Basic Engineering Materials

Mike Doyle

December 2013
Material Properties

• Tensile Strength

The ability of a material to withstand a stretching load without breaking

• Compressive Strength

The ability of a material to withstand a squeezing load without breaking

• Shear Strength

The ability of the material to withstand loads which have a cutting action
Material Properties

• Impact Strength

  The ability of a material to withstand an impact or hammering load. This is often called toughness.

• Elasticity

  The ability of a material to deform under load and return to its original shape when the load is removed. E.g. a spring
Material Properties

• Plasticity
  • This is the ability of a material to deform under load and retain its new shape when the load is removed

• Ductility
  • This is the term used when a material is deformed by a tensile load

• Malleability
  • This is the term used when the material is deformed by a compressive load
Material Properties

• Hardness

This is the ability of a material to withstand scratching or indentation by another hard body

• Conductivity

This refers to the ability of the material to allow the passage of electricity or heat.

• Malleability

This is the term used when the material is deformed by a compressive load
Methods of Material Identification

• There are a number of simple methods which can be used to identify material types among these are:
  • (a) Colour
  • (b) Mass (weight per unit volume)
  • (c) Magnetic properties
  • (d) Hardenability
Methods of Material Identification

• (e) Spark test
• (f) Melting point
• (g) Action of acids
• (h) Action of alkalis
Methods of Material Identification

• (a) **Colour** –

• The material may be easily identifiable by it's natural colour e.g. brass, copper, gold, aluminium, etc..

• But in addition, the material can be colour coded to identify specific alloy or material grades
# Methods of Material Identification

## Tool Steel

<table>
<thead>
<tr>
<th>TOOL STEEL</th>
<th>COLOUR CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>D2</td>
<td>YELLOW / WHITE</td>
</tr>
<tr>
<td>A2</td>
<td>RED / GREEN</td>
</tr>
<tr>
<td>A6</td>
<td>GOLD / BLACK</td>
</tr>
<tr>
<td>O1</td>
<td>YELLOW</td>
</tr>
<tr>
<td>O6</td>
<td>SILVER / BLACK</td>
</tr>
<tr>
<td>S7</td>
<td>RED / YELLOW</td>
</tr>
</tbody>
</table>

## Carbon Steel

<table>
<thead>
<tr>
<th>CARBON STEEL</th>
<th>COLOUR CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.D. 1018</td>
<td>NO COLOR</td>
</tr>
<tr>
<td>H.R. 1018</td>
<td>GREEN</td>
</tr>
<tr>
<td>C.D. 12L14</td>
<td>BLACK / WHITE</td>
</tr>
<tr>
<td>C.D. 1045</td>
<td>WHITE</td>
</tr>
<tr>
<td>H.R. 1045</td>
<td>ORANGE / BLACK</td>
</tr>
<tr>
<td>A36 PLATE</td>
<td>NO COLOR</td>
</tr>
</tbody>
</table>

- Southern Tool Steel Supplies colour code.
## Methods of Material Identification

### STAINLESS STEEL

<table>
<thead>
<tr>
<th>Steel</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>303</td>
<td>GOLD</td>
</tr>
<tr>
<td>304</td>
<td>GREEN</td>
</tr>
<tr>
<td>304L</td>
<td>GREEN / ORANGE</td>
</tr>
<tr>
<td>316</td>
<td>GOLD / BROWN</td>
</tr>
<tr>
<td>316L</td>
<td>SILVER / GOLD</td>
</tr>
<tr>
<td>17-4</td>
<td>BROWN / YELLOW</td>
</tr>
</tbody>
</table>

### NON-FERROUS

<table>
<thead>
<tr>
<th>Material</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>6061 ALUMINUM</td>
<td>BLUE</td>
</tr>
<tr>
<td>360 BRASS</td>
<td>RED</td>
</tr>
<tr>
<td>932 BRONZE</td>
<td>GREEN</td>
</tr>
<tr>
<td>954 BRONZE</td>
<td>YELLOW</td>
</tr>
<tr>
<td>110 COPPER</td>
<td>WHITE</td>
</tr>
<tr>
<td>CL II COPPER</td>
<td>ORANGE</td>
</tr>
</tbody>
</table>
Methods of Material Identification

• (b) Mass -
• Simple tests such as weighing a given quantity of material sample, can be used to identify materials.

• One unit volume of aluminium has less mass than the equivalent unit volume of lead or gold.
Methods of Material Identification

• (c) Magnetic Properties -
• At times, it may be difficult to distinguish between certain material types.
• In some steels for example stainless steel certain alloys will be attracted by a magnetic field while other alloys in this range are non-magnetic
Methods of Material Identification

• (d) **Hardenability** -
• This is a measure of HARDNESS. It's defined as the ease with which a sample can be hardened.
• Hardenability of steel is defined as the ability of steel to get hardened completely and is a function of critical cooling rate [CCR].
• This property is directly influenced by both
  • (i) Alloy or chemical balance
  • (ii) method of production
• In some cases a material becomes harder when carrying out tasks on it - (work hardening)
Methods of Material Identification

• (e) **Spark Test** -
• Where a piece of metal is held against a grindstone.

• Sparks will be emitted from it.

• Differing metals produce different forms and colours of sparks.
Methods of Material Identification

• (f) Melting Point -
• The melting point of a range of similar alloys, will show a relationship between: The percentage alloy ingredient to the temperature at which the metal melts.

• i.e. with a pure metal the melting point will be high, but this will gradually change to a lower melting point (m.p.) with alloy additions
Methods of Material Identification

- **(g)(h) Acid and Alkalis** -
  - Materials can often be classified by the materials reaction to the presence of specific chemicals.

