gm/cm³ is achieved, helping to retain the tablets beneath the surface of the iron and moderating the release of magnesium. Calcium (as CaSi) is present to control reaction violence and maximise recovery. A range of compositions is possible, but normally Nodulant would contain 10% magnesium plus CaSi and rare earth metals.

Methods of use
Nodulant is intended for use in a sandwich process — placing the tablets in a pocket at the bottom of the ladle and covering with a protective material before filling with metal. Certain aspects of practice apply to all magnesium treatment materials, but it has been found that Nodulant, being essentially a pure magnesium additive is less tolerant of slipshod practice than alloy nodularisers. Some particular points should be mentioned which are applicable to all sandwich treatments:—

Ladles should be tall and narrow, allowing a large head of metal to develop very quickly. A height to diameter ratio of 2:1 is ideal for best magnesium recoveries, and above that should be adequate freeboard to prevent metal being splashed over the top.

A pocket in the base of the ladle is needed and this should be accurately dimensioned so that the treatment agent and cover material fill it without overflowing. Japanese experience with Nodulant suggests that a suitable cover is 1% when treating less than 1 tonne of iron, and 3% when treating more than 1 tonne. Magnesium recoveries of 60–70% have been obtained when using covers as heavy as 5%. The cover material should be compact, dry and rust-free.

Nodulant can be used as the only nodulariser, but it is very successfully used as a partial replacement, either for NiMg in NiMg/MgFeSi mixtures or for some of the MgFeSi where this was the only nodulariser and the silicon pick-up must be restricted. Some examples from foundries illustrate these situations:—

Examples of nodulant in foundries

Example 1 — Is a straightforward example of a large pipe foundry treating 2-7 tonnes of metal each time, at relatively low temperatures and using a very heavy cover. This allows a low addition (0.525%) of nodulariser, and gives high recoveries of 60%.

Example 2 — Shows previous practice and current practice, the results each being an average of over 300 treatments. Noteworthy is the cost saving from replacing the expensive NiMg alloy, which was used because the high initial sulphur level required a high magnesium addition. If the MgFeSi had not been mixed with NiMg or Nodulant, then the silicon increment during nodularising would have been about 1.5 per-cent. Also of interest is the improved lining life which arises from the base silicon level being raised from 1.33 to 1.48 per cent.

Example 3 — This foundry used Nodulant for partial replacement of the MgFeSi nodulariser. This allowed a greater, more controlled use of return scrap, giving a higher silicon content in the furnace, which led to an improved lining life.
1. JAPANESE SPUN PIPE FOUNDRY

MELTING PLANT 22 tonne/hr cupola.
DESULPHURISATION In shaking ladle with calcium carbide to
give 0.008% S.
CAP WEIGHT 2700 kg.
TREATMENT Sandwich process using a ladle with a dam
across the bottom, giving two pockets
which are used alternately.
NODULARISER 0.525% Nodulant (10% Mg, 0.4% rare earths).
COVER MATERIAL 5.5% steel scrap + returns.
TREATMENT TEMP. 1410–1450°C.
COMPOSITION %
BEFORE TREATMENT C 3.60 Si 1.65 Mn 0.40 S 0.08 P 0.035
AFTER TREATMENT C 3.55 Si 1.65 Mn 0.40 S 0.006 P 0.035
Mg 0.030–0.032
MAGNESIUM RECOVERY 60%.

2. ENGINEERING CASTINGS FOUNDRY, U.S.A.

TREATED WEIGHT Original Practice
1130 kg. Current Practice
130 kg.
TREATMENT Sandwich Sandwich
( NODULARISER 1.6% FeSiMg(5) + 1.6% FeSiMg(5) +
0.45% NiMg 0.6% Nodulant
(15% Mg, 30% Si)
COVER MATERIAL 1.2% steel scrap 1.2% steel scrap
TREATMENT TEMP. 1550°C 1550°C
Si IN BARTER 1.32% 1.48%
Si IN BASE IRON 0.025% 0.023%
Si AFTER NODULARISING 0.017% 0.015%
Mg 0.068 0.062
4g RECOVERY 50.2% 48.6%
INDUCTION FURNACE LINING LIFE 3 weeks 4 weeks
COST OF Mg ALLOY PER $39.53 $30.44
TREATMENT

3. AUTOMOTIVE FOUNDRY, U.S.A.

MELTING LARGE Original Practice
5.5 tonne coreless IF 5.5 tonne coreless IF
10% pig iron, returns 10% pig iron, 45% steel,
+ steel depending on 45% returns
% Si
% SILICON 1.30–1.40 1.85–1.90
TREATED WT 410 kg. 410 kg.
TREATMENT METHOD Sandwich Sandwich
NODULARISER 2.7% FeSiMg(5) 1.44% FeSiMg(5)
0.67% Nodulant 0.025
% S BEFORE TREATMENT 0.025 0.020
% S AFTER TREATMENT 0.020 0.040
% Mg 0.040 31.5%
Mg RECOVERY 32.4% Improved by 40%
LINING LIFE

Conclusions
In ductile iron production, it is essential
to control the silicon content of the
castings to obtain the properties
required. Constraints on the final silicon
content enforce limitations on the use of
return scrap and the silicon content of
the base metal. Use of a pure magnesium
nodulariser introduces less silicon during
magnesium treatment. This has the
beneficial effect of allowing the use of a
greater proportion of returns in the
charge and the higher silicon levels in the
furnace bath improve lining life. Tablets of
elemental magnesium and iron constitute a pure magnesium material
which is suitable for use in the sandwich
process.

Sandiron House Group
The Hinkley Group of Associated Companies consists of several separate
entities, each of which operates independently of the others, although
they share the same Head Office at Sandiron House, Beauchief, Sheffield,
S7 2RA.

Recently, Thomas Tilling Limited
acquired the share capital of Hinkleys
Limited who are major producers of
high quality silica sands for the foundry
industries.

This acquisition by Tillings in no way
affects the ownership or viability of the
other companies, which continue in
business as before.

The remaining companies are more
aligned with the refractory and
metallurgical industries and have wide
overseas interests

It is the future policy of the Group to
increase their sales and influence in the
major steelmaking areas of the world
under the direction of their Joint Chief
Executives Mr. D. N. and Mr. G. C.
Hinckley.

The Machining of Cast Aluminium
Alloys
The Association of Light Alloy Refiners in collaboration with the Light Metal
Founders Association has recently
produced a booklet entitled “The
Machining of Cast Aluminium Alloys”.
Copies of this booklet are being made
available to members of ALARS at a
price of £1 per copy plus postage and to
non-members at a price of £2 per copy
plus postage. ALARS also announces
that in view of increased costs the
following prices of its publications apply
with effect from 1 September 1980:

The Properties and Characteristics of
Aluminium Castings Alloys
Price to members £1 per copy, plus
postage.
Price to non-members £4 per copy, plus
postage.

Melting Practice for Aluminium Alloy
Castings
Price to members £1 per copy, plus
postage.
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Orders for these publications should be
to The Technical Office, The
Association of Light Alloy Refiners
Limited, 635 Grand Buildings, Trafalgar
Square, London WC2N 5HN.