PUMP CONFIGURATION AND FLOW THROUGH A PIPE

Introduction and Scope

Most chemical and biological processes involve pumping-piping systems to transport materials to reaction chambers, storage and other unitary processes. Materials to be transported can be gases, liquids, or two-phase flows. The xanthan gum produced during from fermentation will need to be transported to a separation unit. The fermentation broth, including the cells and the gum, will exhibit flow requirements close to that of water. For this experiment, we will test pump and pipe configurations using water as the fluid of interest.

Two important factors are involved in the design of transport systems, the selection of the appropriate pump(s) and configuration to produce the required flow, and the calculation of the pressure drop across the piping system to set up a system able compensate for pressure loss.

The performance of a centrifugal pump is often described in terms of characteristic curves. Common curves include pressure-rise, total power and flow power and efficiency versus volumetric flow rate. In this experiment the characteristic curves and friction factors are to be determined for three pumping configurations and four different piping systems.

AIMS

- Determine the characteristic curve (pressure-rise across the pump versus volumetric flow rate through the pump) for three different arrangements of centrifugal pumps: single, series, and parallel (Figure 1). Figure 2 illustrates the path of flow of a fluid in a centrifugal pump. Compare the characteristic curves with actual pump performance.

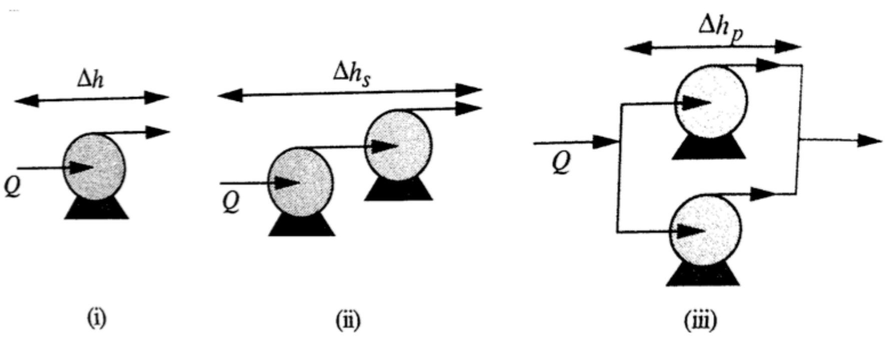

Figure 1: Centrifugal Pump Arrangements: (i) a single pump, (ii) two in series, (iii) two in parallel. (McCabe, Smith, and Harriott, 2001)

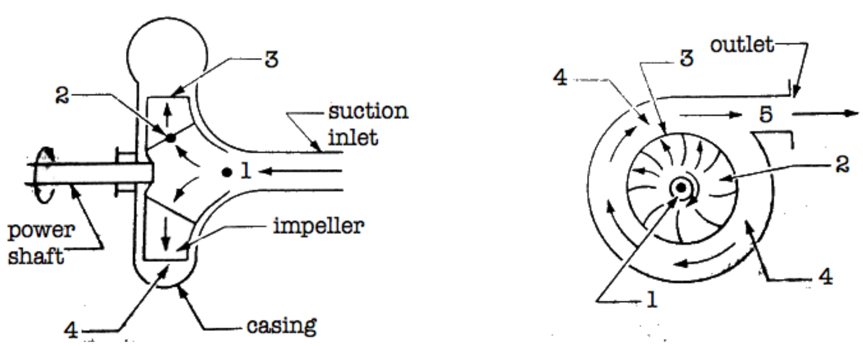

Figure 2: Two views of a centrifugal pump. The numbers denote the path of flow. (Geankoplis, 2003)

- Determine the frictional losses of the piping station using copper tubing in the configurations for 1”, ¾”, and ½” (straight and coiled). The goal is to obtain the Darcy friction factor (*f*) for each configuration. Compare the value obtained with the Darcy friction factor generated by the Colebrook equation or any other equation for this purpose. You will need to take the restrictions and specifications for the use of these equations such as Reynolds number and piping material into account. Figure 3 depicts typical characteristic curves for centrifugal pumps in different arrangements.
- Generate a Moody’s diagram with the frictional losses calculated from the data recordings for cooper tubing, and compare the result with a Moody’s diagram from literature.

