THE USE OF SILICON CONTAINING ALLOYS IN IRON FOUNDRIES

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In modern materials like aluminum castings, as well as in the traditional cast irons, silicon is a necessary and very useful alloying element. The demand for silicon in cast iron is split between ferrosilicon used for increasing the silicon content of the melt, magnesium ferrosilicon for the production of ductile cast iron and inoculants for improving the quality of the castings.

In past decades, cast iron has improved from "grey iron" to a variety of exciting new materials, such as ductile cast iron and compacted graphite cast iron. Quality and shape of castings have changed: steel mill ingots have gone and modern castings with thin walls of great strength, for instance automotive castings, are state of the art.

New methods of magnesium treatment, like tundish cover, Flotret and Inmould, have been developed to produce ductile iron; new inoculants and improved methods of addition, for example, mould inoculations, inoculating wire or stream inoculation serve the foundries to permit them to produce high-quality castings.

For thirty years, SKW, as a ferroalloy producer, has participated in the development of ferroalloys and processes for improving the quality of cast iron. Improved quality of castings will help the iron foundry industries survive in the competitive market for high performance materials.

THE ROLE OF SILICON IN CAST IRON

Cast iron is an alloy, containing mainly elements of iron, carbon and silicon. The addition of silicon per unit of cast iron is much higher than in steel. This is the reason why, when compared to the steel industry, the smaller foundry industry consumes a considerably larger part of the silicon contained in ferroalloys.

Silicon is added to cast iron as:

- ferrosilicon or silicon carbide in the furnace
- magnesium ferrosilicon master alloys in the production of ductile iron
- inoculants for grey and ductile iron

Altogether approximately 1 % - 1.5 % of silicon will be added to the iron depending upon the type of furnace, the type cast iron being produced, and the amount of pig iron used in the basic raw material charge. In steel production, the average addition of silicon is 0.2 %. Based on these figures, the approximate consumption of silicon contained in ferroalloys can be estimated as follows: Attachement # 1

Si-consumption in steel and cast iron production

Country	Steel production 1)	Si-cons. 0,2 %	Cast Iron production 2)	Si-cons. Ø 1,2 %
1984	000. MT	000. MT	000.MT	000. MT
USA	82.713	165,4	10.020	120,2
Japan	105.585	211,2	5.235	62,8
FRG	39.389	78,8	3.169	38,0
France	19.005	38,0	1.719	20,6
Great Britain	15.202	30,4	1.376	16,5
Italy	24.026	48,1	1.313	15,8

1) acc. IISI
2) in some countries estimates

These figures cannot be very exacting, because in some countries more or less silicon is added as silicomanganese to the steel or as silicon carbide to cast iron, but they do make clear that the demand of the iron foundries for silicon units is an important factor for all ferroalloy producers, accounting for approximately one-third of the total demand for silicon.

In this paper, we shall pay attention to the more advanced silicon alloys used in cast iron production, that is nodularizers and inoculants, which help the foundry industry to fill increasing quality requirements.

1. DEVELOPMENT OF CAST IRON PRODUCTION

During the recent decades, considerable changes have taken place regarding the use of castings. This was greatly impacted on by the development of nodular cast iron. With increased quality, cast iron replaced forged and cast steel parts. This was only possible with the new and better methods of magnesium ferrosilicon treatment and inoculation which are discussed in Points 2 and 3 of this paper. Attachement # 2

Production of Ductile Iron

Country/Region	MT	1961	1975	1980	1983
West Europe	T Tons	160	1,910	2,135	2,377
USA	T Tons	170	1,656	2,147	1,802
Japan	T Tons	150	962	1,611	1,682

On the basis of these figures from the German Market, which is similar to other industrial countries, it can be seen that the shipments of cast iron to various groups of customers have changed during the past ten years: Attachement # 3

Cast iron production in West-Germany (various groups of customers)

Grey Cast Iron	T tons	1975	1980	1984	Tendency
Pipes		144	30	22	--
Houses and sanitary castings		161	149	93	-
Ingots for steel plants		491	329	148	--
Machine building		939	926	746	+-
Vehicles		811	942	926	+
Ductile Iron	T tons				
Pipes (Pressure Pipes)		326	292	320	+-
Machine buidling		107	156	169	+
Vehicles		61	129	218	++

	1975	1980	1984	Tendency
Steel + Malleable Cast Iron T tons				
Rolls	63	38	29	-
Machine building	169	112	72	-
Vehicles	166	137	92	-

The demand of the capital goods industry for castings, especially the machine building trade, has been maintained. Increased demand for cast iron is seen in the vehicles industry and in pressure pipe.

