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THE GEORGE W. WOODRUFF SCHOOL OF MECHANICAL ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY

DESIGN QUALIFIER

FALL 2011

WRITTEN EXAMINATION

We are interested in learning what you know and your ability to reason in the formulation and solution of design problems.

<u>If you find any part of this exam confusing, please state your assumptions and rephrase the question and proceed.</u>

<u>Please read the entire exam first.</u>

<u>Questions 1, 2a and 2b carry equal points.</u>

<u>Allocate your time carefully so that you cover all three parts that you are being examined on in these two questions, namely Methodology and Analysis.</u>

ORAL EXAMINATION

Please arrive a half an hour before the scheduled time for the oral exam. During this period we will give you a question to think about. The scope of the oral exam is as follows:

* provide an opportunity for you to state how design fits into your research activities;
* probe your understanding on the question that we posed to you in the preceding half hour.

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QUESTION 1. – DESIGN METHODOLOGY

BACKGROUND AND MOTIVATION

An electric drip coffee maker can also be referred to as a dripolator. It normally works by admitting water from a cold water reservoir into a flexible hose in the base of the reservoir leading directly to a thin metal tube or heating chamber (usually, of aluminum), where a heating element surrounding the metal tube heats the water. The heated water moves through the machine using the thermosiphon principle. Thermally induced pressure and siphoning effect move the heated water through an insulated rubber or vinyl riser hose, into a spray head, and onto the ground coffee, which is contained in a brew basket mounted below the spray head. The coffee passes through a filter and drips down into the carafe. A one-way valve in the tubing prevents water from siphoning back into the reservoir. A thermostat attached to the heating element turns off the heating element as needed to prevent overheating the water in the metal tube (overheating would produce only steam in the supply hose), then turns back on when the water cools below a certain threshold. For a standard 10-12 cup drip coffeemaker, using a more powerful thermostatically-controlled heating element (in terms of wattage produced), can heat increased amounts of water more quickly using larger heating chambers, generally producing higher average water temperatures at the spray head over the entire brewing cycle. This process can be further improved by changing the aluminum construction of most heating chambers to a metal with superior heat transfer qualities, such as copper.

Electric Drip Coffeemaker Design

Brand A

Brand B

Brand C

DESIGN PROBLEM

A number of inventors patented various coffeemaker designs using an automated form of the drip brew method. Subsequent designs have featured changes in heating elements, spray head, and brew-basket design, as well as the addition of timers and clocks for automatic-start, water filtration, filter and carafe design, and even built-in coffee grinding mechanisms. Three existing products in the market are shown in the above figure, including Brand A, Brand B, and Brand C.

TASK

Assume that you are in charge of a design team responsible for developing a new electric drip coffee maker design for your company. Your boss wants you to start from benchmarking with your competitors and to document your design process thoroughly. You are advised to follow the general guidelines of design methodology and turn in a report documenting main deliverables.

DELIVERABLES (YOU ARE REQUIRED TO ELABORATED THESE ISSUES)

1.1 *Requirement Analysis:* To clarify the design task, you need to identify the customer needs to be met by your design. Develop a list of functional requirements for your design in solution neutral terms. Prioritize the importance of design criteria? **(2 pts.)**

1.2 *Conceptual Design:* Compose appropriate function structure diagrams that characterize the overall function and its decomposition into sub-functions. Transform the function structure into working principles of your design solution(s), to the module levels. **(2 pts.)**

1.3 *Design Evaluation:* Formulate a structured, systematic procedure for evaluating your design concept(s) and benchmarking with existing designs (Brand A, Brand B, and Brand C). You may use one of the popular methods, such as Pugh Selection Matrix, QFD, or multi-attribute decision making, etc. **(2 pts.)**

1.4 *Embodiment:* What are the major issues that you should deal with at the embodiment design stage? Outline what types of engineering analysis that may be needed in order to justify the technical feasibility of your design. **(2 pts.)**

1.5 *Product Costing:* How would you estimate the cost of your design? Please outline a systematic procedure. If considering mass production of your design, what are the critical issues for managing product cost of your design? **(2 pts.)**

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PROBLEM #2: COMPONENT DESIGN ANALYSES

Problem 2a: Short Answer Questions

Please write a complete descriptive answer in the space provided.

1. Consider the following gear transmission systems: spur/pinion; miter/bevel; rack/pinion; worm gear; ballscrews; planetary; helical

    a. Which is commonly used for large gear ratios (e.g., 50:1)? **(0.3 pt.)**

    b. Which is commonly used for 90˚ shaft configurations? **(0.3 pt.)**

    c. Which can be used for the same applications as spur/pinion systems but are less noisy? **(0.3 pt.)**

    d. Which has the lowest efficiency? **(0.3 pt.)**

    e. Which (multiple answers) are tolerant of axial loads? **(1.0 pt.)**

2. In a bolted joint how many threads typically take the stress? **(0.6 pt.)**

3. How is energy stored in a flywheel? What is the effect of changing the flywheel

    a. mass, **(0.3 pt.)**

    b. radius, **(0.3 pt.)**

    c. angular velocity **(0.3 pt.)**

    on the energy stored keeping other variables constant?

