Addition of silicon carbide to cast irons

What is silicon carbide?

Silicon carbide is a chemically and thermally stable compound formed by combination of the elements silicon and carbon. The reaction requires the application of considerable energy and occurs as follows

\[
\text{SiO}_2 + 3\text{C} \rightarrow \text{heat} \rightarrow \text{SiC} + 2\text{CO}
\]

The material does not occur in nature and consequently all available supplies are produced synthetically by the reduction of pure silica sand with petroleum coke, at very high temperature and over a long period of time. The resulting crystalline product is then graded for various industrial uses.

Advantages

Alloying

As an alloying addition silicon carbide has several advantages, largely brought about by the method of manufacture, availability of high-purity raw materials and relatively low cost. This leads to a cost-effective way of adding carbon and silicon to the melt whilst providing significant price stability when compared with the fluctuating prices of ferro-silicon, petroleum coke and graphite.

As a carburizer

- can be used in both cupola and electric furnace operation
- very high purity, being low in both sulphur and nitrogen
- reduces scrap caused by nitrogen defects (see Broadsheet No 41)
- can eliminate the need for titanium addition to counteract above defects (see Broadsheet 294)
- avoids loss in mechanical properties of ductile iron by sulphur contamination (see Broadsheets 234 and 291).

As a silicon additive

- low aluminium content compared with normal metallurgical grades of ferro-silicon, reducing tendency for hydrogen pinhole defects
- cost advantage over special low aluminium grades of ferro-silicon (see Broadsheets 7 and 43).

As a de-oxidant

- produces lower and less fluid slag levels than alternative materials
- reduces susceptibility to slag-related defects, particularly with heavily oxidized charge materials
- lowers attack of furnace lining with less slag build-up, giving longer furnace life and reduced maintenance and downtime.

Nucleation

Silicon carbide has a unique effect on the solidification mechanism of grey and ductile iron. The compound does not melt but dissociates into silicon and carbon particles and dissolves in a relatively controlled manner. This supplies a large number of potential nucleation sites for graphite and possibly austenite dendrite formation over an extended period. This produces a high level of nucleation in the furnace, giving lower carbide contents and chill depth.

Uses

The exceptional properties of silicon carbide such as high hardness, refractoriness and unreactivity render it suitable for a number of uses. These include grinding wheels and powders (carborundum); furnace furniture, refractory rods and tubes for thermal treatments of metals and ceramics; metallurgical structure reinforcement for aluminium metal-matrix composites (MMCs); melting and holding crucibles and pouring ladles.

It is also used in the iron founding industry as a denser material for chilling certain parts of sand moulds and more importantly as an additive to iron charge materials for molten iron production.

Why add silicon carbide to iron

Silicon carbide can be added to grey, malleable and ductile iron and is suitable, in different forms, for both cupola and electric melting. Its main use has been to provide the required silicon level as a very high purity alternative to ferro-silicon.

However, the relatively high carbon content also supplements the carbon level in the iron, thereby reducing the need for more expensive carburizers such as high-purity graphite. The beneficial effect on solidification nucleation, which has been reported by researchers and foundries alike, is also important.

This effect is thought to act on both austenite dendrite formation and on graphite precipitation, thus refining the metallurgical structure and consequently increasing mechanical properties and reducing chill.
in both grey and ductile iron; better flake graphite formation; higher nodule counts; enhanced response to post inoculation and much longer fade times. In addition, research and practice have demonstrated a solidification mode which reduces secondary shrinkage.

The potential benefits ensuing from the above are:
- higher and more consistent tensile properties in grey iron
- higher elongation and impact properties in ductile irons
- reduced shrinkage defects, particularly with regard to interconnected microporosity in ductile irons
- improved machining characteristics of grey and ductile irons
- reduced requirement for annealing heat treatments
- less variations due to inoculant fade
- reduced post inoculation treatments
- higher nodule counts reduce likelihood of pearlite in ferritic ductile irons

Disadvantages

There are few known disadvantages to the use of this material. Nevertheless, certain aspects should be borne in mind:
- carbon content cannot be increased without an accompanying proportional increase in silicon (and vice versa) and so supplementary additions may be needed
- charge calculation are slightly more complicated
- reduced pearlite levels can produce unexpectedly low strengths in pearlitic and partially pearlitic ductile irons and so alloy additions may need to be increased
- increased nucleation can lead to greater expansive forces and therefore increased shrinkage porosity in heavily inoculated irons
- silicon carbide cannot be used successfully as a late inoculant due mainly to its slow assimilation into the melt and so its uses are restricted to alloying and pre-conditioning.

Technical data

There are several grades of silicon carbide available. The most commonly used form is granulated and is used in electric furnace charges. A typical composition is:

<table>
<thead>
<tr>
<th>Component</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon carbide</td>
<td>88–92</td>
</tr>
<tr>
<td>Free silicon</td>
<td>0.5</td>
</tr>
<tr>
<td>Free silica</td>
<td>3.75</td>
</tr>
<tr>
<td>Free carbon</td>
<td>3.5</td>
</tr>
<tr>
<td>Aluminium</td>
<td>0.2</td>
</tr>
<tr>
<td>Alumina</td>
<td>0.2</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.02–0.04</td>
</tr>
<tr>
<td>Iron</td>
<td>0.15</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.4</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.025–0.04</td>
</tr>
</tbody>
</table>

As a general rule it is reasonable to assume that the material contains 63% Si and 31% C for charge calculations. Recovery of both elements is extremely good. In coreless induction furnaces this is about 90%. A 1% addition by weight of silicon carbide to the charge gives approximately 0.56% silicon and 0.27% carbon increase.

The granular form is not suitable for cupola additions unless injected. The normal form for cupola addition is in compacted briquettes, with a binder and a fluxing additive. The silicon carbide content of the briquettes varies from 35% to 75%, depending on the grade selected.

Physical properties

- Dissociation temperature = 2700 °C approx
- Dissolution temperature (in molten iron) = 1300 °C and above
- Density = 3.2 g/cm³
- Bulk density depends on form, granules average 1.3 g/cm³

Environmental considerations

Silicon carbide is virtually chemically inert and in the form supplied to foundries, as far as known, presents no special hazard. In particular form it is currently regarded only as a nuisance dust with a long term (8 hour) Occupation Exposure Standard (or OES) of 10mg/m³ for total inhalable dust and 5 mg/m³ for respirable dust (see Broadsheet 163-19).

Recommended further reading