Fluid mechanics

EGME 333 – Fall 2022
Design project, due on December 6, 2022 at 2:00 p.m.

The design project will focus on the design of a centrifugal pump by selecting the pipe size, pump impeller size, and speed for a pump-piping system. Students are allowed and encouraged to work in teams (up to 3 students). Each team will submit a Technical Memorandum (a brief report) that illustrates the design process, analysis, and figures.

Client statement

It is desired to design a pump-piping system to keep a 1-million-gallon capacity water tank filled. The plan is to use a modified (in size and speed) version of the model A centrifugal pump. Provided is the test data for a small model of this pump: $D = 5.45$ in, $\omega = 1,760$ rpm, tested with water at 20°C:

Q (gpm)	h_a (ft)	Efficiency, %
0	28	0
5	28	13
10	29	25
15	29	35
20	28	44
25	28	48
30	27	51
35	26	53
40	25	54
45	23	55
50	21	53
55	18	50
60	15	45

where Q is the volumetric flow rate and $h_a = \dfrac{\Delta p}{\gamma}$ is the centrifugal *pump head.*

The tank is to be filled daily with groundwater at 10°C from an aquifer, which is 0.8 miles from the tank and 150 ft lower than the tank. The estimated daily water use is 1.5 million gal/day. Filling time should not exceed 8 hours per day. The piping system should have four *butterfly* valves with variable openings, 10 90° elbows, and galvanized-iron pipe of a size to be selected in the design.

Costs

The design should be economical both in capital costs and operating expenses. Use the following cost estimates for system components:

Pump and motor	\$3,500 plus \$1,500 per inch of impeller size
Pump speed	Between 900 and 1800 rpm
Valves	\$300 + \$200 per inch of pipe size
Elbows	\$50 plus \$50 per inch of pipe size
Pipes	\$1 per inch of diameter per foot of length
Electricity cost	10¢ per kilowatt-hour

Project requirements

Select the combination of pipe diameter, pump impeller diameter, and speed for this task (using the data provided), that yields the lowest cost after 20 years of operation.

- No team may be bigger than 3 students. Students will select their own team members.
- Team list (%10) **due at 2:00 p.m. on Tuesday, November 29, 2022**. Email a list of all members with CWID. Students who wish to attempt this project individually may do so, but must also turn in a list of one member. Students may not switch teams after this date.
- Write a Technical Memorandum (%90) that illustrates the design process, analysis, and figures. A template will be provided.
    1. *Problem description* - Describe the problem and design objectives based on your interpretation of the *Client statement*.
        - What are your design parameters (variables that you control)?
        - What criteria will you use to select the best design?
        - What are the design requirements and constraints?

        Note: Do not just copy the *Client statement*.
    2. *Pump-pipe sizing* - Present the logical steps used to perform your analysis.
        - Present an overview of the steps taken in your design process.

          Note: this is not asking for a detailed set of calculations. Those belong in the *Appendix*
        - Present graphs of your analysis that show how head (pump head or head loss) vary with flow rate? Use this to show the how pipe diameter, pump impeller diameter, and speed affect the design
    3. *Cost analysis* - Give a cost analysis of your design. Show what the effect of pipe diameter, impeller diameter, and speed is on both overhead cost and operational costs.
    4. *Design description* - Describe the combination of pipe diameter, impeller diameter, and operational speed that you have selected. What are the corresponding overhead costs, operational costs, and total costs.
    5. *Appendix* - Attach copies of all work, spreadsheets, and MATLAB codes used in the project.
- The report is **due on Tuesday, December 6, 2022.** Late projects will receive a 5 point reduction for every hour after the deadline. Reports will be uploaded to *Gradescope*, one report per team.

Figures

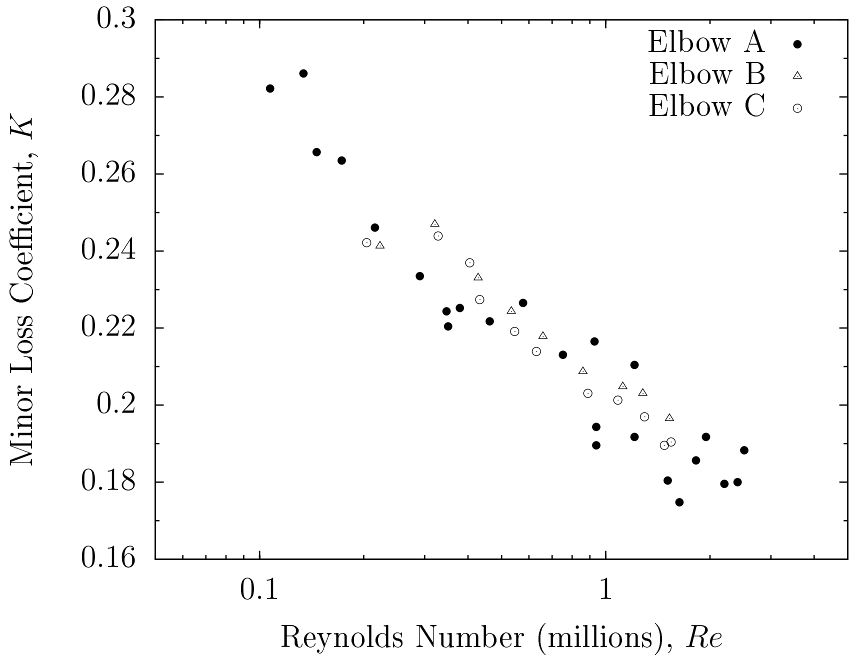

Figure 1: *Measured loss K coefficients for 90° elbows.*

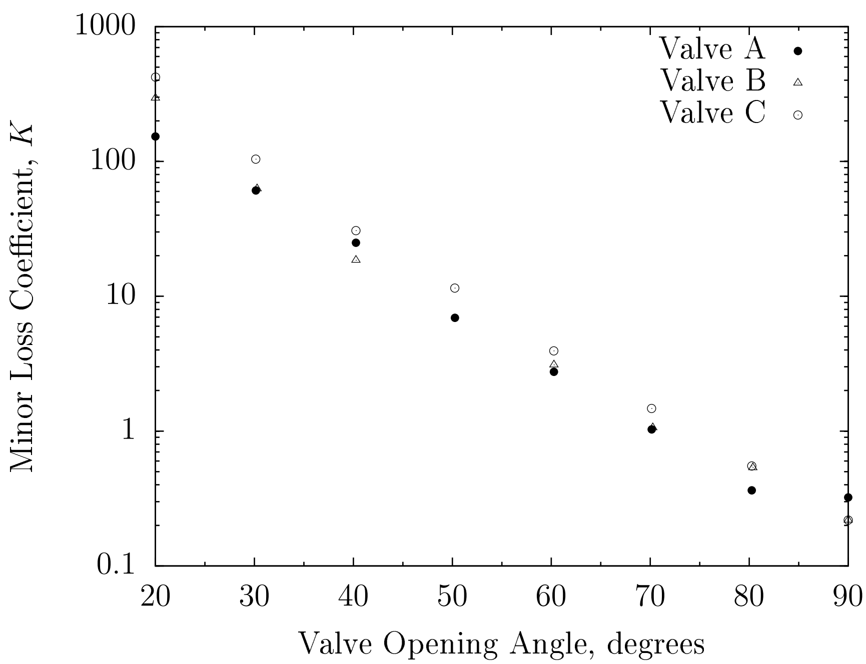

Figure 2: *Measured loss K coefficients for three butterfly valves of different manufacturers.*