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

DESIGN QUALIFIER

SPRING 2013

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 I, IIA and IIB 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:

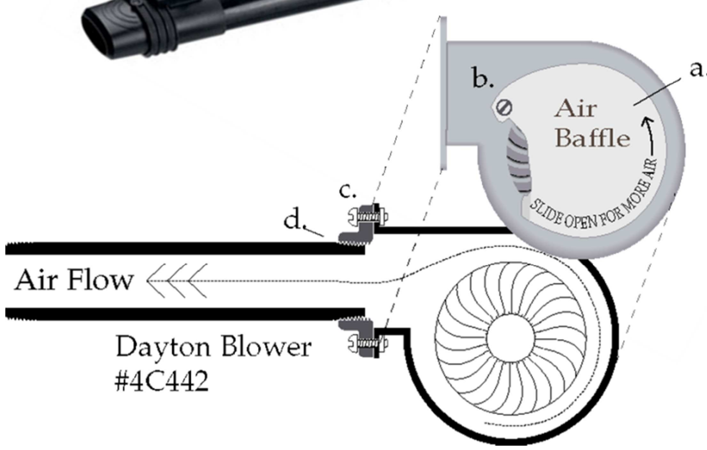
* provide an opportunity for you to state how design fits into your research activities;
* probe your understanding on the question that we posed to you in the preceding half hour.

QUESTION I. – DESIGN METHODOLOGY

BACKGROUND AND MOTIVATION

A leaf blower is a gardening tool that propels air out of a nozzle to move yard debris such as leaves. Leaf blowers are usually powered by a two-stroke engine or an electric motor, but four-stroke engines were recently introduced to partially address air pollution concerns (i.e., gas-operated blowers). Leaf blowers are typically self-contained handheld units, or backpack mounted units with a handheld wand. The latter is more ergonomic for prolonged use. Some units can also suck in leaves and small twigs via a vacuum, and shred them into a bag. Such a configuration is called a blower vacuum.

Electric Blower Design



DESIGN PROBLEM

Not causing any pollution, an electric leaf blower or battery powered leaf blower has a number of advantages over gas-powered units. Electric leaf blowers are lighter (7 to 9 pounds), quieter and vibrate less. An electric motor drives the fan, so there's no need to mix fuel or refill. For quick daily sweeps of patios and other hard surfaces, cordless leaf blowers are typically quieter, very light (only 5.5 pounds), and batteries usually last for approximately 15 minutes of operation, ample time for most decks and driveways. Most blowers require a battery recharge time of 3 hours. Some electric blower models are even more versatile and come with additional accessories for clean up.. It is also possible to design blowers with variable speed adjustment for superior control.

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TASK

Assume that you are in charge of a design team responsible for developing a new electric leaf blower 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 a systematic design methodology and turn in a report documenting the main deliverables as follows.

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). Hint: You may use one of the formal 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. **(1 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.)**

1.6 *Pricing:* How would you estimate the market size (i.e., product demand) for your product? What are the tradeoffs underlying the pricing decisions for selling your product? **(1 pt.)**

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Question IIA – Machine Design Analysis (10 pts)

When the operator leans forward on the Segway human transporter, shown in Figure 1, the device starts to pitch forward. The wheels accelerate forward in an attempt to get back under the center of gravity and stop the forward fall. In order to turn, the wheels rotate at unequal speeds causing the machine to travel in an arc. The operator controls the turn by twisting a grip on the left handlebar.

In addition to controlling the turn, the handlebars must also help balance the person. The handlebars must provide stabilizing forces in both the pitch (forward-backward) direction and the roll (side-to-side) motion. Furthermore, the rider may apply a yaw torque (like a steering wheel motion) to the handlebars. If the forces and/or torques are too high, then the handlebars may break. They can also twist unexpectedly in the yaw direction if the height adjustor becomes loose, as shown in Figure 2. Obviously, if the handlebars break or twist, the rider might fall off when they need stabilizing help from the handlebars.

Figure 1: Segway Personal Transporter.

Figure 2: Handlebar Twisting.

a) The handlebar can be adjusted up or down to match the height of the rider. The adjustment height is between 1-1.2m from the base of the machine. Assume the rider applies a force of 100 Newtons directly forward to the handlebars (50 Newtons forward on both the right and the left handles). What is the maximum torque experienced by the handlebars? Assume the vertical shaft of the handlebars is a uniform circular rod. Where is the maximum shear stress located? (3pts).

b) The height adjustor is a plastic twist nut that compresses a rubber gasket to create compressive forces that hold the upper handlebar shaft in place relative to the fixed lower segment of the shaft. Assume the upper shaft is 8cm in diameter and the rider applies a 50 Newton forward force on one handle, while simultaneously applying a negative 50 Newton (pulling back) force on the other handle. What design specification must the height adjustor meet to keep the handlebars from twisting, as was shown in Figure 2? (2 pts)

c) Assume the coefficient of friction between the handlebar shaft and the rubber gasket in the height adjustor is 0.8. What compressive force must be generated to keep the shaft from twisting? (2 pts)

d) Assume that the maximum expected loads in the side-to-side (roll) direction are 50% larger than in the front-to-back (pitch), what would be the optimal cross sectional shape of the handlebar shaft (assume a uniform shape in the vertical direction)? (3 pts)

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

In Figure 1, a cross-sectional drawing of an AVA ("aktiebolaget vapor ackumulator") pressure regulator/control valve assembly for steam systems is given. Basically, steam is flowing through the pipes as indicated in Figure 1, and turning the hand wheel at the top will open or close the valve labeled K. If K is closed, the steam flow is blocked. Right now, the valve is shown in the closed position. As you can see in Figure 1, there are a number of studs keeping the main sections of the assembly clamped together. Three different sets are labeled 1, 2, and 3 in Figure 1.

