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

DESIGN QUALIFIER

SPRING 2012

WRITTEN EXAMINATION

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

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

Please read the entire exam first.

Questions 1, 2A and 2B carry equal points.

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.

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

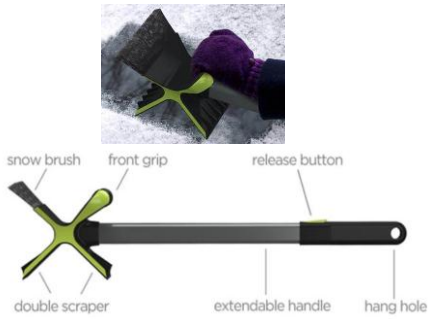
BACKGROUND AND MOTIVATION

An ice scraper is a handheld tool for removing frost, ice, and snow from windows, usually on automobiles. Basic scrapers have a plastic blade and handle, though some have blades made out of metal. More complex models often include brushes to help remove collected snow, or squeegees to remove water if the ambient temperature is near the melting point. Alternatively, the handle can be inside a glove-like enclosure to help keep the user's hands warm and dry while using the scraper. The blade of an ice scraper is usually flat if it is made out of metal, though some varieties include ridges that can be helpful if it is necessary to break up a sheet of ice (such as what collects in freezing rain). Plastic blades tend to have a more complex shape with several thick "fingers" linked together. This form helps the blade to flex, since most modern car windows have a slight curvature. The "fingers" also often have ridges on top, so the scraper can be flipped over to break up thick ice. More complex designs exist to improve ice clearance on curved glass on automobiles.

Ice Scraper/Dozer Design

Brand A

Brand B



Brand C

DESIGN PROBLEM

A number of inventors have patented various ice scraper designs. Three existing products in the market are shown in the above figure, namely Brand A, Brand B, and Brand C.

TASK

Assume that you are in charge of a design team responsible for developing a new ice scraper 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 pt.)**

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 pt.)**

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 pt.)**

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 pt.)**

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 pt.)**

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QUESTION #2A: COMPONENT DESIGN ANALYSES-Short Answer Questions

Please write a complete descriptive answer in the space provided.

1. What is a Pressure Line (Line of Action or Common Normal)? **[0.5 pt.]**

2. Describe the Pressure Angle. **[0.5 pt.]**

3. What effect does changing the Center Distance, C, have on the Velocity Ratio, Pressure Angle and Backlash? **[1.5 pts.]**

4. What causes Backlash? Give two reasons why Backlash is undesirable **[1.5 pts.]**

5. What is a Conjugate Action? **[0.5 pt.]**

6. Why is it desirable to have Contact Ratio, $m_p > 1$? [**0.5 pt.]**

7. During fatigue conditions in bearings, failure occurs with separation of scale-like particles from surface called _____? [**0.5 pt.]**

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8. What is the other important function of lubrication (such as oil or grease) other than reducing friction in bearings? [**0.5 pt.]**

9. In bearings, a rotating Outer Ring, V = 1.2, is simply an acknowledgment that fatigue life is _____. **[0.5 pt.]**

10. Is buckling an issue with an Extension Spring? Please explain **[0.5 pt.]**

11. Why are the ends of Torsion Spring coils extended tangentially? **[0.5 pt.]**

12. For an Extension Spring, what do we mean by a standard end? **[0.5 pt.]**

13. What is the difference between a confined and an unconfined gasket **[1 pt.]**

14. Name the two types of Joint Stiffness Models **[0.5 pt.]**

15. Why do we use lock washers? **[0.5 pt.]**

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QUESTION 2B –Machine Design Analysis (10 pts)

Internal Combustion Engine Connecting Rod Bolt Analysis

In Figure 1, a drawing of a typical four-cylinder internal combustion (IC) engine is given. The four pistons drive a crankshaft through the connecting rods. In Figure 2, a picture of a typical connecting rod is given. In Figure 3, a detailed drawing is given of one of the connecting rod connection to the crankshaft.

