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

DESIGN QUALIFIER

SPRING 2005

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 or 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.

A document containing some formulae is available for you to use in answering Question 2

ORAL EXAMINATION

Please arrive 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 of the question that we posed to you in the preceding half hour.

QUESTION 1 – METHOD & REALIZABILITY

Background

Due to significant increases in terrorist activities, security has become a major concern in the US. For instance, at the airport, we have all become accustomed to a stringent screening process for both luggage and passengers. So far, these additional measures have been effective at foiling new terrorist attacks, but they have also introduced a significant burden. The implementation of the current screening process requires significant resources: high-tech equipment, manpower and time. In this question, you are asked to consider how some of these resource requirements can be reduced through the development of a new baggage handling system in which security screening has been considered as an integral part.

An example of an X-ray based Explosives Detection System (EDS)

Task

Assume that you are in charge of the design team responsible for developing a new baggage handling system for the Atlanta Airport. Before 2001, bags were transported directly from the check-in counters to the appropriate airplanes. After 2001, this process was modified to include an X-ray security screening. Since the baggage handling system was not originally conceived to include such X-ray equipment, an ad-hoc and cumbersome solution was implemented in which the passengers themselves needed to carry their luggage from the check-in counter to the screening area. To relieve the passengers from this burden, you have been asked to develop a new system in which the luggage is transported automatically from the check-in counter to a new screening area and from the screening area to the appropriate airplanes.

In the redesign of the baggage handling system, it is critical that no security measures are compromised. For instance, it is important that the owner of a bag is present during screening so that permission to search the bag can be granted immediately if necessary. Yet, it is also important that the passengers are allowed to leave the screening area as soon as their bags have been cleared.

The airport authority, who is the principal customer for this design project, has provided you with statistical data indicating that the number of bags per minute passing through the system vary by the time of day and range from 40 bags per minute during slow periods to 150 bags per minute during peak hours. The baggage handling system should be architected such that it can distribute the load (expressed in bags/minute) equally over an adjustable number of scanning machines – by adjusting the number of machines in operation, on average fewer operators are required which significantly reduces the operational cost.

Your boss wants you to start from scratch and document your design process thoroughly – but this is not possible for lack of time. A senior engineer has suggested that you follow the general guidelines given below and turn in a report documenting each of the six steps.

Deliverables

Method

1. *Clarify the Task:* State the overall function of your system. What are the most important drivers/design criteria? Are there additional requirements that the customer may have forgotten to make explicit?

2. *Conceptual Design:* State and implement the steps (including a specification list and functional diagrams/decomposition) for transforming the overall function that you have identified into at least three alternative design solutions. Ensure that you have identified the important sub functions for each of modes of operation of the system. Sketch and describe the workings of these alternatives.

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

Realizability

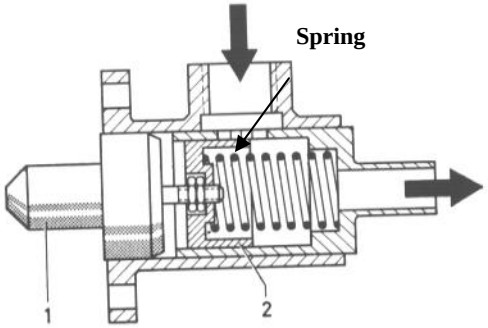
4. *Embodiment:* Further develop the alternative that you have selected.

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, and other criteria that you feel are important to consider in this phase of design.

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

QUESTION 2 - COMPONENT DESIGN ANALYSIS

One of the components of the screening system is shown below. It is a valve that opens and closes, and which is part of a subsystem for testing for explosive chemicals. Air gets sucked into the system following the arrows. The plunger 1 is connected to piston 2 by means of a threaded end and two nuts. A spring ensures that the piston and plunger are pushed back into is original position.



The designers have proposed a change in the valve. Specifically, they want to replace the single spring using two springs referred to as the inner and outer spring. Both springs have squared and ground ends.

Assume the following values for wire diameters (d), mean coil diameters (D) and total number of coils (N_{total}):

- The dimensions for the outer engaging spring (item 10)are d = 3 mm, D = 15 mm, N_{total} = 12
- The dimensions for the inner engaging spring (item 11) are d = 2 mm, D = 10 mm, N_{total} = 12
- Both are made of A228 music wire with a modulus of rigidity G = 79.3 GPa and Modulus of Elasticity E = 206.8 GPa.

a) It is considered to be a good practice to have the inner and outer spring wires wound alternatively with a left hand and right hand helix. Can you explain why?

b) Calculate the force required to move the stem, i.e., compress the two springs, 23 mm.

c) If a designer would recommend two springs with the following dimensions:

Outer engaging spring: d = 3 mm, D = 12 mm, N_{total} = 12
Inner engaging spring: d = 2 mm, D = 10 mm, N_{total} = 12

Would this be a good recommendation? Why or why not?

d) Give two very different design modifications that you can make to ensure that the inner spring will never buckle.

Part of the screening system is a conveyor belt powered by an electromotor with a simple two gear transmission. Assume that gear 1 (the pinion gear) is a spur gear that has 9 teeth and a

module m of 4 mm. The gear ratio between the gear2 and gear 1 is 11 to 1. The electromotor provides 2 kW of power to drive the gears and conveyor.

e) What are the pitch diameters of gears 1 and 2?

f) What is so special about an involute gear profile?

g) An engineer decides to change gear 1 with a gear that has a module of 4 mm and gear 2 with a new gear that has a module of 5 mm. Is that a good idea or not? Why or why not?

Useful equations: $k = d^4 G / (8D^3 N_a)$