Solution to FMS Homework 2, SS 2017

1. Checklist before you start this homework. (The boxes are clickable.)

   ☒ I have finished reading Chapter 1 (p. 1~15) of the textbook.

2. Question 1.1 from your textbook (p.16). You should consider that many of the devices combine multiple materials to provide the properties/functionality of the device. Thus, you should consider more than one material and its properties. How would this problem help you with respect to materials selection in a future job? I will enclose a sample investigation report (Appendix 1) at the end of the homework for Lightweight Bicycle Frames, so you are not supposed to select this item unless you can provide different insights.

   An excellent solution to this question is enclosed in Appendix 1. Minimally adequate answers get 50% of the total score. If no references or sources are provided, actually you would get 0% of the total score.

3. List three items (in addition to those shown in Figure 1.9) made from metals or their alloys. For each item, note the specific metal or alloy used and at least one characteristic that makes it the material of choice.

   Kitchen Appliances Some made from stainless steel. Stainless steel is an alloy of iron, low levels of carbon, and chromium. The chromium gives the steel resistance to iron rust.

   Solder Usually an alloy of tin and lead. Chosen because it has a low melting point.

   Solder It can be made of 50% tin and 50% lead. Low melting point of the tin-lead alloy makes processing and soldering possible at relatively low temperatures (lower than the pieces it is intended to join).

   Jewelry sometimes sterling silver. Sterling silver is an alloy of mostly pure silver, with some amount of copper. This is chosen, even over pure silver, because it is stronger due to the copper, but is still ductile. It also has a lower cost than precious metals.

   Jewelry It can be made of a silver alloy called sterling silver: 92.5% pure silver and 7.5% another material usually copper. Silver is very soft and therefore easy to be processed in different shapes.

   Cast-iron skillets Made of cast-iron (surprise, surprise) because it distributes heat evenly and retains heat well.

Pots Many pots are made from stainless steel because it's non-reactive (meaning you can cook any kind of food in it), heavy, durable, and dishwasher safe.

Bridges Often made of steel because it's cheap and durable.

Sewing needle, shower head, and doorknob. All of these materials are very stiff and are resistant to fracturing. They all also have a lustrous appearance when polished. I also tested attaching a magnet to each of these items, and the magnet stuck to all three.

Zipper It can be made of brass, which is an alloy of copper and zinc. Its color is very similar to gold, but much cheaper.

4. Classify each of the following materials as to whether it is a metal, ceramic, or polymer. Justify each choice: (a) brass; (b) magnesium oxide (MgO); (c) Plexiglas®; (d) polychloroprene; (e) boron carbide (B_4C); and (f) cast iron.

Example better answers (100%)

a) Brass is a metal. It is stiff and does not fracture easily. I also know that it is an alloy between zinc and copper which are both metals.
b) Magnesium oxide (MgO) is a ceramic. Ceramics are compounds between metals and nonmetals. Magnesium is a metal while oxygen is a nonmetal.
c) Plexiglas is a polymer. The molecular name of Plexiglas is polymethyl methacrylate. Just based on this name I know it is a polymer because it is made up of a long chain of methyl methacrylate.
d) Polychloroprene is also a polymer. Again, I can tell because of the name.
e) Boron carbide (B_4C) is a ceramic. I know this because it is a compound between a metal (boron) and a nonmetal (carbon).
f) Cast iron is a metal. It is an iron carbon alloy, and is also relatively brittle.

Another Example (100%)

a) Brass is a metal alloy (combination of two metals)
b) Magnesium oxide (MgO) is a ceramic (it is an oxide compound between metallic and nonmetallic elements)
c) Plexiglass® is a polymer (poly(methyl methacrylate) has a chain-like structure with a backbone of carbon atoms)
d) Polychropropene is a polymer (it has a chain-like structure with a backbone of carbon atoms)
e) Boron carbide is a ceramic (compound between metallic and nonmetallic elements)
f) Cast iron is a metal alloy (it is made of iron (metal) and carbon (nonmetallic) elements.