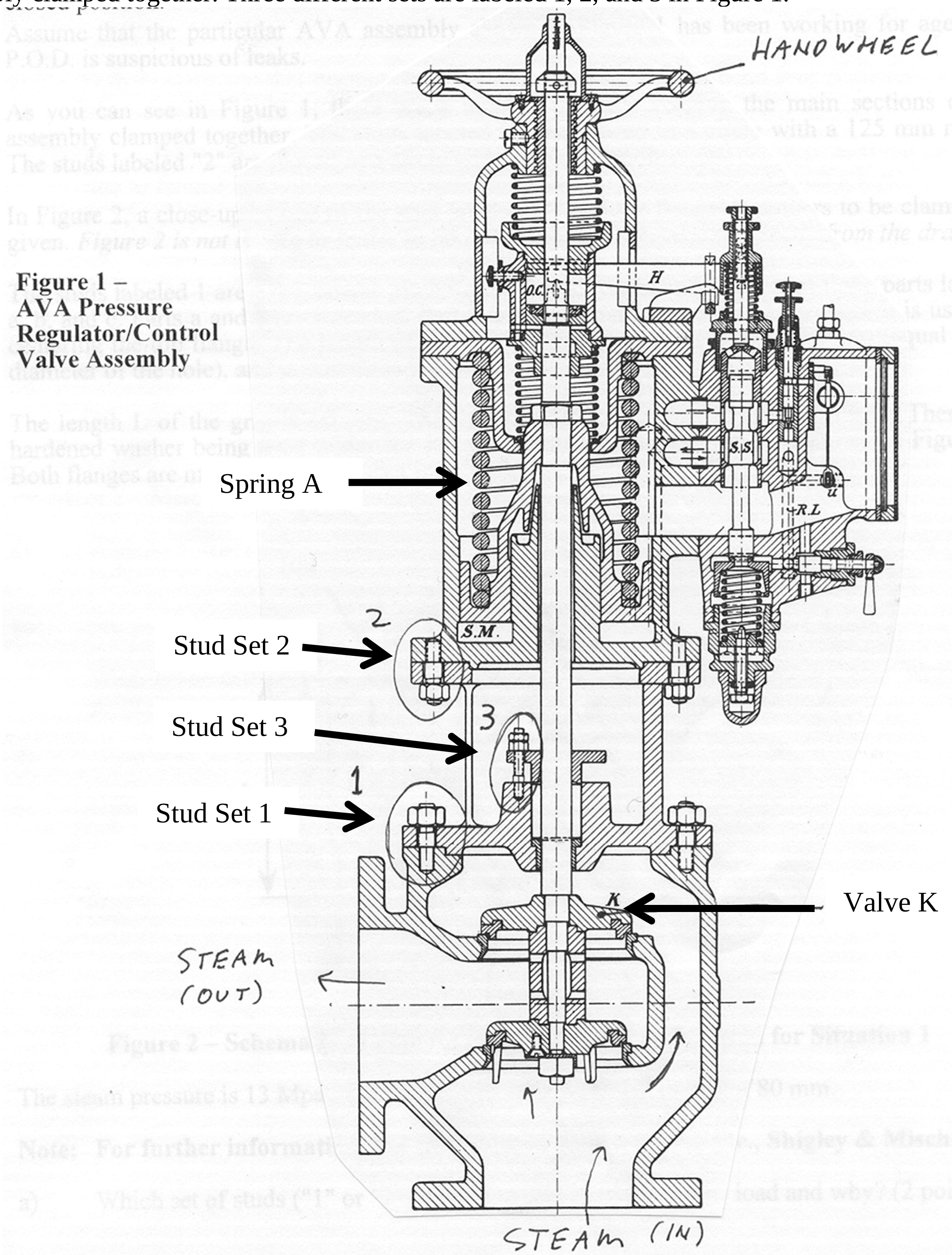

Figure 1 – AVA Pressure Regulator/Control Valve Assembly

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II B.1. In Figure 1, which set of studs ("1" or "2") do you expect to take a higher load and why? (1 pt.)

II B.2. Why are two nuts used in situation 3 in Figure 1? (**1 pt**.)

II B.3. In general, why would you not recommend reusing the nuts for stud-nut combination after, say, an overhaul has taken place for the valve apparatus in Figure 1? (**1 pt.**)

II B.4. Will Spring A in Figure 1 ever buckle, and why/why not? (**1 pt.**)

II B.5. Why do you always have to check for yielding if you use the Goodman criteria for fatigue failure (**1 pt.**)

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II B.6. In what kind of loading situation should rivets NOT be used, and why? **(1 pt.)**

II B.7. Compare and contrast ball bearings and roller bearings in terms of speed and load carrying capabilities. (**1 pt.**)

II B.8. Why is it desirable to have Contact Ratio, $m_p > 1$ in a gear system? (**1 pt.**)

II B.9. What are two reasons why epicyclical gear systems are often preferred over regular gear systems? (**1pt.**)

II B.10. What is the main type of stress present in torsion springs, and why? (**1pt.**)