4. Consider the following belt transmission systems: flat belt; V-belt; timing belt
    a. Which is most impervious to stretching or slipping? **(0.3 pt.)**
    b. Which is the least efficient? **(0.3 pt.)**
    c. What is one advantage of V-belts over flat belts? **(0.3 pt.)**
5. Consider the following mechanisms: pneumatics; solenoids; hydraulics
    a. Which are the lowest cost? **(0.3 pt.)**
    b. Which can generate the highest forces? **(0.3 pt.)**
    c. What is one application of solenoids? **(0.3 pt.)**
6. The following question concern bearings
    a. What are 3 purposes of lubrication? **(0.9 pt.)**
    b. What are 2 reasons for preloading? **(0.6 pt.)**
7. Describe an instance where set screws would be preferable to bolts or cap screws. (**0.6 pt.**)
8. Describe the function of the involute geometry in gear design. (**0.3 pt.)**
    a. What happens if the involute geometry is not used? **(0.3 pt.)**

9. What is the effect of temperature on

    a. Material strength? **(0.3 pt.)**

    b. Material brittleness? **(0.3 pt.)**

10. Imagine that you are walking past the Tech Tower and find a broken steel shaft on the ground next to the old steam engine. After inspecting the shaft visually, what are four possible types of failure and what features on the shaft would indicate that this failure had occurred? **(1.2 pts.)**

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Problem 2b –Machine Design Analysis

In Figure 1, a schematic of a Diesel engine valve train is given. The (input) rotation of the cam causes the push rod to push the rocker arm. The rocker arms lever action pushes the valve down, opening it to allow an air/fuel mixture to enter. The valve spring ensures that the valve is pushed back into a closed position.

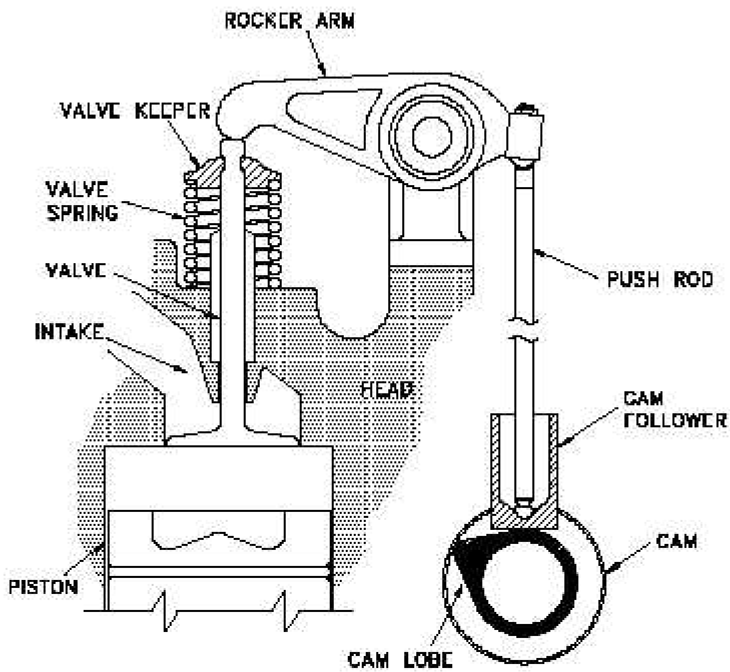

Figure 1 – Diesel Engine Valve Train Schematic (<u>not drawn to scale</u>)

A helical compression spring is used to push back the valve. The spring has squared and ground ends and has a 3.5 mm wire diameter. Assume that the spring material is hard drawn steel wire with a modulus of rigidity of 79.3 GPa and an ultimate tensile strength of 965 Mpa. The spring has a free length of 10 cm, a 1 cm coil pitch, and a mean coil diameter of 4 cm.

a) Calculate the solid length of the spring **(2 pts)**

b) If we assumed for the moment that the spring has 10 active coils, calculate the spring rate and the difference between the minimum and maximum force exerted by the spring. **(3 pts)**

c) Instead of a straight compression spring, a conical shaped spring like shown in Figure 2 is used. Assume that the number of coils remains the same and that D_{top} = 3 cm and D_{bottom} = 5 cm. Assuming the load remains the same, calculate the minimum wire diameter needed to prevent failure through static yielding. **(3 pts)**

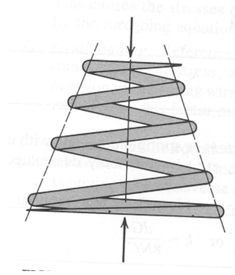

Figure 2 – Conical Spring

d) A single row deep-groove ball bearing with 10 mm bore and 30 mm outer diameter is used on the rocker arm shaft in Figure 1. If the force on the bearing is 500 N and the bearing's basic load rating is 5.07 kN, what is the L_{10} life of the bearing? Assume no slip between the shaft and bearing. **(2 pts)**

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