5. Please read Appendix 2 for a guide to the Student Companion Site and learning-style survey, and write a paragraph (see Step 7 of Appendix 2) according to the results of your own investigation.

See following pages for Appendices.

Appendix 1

A Sample Investigation Report for Lightweight Bicycle Frames

The item selected for studying is the lightweight bicycle frame. In fact, several different materials can be used for bicycle frame featuring lightweight, and there is no consensus on which one is the best. This short essay will discuss the most common materials used for this purpose and their properties.

Lightweight bicycles generally require that the frame material has low density, while achieving high strength and durability. Steel was the most conventional material for bicycle frames decades ago. It is nowhere near ideal for lightweight bikes, since the density of various types of steels usually ranges between 7,750 and 8,050 kg/m^3 [1]. This is nearly twice as heavy as the common lightweight materials to be discussed below.

The first material common for lightweight bicycles is aluminum. Since its introduction as a material bicycle frame material about 30 years ago, aluminum is now the most common material, thanks to its low density and stiffness, as well as affordability [2]. With the density only 1/3 of the steel, the aluminum results in significantly lighter frames. Besides, the stiffness is also lower, leading to improved machinability compared with steel [3]. However, lower strength is a problem for pure aluminum, so an aluminum alloy is generally used, of which the 6000 series aluminum alloy is a common choice because of the excellent machinability and decent strength. While the 7000 series aluminum alloy is stronger, it is much harder and therefore the machinability is poor [4]. In order to achieve enough strength, however, the tubes have to be made in larger diameter compared with steel, which reduces the advantage of lower density.

Titanium is a potentially good choice for lightweight bicycle frames due to its combination of strength and low weight. The stiffness and density (about $4.43 g/cm^3$) of titanium alloys are about half of those of steel. An additional desirable characteristic of titanium is its resistance to corrosion. The family of titanium alloys offers a wide spectrum of strength and combinations of strength and fracture toughness [5]. Today, most titanium bicycle frames use the 3Al/2.5V alloy (3% aluminum/2.5% vanadium). Nevertheless, titanium frames are expensive to make not only due to the high material costs of titanium, but due to the welding of titanium tubes being demanding [2].

Carbon fiber is becoming the most preferred lightweight bicycle frame material. It is known for both its low weight and its ultra-high strength, stiffness, and durability. Carbon fiber consists of non-metallic graphite fiber cloth that is layered together with a high strength epoxy resin to form a matrix, which arranges the individual fibers to form a strong structure. The fatigue life of carbon fiber is almost infinite, unlike its metal counterparts [6]. Another unique feature of carbon fiber composites is that they can be molded and tuned to orient the strength wherever necessary. Therefore, it is almost ideal for high performance lightweight bikes due to its customizability in strength orientation. Although carbon fiber is expensive, it is still the most popular lightweight material for performance and racing bicycles nowadays.

In summary, a number of materials are available for lightweight bicycle frames. Each of them has unique properties that enable them to stand out.

References

[1] Elert, Glenn. "Density of Steel". Retrieved 04/23/2009.

[2] "Which frame material is the best?", http://bigshark.com/articles/which-frame-material- is-the-best-pg531.htm. Retrieved 08/24/2016.

[3] Wikipedia "Aluminum", https://en.wikipedia.org/wiki/Aluminium. Retrieved 08/24/2016.

[4] Wikipedia "Aluminum Alloy", https://en.wikipedia.org/wiki/Aluminium_alloy. Retrieved 08/24/2016.

[5] http://www.rtiintl.com/Titanium/RTI-Titanium-Alloy-Guide.pdf. Retrieved 08/24/2016.

[6] http://cyclingtips.com/2015/08/what-is-the-lifespan-of-a-carbon-frame/. Retrieved 08/24/2016.