

Question 1

- (a) List the four classifications of steels. For each, briefly describe the properties and typical applications.
- (b) Cite three reasons why ferrous alloys are used so extensively.
- (c) Cite three characteristics of ferrous alloys that limit their utilization.

Solutions

- (a) Four classifications of steels, and, for each, to describe properties and cite typical applications:
 - Low Carbon Steels
 - ü Properties: nonresponsive to heat treatments; relatively soft and weak; machinable and weldable.
 - ü Typical applications: automobile bodies, structural shapes, pipelines, buildings, bridges, and tin cans.
 - Medium Carbon Steels
 - ü Properties: heat treatable, relatively large combinations of mechanical characteristics.
 - ü Typical applications: railway wheels and tracks, gears, crankshafts, and machine parts.
 - High Carbon Steels
 - ü Properties: hard, strong, and relatively brittle.
 - ü Typical applications: chisels, hammers, knives, and hacksaw blades.
 - High Alloy Steels (Stainless and Tool)
 - ü Properties: hard and wear resistant; resistant to corrosion in a large variety of environments.
 - ü Typical applications: cutting tools, drills, cutlery, food processing, and surgical tools.
- (b) Ferrous alloys are used extensively because:
 - ü Iron ores exist in abundant quantities.
 - ü Economical extraction, refining, and fabrication techniques are available.
 - ü The alloys may be tailored to have a wide range of properties.
- (c) Disadvantages of ferrous alloys are:
 - ü They are susceptible to corrosion
 - ü They have a relatively high density
 - ü They have relatively low electrical conductivities

Question 2:

A structural member 100 mm long must be able to support a load of 50,000 N without experiencing any plastic deformation. Given the following data for brass, steel, aluminium, and titanium, rank them from least to greatest weight in accordance with these criteria.

Alloy	Yield strength (MPa)	Density (g/cm ³)
Brass	415	8.5
Steel	860	7.9
Aluminium	310	2.7
Titanium	550	4.5

Solution

From Equation 6.1, the cross-sectional area (A_0) must necessarily carry the load (F) without exceeding the yield strength (σ_y), as

$$A_0 = \frac{F}{\sigma_y}$$

Now, given the length l , the volume of material required (V) is just

$$V = lA_0 = \frac{lF}{\sigma_y}$$

Finally, the mass of the member (m) is

$$m = V\rho = \frac{\rho lF}{\sigma_y}$$

Using the values given for these alloys

$$m(\text{brass}) = \frac{\left(8.5 \frac{\text{g}}{\text{cm}^3}\right) (10\text{cm}) (50000\text{N})}{\left(415 \times 10^6 \frac{\text{N}}{\text{m}^2}\right) \left(\frac{1\text{m}}{10^2\text{cm}}\right)^2} = 102\text{ g}$$

$$m(\text{Steel}) = \frac{\left(7.9 \frac{\text{g}}{\text{cm}^3}\right) (10\text{cm}) (50000\text{N})}{\left(860 \times 10^6 \frac{\text{N}}{\text{m}^2}\right) \left(\frac{1\text{m}}{10^2\text{cm}}\right)^2} = 46\text{ g}$$

$$m(\text{aluminium}) = \frac{\left(2.7 \frac{\text{g}}{\text{cm}^3}\right) (10\text{cm}) (50000\text{N})}{\left(310 \times 10^6 \frac{\text{N}}{\text{m}^2}\right) \left(\frac{1\text{m}}{10^2\text{cm}}\right)^2} = 43.5\text{ g}$$

$$m(\text{titanium}) = \frac{\left(4.5 \frac{\text{g}}{\text{cm}^3}\right) (10\text{cm}) (50000\text{N})}{\left(550 \times 10^6 \frac{\text{N}}{\text{m}^2}\right) \left(\frac{1\text{m}}{10^2\text{cm}}\right)^2} = 40.9\text{ g}$$

Thus, titanium would have the minimum weight (or mass), followed by aluminum, steel, and brass.

