Manufacturing Processes
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MANUFACTURING PROCESSES

Engineering Materials

CLASSIFICATION OF ENGINEERING MATERIALS

- METALS
- PLASTICS
- CERAMICS
- COMPOSITES

METALS

METALS

- A **METAL** is an element, compound, or alloy that is a good conductor of both electricity and heat.
- Metals are usually malleable, ductile and shiny, that is they reflect most of incident light.
- Metals are element substances which readily give up electrons to form metallic bonds and conduct electricity.

METALS

- Following are the properties which make metals a suitable engineering material:-

1. ***High stiffness and strength***. Metals can be alloyed for high rigidity, strength, and hardness ; thus, they are used to provide the structural framework for most engineered products.
2. ***Toughness*** . Metals have the capacity to absorb energy better than other classes of materials.

METALS

3. ***Good electrical conductivity***. Metals are conductors because of their metallic bonding that permits the free movement of electrons as charge carriers.
4. ***Good thermal conductivity***. Metallic bonding also explains why metals generally conduct heat better than ceramics or polymers.
5. ***Low cost***. Many common metals a re available at relatively low cost per unit weight an dare often the material of choice simply because of their low cost.

ALLOYS

ALLOYS

- An **ALLOY** is a mixture of two or more elements in solid solution in which the major component is a metal.
- Most pure metals are either too soft, brittle or chemically reactive for practical use.
- Combining different ratios of metals as alloys modifies the properties of pure metals to produce desirable characteristics.
- The aim of making alloys is generally to make them less brittle, harder, resistant to corrosion, or have a more desirable color and luster.

PURPOSE OF ALLOYING

- To improve hardness, toughness and tensile strength.
- To improve wear resistance.
- To improve corrosion resistance.
- To improve ability to retain shape at high temp.
- To improve machinability.
- To improve elasticity.
- To improve cutting ability.

METALS & ALLOYS

- FERROUS
- NON FERROUS

FERROUS METALS & ALLOYS

- **FERROUS METALS** are those which contain a high proportion of the element ***IRON***.
- This group includes **STEEL** & **CAST IRON**.
- These metals constitute the most important group commercially, more than **(3/4)th** of the metal tonnage throughout the world.
- Pure iron has limited commercial use, but when alloyed with carbon, iron has more uses and greater commercial value than any other metal.

NON-FERROUS METALS & ALLOYS

- **Nonferrous metals** include the other metallic elements and their alloys.
- In almost all cases, the **alloys are more important** commercially than the pure metals.
- The nonferrous metals include the pure metals and alloys of ***aluminium, copper, gold, magnesium, nickel, silver, tin, titanium, zinc, and other metals.***

PLASTICS

PLASTICS

- A **PLASTIC** material is any of a wide range of synthetic or semi-synthetic organic solids that are moldable.
- Plastics are typically organic polymers of high molecular mass, but they often contain other substances.
- They are usually synthetic, most commonly derived from petrochemicals, but many are partially natural.

CERAMICS

CERAMICS

- A **ceramic** is an inorganic, nonmetallic solid prepared by the action of heat and subsequent cooling.
- Any of various hard, brittle, heat-resistant and corrosion-resistant materials made by shaping and then firing a nonmetallic mineral, such as clay, at a high temperature.

CERAMICS

- Ceramics offer many advantages compared to other materials.
- They are harder and stiffer than steel; more heat and corrosion resistant than metals or polymers; less dense than most metals and their alloys; and their raw materials are both plentiful and inexpensive.

COMPOSITES

COMPOSITES

COMPOSITES

- A typical **COMPOSITE MATERIAL** is a system of materials composing of two or more materials (mixed and bonded) on a macroscopic scale.
- For example, concrete is made up of cement, sand, stones, and water.
- If the composition occurs on a microscopic scale (molecular level), the new material is then called an alloy for metals or a polymer for plastics.

COMPOSITES

- Generally, a composite material is composed of **REINFORCEMENT** (fibers, particles, flakes, and/or fillers) embedded in a **MATRIX** (polymers, metals, or Ceramics).
- The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix.
- When designed properly, the new combined material exhibits better strength than would each individual material.

STEELS

STEELS

- **Steel** can be defined as an iron–carbon alloy containing **0.02% to 2.11 % carbon**.
- It is the most important category within the ferrous metal group.
- Its composition often includes other alloying elements as well, such as manganese, chromium, nickel, and molybdenum, to enhance the properties of the metal.

