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**Cast Irons**

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**Acknowledgement**

Mr John Gibson is a highly regarded educator and engineer. John taught Industrial Arts at a number of high schools before taking a position at Sydney Teachers’ College, then University of Sydney. He had an engineering education consultancy and has extensive experiencing working with NESA on Engineering Studies syllabus development and the HSC examination committee. The STEM Industry School Partnerships (SISP) Program asked John for his responses to the iTeachSTEM topic discussion questions. SISP is grateful to John for submitting these example discussion responses.

# Describe the manufacturing process for cast iron.

Cast iron became available to industry during the 1770s at a time when large quantities of the metal were produced in special furnaces known as Cupolas. A typical furnace charge would include pig iron, scrap steel, any alloy element and, a flux. The furnace melts the charge to liquid, which is tapped into crucibles ready to be poured into the casting box.

1. **Describe the application of cast iron in braking systems.**

The most common use of cast iron in the braking systems of vehicles is for the production of disc brake callipers and rotors, the two major parts of modern brake systems.

Although common cast irons are brittle and have low strength, they are cheap and suited to the foundry process which is used to produce components. Cast irons are closely related to steels but their structure, properties and applications are vastly different.

1. **Describe the microstructure of cast irons.**

Cast irons have a very complex microstructure due to the fact that there are four variables that govern their structure – the carbon content (composition), the alloy content (Si), the cooling rate during production and, any heat treatment.

**Composition**

In theory, Plain Carbon Steels can have compositions from 0.05%C to 2%C.

In practice, Plain Carbon Steels have compositions from 0.15%C to 1.3%C.

In theory, Cast Irons can have a composition from 2%C to 6.67%C.

In practice, Cast Irons have compositions from 2.5%C to 4.5%C.

If we examine the cooling sequence for a 2.5%C (97.5%Fe) cast iron, the metal begins to solidify around 1200°C and, solidifies at 1130°C (Eutectic Reaction). Another reaction within the alloy causes a second change in structure. This is the eutectoid reaction at 723°C.

Another feature of these alloys is the effect caused by a reaction in the phase Cementite – Iron Carbide. Depending on the temperature and composition of a particular alloy, Iron Carbide can remain a stable compound. As such, it is strong, very hard and, brittle but, given the correct condition, the Cementite can break down to iron plus carbon.

The iron that is the result of the change joins with the other iron grains, leaving an amount of carbon in the structure. This carbon is in the form of graphite and, as graphite (carbon) is ‘black’, it is very easily seen on the surface of a cast iron piece as short fibres.

As iron and cementite are silvery white, these alloys are termed **White Cast Irons**.

As graphite (carbon) is black and the other phases around it are metallic, alloys containing free graphite are termed **Grey Cast Irons**.

Another process available from the structure of cast irons is the fact that we can produce the graphite in different shapes. Cast irons with differing shaped graphite are named accordingly:

Nodular GCI; Flake Graphite GCI; Spheroidal Graphite GCI

Other forms of grey cast irons include:

Pearlite GCI, Malleable GCI and, Martensitic GCI.

1. **Describe the manufacturing process used to produce brake cylinders in cast iron**.

Components made from cast irons are generally produced by the process known as **Sand Casting**. In this process, a pattern, the shape and size of the item to be produced, is first prepared. The pattern is placed in one half of a split box and held in place by pressing moulding sand onto it. When done, the box is inverted and the other half filled with sand and tamped down around the pattern. Provision is made for liquid to be poured into the mould from the crucible. The pattern is removed and the two halves of the moulding box placed together. Molten cast iron at around 1300°C is poured into the mould and allowed to solidify. When cold, the cast item is removed from the sand box and dressed up.

1. **Discuss the similarities between the structure of steel and cast iron for brake rotors.**

The microstructure of commercial plain carbon steel shows variations of three components – Ferrite, Cementite and, Pearlite. Strange as it might seem, the microstructure of grey cast iron also shows its components as Ferrite, Cementite and, Pearlite but includes Graphite (carbon). If that is not enough to confuse things, the component Pearlite itself is made up of Cementite and Ferrite. Then we need to add that carbon can be free or combined. There are microstructural differences and, property differences (strength ductility, toughness, corrosion resistance, etc). Then there are cooling rate and heat treatment differences, where applied.

*Did someone* really *comment the steel and cast iron are complex materials!?*

1. **Discuss the properties of cast iron that make it preferable to steel in the production of brake rotors.**

Cast iron is very good when under a compressive load, has very good wear resistance, does not corrode (unlike steel) and, the free graphite (carbon) acts as a dry lubricant to the system.

1. **What properties are required of a material to be used as a brake pad?**

Compressive strength, wear-resistance, a high co-efficient of friction, machinability.

1. **Describe how composite brake pads/shoes are manufactured.**

A current production process involves preparation of the disc pad back-plate which is punched out of 5mm thick, low to medium carbon steel. Plates are cleaned and surfaces roughened.

Components for the ‘pads’ are mixed to a set formula and include friction particles and selected powdered metal (to dissipate heat). These are then thoroughly mixed into a resin ready to be heated and compressed onto the back-plate in a **hot compression moulding** machine.

When cured, the pads are cooled and dressed ready for packaging.