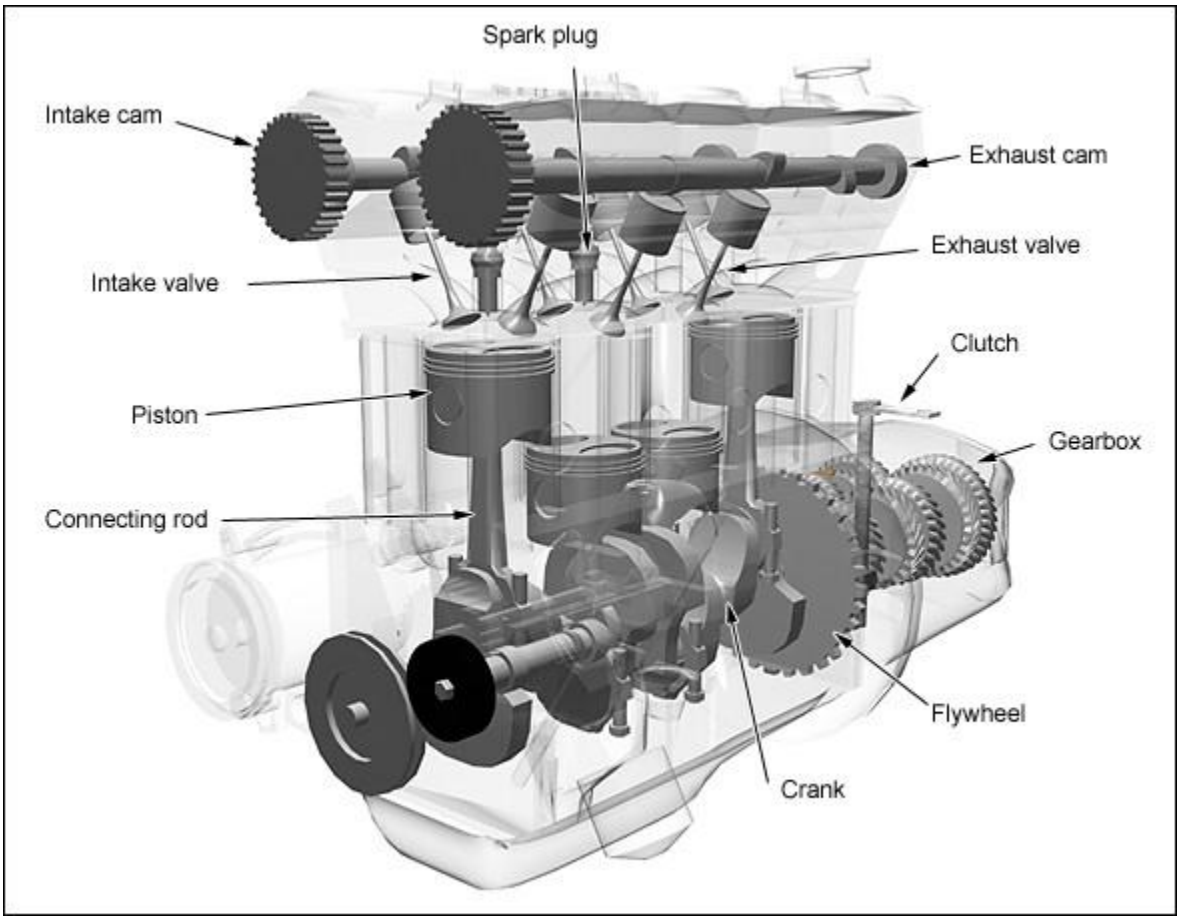

Figure 1 – Typical Four Cylinder Internal Combustion Engine.