STEELS

- Applications of steel include construction (bridges, I-beams, and nails), transportation (trucks, rails, and railroads), and consumer products (automobiles and appliances).
- Normally most steels range between **0.05% & 1.1%** of Carbon.
- It often includes *other alloying ingredients*, such as **manganese, chromium, nickel**, and/or **molybdenum**; but it is the **CARBON** content that turns iron into steel.

STEELS

- Hundreds of compositions of steel are available commercially.
- For purposes of organization here, the vast majority of commercially important steels can be grouped into the following categories :
  1. **Plain carbon steels**
  2. **Low alloy steels**
  3. **Stainless steels**
  4. **Tool steels**

(1) PLAIN CARBON STEELS

- These steels contain carbon as the principal alloying element, with only small amounts of other elements (about 0.4% manganese plus lesser amounts of silicon, phosphorus, and sulphur).
- Increasing carbon content strengthens and hardens the steel, but its ductility is reduced.

(1) PLAIN CARBON STEELS

- The plain carbon steels are typically classified into three groups according to their carbon content:
  a) **Low carbon steel**
  b) **Medium carbon steel**
  c) **High carbon steel**

(a) *Low Carbon Steel*

- **Low carbon steels** contain **less than 0.20% C** and are by far the most widely used steels.
- Typical applications are automobile sheet-metal parts, plate steel for fabrication, and railroad rails.
- These steels are relatively easy to form, which accounts for their popularity where high strength is not required.

(b) *Medium Carbon Steel*

- **Medium carbon steels** range in carbon between **0.20% and 0.50%** and are specified for applications requiring higher strength than the low-C steels.
- Applications include machinery components and engine parts such as crankshafts and connecting rods.

(c) *High Carbon Steel*

- **High carbon steels** contain carbon in amounts **greater than 0.50%.**
- They are specified for still higher strength applications and where stiffness and hardness are needed.
- Springs, cutting tools and blades, and wear-resistant parts are examples.

(2) LOW ALLOY STEELS

- **Low alloy steels** are iron–carbon alloys that **contain additional alloying elements** in amounts totalling **less than about 5% by weight**.
- Owing to these additions, low alloy steels have mechanical properties that are superior to those of the plain carbon steels for given applications.

(2) LOW ALLOY STEELS

- Superior properties usually mean **higher strength, hardness, hot hardness, wear resistance, toughness,** and more desirable combinations of these properties.
- Common alloying elements added to steel are:
  a. **Chromium**
  b. **Manganese**
  c. **Molybdenum**
  d. **Nickel**
  e. **Vanadium**

(2) LOW ALLOY STEELS

- These alloying elements are added sometimes individually but usually in combinations.
- The effects of the principal alloying ingredients can be summarized in the following slides.

a. *Chromium (Cr)*

- Chromium (Cr) improves strength, hardness, wear resistance, and hot hardness.
- It is one of the **most effective** alloying ingredients **for increasing harden ability.**
- In significant proportions, Cr **improves corrosion resistance.**

b. *Manganese (Mn)*

- Manganese (Mn) improves the strength and hardness of steel.
- When the steel is heat treated, **hardenability is improved** with increased manganese.
- Because of these benefits, manganese is a widely used alloying ingredient in steel.

c. *Molybdenum (Mo)*

- Molybdenum (Mo) increases toughness and hot hardness.
- It also improves hardenability and forms carbides for **wear resistance.**

d. *Nickel (Ni)*

- Nickel (Ni) improves strength and toughness.
- It increases hardenability but not as much as some of the other alloying elements in steel.
- In significant amounts it improves **corrosion resistance** and is the **other major ingredient** (besides chromium) **in certain types of stainless steel.**

e. *Vanadium (V)*

- Vanadium (V) inhibits **grain growth during elevated temperature** processing and heat treatment, **which enhances strength and toughness of steel.**
- It also forms carbides that increase **wear resistance.**

(3) STAINLESS STEELS

(3) STAINLESS STEELS

- Stainless steels are a group of **highly alloyed steels** designed to **provide high corrosion resistance.**
- The principal alloying element in stainless steel is **chromium, usually above 15%.**
- The **chromium** in the alloy forms a thin, impervious oxide film in an oxidizing atmosphere, which **protects the surface from corrosion.**

(3) STAINLESS STEELS

- **Nickel** is another alloying ingredient used in certain stainless steels to **increase corrosion protection.**
- Carbon is used to strengthen and harden the metal; however, **increasing the carbon** content has the effect of **reducing corrosion protection** because chromium carbide forms to reduce the amount of free Cr available in the alloy.