The steadily improved cast-iron qualities made it possible to replace welded and forged parts with casting. In addition, there are cases where castings open entire new technical solutions, for example exhaust-gas turbo superchargers, and special applications in the energy field. An important thrust on the need for high performance castings is coming from the automotive industry, which has been forced to lighten the vehicle because of the energy crisis, which started in the early 1970's. The most interesting figures for producers of alloys are:

a) Despite the cutback in grey iron in general, the demand of machine building and vehicular industry have remained stable. Both industries need high quality castings which require inoculation.

b) Ductile iron in the same customer groups increased sharply, representing a further strong market for producers of magnesium ferro silicon alloys and inoculants.

2. CHANGE OF QUALITY REQUIREMENTS, INCREASING INFLUENCE OF TREATMENT METHODS

Technology and materials are in the forefront of the foundries' needs. The healthy interplay between the casting users and the actual abilities of the foundries to meet these needs resulted in enormous development within the last few years. New materials became state of the art; for example, cast iron with nodular graphite and cast iron with vermicular graphite.

Not only has the quality of the castings experienced this upsurge in quality, but also the processes, the facilities and the treatment, as well as the ferroalloys used, have participated in this forward thrust in technology.

In spite of the impressive development in the quality and performance of high technology castings, there will be competition from new materials as seen in the selection of light metal and ceramic parts in the internal combustion engine and plastic for waste water pipes and shaped parts, as seen in Section 1 of this paper. Quality, not quantity, is demanded, but quality is not simple to produce and may not be achieved in a single process. Quality must be sought daily through a steady improvement in casting processes. Quality in total requires quality in detail and also quality of the ferroalloys used in the process. The efforts of the foundries with regard to the development of new fields of application for castings in order to maintain the performance and capability of the foundry industry also have to be of interest to the ferroalloy producers to secure the market for ferrosilicon alloys. The ferroalloy producers must contribute to the making and marketing of special alloys, treatment know-how, and assist the foundrymen in finding solutions to specific foundry metallurgical problems. It is in the best interest of the ferrosilicon alloy producers to encourage the foundrymen to develop high performance cast irons that require specialty silicon alloys made to high engineering standards.

3. DUCTILE IRON, NEW METHODS OF PRODUCTION, FERROSILICON MASTER ALLOYS AND INOCULANTS FOR SPHEROIDAL GRAPHITE AND GREY CAST IRON

The 7th of May 1948 is regarded as the birthday of ductile iron when H. Morrogh of BCIRA presented a paper describing the addition of cerium to hypereutectic iron to form spheroidal graphite.

A WORD ABOUT STEEL AND IRONS

Pure, carbon-free iron is practically never used as a cast material. Steel contains up to about 0.9 % carbon. White irons contains 2 % to about 3.3 % carbon and can be used but they are highly abrasive and their application is limited due to the brittle nature of the alloy. It is a true cast iron, but most of the contained carbon is present as iron carbide, a hard and brittle compound, Fe_3C.

The carbon contents of white and malleable irons overlap. Indeed, malleable iron must solidify as white iron. A lenghty heat treament of the white iron castings decomposes the Fe_3C into steel and nodules of graphite.

In grey and ductile irons, most carbon in excess of carbon solubility in the solid iron is present as finely dispersed graphite shapes, rather than as Fe_3C. In grey cast irons, the grey iron flakes act as a stress raiser and under stress help crack propagation. As a result, grey cast irons are weak, with ultimate tensile strength between 150 and 400 N/mm^2 with practically no ductility.

Cast iron with spheroidal graphite became an industrial realty in 1948. A suitable treatment of the molten iron, normally with magnesium master alloys, causes the precipitating graphite to form in the shape of spheroidals rather than flakes. The nearly spheroidal shape of the graphite removes the stress effect of the graphite flakes of grey iron. Thus, iron with spheroidal graphite is known as ductile iron or SG iron.

OUR INTEREST: TREATMENT ALLOYS AND METHODS

Spheroidal graphite can be obtained by treating the base iron with several elements such as cerium, magnesium and/or calcium. In commercial practice, magnesium is the most commonly used graphite nodulizer. Other elements are usually added with the magnesium to minimize reactive violence, for example nickel and ferrosilicon, but, also, often with the aim of obtaining the optimum metallurgical condition - that is free from carbide in the as-cast condition.