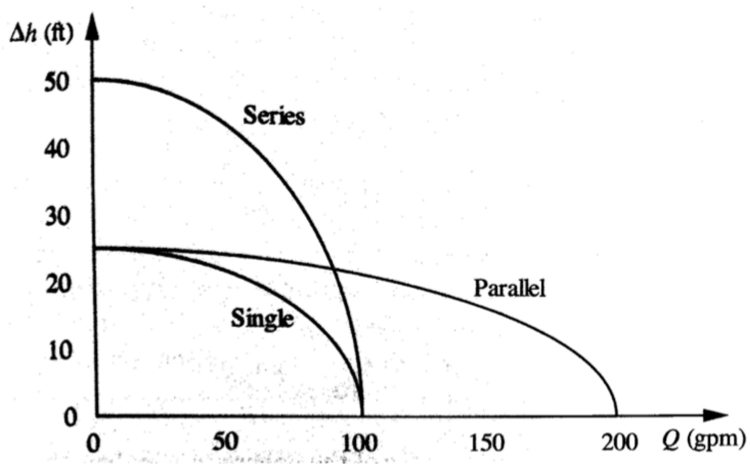

Figure 3: Performance curves for three different pump arrangements. (McCabe, Smith, and Harriott, 2001)

- Make recommendations on piping and pumping configurations to meet a hypothetical need to transport a fluid with characteristics similar to water:
  - How many pumps and in what configuration is needed to motivate 1300 gallons per hour to a chamber located 5’ off the ground
  - How many pumps and in what configuration will transport 260 gallons per hour to a reactor vessel that has a fluid inlet that is 13’ from ground level.

PROCEDURE

Characteristic curves:

Set the pumps to obtain the configuration desired. All three configurations must be performed: Single pump, two-pumps in series and two-pumps in parallel.

- To characterize the pumping configurations, the largest pipe size should be used (1”).
  - Be sure that all the valves of the other pipes are closed. The valve on the largest diameter pipe can be adjusted to allow for different amounts of flow and pressure to be measured (both quantities are needed to characterize the pumping system).
- Record at least 10 different flow points and the pressure drop generated for each configuration.
  - Depending on the configurations, the maximum flow varies. Be aware of this variation, as you will need to measure 10 points to cover the flow range.

Darcy friction factor:
For this experiment, use the pumping configuration that allows the highest flow range.

1. Set the piping system to test the configuration desired. All four configurations must be examined: 1”, ¾”, ½” straight and ½” coiled.
   a. Each section of pipe can be isolated by ball valves that can be opened and partially closed to restrict the level of flow.
2. Adjust the flow desired and record the pressure drop. For flows below 5 gpm, use the appropriate flow-meter.
   a. Take at least 12 measurements of different flows and pressure drops covering all the flow range. Record **all** specifications of the equipment that you think will be necessary for calculations.

DATA ANALYSIS

- Use the flow and pressure drop to generate the characteristic curves for each pumping configuration. Compare with actual results.
  - Analyze the following
    1. What are the reasons why the curves are different in terms of how the configurations manage the fluid
    2. Why some give more pressure drop and others are able to handle more flow but with less pressure loss etc.
    3. In what process/situations are useful each configuration.
- Use the pressure drop data to calculate the Darcy friction factor, *f*, for the different flows, you do not need a Moody’s diagram at this point because the aim is for you to use the data to calculate *f*. For this purpose, use the equations from the background section. Remember that the pressure drop in the system is the summation of minor and major losses. Refer to the literature to find the coefficients you might need. Any assumption should be mentioned and justified.

- The second step is to calculate the Darcy friction factor using equations from the literature such as the Colebrook equation, this will allow you to compare the friction factors. The equations rely on Reynolds number and other factors and the pressure drop is not involved. The solution usually requires iterations, for this set up use Goal Seek from Microsoft Excel® to facilitate the calculations.

  To use goal seek:
  Select cell you wish to change. Select Goal Seek within the What-if Analysis. The set cell should be the value you wish to change. Set the To value entry to the value you desire and then select which cell you wish to modify to obtain the value in the set cell. Select OK.
- With the Darcy factor (*f*) obtained previously (using pressure drop and the equation) generate your own Moody’s diagram for cooper tubing Re vs. Darcy friction factor. Analyze any difference if exists and the possible causes.

- Finally to determine the appropriate configuration to each of the hypothetical requirements, select the pumping arrangement that allows those flows (not all the pumping configurations will be able to handle them).

- After selecting the pumping configuration, use the pressure drop of each piping configuration (1”, ¾”, ½” straight and coiled) and the height specified to fit Bernoulli’s equation. Remember that the pressure measurements taken during this lab are total pressure drop.

- Analyze whether the Bernoulli equation can or cannot be satisfied and subsequently whether the system we have is able to fit the hypothetical requirements or not. Will additional pumps be required? If not make suggestions about what can be made in terms of capacity-configurations of the pumps, pipe diameter, material etc.

REFERENCES

Geankoplis, C.J., *Transport Processes and Separation Process Principles*, 4th Ed., Prentice Hall (2003)

McCabe, W.L, J.C. Smith and P. Harriott, *Unit Operations of Chemical Engineering*, 6th Ed., McGraw-Hill (2001)