(3) STAINLESS STEELS

- Stainless steels are traditionally divided into three groups, named for the predominant phase present in the alloy at ambient temperature.
  i. **Austenitic stainless steels**
  ii. **Ferritic stainless steels**
  iii. **Martensitic stainless steels**

i. *Austenitic Stainless Steels*

- Austenitic stainless steels have a typical composition of around **18% Cr and 8% Ni** and are the **most corrosion resistant** of the three groups.
- Owing to this composition , they are sometimes identified as **18-8 stainless**.
- They are **nonmagnetic** and very ductile; but they show significant work hardening.
- They contain **0.08 - 0.15% carbon.**

i. *Austenitic Stainless Steels*

- Austenitic stainless steels are used to fabricate chemical and **food processing equipment**, as well as machinery parts requiring high corrosion resistance.

ii. *Ferritic Stainless Steels*

- Ferritic stainless steels have around **15% to 20% chromium** , low **carbon** (**below 0.10%**), and **no nickel**.
- Ferritic stainless steels are **magnetic** and are **less ductile and corrosion resistant** than the austenitics.
- Parts made of ferritic stainless steels range from **kitchen utensils** to **jet engine components**.

iii. *Martensitic Stainless Steels*

- Martensitic stainless steels have a **higher carbon content (0.15–0.65%)** .
- They have as much as **18% Cr** but **no Ni**.
- They are **strong, hard, and fatigue resistant**, but **not generally as corrosion resistant** as the other two groups.
- Typical products include **turbine blades, cutlery** and **surgical instruments.**

(4) Tool Steels

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(4) Tool Steels

(4) Tool Steels

- Tool steels are a class of (usually) highly alloyed steels designed for use as industrial cutting tools, dies, and moulds.
- To perform in these applications, they must possess high strength, hardness, hot hardness, wear resistance, and toughness under impact.
- To obtain these properties, tool steels are heat treated.

(4) Tool Steels

- Principal reasons for the high levels of alloying elements are
  - improved hardenability
  - reduced distortion during heat treatment
  - hot hardness
  - formation of hard metallic carbides for abrasion resistance
  - enhanced toughness

HIGH-SPEED TOOL STEELS

- High-speed tool steels are used as cutting tools in machining processes.
- They are formulated for high wear resistance and hot hardness.
- The original high-speed steels (HSS) were developed around 1900.
- They permitted dramatic increases in cutting speed compared to previously used tools; hence their name.

HIGH-SPEED TOOL STEELS

Grade	C	Cr	Mo	W	V
T1	0.7	4.0	-	**18.0**	1.0
M2	0.8	4.0	**5.0**	6.0	2.0

CAST IRON

- **CAST IRON** is an alloy of iron and carbon **(2.11% to 4%)** used in casting (primarily sand casting).
- Silicon is also present in the alloy (in amounts from 0.5% to 3%), and other elements are often added also, to obtain desirable properties in the cast part.
- There are several types of cast iron, the most important being **GRAY CAST IRON**.

TYPES OF CAST IRON

- **GRAY CAST IRON. (2.5% to 4%)**
- **DUCTILE OR NODULAR CAST IRON.(3-4%)**
- **WHITE CAST IRON. (2.5%)**

GRAY CAST IRON

- **GRAY CAST IRON** accounts for the largest tonnage among the cast irons.
- It has a composition in the range **2.5% to 4% carbon** and **1% to 3% silicon.**
- This chemistry results in the formation of graphite (carbon) flakes distributed through out the cast product upon solidification.
- The structure causes the surface of the metal to have a gray colour when fractured; hence the name gray cast iron .

