MECH 325
Assignment for Module #1: Gears and Power screws

Due at start of class on Tuesday, October 15, 2019

Scenario

A device to provide a pressurized supply of a thick liquid-gel is shown in Figure 1. A motor connects through a gear train (not shown) to the power screw. The objective of this exercise is to specify a power screw to be used and to design a gear train to connect the motor to the power screw.

The pressurization chamber has a circular cross-section with 10 cm diameter and a small exit nozzle on the bottom. During a compression (downward) stoke, the pressure in chamber can be assumed to vary proportionally to the compaction platen downward speed, *v*, according to

$$P_{\text{compression}} = 5\,\tfrac{\text{kPa}}{\text{mm/s}} \cdot v$$

where *v* is measured in mm/s. During the intake (upward) stroke, new gel is drawn into the pressurization chamber through a valve (not shown). Assume the pressure during this intake is low enough that it can be ignored. Each stroke is 10 cm in length. The minimum acceptable volume flow rate out of the device is 200 mL/sec, but a higher flow rate is desirable, if possible. The device is used 40 times per day, 250 days per year, and is intended to last 4 years without maintenance.

The metric used to evaluate the design is the ratio of maximum volume flow rate out of the chamber to the system cost. The cost is computed using the catalog value of the gears, power screw, and power screw nut. Thus, the performance metric is:

Performance = max. flow rate/cost [mL/($·s)]

Component Specifications

Power Screw

You are free to select any power screw and nut available from the list of approved suppliers below (see "Additional Comments" section for details). You may neglect the cost of machining the nut and attaching it to the sleeve (shown in the figure). The nut is supported by a bearing, whose friction torque can be neglected.

Gear Train

You are free to select any combination of gears available from the approved suppliers below. You will need to show the mounting arrangement of your gears, but you do not need to design, analyze, or cost the mounting assembly. You may position the motor in any orientation, but, again, you do not need to design, analyze, or cost the motor or the motor mounting assembly.

Your gear train must adapt to both the power screw sleeve (shown in the figure) and the motor shaft (0.5 in diameter). You are free to adapt or modify the design of the sleeve shown, but you must allow reasonable wall thickness and reasonable clearance to the power screw. Likewise, you may increase the bore size of any gears with hubs, as well as add an expander sleeve, up to a 0.0625 in wall thickness, in order to adapt a gear to the motor shaft.