- Certain plastics behave well in the presence of certain acids and or alkali substances from the point of view of being resistant to these mediums, while other plastics are easily dissolved by these chemical agents.
Methods of Material Identification

• All acids will attack steels.

• Whenever there is moisture combined with oxygen, rusting takes place (damp atmosphere).

• Common salt will accelerate corrosion when combined with water.
Effects of Production on Material Properties

• (I) Cutting (Mechanical)

• Low Carbon Steel [LCS] may be cut using any cutting machine with no adverse effects on the physical properties of the material.
Effects of Production on Material Properties

• (ii) Cutting (Thermal)
  • Low Carbon Steel is the material most readily cut by oxy-fuel gas because its very high iron content. The carbon tends to migrate to the cut edge and upon cooling causes a hard surface to form on the cut edge.
Effects of Production on Material Properties

• (iii) Forming
  • L.C.S. has good ductility and plasticity, which enables it to be worked cold by rolling, flanging, bending and pressing. Bending whenever possible should be carried out across the grain for maximum strength. Heating increases malleability, softness and plasticity and allows maximum stretching and compression without work hardening and cracking on sharp bends.
Effects of Production on Material Properties

(iv) Joining

- Welding – L.C.S. can be joined by all of the welding methods in use at the present time.
- This is the main reason for common use in fabrication
- Bolting – in general fabrications black bolts are used as temporary or permanent fastenings.
Effects of Production on Material Properties

(iv) Joining

- High strength friction grip (H.S.F.G), turned barrel, load indicating bolts and washers are for permanent fastenings.
- Riveting – Riveting in most cases has been superseded by welding and bolting, except for some repairs on older ships and some low pressure boilers, structures that are subjected to vibration e.g. bridge stiffeners are often riveted.
Common Engineering Metals

• Before investigating the metals in common use today, it is important to understand the difference between the two main groups into which all metals fall:-

• Ferrous

• Non-ferrous
Common Engineering Metals

• Ferrous
• Basically a ferrous metal is one which contains iron. The Latin word 'ferrum' means containing or based on iron.
• Group includes:
  • Carbon steels
  • Cast iron
  • Etc...
Common Engineering Metals

• Non-Ferrous
• A non-ferrous metal simply contains no percentage of iron.
• This group of metals includes:
  • Aluminium
  • Copper
  • Lead
  • Tin
  • Some thirty other metals commonly used
Common Engineering Metals

• Carbon Steels
• Carbon steel is the most commonly used material for general fabrication work.
• Because it possesses the most desirable working properties.
• These properties are due to the composition of the steel
Common Engineering Metals

• Carbon Steels
• Iron (ferrite) imparts
  • Ductility
  • Malleability
  • Plasticity
  • Magnetism
  • Softness
  • And some elasticity
Common Engineering Metals

- Carbon Steels
- Disadvantages include:
  - Readily forming rust
  - Heavy scaling when at red heat
- The more carbon added, the higher the tensile strength and hardness
- But also reduces the other desirable properties
  - Ductility
  - Malleability
- Greater risk of welds and bends cracking
Common Engineering Metals

• Carbon Steels
• Low carbon steel does not work harden rapidly

• Cold bending and hammering does cause work hardening

• This hardening can be removed by treatment
Identification

• When steel is filed it has a silver grey colour

• or when allowed to weather it turns to the characteristic rust colour

• it is also magnetic
Identification

• Grey cast iron
• Has very poor
  • Ductility
  • Plasticity
  • Toughness
  • And malleability
• Has good
  • Compressive strength
Identification

• Grey cast iron
• Ability to absorb and dampen vibrations makes it an excellent material for heavy machine bedplates/stools.
• The more graphite present the lower the melting point
• Grey cast iron is extremely notch sensitive
Identification

• Corrosion
• Very good corrosion resistance to atmosphere, seawater and weak acids
• Cutting – (Mechanical)
• Grey cast iron may be:
  • Drilled
  • Sawed
  • Or machined
• Can not be
  • Sheared or punched
Identification

- (Thermal)
- grey cast iron:
  - Can be cut using oxy-fuel gas equipment
  - Must use a weaving action of the blowpipe
  - Produces a wide kerf but acceptable cut
• Forming
• May be cast in moulds to form quite intricate shapes and for large numbers of that particular shape.
• It is often more economical than fabrication.
• Joining (Welding)
• May be fusion welded by Manual Metal Arc [MMA].

• Bronze welding is a common jointing
• Advisable to pre-heat and cool slowly
• Joining (Bolting)
• Sections may be bolted provided no bending stresses are induced

• Ordinary steel bolts are used

• Riveting is not normally used
• Copper
• Copper is very soft in the annealed condition but rapidly becomes harder during cold working
  • Eg
    • Hammering
    • Rolling or
    • Pressing

• Any increase in hardness is accompanied by an increase in tensile strength but with a loss in ductility
• Copper
• Copper is excellent for
  • deep drawing
  • Extrusion
  • And drawing into wire
• To anneal copper heat to a dull red (500oC) and allow cooling in air or quenching in water to remove oxide scale.
• Copper – (Corrosion)
• Copper has a high corrosion resistance to most acids but is attacked by nitric and hydrochloric acids quite vigorously
Shape of Ductile Specimen at Various Stages of Testing

- Elastic deformation
- Uniform plastic deformation
- Non-uniform plastic deformation

- Elastic strain
- Plastic strain
- Total strain

- Ultimate tensile strength
- Fracture strength
- Yield strength

- Young's modulus = slope = stress/strain