Question 3:

- (a) How can fatigue wear be reduced?
- (b) Why is the abrasive wear resistance of a material a function of its hardness?
- (c) Why is it difficult to use friction sawing on nonferrous metals? Explain.

Solution

- (a)
 1. Reducing the load and sliding distance and increasing the hardness
 2. Improving the quality of the contacting materials, such as eliminating inclusions, impurities, and voids;
 3. Improving the surface finish and integrity during the manufacturing process;
 4. Surface working, such as shot peening or other treatments;
 5. Reducing contact stresses; and
 6. Reducing the number of total cycles.
- (b) Higher hardness indicates greater resistance to penetration, hence less penetration of the abrasive particles or hard protrusions into surfaces, and the grooves produced are not as deep. Thus, abrasive wear is a function of hardness
- (c) Nonferrous metals have a tendency to adhere to the blade, caused by adhesion at the high temperatures and attributable to the softness of these materials. Note also that these materials typically have high thermal conductivity, so if the metal has melted, it will quickly solidify and make the operation more difficult.

Question 4:

Give the distinctive features, limitations, and applications of the following alloy groups: titanium alloys, refractory metals, superalloys, and noble metals.

Solution• **Titanium Alloys**

- ü Distinctive features: relatively low density, high melting temperatures, and high strengths are possible.
- ü Limitation: because of chemical reactivity with other materials at elevated temperatures, these alloys are expensive to refine.
- ü Applications: aircraft structures, space vehicles, and in chemical and petroleum industries.

• **Refractory Metals**

- ü Distinctive features: extremely high melting temperatures; large elastic moduli, hardnesses, and strengths.
- ü Limitation: some experience rapid oxidation at elevated temperatures.
- ü Applications: extrusion dies, structural parts in space vehicles, incandescent light filaments, x-ray tubes, and welding electrodes.

• **Superalloys**

- ü Distinctive features: able to withstand high temperatures and oxidizing atmospheres for long time periods.
- ü Limitations: Very expensive
- ü Applications: aircraft turbines, nuclear reactors, and petrochemical equipment

• **Noble Metals**

- ü Distinctive features: highly resistant to oxidation, especially at elevated temperatures; soft and ductile
- ü Limitation: expensive
- ü Applications: jewelry, dental restoration materials, coins, catalysts, and thermocouples

Question 5:

Below is a list of metals and alloys:

Plain carbon steel, Magnesium, Brass, Zinc, Gray cast iron, Tool steel, Platinum, Aluminum, Stainless steel, Tungsten, Titanium alloys.

Select from this list the one metal or alloy that is best suited for each of the following applications, and cite at least one reason for your choice:

- a) The block of an internal combustion engine
- b) Condensing heat exchanger for steam
- c) Jet engine turbofan blades
- d) Drill bit
- e) Cryogenic (i.e., very low temperature) container
- f) As a pyrotechnic (i.e., in flares and fireworks)
- g) High-temperature furnace elements to be used in oxidizing atmospheres

Solution

- a) Gray cast iron would be the best choice for an engine block because it is relatively easy to cast, is wear resistant, has good vibration damping characteristics, and is relatively inexpensive.
- b) Stainless steel would be the best choice for a heat exchanger to condense steam because it is corrosion resistant to the steam and condensate.
- c) Titanium alloys are the best choice for high-speed aircraft jet engine turbofan blades because they are lightweight, strong, and easily fabricated very resistant to corrosion. However, one drawback is their cost.
- d) A tool steel would be the best choice for a drill bit because it is very hard retains its hardness at high temperature and is wear resistant, and, thus, will retain a sharp cutting edge.
- e) For a cryogenic (low-temperature) container, an aluminum alloy would be the best choice; aluminum alloys have an FCC crystal structure, and therefore, are ductile at very low temperatures.
- f) As a pyrotechnic in flares and fireworks, magnesium is the best choice because it ignites easily and burns readily in air with a very bright flame.
- g) Platinum is the best choice for high-temperature furnace elements to be used in oxidizing atmospheres because it is very ductile, has a relatively very high melting temperature, and is highly resistant to oxidation.