Feature Article

Workshop Basics: Part 1- Engineering Materials**

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INTRODUCTION

Metallurgy and its application to produce new engineering materials play a very important role in workshop practice. One of the most important metallurgical application is the development of jet engines for aircrafts where the need for alloys that can withstand high temperatures is critical. In palm oil mills, the main requirement are confined to materials often in the form of alloys possessing the properties of corrosion resistance, erosion, strength and other requirements. There are continuously being manufactured to suit the different engineering requirements. It will therefore be useful for the workshop crew to gain some insight into the properties of such materials. This article was originally prepared and published in the *Engineering New Issue No. 32* by the late Ir Jack Maycock to improve the technical knowledge of the workshop foreman, artisans and fitters. It will also serve the maintenance engineers as a reference material. The maintenance engineers are encouraged to use the material contained in this article to give lectures to their maintenance team in a simple language so that they understand the fundamental principles. They can be tested orally to gauge the knowledge they have gained and certificates issued by the manager or the authorised person.

TYPES OF MATERIALS

The main materials found in palm oil mills can be grouped as in *Figure 1*.

COMMON PROPERTIES OF MATERIALS

In order that we can compare these various materials and their uses, let us define the terms generally used for describing the properties of materials:

- tensile strength - the ability to withstand a stretching load without breaking.
- compressive – the ability to withstand a squeezing strength or compressing local load without breaking.
- shear strength – the ability to withstand off-set loads or transverse cutting actions.
- toughness - the ability to withstand an impact or hammering load.

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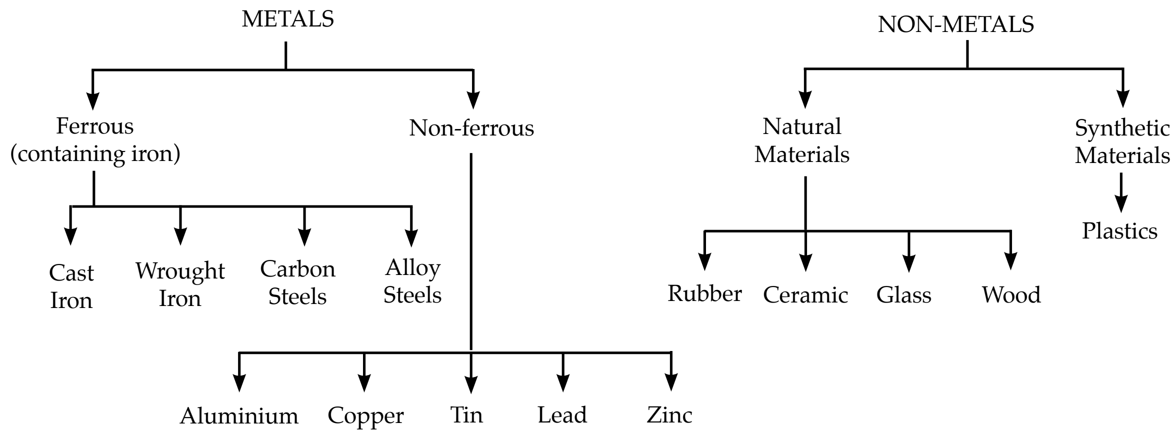


Figure 1. Main materials frond in palm oil mills.

- elasticity – the ability to deform under load and return to original shape when the load is removed.
- plasticity – the ability to deform under load and retain the new shape when the load is removed.
- ductility - when the deforming load described in plasticity is tensile load (for example when wire-drawing).
- malleability – when the deforming load described in plasticity is a compressive load (for example when forging).
- hardness – the ability to withstand scratching or indentation by another hard body.
- corrosion – the ability to withstand chemical and resistance to electro-chemical attack.
- conductivity – this can refer to both electrical and thermal and is the ability to allow the passage of electricity or heat.
- fusibility – the ease with which a material will melt.

FERROUS METALS

Ferrous is defined as containing or relating to iron and iron is a soft, grey metal which is rarely found in its pure state. However, when alloyed with the non-metal carbon, very useful metals are produced. Coke is a form of carbon and it is from the coke used in the blast furnaces that iron/carbon alloys are initially formed. The addition of carbon to iron makes it harder and stronger and of greater use in engineering. The effects of carbon content on the properties of plain carbon steels in the annealed state are shown in *Figure 2*.

Ferrous metals can be considered under four main headings, *i.e.* cast iron, wrought iron, plan carbon steels and alloy steels.

