Design & Optimisation of Energy Systems Assignment 1

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1 Note

All the below problems have been solved using MATLAB, the code used can be found in the link:
https://github.com/RAAKASH/ME6280/tree/master/Assignment1.

2 Question-1

The analytical equations derived by hand were then used to generate the below plots in MATLAB.
The below plots show the variation of the pumping power, the total head as a function of diameter.

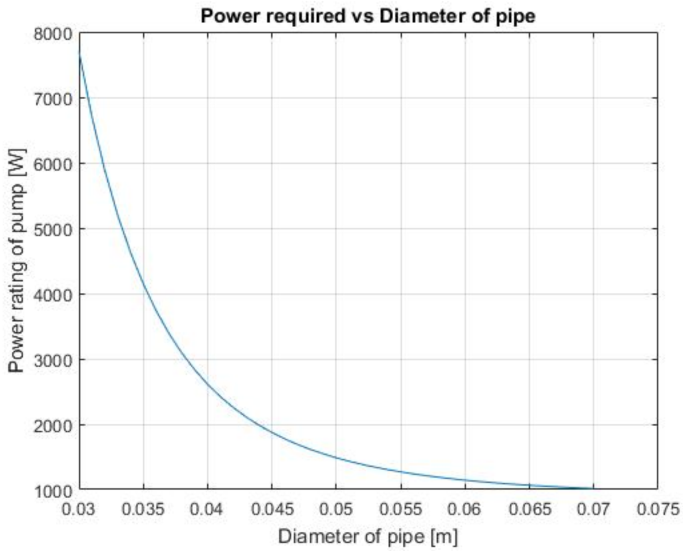

Figure 1: Power vs Diameter of pipe

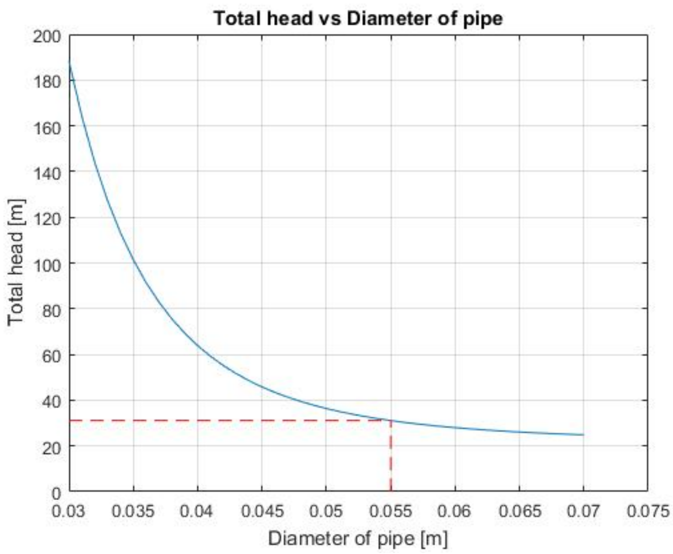

Figure 2: Total head vs Diameter of pipe

3 Question-2

The system is basically to pump water to an overhead tank of an apartment whose daily consumption of water is equal to 24000 litres. In the previous problem we had assumed that the whole pumping business of 12000 $\frac{l}{hr}$ was done by a single pump, but in the actual scenario it isn't feasible hence **2 pumps** of brand **Kirloskar** , model **DC-3M** has been used to meet the demand of *24000 l* in about 5 hrs.

The cost of the system as a whole has been broken down in to **3 sub parts** as follows:

1. **Fixed Cost** : The fixed cost of the 2 pumps, the necessary piping systems form the **Fixed cost** function. It can be seen that the cost of the piping system actually depends on both the length as well as the diameter of the pipe. Hence an empirical relation has been used, which is shown below:

$$Cost\_pipe = 1.2654L(D)^{1.327}$$

, Where L is the length of the pipe in **m**, d the diameter of the pipe in **mm**.
The total cost hence given by :

$$Total\_Fixed\_Cost = 2Cost\_pump + 2Cost\_pipe = 2 * 5891 + 2Cost\_pipe \tag{1}$$

2. **Running Cost**: Running Cost basically comprises of the electricity cost which is given as $Rs5.5/unit$, increasing at a rate of 6/7% every year. The η of the pump is approximately 70%. Hence the electricity cost for a period of **n** years is given by:

$$Electricity\_Cost = \frac{5.5}{1000}\frac{\Delta PV}{\eta}\left(\sum_{i=0}^{n}\left(1+\frac{6}{100}\right)^{i}\right)$$

3. **Maintenance Cost**: The Maintenance cost was approximated as about **1% of the fixed cost** every 3 months. This includes the servicing of the pump as well as the piping system.

The total cost is simply the sum of the above subparts. It can basically be seen that the each and every component of the total cost is a function of the diameter of the pipe, hence the optimisation problem is set as follows:

$$min(Total\_Cost(D))$$

Since the optimisation problem is set we can obtain the results of various cases:

1. **Life of system = 20 years, Increase in electricity cost = 6%**.