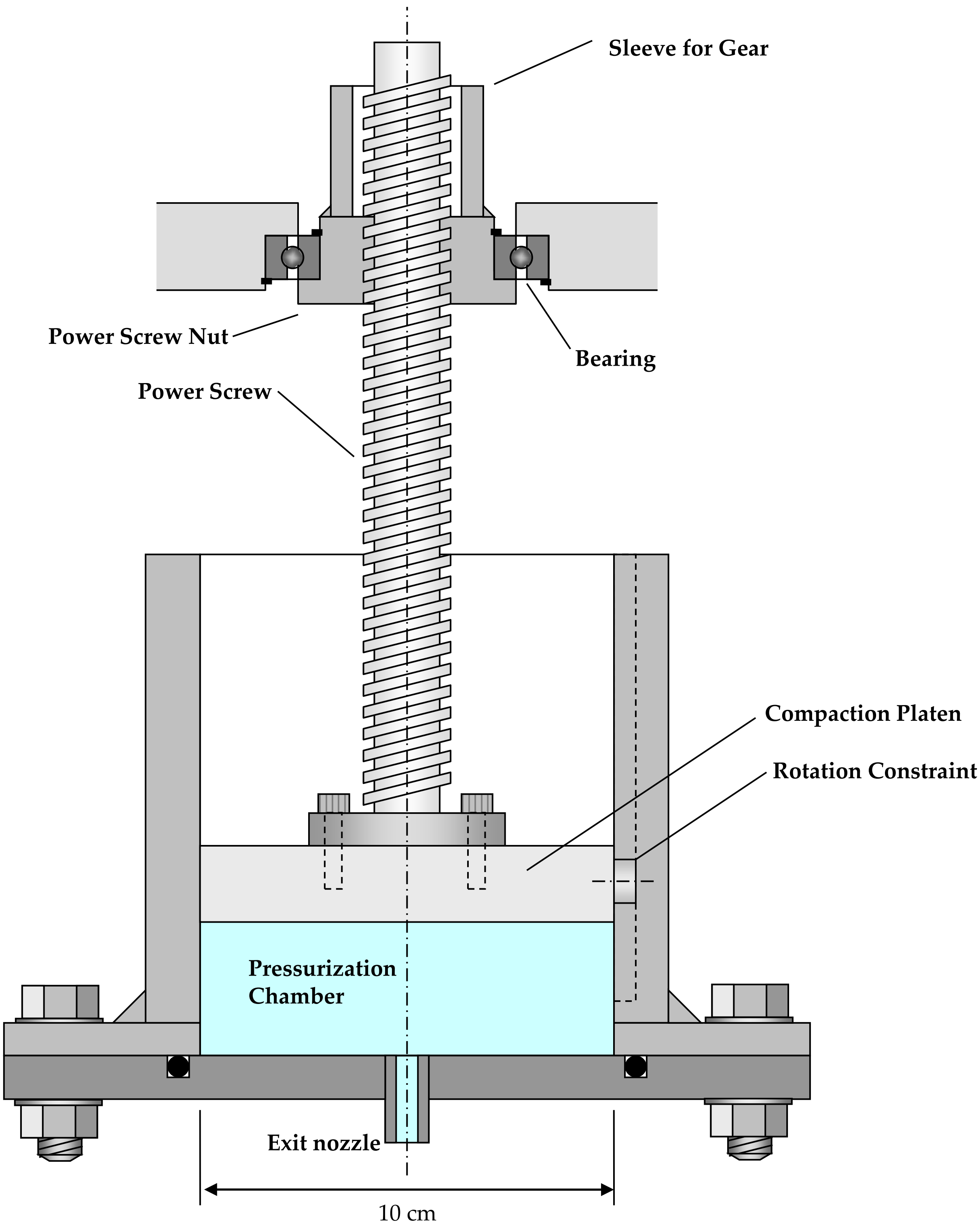

Figure 1. Compaction Chamber

Driving Motor

The driving DC motor has a stall torque of 5 Nm and a no-load speed of 5000 rpm, as shown in Figure 3.

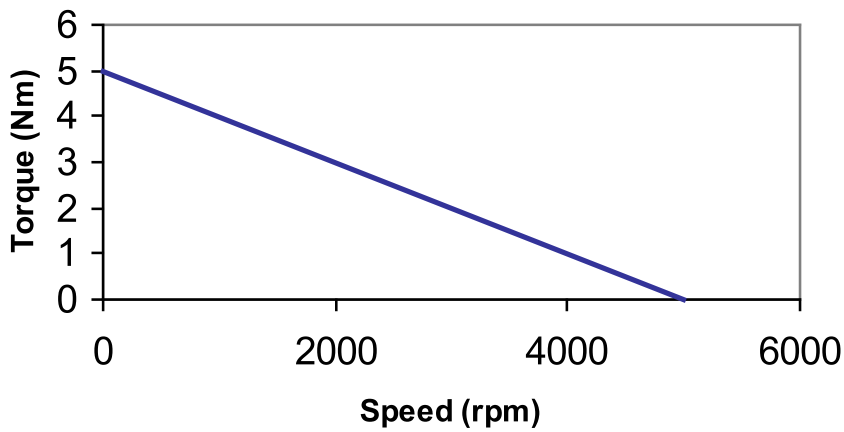

Figure 2. Motor Torque-Speed Curve

Additional Comments

The additional gear box can be considered "closed". It can be single or multi-stage, and can be in a parallel or right-angle shaft arrangement.

The following operational factors are known:

- the motor provides in light shock loading, but the cylinder has smooth loading
- the gear train must operate for a minimum of 4×10^4 full cycles (compression and intake) of the power screw; assume 40 cycles per day over a 250-day work-year
- the reliability of components must be 0.999 or better
- the safety factor must be at least 2.0

Justify the choice of any other values you use.