Cast Iron

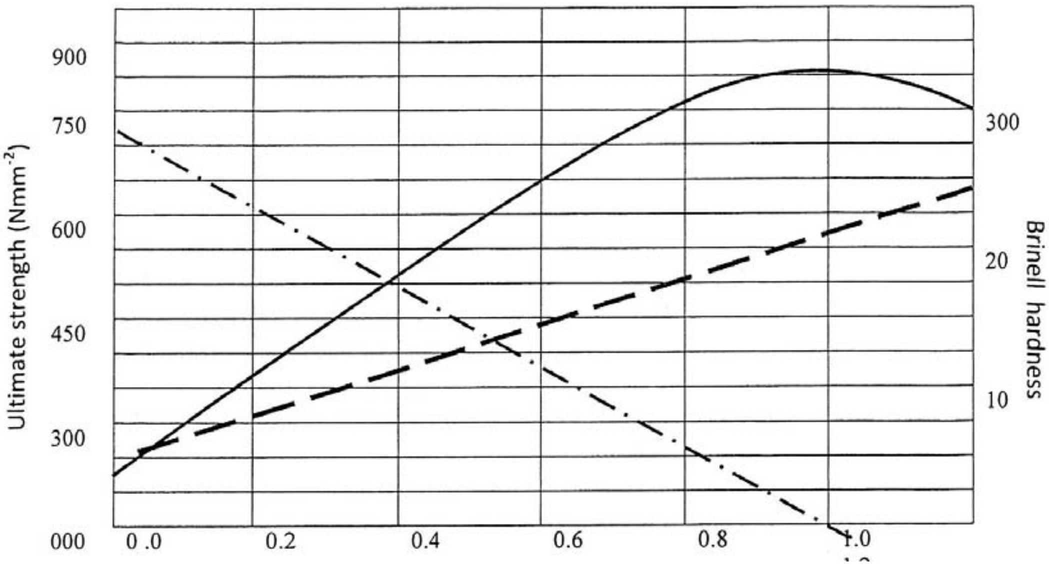
There are three basic types of cast iron, *i.e.* grey, malleable and spheroidal graphite (SG).

Grey Cast Iron

This is a low cast material that can be used for many purposes, *e.g.* machine frames, pump bodies and general castings. It has a high compressive strength but a low tensile strength and is also very brittle. Grey cast irons generally have carbon contents in excess of 3% and some of this carbon is free and appears as flakes of graphite. This graphite promotes good machining characteristics and give the material good anti-friction properties.

Malleable Cast Iron

This is a white cast iron of low carbon content, 2.5% to 3.0%, that has been cast



Note: 1 Nmm^{-2} = 64.7 psi.

Figure 2. The effect of carbon content on the properties of plane annealed carbon steels.

and then subjected to a heat treatment process to increase its strength and ductility by breaking-down the graphite particles. It is used when a stronger less brittle material than grey cast iron is required.

Spheroidal Graphite Cast Iron

This is a heavy-duty cast iron and is made by adding magnesium to ordinary grey cast iron which results in the redistribution of the graphite flakes as fine spheroids. It has superior mechanical properties and is used for highly stressed components such as motor car engine crankshafts.

Wrought Iron

Wrought iron has a very low carbon content and contains trapped fibres of slag that promote corrosion resistance and prevent sudden fractures from occurring. It is used mainly for crane hooks and lifting chains.

Plain Carbon Steels

Plain carbon steels are alloys of iron and carbon in which the iron and carbon are chemically combined at all times (you will remember that in cast irons some of the carbon is free). A general grouping of plain carbon steels is given in *Table 1*.

Dead Mill Steel

This has a low carbon content which, as a consequence, make it very ductile enabling it to be pressed into complicated shapes without heating.

Mild Steel

This is relatively soft and ductile. It can be forged and drawn in the hot or cold condition. It is easily machined and is the most commonly used type of steel in the engineering world.

TABLE 1. GENERAL GROUPING OF PLAIN CARBON STEEL

Group	Carbon content (%)	Some uses
Dead mild steel	0.1 to 0.15	Sheet for pressing out such shapes as motor car body panels. Thin wire, rod and drawn tubes.
Mild steel workshop	0.15 to 0.3	General purpose bars, boiler plate, girders.
Medium carbon steel	0.3 to 0.5 0.5. to 0.8	Crankshaft forgings, axles leaf springs, cold chisels.
High chisels carbon dies steel	0.8 to 1.0 1.0 to 1.2 1.2 to 1.4	Coil spring, wood files, drills, taps and fine-edge tools (knives, *etc.*)

Medium Carbon Steel

This is harder, tougher and less ductile than mild steel and responds to heat treatment to further increase its toughness and hardness. Steel with the carbon range 0.3% to 0.5% are used for tools like screw drivers, spanners, and hammer heads. Those with the carbon range 0.5% to 0.8% are used for high stressed components such as gears, crankshafts, connecting rods, *etc*.

