Assignment 4: Material Selection and High-Level Assembly Design

24-370 Engineering Design I

Due @ 12:30, Wednesday February 23nd 2011

Part 1: Materials Selection

Find mechanical properties for candidate materials, and choose materials with favorable properties.

1.a - Material property look-up. Use your favorite source of material property data to find estimates of the following. Where there are multiple entries, be sure to use a generic entry or the average values from an overview. Be sure to report values at room temperature.

1.a.i - What is the (tensile) yield stress, in ksi, of 7075-T6 Aluminum?

1.a.ii - What is the coefficient of friction of unreinforced PEEK (Polyetheretherketone)?

1.a.iii - What is the modulus of elasticity of AISI 440 stainless steel?

1.a.iv - If your SolidWorks simulation suggests a peak Von Mises stress of 50 MPa, and your part is made of an average molded ABS (Acrylonitrile Butadiene Styrene) will your part yield?

1.b - Simple design charts. Using the material design charts shown in figures 2-16 and 2-19 from Shigley (provided in the appendix below) please find a type of material with:

1.b.i - High yield strength

1.b.ii - Low elastic modulus

1.b.iii - High density

1.c - Advanced design charts. Find the desirable material property ratios for a square beam in bending, using the analytical method discussed in class. The beam will be cantilevered, with a force ***F*** applied to the free end a distance ***L*** from the fixed end. The cross-section of the beam is square, with width ***b*** and height ***b***.

1.c.i - Stress equation. First, derive the symbolic equation relating the factor of safety, ***fos***, yield strength, S_y, and the geometric properties of the beam.

1.c.ii - Mass equation. Next, derive the symbolic equation relating mass of the beam, m, to the geometric properties of the beam.

1.c.iii - Synthesis. Treating the beam width as the free geometric parameter, substitute your result from i into your equation from ii. All other things being equal, what material properties are favorable for this beam?

1.c.iv - Chart. Using the material design charts provided, use the desirable relationship from iii to pick a strong candidate material type, assuming you wish to minimize mass. Are there any potential issues or other considerations for this type of material?

1.d - Intuitive material selection. Thinking like a robotics guru, what types of materials might you first try for the following qualitative scenarios:

1.d.i - A small, multi-featured, high-stress component?

1.d.ii - A large, simple shape where mass and stiffness are critical?

1.d.iii - A medium, multi-featured, medium-stress component?

Part 2: General principles for assembly design

2.a -Loading implications. Use free-body diagrams to understand how forces in your assembly will change as you modify the attachment geometry.

2.a.i - Simple support. Sketch a side view of a horizontal shaft with a downward force ***F*** in the middle, being simply supported by two bearings. What are the reaction forces in the bearings? How will the peak stress in the *shaft* change as the bearings move closer to one another and the force application point?

2.a.ii - Cantilever support. Sketch a side view of a horizontal shaft with a downward force ***F*** on one end, being supported in cantilever by two bearings equally spaced along the shaft. What are the reaction forces in the bearings? How does this compare to your answer from i? How will this change if the bearings are moved closer to one another, but remain the same distance from the force application point?

2.b - Tolerance implications. Use geometry calculations to determine the sensitivity of critical positions to errors in part dimension.

2.b.i - Simple support. Consider the shaft from 2.a.i, this time with an eye towards tolerances. If one of the bearings is lower than the other by a displacement $\Delta h = 0.01\,\Delta L$, where ΔL is the distance between the bearings, what will be the angular displacement of the shaft? How will this change if the bearings move closer to one another and the force application point?

2.b.ii - Cantilever support. Consider the shaft from 2.a.ii, this time with an eye towards tolerances. If the bearings are moved closer to one another, but remain the same distance from the force application point, how will this affect the dimensional stability of the shaft?

2.c - Constraint. Use ideas from lecture to answer the following questions.

2.c.i - If your assembly is perfectly constrained, how would you be able to tell using a free body diagram and force and moment balances?

2.c.ii - If your assembly is under-constrained, how will this be reflected in your static balances?

2.c.iii - If your assembly is over-constrained, how will this be reflected in your static balances?

2.c.iv - What are some problems associated with over-constraint?