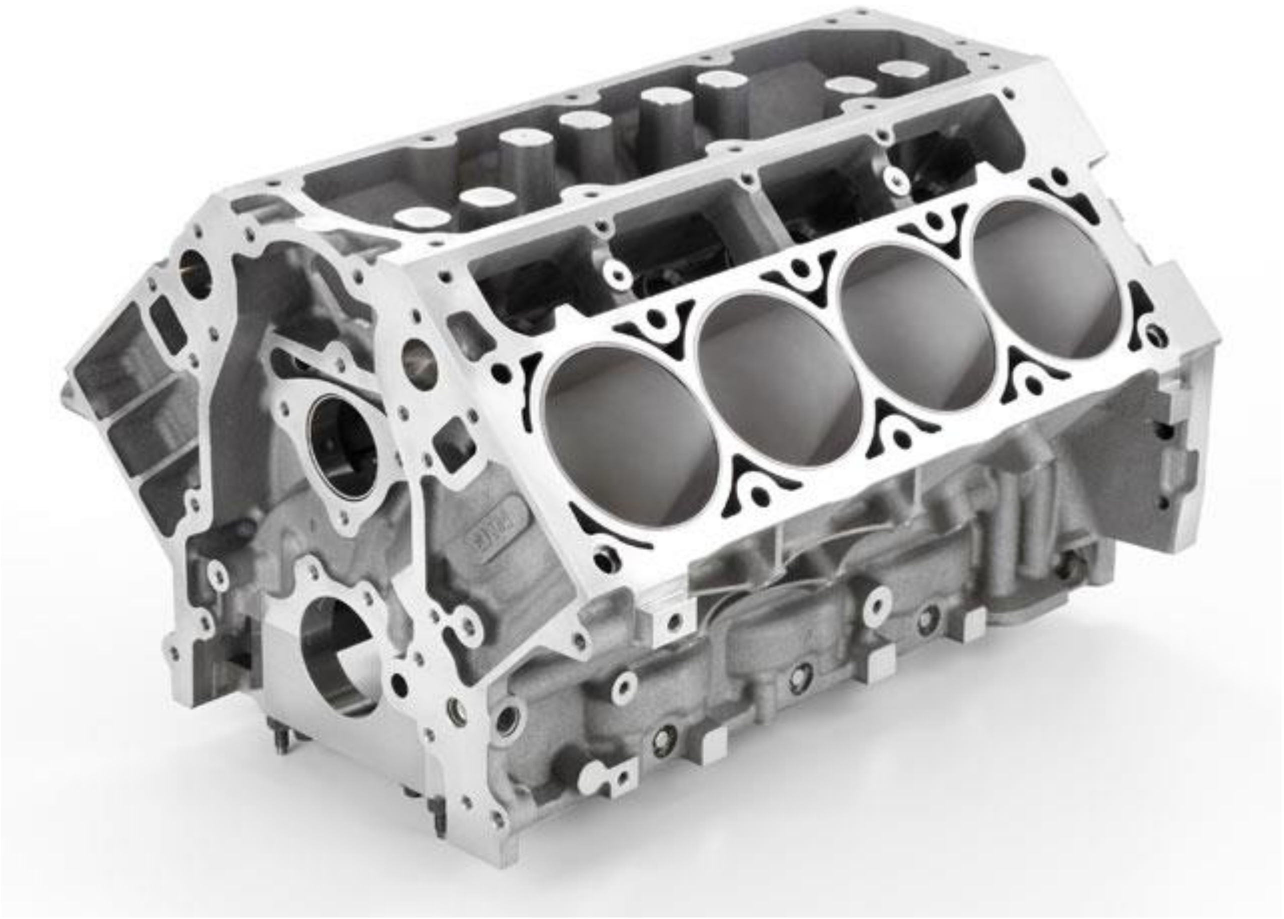
GRAY CAST IRON

- The dispersion of graphite flakes accounts for two attractive properties :
  1. Good vibration damping, which is desirable in engines and other machinery; and
  2. Internal lubricating qualities, which makes the cast metal machinable.