For the power screw and all gears you select, specify dimensions (e.g. diameter, pitch diameter, width, etc.) and materials. In addition, you must specify a catalogue source for your component part numbers and the cost per component, as well as the total cost for your design (all values in US$, for simplicity). To simplify this process, specify parts only from the following catalogues:

- Motion Canada https://www.motioncanada.ca
- Manhattan Supply Company: http://www1.mscdirect.com
- McMaster-Carr: www.mcmaster.com
- W.W. Grainger: http://www.grainger.com

Since this is a feasibility study that will allow a final decision to be made by a project manager, there is no need at this time to design, specify or calculate bearings, housings, shaft couplings or other components. Ancillary gear specifications (such as mounting method, set screws, etc.) are not needed. The cost you specify should only refer to the gear components and the power screw and power screw nut.

Reporting Requirements

There are two required documents for this assignment: a report for formal marking (80% of mark) and a poster for class review (10%). Your notes from an in-class review discussion will be handed in and marked as well (10%).

Report

The team report will be handed in at the beginning of class on Oct. 15th. It will be convenient for you to have a copy of your report in class, (either in hardcopy or on a laptop).

Your report shall consist of:

- A **title page** with the assignment number, your group number, and names and student numbers for all team members.
- A **summary** of your approach to the problem, your assumptions and methods, your final design, and the design and performance information requested below. Point-form writing, tables, and figures are all encouraged. **The summary must not exceed 2 pages and text should be computer-generated.**
- An **appendix** providing your detailed, final calculations. The appendix can be hand-written or computer-generated and **must not exceed 10 pages**.

The report must contain the following design and performance information in the summary (supporting calculations must also be provided, either directly in the summary or in the appendix):

- a sketch and description of your chosen device, including geometry and materials of the gears and power screw
- input power, torque and rotational speed to your gear box design (i.e. design motor output)
- input power, torque and rotational speed to the power screw (i.e. output of your gearbox)
- gear train value, e, and efficiency, η, of your gearbox
- the gel flow rate (mL/s) during the compression stroke
- the overall cost (gear and power screw components) for your design
- the performance metric from page 1 (volume flow rate /cost [mL/($·s)])

Poster

When you hand in your report, it will be time to display your poster in class for other teams to review.

Your poster should contain a sketch or drawing of your proposed solution along with a summary of key assumptions, values, and calculations. It should also specify the total cost of your design, the maximum flow rate, and the flow rate-to-cost performance metric from page 1. **Remember to bring your poster to class and do not be late!**

The poster is limited to 11″×17″ (you may tape two 8.5″×11″ sheets of paper together if you wish). All poster text must be in 18 pt or larger font. This is to limit your content to only the most important points, as well as to ensure others can read your poster from a distance.

After hanging the poster, you will have time to review all of the other teams' posters in a "gallery walk". During this time you will note down any errors, omissions, unrealistic assumptions, and so on that other teams have made. In addition, you should be looking for unsupported decisions other teams have made (e.g. specifying a particular dimension without explaining how that value was determined). Part of your mark on this assignment (10%) will depend on your critical analysis of other teams' designs as noted on the review sheets you submit at the end of the gallery walk.

Note: your mark on the poster is based primarily on *content*, not appearance or presentation (provided your poster is neat and legible). Likewise, your critique of other teams' work should be based on *their* content. In other words, rather than spending a great deal of time generating a "pretty" poster, you should focus on providing a clear description of your design with sufficient support and justification. It is perfect acceptable to neatly generate all drawings, sketches, and equations by hand.

A class discussion of the designs will follow the gallery showing.

Addendum

After reviewing other teams' designs, if your team feels that your report could be improved substantially due to oversights, you may submit a 1-page, 12-pt font addendum with clarifications and/or amplifications. This can be handed in as a hardcopy to the Mech Office (CEME 2054) or emailed as a PDF file but must be received by Prof. Jon Mikkelsen mikk@mech.ubc.ca within 24 hours of the end of the class. This is not intended as an opportunity for you to completely change your design. Any extra points gain in the addendum will be worth ½ of their value had they been provided in the original report.