Department of Mechanical Engineering

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

2.800 TRIBOLOGY

Fall 2003

Homework # 4   **Due: Tuesday, 14 October 2003**

4.1
The following "problems" are designed to sensitize you to the good and bad aspects of friction and wear. Try to be as creative and innovative as possible in answering the following.

(a) Tribology is defined as "the Science and Technology of Interacting Surfaces in Relative Motion and of the Practices Related Thereto." What is meant by the word "interact" and what kinds of interaction may surfaces have?

(b) It is estimated that about <u>six</u> percent of the Gross National Product of the US, and that of many industrialized countries, is wasted because of friction and wear. To appreciate the magnitude of the problem list at least ten items that need replacement, repair, etc. because of wear. You may list them in the order of their size, cost, reliability, liability, etc.

(c) List six components or products that exclusively rely on friction for their operation. Write a sentence or two about each item describing how it works. You may furnish an equation or two if you happen to know.

(d) Wear is usually an unwelcome guest, but numerous manufacturing processes depend on the gradual removal of material. Can you list at least six cases and explain why wear is to be welcomed with open arms?

(e) Lubrication, by definition, is the means by which friction is reduced. Lubricants may be in the form of solids, liquids, or gases. Please list a few lubricated systems in each class.

(f) The human body (for that matter anything living and moving) is an exquisite machine ever designed to survive and multiply on this planet. List a few limbs or organs of the human body that function as tribological elements and describe their form and function.

4.2

The central concept underlying lubrication is to provide a thin, soft film between sliding (or rolling) surfaces. As remarked earlier, solids, liquids, or gases may lubricate sliding surfaces. The functions of a liquid boundary lubricant are to: (a) provide a layer of low-shear-strength solid-like adsorbed layer, (b) prevent wear particle agglomeration by discouraging adhesion and (c) if present in large quantities, transport wear particles away from the contact. In the case of a solid lubricant, of course, the last requirement cannot be met. In this problem we address solid lubrication.

(a) What are the functional requirements of a solid lubricant?

(b) Write down an equation for friction coefficient and estimate its value for a few cases.

(c) List a number of solid lubricants that satisfy the above requirements at high pressures and/or temperatures.

(d) The layered solids are particularly attractive as lubricants. List a few, other than MoS_2 and graphite.

4.3

We wish to design a hydrodynamic bearing by the Axiomatic Design Methodology (ADM). (The decision to use a hydrodynamic bearing in a machine has already been made due to other considerations). Let us focus on a thrust bearing for simplicity. In each step below, first list the various quantities in words and then in symbols. Keep track of the unit of each quantity.

(a) List the set of functional requirements {F} of the bearing.

(b) List a set of design variables {D} that are likely to be related to {F}.

You must have as many design variables as there are functional requirements to begin with. If not, the design becomes hopelessly coupled. Moreover, none of the elements of the set {F} should be an element of the set {D}.

(c) Write down the appropriate constraint set {C}. Again, none of the elements of the constraint set {C} should be an element of {F} or {D}.

(d) Now, from what you know about hydrodynamic lubrication theory, write down the relationships among the elements of {F}, {D}, and possibly {C}. Let the relationships represent another set -- the design matrix set {M}. The set {M} must be linear in that each element should be independent of the elements of {D}. If not you may have to redefine {D}.

(e) Is the design uncoupled, or at least decoupled?

(f) If not, modify the design such that it is at least decoupled.

Comments on the Problems

• The problems are designed to assist you "discover" Tribology and not to test you every week. Thus the problems may go beyond what is taught in the class, but in a constructive way.

• Don't put off the homework till Monday evening. All the problems perhaps cannot be solved in one sitting. The best way is to work out one problem a day, after reading the relevant material.

• Finally, on Monday you may sit down and tidy up the solutions and submit it in the class on Tuesday.

• You are expected to work on the problems alone. While this convention cannot be enforced, try not to consult with your friends too much. The joy of discovering is far more important than just solving and submitting the problem sets.

• All problem sets will be graded and amply annotated and thus solutions will not be furnished. However, certain difficulties associated with the problems will be addressed in the class, if necessary.