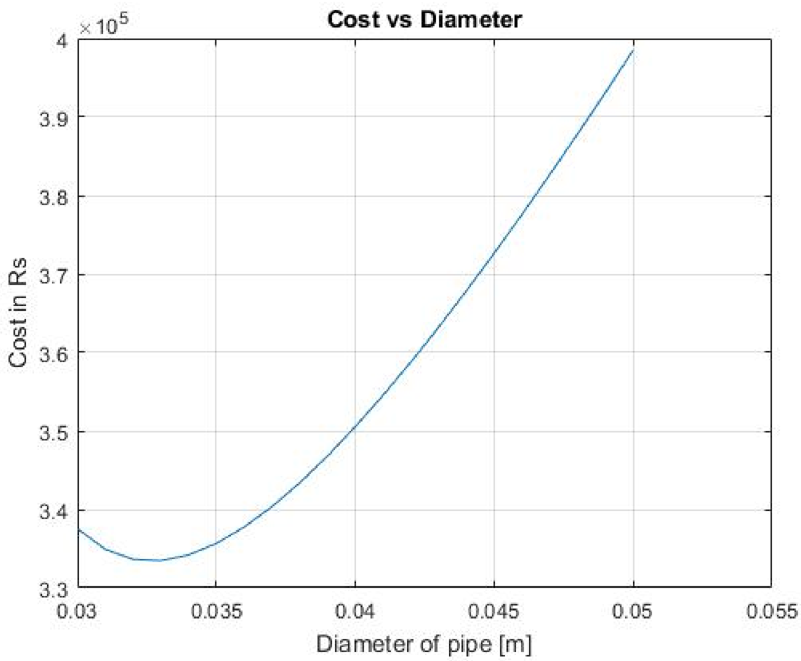

Figure 3: Total Cost vs Diameter of pipe

The optimal diameter has been found to be **32.7 mm**, the corresponding head to be = **27.037 m**.

2. **Life of system = 20 years, Increase in electricity cost = 7%.**

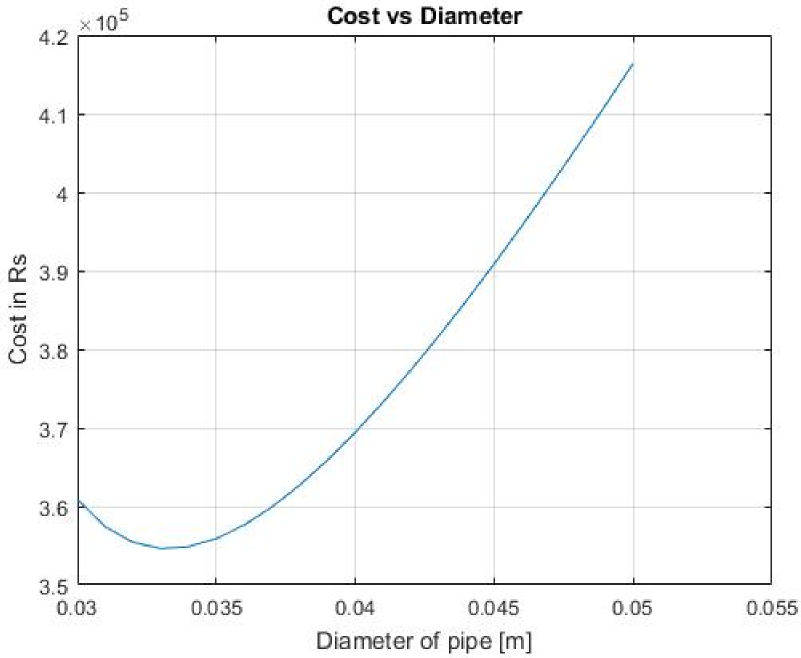

Figure 4: Total Cost vs Diameter of pipe

The optimal diameter has been found to be **33.3 mm**, the corresponding head to be = **26.62 m**. It can be seen that as the percent increase in electricity cost increases there is an increase in the diameter of the pipe which seems reasonable since to counter the increase in electricity cost we need to decrease the head which can be done only by increasing the diameter.