The technical role of magnesium in the formation of nodular instead of flake graphite is still being debated in the metallurgical fraternity. Magnesium changes the surface tension between the graphite and the liquid iron and apparently in this way assists in the formation of nodules rather than flakes.

Currently, the most commonly used treatment for the production of nodular iron is magnesium ferrosilicon.In 1979, the Molten Metals Process Committee of the Ductile Iron Division of the American Foundrymen's Society gave a detailed report on the current treatment practices in the United States. This study reported that 57 % of the U.S. producers of ductile iron treated with a 5 - 6 % magnesium ferrosilicon alloy. Three percent of the producers use pure magnesium, the balance being nickel-based magnesium alloys, except for one foundry, which used magnesium impregnated coke. These figures are fairly typical of the foundry practices worldwide.

DUCTILE IRON - PRODUCTION AND APPLICATION

The foundry industry is sometimes referred to as "the hidden giant" and indeed it is. In the 1970's, there were as many as 4,800 plants in the United States involved in the casting of alloys. Presently, there are approximately 350 foundries in the United States capable of producing ductile iron. Worldwide, this number of foundries capable of producing ductile iron is estimated to be between 2,000 and 3,000, presenting a large but scattered market for suppliers.

Ductile iron, having the strength of cast iron, but the more favorable cost and ease of castability of grey iron, has made great strides since its discovery. Cast spun ductile iron pipes was one of the first applications for this new super iron and now constitutes the largest single tonnage outlet.

Automotive castings represent the second largest market for ductile iron castings, with the passenger car engine crankshafts as one of the notable applications.

Automotive castings are part of the larger group of engineering castings. The wide application of ductile iron, however, does not make the casting industry recession-proof.

There are different methods of adding magnesium ferrosilicon or pure magnesium to the molten iron. The basis goal of all methods is to introduce the magnesium to the liquid iron at the lowest cost, considering metallurgical and environmental objectives. There are six main processes: Attachement # 4

a) overpouring ladle method
b) in-the-mold-treatment
c) osmosis (Gazal) treatment
d) Flotret Method
e) Pluning Method
f) The Fischer Converter

All of these processes have their advantages depending upon conditions. Important influences are type of castings, supply of molten iron, melting equipment, raw materials, environmental factors and, of course, not the least, process costs.

It is up to us, as ferroalloy producers, to convince the customers that magnesium ferrosilicon is the ultimate way of adding magnesium. Attachement # 5

After the iron is ready to be poured, a second step has to be done to produce quality cast iron: Inoculation. This in another outlet for silicon containing alloys. Inoculation of cast iron is not easy to define. However, the best attempts can be briefly summarized in two separate statements:

- The late addition of certain silicon alloys to molten iron changes the graphite distribution, improves its mechanical properties and reduces the chill tendency, which cannot be explained on the basis of analytical change with respect to silicon alone.

- It also assures solidification of the austenite-graphite system.

In addition to the many definitions for inoculation, the literature has many explanations for the mechanism of inoculation. Although space will not permit a complete discussion of all theories, the six basic theories are:

1. The Silicate-Slime Theory
2. The Gas Theory
3. Undercooling Theory
4. The Graphite Nucleus Theory
5. The Carbide Stability Theory
6. Surface Tension or Surface Energy Theory

Because of the different theories, there are a large number of proprietary inoculants.

Attachement # 6

Because of varying process techniques in different foundries, our inoculants are used with different effectiveness. The rate of addition varies from 0.03 % to 1 % of the liquid iron treated.

Different processing techniques result in the need for inoculants of different sizes and size distribution. Size is a critical factor determining the cost of producing inoculants. The foundryman can inoculate in many places in his process:

Attachement # 7

1. Preconditioning in furnace
2. Transfer Ladle
3. Pouring Ladle
4. Metal Stream (MSI, wire-inoculation)
5. In mold as inserts

The inoculation technology aims for a better preconditioning in the furnace combined with relatively small amounts of metal stream inoculants or the in mold technology.

The field of inoculation is a very important part of our ferroalloy activities. Compared to the quantities of magnesium ferrosilicon sold, the inoculants are relatively a small market, but a sophisticated and interesting part of the ferroalloy producers' product line.

CONCLUSIONS

"Casting in Future" was the slogan of the last international Foundry Trade Fair held in Düsseldorf in 1984.

