Changes in the nitrogen content of cast iron during melting and holding in a coreless induction furnace

Why nitrogen is important
During melting and holding in a coreless induction furnace the nitrogen content of iron castings can change, and this change can cause important variations in their structure, strength, and soundness—in the form of fissure and blowhole defects. Increasing amounts of nitrogen, up to 0.01 per cent, can improve the mechanical properties of grey iron owing to the formation of compacted graphite (BCIRA Broadsheet 41), but at higher levels it can produce unsoundness in castings, arising from the liberation of excess nitrogen during solidification. High nitrogen content in malleable iron impairs annealability and promotes pearlite formation.

Sources of nitrogen
Many metallic charge materials contain nitrogen, part of which will be retained during melting. Some carburizing materials may also contain a large quantity of nitrogen, some of which can be dissolved by molten iron. Graphite additives generally have a very low nitrogen content, but other carburizers may contain up to 1 per cent of nitrogen.

The air above the metal in a coreless furnace contains 79 per cent (by volume) of nitrogen, which may under some conditions dissolve in the iron.

Solubility of nitrogen in iron
The solubility of nitrogen in iron increases as the carbon and silicon contents decrease, and also increases with temperature. Fig. 1 shows how the solubility is affected by carbon and silicon content, at 1400 and 1550°C.

Changes in nitrogen during melting
High-nitrogen carburizers will increase the nitrogen content of iron during melting, and may lead to nitrogen contents well above the equilibrium solubility values given in Fig. 1.

When a high-nitrogen carburizer is not used in the charge, the nitrogen content of the metal may either increase or decrease during melting, depending on the nitrogen content of the charge material. If the nitrogen content of the charge is below the solubility value of Fig. 1, the iron will tend to pick up nitrogen from the atmosphere; if then the metal is repeatedly remelted, the nitrogen level will slowly increase until the solubility value is reached, where it will remain constant. If the nitrogen content of the charge is initially above the solubility value, the metal will lose nitrogen each time it is remelted—until the solubility value is reached, Fig. 2.
Changes in nitrogen content during holding
The nitrogen content of iron may either increase or decrease while the metal is held in a coreless induction furnace, depending on its initial level in the iron. At a low nitrogen content the metal will slowly absorb nitrogen from the atmosphere until the solubility value is attained, whilst at a high nitrogen level it will slowly lose nitrogen until the solubility value for the particular iron composition is reached. Once it reaches the solubility value the nitrogen content will remain constant, Fig. 3.

Use of high-nitrogen carburizers
Up to 50 per cent of the nitrogen in a carburizer can be absorbed by the metal during melting. When a high-nitrogen carburizer is used, the nitrogen content of the iron will increase while the carburizer is being dissolved, but during subsequent superheating and holding operations the nitrogen content will approach the solubility value, as described above. If a high nitrogen content has been produced by this means, it will subsequently diminish and approach the solubility value—Fig. 4; the rate of nitrogen-loss will decrease as the excess of nitrogen content above the solubility value decreases, but it will be increased by more stirring of the melt.

Fig. 3  Changes in the nitrogen content during holding.

Fig. 4  Effect of using high-nitrogen carburizer on the nitrogen content of iron.

Importance of changes in nitrogen
The use of metallic charge materials or carburizers having a high nitrogen content can produce high levels of nitrogen in the metal, which may lead to unsoundness in any castings made.

The decrease in nitrogen content of iron, due to remelting and holding in a coreless induction furnace, tends to reduce the likelihood of unsoundness.

Absorption of nitrogen from the atmosphere by iron initially of very low nitrogen content should not be enough to cause unsoundness in castings. High nitrogen contents (but below the level at which unsoundness is caused) promote compacted-graphite structures.

The effects of nitrogen can be neutralized by small additions of titanium or aluminium.

Recommended further reading


*Available only to BCIRA Members.