3. **Life of system = 16 years, Increase in electricity cost = 6%.**

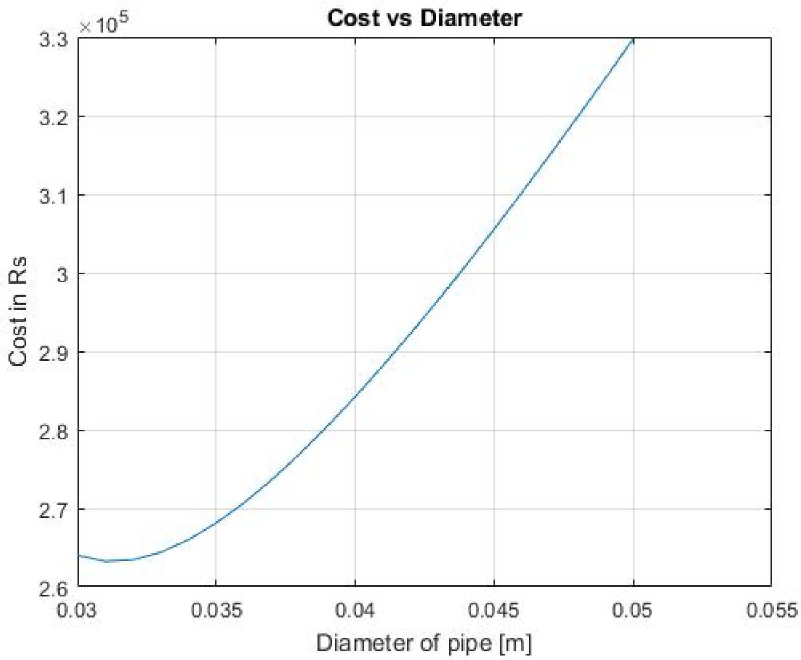

Figure 5: Total Cost vs Diameter of pipe

The optimal diameter has been found to be **31.3 mm**, the corresponding head to be = **28.207 m**. Again the decrease in pipe diameter seems reasonable when compared to **case 1** since decreasing the lifetime decreases the running cost hence an optimal solution could be obtained by decreasing the piping system cost which can be done only with the decrease in diameter.

4. **Life of system = 16 years, Increase in electricity cost = 7%.**

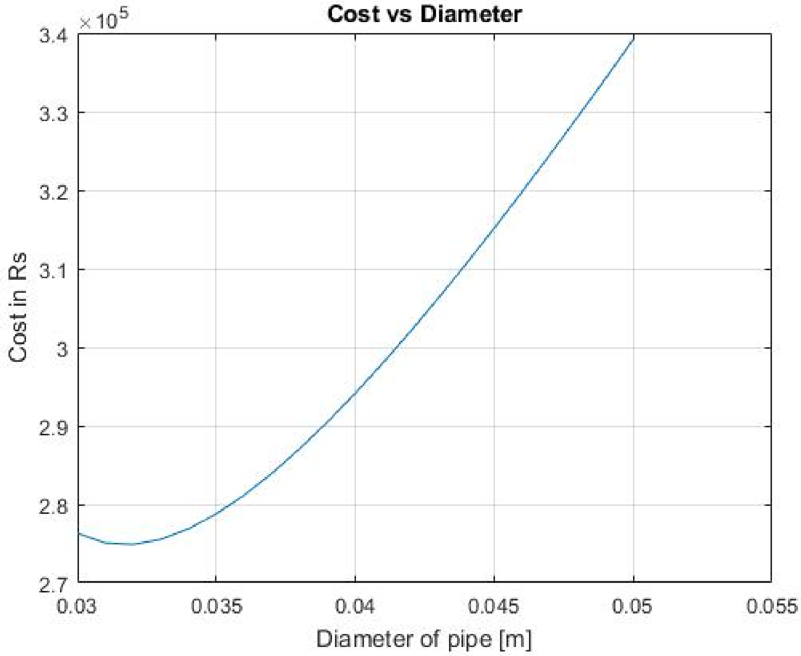

Figure 6: Total Cost vs Diameter of pipe

The optimal diameter has been found to be **31.7 mm**, the corresponding head to be = **27.817 m**. Again the decrease in pipe diameter seems reasonable when compared to **case 2** since decreasing the lifetime decreases the running cost hence an optimal solution could be obtained by decreasing the piping system cost which can be done only with the decrease in diameter.

3.1 Summary

It is not feasible to actually obtain pipes with the above optimal diameters, hence it should be rounded of to the nearest standard pipe diameter value.
We can thus conclude this question by drawing a general trend between the optimal pipe diameters with the increase in electricity cost as follows:

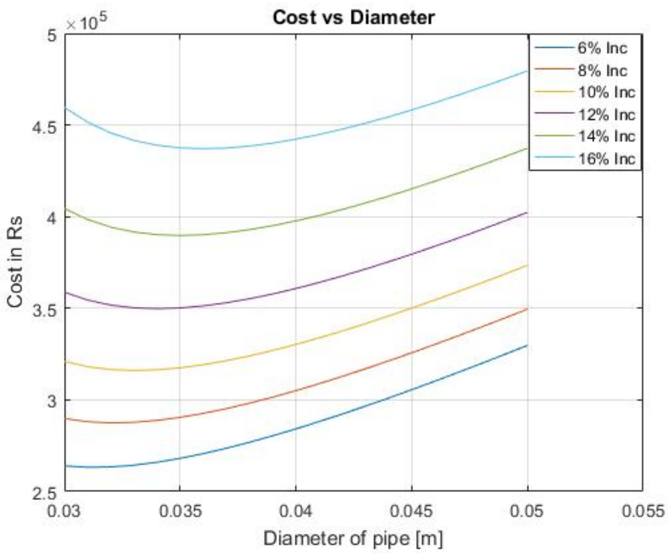

Figure 7: Variation of Total cost of the system as a function of diameter for various percentages of increase in electricity cost

It can be clearly seen from the graph that the optimal pipe diameer shifts to the right with increase in electricity cost (ie) electricity cost increases there is an increase in the diameter of the pipe and vice versa.