What will the future bring the ferroalloy industry? From the figures it can be seen that there are several markets for castings, which still grow. It will not so much be the tonnages that grow, but the quality and diversity of foundry products.

To predict our business with nodulizers and inoculants, it is necessary to have a look to the customers of the foundries. This means the performance of the car industry, the engineering sector and the public capital spent for infrastructure will mainly determine the quantity of material used. Whether this material is produced by foundries can to a certain degree be influenced by their suppliers, among others by the ferroalloy industry. Is is up to us, in collaboration with foundries, with foundrymen's societies and universities, to improve the quality of castings that helps the foundries to survive and thereby insuring a place for the ferroalloy producers in the foundries of the future.

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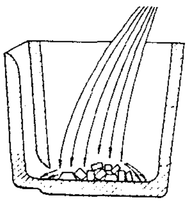
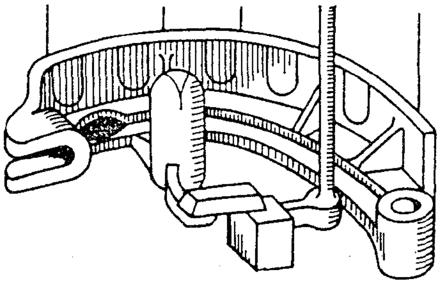
SPEROIDIZING TREATMENT METHODS

Attachement # 4

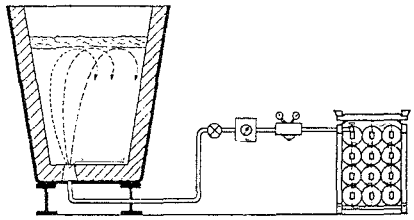
Overpouring



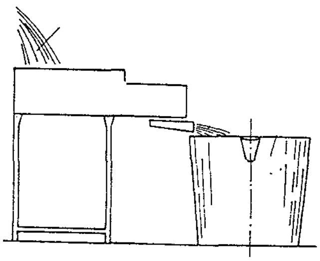
Inmold



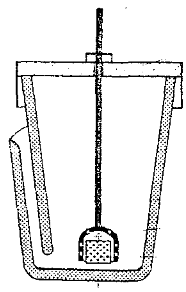
Osmosis (Gazal)



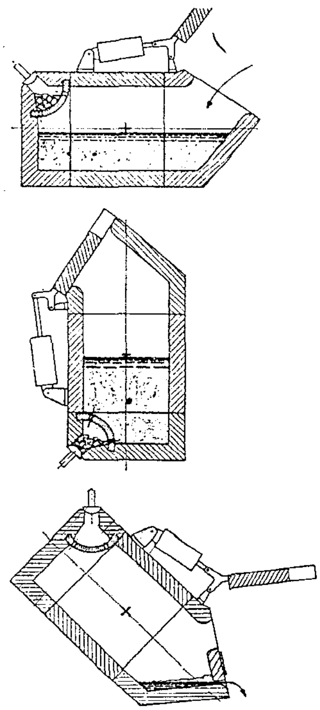
Flotret



Plunging



Konverter



Attachment # 5

SPHERODIZING TREATMENT METHODS AND ALLOYS

Process	Alloy	Add %	Recovery % (Mg)	Silicon % (Alloy)
Overpouring	FesiMg 5/10	1,2 - 2,5	45 - 60	44 - 49
Inmold	FesiMg 6	0,7 - 1,2	60 - 80	44 - 70
Osmosis	FesiMg 5	1,8 - 2	40 - 50	44 - 49
Flotret	FesiMg 3/5	1,3 - 1,6	50 - 65	44 - 49
Plunging	FesiMg 15/30/40	0,8 - 1,2	25 - 60	45 - 55
Konverter	Pure Magnesium	0,05 - 0,1	50	-

Attachment # 6

MOST COMMENLY INOCULANTS, BASED ON FESI 75 AND FESI 50 FOR S.G., C.G. AND GREY CAST IRON

	INOCULATING GRADE	PROPRIETARY INOCULANTS
Fesi 75 Fesi 50	Al Ca	Ba Zr Sr Mn RE Mg Bi
	Ferrosilicon	SB 5, SZR 504, VP 216, Germalloy, Optigran, Inoculoy 63 ZL 80, Spherix, Zircograph, Zircocal Superseed, Vaxon, Vaxon D

Attachement # 7

WHEN TO INOCULATE