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

DESIGN QUALIFIER

SPRING 2010

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

Please read the entire exam first.

Questions 1 and 2 carry equal points. Both have multiple parts.

Allocate your time carefully so that you cover all three parts that you are being examined on in these two questions, namely Methods, Realizability 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- METHOD AND REALIZABILITY

DC, 2/14/2010:
Government to fund autonomous snowplow design competition

BACKGROUND AND MOTIVATION

This winter season has been one of the toughest in years and brought along many blizzards and excessive amounts of snow. Homeowners across the country keep struggling with removing snow from their driveways, as this is a very tedious task, especially for the elderly. In response to this, the government has allocated funds for a design competition that targets the development of autonomous snow plows. – Your task is to represent Georgia Tech in this competition and bring home the bacon.

DESIGN PROBLEM

Your brief is to design an autonomous snowplow for normally sized residential driveways. Autonomous means that your devise is to activate automatically when it detects that a reasonable amount of snow has accumulated. The main task of your device is to clear the driveway and then go back in standby mode. In addition to detecting the amount of snow accumulated, you device needs to be capable of detecting the parameter of the driveway. Furthermore, your snowplow is expected to be environmentally friendly in terms of operation and energy consumption.
Assuming that you are successful in designing such a snowplow, representatives of the Whitehouse would also like to know how your devise could be scaled in order to create a product family of snowplows to be used for larger scale areas, such as a university campus of the area surrounding the Whitehouse.

Task

You have been selected to represent Georgia Tech in this design competition.

- Identify the customer requirements to be met by your design.
- What might be an appropriate underlying working principle to realize this type of device?
- What function structure may provide the most flexibility for designing autonomous snowplows for the above-mentioned purpose?
- What are the key components of such a snowplow?

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Deliverables

Method

1.1 *Clarify the Task:* State the overall function of your system in solution neutral terms. What are the most important drivers/design criteria? Define a design requirements list.

1.2 *Conceptual Design:* State and implement the steps (including functional diagrams/decomposition) for transforming the overall function that you have identified for your product family into an appropriate number of alternative design solutions. Ensure that you have identified the important sub functions. Sketch and describe the workings of these alternatives.

1.3 *Selection:* Suggest a structured approach to selecting one of the alternatives for further development.

Realizability

1.4 *Embodiment:* Further develop the alternative that you have selected.

1.5 *Costing:* How would you estimate the cost of your design? You may critically evaluate the design in terms of manufacturability, initial cost, maintenance cost, reliability, manipulation performance, energy consumption, and other criteria that you feel are important to consider in this phase of design.

1.6 *Pricing:* Based on the preceding analysis, how would you estimate the market size for such a product and set the price for selling/operating such a system? Be brief.

1.7 *Return on investment:* In addition to costing and pricing, estimate if offering such snowplows for a rental fee per month in areas that usually do not get large amounts of snow would be a viable business idea. Justify.

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QUESTIONS IIA. COMPONENT DESIGN ANALYSES

In the snowplow, designers are thinking of using a 1”-12 UNF steel bolt of SAE grade 5 for joining two surfaces. The bolt is under direct shear loading. The coefficient of friction between mating surfaces is 0.4. The bolt is tightened to its full proof strength. Tensile area is 0.663 in^2 Proof strength is 85 kpsi, and yield strength is 92 kpsi

a) What shear force would the friction carry? (3 points).

b) What shear load can the bolt withstand without yielding if the friction between clamped members is completely lost? Base the calculation on the thread root area. (3 points).

The designers are contemplating using a hydraulic cylinder for activating the shuffle of the snow plow. The hydraulic cylinder is capped by a flange, like shown in Figure 2. A tensile load is induced on the bolt-nut combination by the pressure inside the cylinder. The hydraulic cylinder has an inside diameter of 100 mm.