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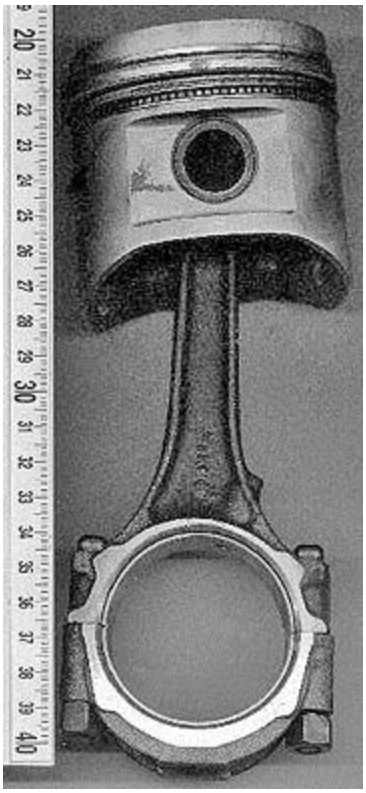

Figure 2 – A Connecting Rod

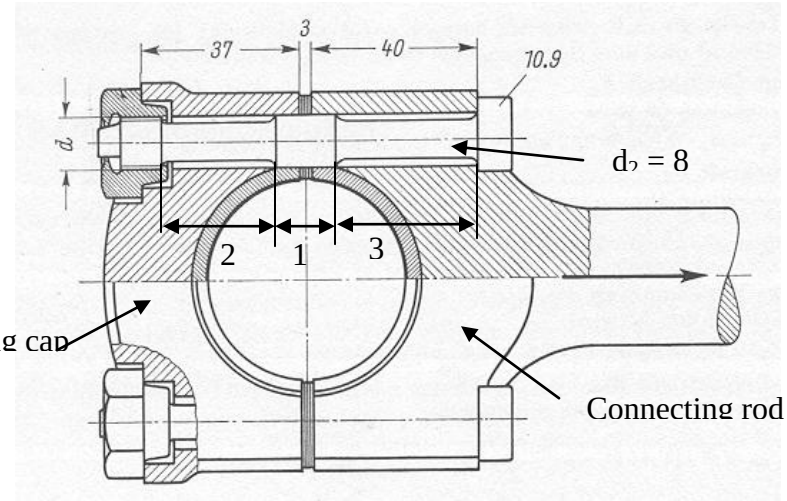

Figure 3 – Connecting Rod Drawing and Dimensions (all dimensions are in millimeters)

As you see in Figure 3, two bolts connect the bearing cap to the connecting rod. Your concern is the bolt-nut combination used for clamping the bearing cap on the connecting rod in Figure 3. The bearing cap is made of gray cast iron, whereas the connecting rod is made out of carbon steel. The modulus of elasticity E for carbon steel is 207 GPa. The modulus of elasticity E for cast iron is 100 GPa. The diameter (d) of the bolt hole is 10 mm - the same as the outer diameter

of the bolt shank at its thickest point. As shown in Figure 3, the bolts have two slender areas where the shank diameter d_2 is 8 mm. M10 coarse pitch bolts grade 10.9 are used with a proof strength of 830 Mpa and a thread tensile stress area of 58.0 mm^2.

Assume that a tensile load is induced on the bearing cap and bolt nut combination through the crankshaft. Assume that the minimum load is zero and that the maximum tensile load on the bearing cap occurs when the maximum pressure in a cylinder is reached, which is 50 x 10^5 Pascal. The cylinder is 84 mm in diameter.

a) Calculate the stiffness of the bolt in Figure 3. (2 pts)

b) Narratively, explain how you would go about calculating the stiffness of the members. What assumptions would you make? (1 pt)

Assume a joint constant of C = 0.25 for the next two questions.

c) What is the minimum required torque to avoid joint separation? (2 pts)

d) What is the maximum allowable bolt pre-load before bolt failure would occur? Assume static loading for simplicity. (2 pts)

e) Why would you not recommend reusing the nuts for the connecting rod after, say, an engine overhaul has taken place? (1 pt)

f) The shape of the nuts used in Figure 2 is different than regular nuts that you typically see. Can you explain what the purpose (or intended purpose) of these special nuts is? (1 pt)

g) What are some (more than one) advantages and disadvantages of using journal bearings for the crankshaft? (1 pt)

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