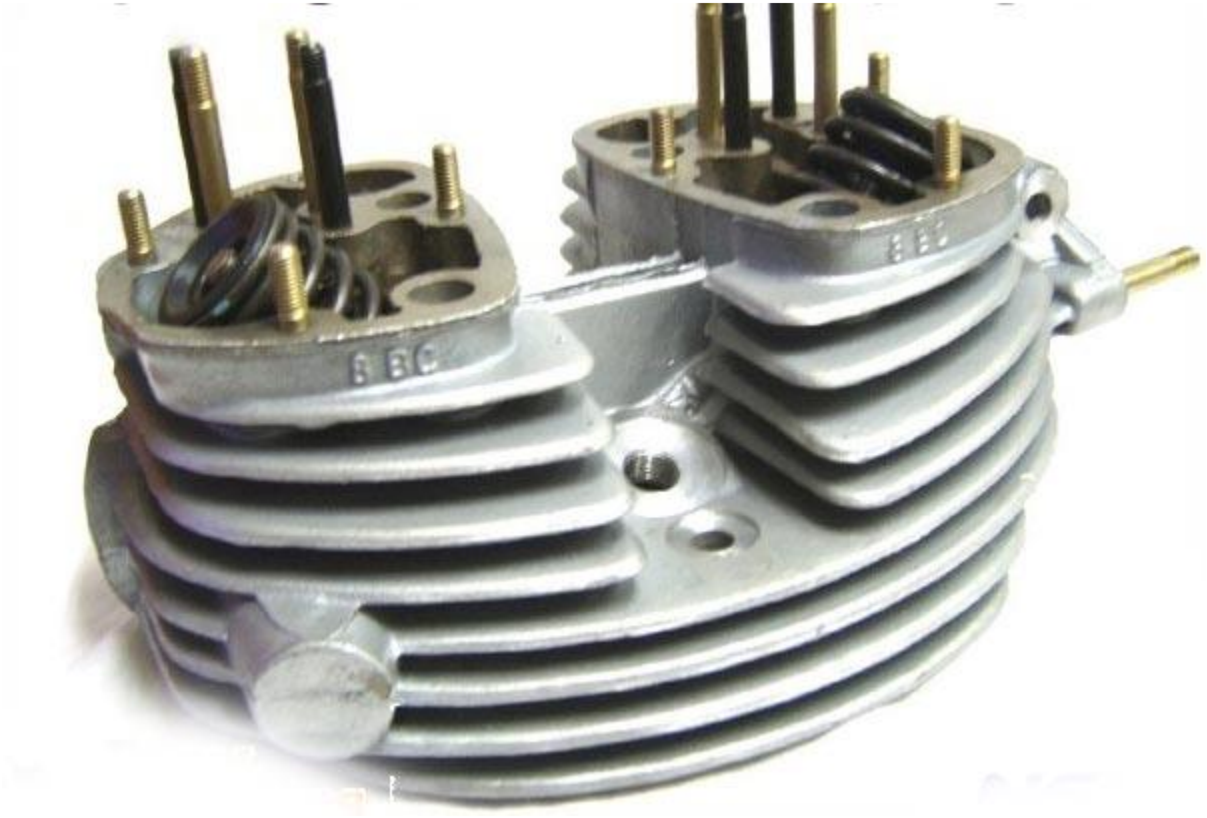
GRAY CAST IRON

- The compressive strength of gray cast iron is significantly greater than its tensile strength.
- Ductility of gray cast iron is very low; it is a relatively brittle material.
- Products made from gray cast iron include automotive engine blocks and heads, motor housings, gears, flywheels, water pipes and machine tool bases .

GRAY CAST IRON

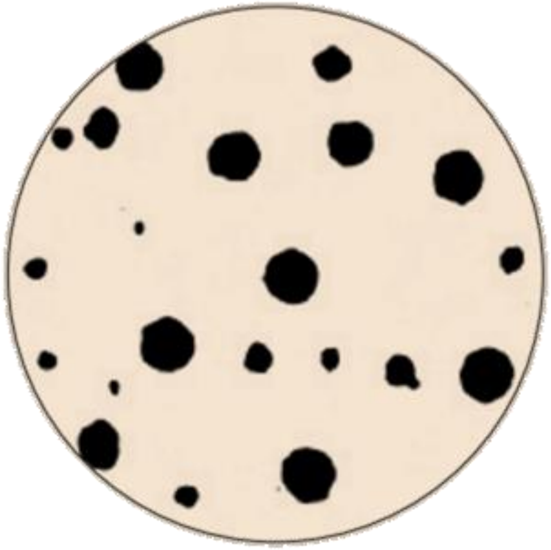


GRAY CAST IRON



DUCTILE CAST IRON

- This is an iron with the composition of gray iron in which the molten metal is chemically treated before pouring to cause the formation of graphite spheroids **(spherical nodules)** rather than flakes.
- Carbon **(3-4%)**



DUCTILE CAST IRON

- This results in a stronger and more ductile iron, hence its name **(Ductile/Nodular Cast Iron).**
- Applications include machinery components requiring high strength and good wear resistance like automotive engine crankshafts, heavy duty gears, military and railroad vehicles.

WHITE CAST IRON

- This cast iron has less carbon **(2.5%)** and silicon**(1.3%)** than gray cast iron .
- It is formed by more rapid cooling of the molten metal after pouring, thus causing the carbon to remain chemically combined with iron in the form of cementite rather than precipitating out of solution in the form of flakes.
- When fractured, the surface has a white crystalline appearance that gives the iron its name.

WHITE CAST IRON

- White cast iron is strong, hard and brittle, and its wear resistance is excellent.
- These properties make white cast iron suitable for applications in which wear resistance is required.
- Typical applications include brake shoes, shot blasting nozzles, mill liners, crushers, pump impellers and other abrasion resistant parts.