Appendix: Material property tables

Reproduced from Shigley's Mechanical Engineering Design, Budynas & Nisbett

Figure 2–16

Young's modulus E versus density ρ for various materials. *(Figure courtesy of Prof. Mike Ashby, Granta Design, Cambridge, U.K.)*

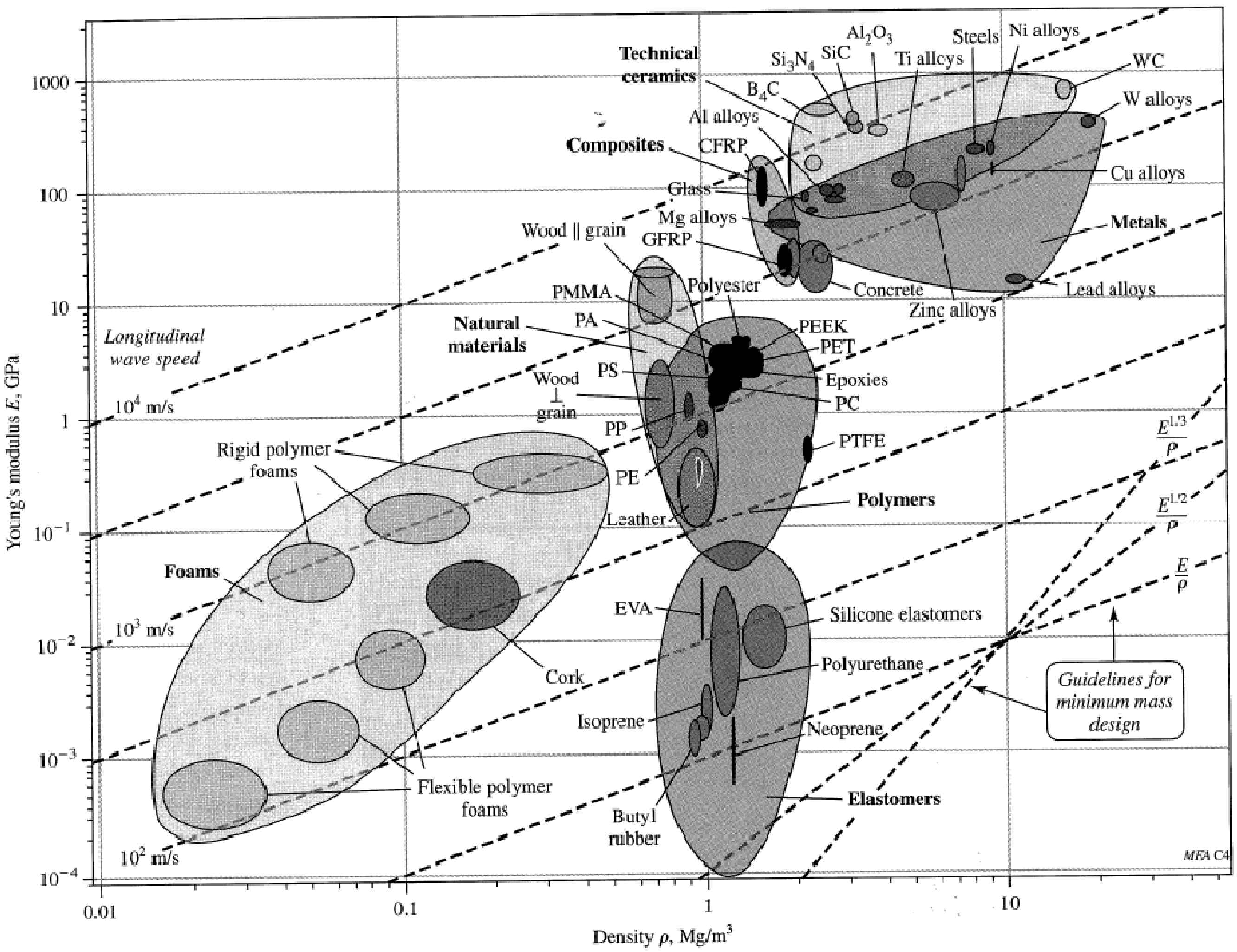

Figure 2–19

Strength S versus density ρ for various materials. For *metals,* S is the 0.2 percent offset yield strength. For *polymers,* S is the 1 percent yield strength. For *ceramics and glasses,* S is the compressive crushing strength. For *composites,* S is the tensile strength. For *elastomers,* S is the tear strength. *(Figure courtesy of Prof. Mike Ashby, Granta Design, Cambridge, U.K.)*