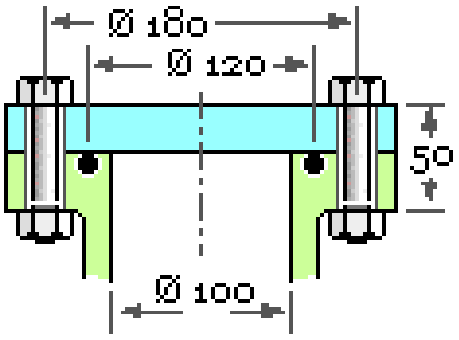

Figure 2 –Bolted Flange of Hydraulic Cylinder

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In Figure 3, a close up of the bolted flange is shown.

ISO grade 8.8, M20 bolts, with rolled thread and fine pitch, are being considered for this design. These bolts have a proofstrength of 600 Mpa and a tensile stress area of 272 mm^2. Although not shown in Figure 2, assume a washer is used with a diameter D equal to 1.5 times the nominal diameter of the bolt. The threaded portion of the bolt in the grip is 15 mm. As shown in Figure 2, a filler/gasket ring (made of copper) is used between the two flanges.

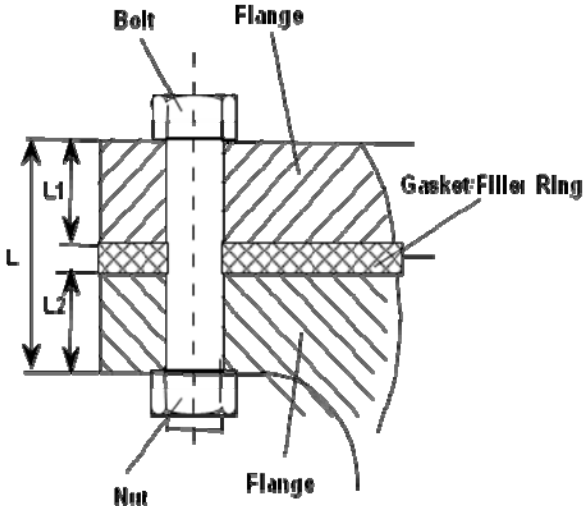

Figure 3 – Close-up of Bolted Flange

Both flanges are made out of gray cast iron (E = 100 Gpa). The modulus of elasticity is 119 Gpa for the copper filler/gasket ring and 207 Gpa for the steel bolt.

The dimensions indicated in Figure 3 are as follows; L = 50 mm and L1 = L2 = 22 mm. The center of the bolt hole is 65 mm from the edge of the flanges. Clearly, Figure 3 is not drawn to scale, so do not derive any dimensions directly from the drawing.

a) Assuming a joint constant of C = 0.20, what is the stiffness of the members? (6 points).

b) Assume that the hydraulic pressure is a constant value of 7 MPa. What would be the absolute theoretical minimum number of bolts we could use if we wanted a load factor of safety of 6.0 for avoiding joint separation, and a load factor of safety of 6.0 for withstanding the (static) load, and wanted a preload of 75% of the proofload in each bolt? Assume that the joint constant C = 0.20 (8 points)

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QUESTIONS IIB. Please write a complete descriptive answer in the space provided.

II B.1. Helical Gears are used in some machine transmissions because they are more efficient. Is this true or false? If it is false, then why are they used in some transmissions? (**1 pt.)**

II B.2. Name two advantages of a Worm Gear (**1 pt**.)

II B.3. Define Line of Action (Common Normal) for a gearset (**1 pt.**)

II B.4. Give two reasons why a Contact Ration, M_p, equal to 1 is undesirable?(**1 pt.**)

II B.5. Give two reasons why washers are used in bolted connections? (**1 pt.**)

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II B.6. Discuss the process of Shot Peening **(1 pt.)**

II B.7. List two advantages of Shot Peening (**1 pt.**)

II B.8. What is the advantage of high preload in a suitably sized bolt? (**1 pt.**)

II B.9. How does the curvature of a Spring Wire affect the stress on the inside and outside of a spring? (**1pt.**)

II B.10. What type of stresses are present on Torsion Springs, and why are they present on Torsion Springs? (**1pt.**)