High Carbon Steel

This is harder, less ductile and slightly less tough than the medium range of carbon steels. It is mainly used in the heat treated condition for the manufacture of cutting tools, ball bearings, springs, wear-resistant components, *etc*.

Alloy Steels

These are plain carbon steels to which other, more exotic, metals have been added to give the resulting metal specific properties.

The most common alloying metals added to steels are:

- nickel, refines the grain and strengthens the steel;
- chromium, improves the response of the steel to heat treatment and the corrosion resistance of the steel;
- molybdenum, reduces temper brittleness, and enables an alloy steel to operate continuously at high temperatures without becoming brittle;
- manganese, improves wear resistance. Steel containing a high percentage (14%) of manganese are used for bulldozer and plough blades; and
- tungsten and cobalt, improve the ability of a steel to remain hard at high temperatures and are used extensively in cutting tools materials. Stainless steels usually contain both nickel and chromium. High-speed steel, which is used for power operated cutting tools contains tungsten and cobalt which largely superseded the use of high carbon steel.

NON-FERROUS METALS

There are 38 metals known to man which do not contain iron but we will only consider those most commonly used by engineers as shown in *Table 2*.

The two most important non-ferrous metals are aluminium and copper. Besides being used in their pure state it also forms the bases of many alloys. Tin and lead also form a useful range of alloys.

Aluminium and its Alloys

In its pure form, aluminium has very little use structurally being very soft and duc-

TABLE 2. COMMON NON-FERROUS METALS

Metal	Density ($kg\ m^{-2}$)	Melting point (°C)	Properties	Typical uses
Aluminium	2 700	660	Lightest of the commonly used metals. High electrical and thermal conductivity. Soft, ductile and low tensile strength 93 MNm^{-2}.	The base of many engineering alloys. Lightweight electrical conductors.
Copper	8 900	1 083	Soft, ductile and low tensile strength: 232 MNm^{-2}. Second only to silver in conductivity, it is much easier to joint by soldering and brazing than aluminium. Corrosion resistance.	The base of brass and bronze alloys. It is used extensively for electrical conductors and heat exchanger, such as motor car radiators.
Lead	11 300	328	Soft, ductile and very low tensile strength. High corrosion resistance.	Electric cable sheaths. The base of 'solder' alloys. The grids for 'accumulator' plates. Lining chemical plant. Added to other metals to make them 'free-cutting'.
Tin	7 300	232	Resists corrosion.	Coats sheet mild steel to give 'tin plate'. Used in soft solders. One of the bases of 'white metal' bearings. An alloying element in bronzes.
Zinc	7 100	420	Soft, ductile and low tensile strength.	Used extensively to coat sheet steel to give corrosion resistance 'galvanised iron'. The base of die-casting alloys. An alloying element in brass.

tile. It is resistant to normal atmospheric corrosion and is second to only copper in electrical and thermal conductivity. Aluminium alloys cover a wide range of engineering materials and are generally classified into four groups:

- wrought alloys (not heat-treatable);
- cast alloys (not heat-treatable);
- wrought alloys (heat-treatable); and
- cast alloy (heat-treatable).

Copper and its Alloys

Pure copper is relatively strong, is very ductile and is corrosion resistant. Although it can be used in its pure state as a structural

material it is the basis of many useful brass alloys, tin-bronze alloys, phosphor–bronze alloys, gun-metal alloys, and aluminium-bronze alloys. Details of these alloys are given in the Datasheet section.

Tin

Pure tin is very erosion resistant and as such, is used for coating steel to produce what is commonly termed 'tin plate'. Tin plate is used extensively in the food canning industry. Tin is also widely used in the production of bronze alloys. Another use of tin is the production of a whole range of soft solders when alloyed with lead as shown in *Table 3*.

Lead

Lead is a soft ductile metal with very low tensile strength but very high corrosion resistance. It is used for electric cable sheaths, grids for accumulator plates, as shown in *Table 4.*

Zinc

Like lead, zinc is a soft ductile metal with a low tensile strength but good corrosion resistance. It is used extensively as a coating to sheet steel for the production of 'galvanised iron' and the production of brass alloys.

NON-METALLIC MATERIALS

These can be considered under two headings: natural and synthetic.

Natural Non-metallic Materials

These can be listed as follows:

Uses

- rubber – air piping, hoses, transmission belting, packings and anti-vibration mountings.
- wood – general furniture, light roof trusses and casting patterns.
- glass – optical measuring instruments, lenses and sight glasses.
- emery – abrasive grinding wheels.
- ceramics – cutting-tool tips and electrical insulators.
- diamonds – special turning tools.

Synthetic Non-metallic Materials

There is an ever increasing number of synthetic materials being made available in the market and they are steadily taking over engineering duties which, until recently, were considered the prerogative of metals. For this article, we will just list the more common ones used in engineering. Plastic materials can be grouped under four main headings as follows:

Thermo-setting plastic. These undergo a chemical change during moulding and can never be softened by re-heating – they are hard, rigid and brittle.

Thermoplastics. These can be softened by re-heating but they are not as rigid as the thermo-setting group and tend to be tough.

Laminated plastic (tufuol). These are made by impregnating sheets of fibrous materials, such as paper, woven cotton cloth or asbestos with phenolic resin and subjecting them to pressure and heat. They can be formed as solid sheets, rods or tubes and can be machined with ordinary machine tools. They are widely used for making bearings, gears and other engineering components.

Glass reinforced plastic. Woven glass fibre can be bonded together by epoxy and polyester resins to from complex mouldings, *e.g.* crash helmets.

Properties of Plastic

The properties of all plastic can vary widely but they have the following properties in common:

Electric insulation. They have good electrical insulation properties but their useful-

TABLE 3. DETAILS OF SOME TYPICAL ALUMINIUM ALLOYS

Copper	Silicon	% of elements		Magnesium	Other element	Category	Uses
		Iron	Manganese				
0.1 max	0.5 max	0.7 max	0.1 max	-	-	Wrought not heat-treatable	Fabricated assemblies. Electrical conductors. Food and brewing processing plant. Architectural decoration.
0.15 max	0.6 max	0.75 max	1.0 max	4.5 to 5.5.	0.5 chromium	Wrought not heat-treatable	High-strength ship building and engineering products. Good corrosion resistance.
1.6	10.0	-	-	-	-	Cast not heat-treatable	General purpose alloy for moderately stressed pressure die-casting.
-	10.0 to 13.0	-	-	-	-	Cast not heat-treatable	One of the most widely used alloys. Suitable for sand, gravity and pressure die-castings. Excellent foundry characteristics for large marine, automotive and general engineering castings.
4.2	0.7	0.7	0.7	0.7	0.3 titanium (optional)	Wrought heat-treatable	Traditional 'Duralumin' general machining alloy. Widely used for stressed components in aircraft and elsewhere.
-	0.5	1.0	-	0.6	-	Wrought heat-treatable	Corrosion-resistant alloy for lightly stressed components such as glazing bars, window sections and automotive body component.
1.8	2.5	-	-	0.2	0.15 titanium 1.2 nickel	Cast heat-treatable	Suitable for sand and gravity die-casting. High rigidity with moderate strength and shock resistance. A general purpose alloy.
-	-	-	-	10.5	0.2 titanium	Cast heat-treatable	A strong, ductile and highly corrosion-resistance alloy used for aircraft and marine castings both large and small.

TABLE 4. THE COMPOSITION AND MELTING RANGE OF SOFT SOLDERS

Composition			Melting range (°C)	Remarks
Tin	Lead	Antimony		
65	34.4	0.6	183-185	Free running solder for soldering electronic and instrument assemblies. Commonly referred to as electrician's solder.
60	39.5	0.5	183-188	Used for high-class tinsmith's work and is known as tinman's solder.
50	49.5	0.5	183-212	Used for general soldering work in coppersmithing and sheet metal work.
40	59.6	0.4	183-234	Blow-pipe solder. This is supplied in a strip form.
30	69.7	0.3	183-255	Plumber's solder. Due to wide melting range, this solder becomes 'pasty ' and can be moulded and wiped.

ness in this field is limited by their low heat resistance.

Strength/weight ratio. The strength of plastic materials varies considerably with some of the stronger ones, such as nylon, comparing favourably with the weaker metals. All plastics are much lighter than most metals. Therefore, properly selected and proportioned, their strength/weight ratio compares favourably with many light alloys.

Corrosion resistance. All plastic materials are inert to most inorganic chemicals and thus can be used in environments that are hostile to the most corrosion resistant metals. They are also superior to rubber in that they are resistant to attack by oils and greases.