Practical

Elements and evaluation of a centrifugal pump

AIMS

- To take apart a centrifugal pump to determine its inner workings
- To determine the performance curve of a 100 W centrifugal pump
- To use an understanding of pump and system head curves to predict the operating point of a pipe system with a 100W centrifugal pump

SAFETY AND STUDENT DRESS

Operation of experimental equipment should always be in accordance with local safety procedures. Dangers can occur if the equipment is misused or poorly maintained. The equipment is designed to operate safely.

It is a University requirement that student dress and behaviour in the lab must conform to the following safety standards:

- Safety glasses and either long-sleeve/long-leg clothing OR a lab coat must be worn.
- Do not take your safety glasses off while in the lab.
- Footwear must completely cover feet.
- No smoking, drinking, or eating in lab.
- No sitting on table or floor.
- Let the demonstrator know if you need to leave the lab.
- Keep table/work area tidy, notes and other items away from chemicals.
- Handle chemicals and equipment with care.
- Follow the lab supervisor's instruction in case of emergency evacuation.
- Ask question if you are unsure of anything during the practical session.

The laboratory demonstrator will determine whether students meet these requirements. Students not meeting these requirements will be asked to leave the laboratory and will receive zero for this part of the subject assessment.

Take 5 assessment of equipment and setup:

- *Electrical Safety* – pump is connected to the mains power (240V). Ensure water is not spilt onto electrical connections when transferring water into the equipment. Equipment must be drained before dismantling equipment. Spills should be cleaned as soon as possible.

- *Pinch Hazards* – when using barrel unions and pipe clamps. Ensure hair is tied back and no loose items of clothing.
- *Water borne hazards* – if water is left stagnant for long periods of time, bacteria can grow and cause respiratory harm if droplets are inhaled. System should be drained at the end of each day.
- *Hot surfaces* – when pump is running continually, the motor generates heat and the surface becomes hot. Appropriate gloves may be required to handle the pump if it is not given enough time to cool down.

THEORY

For fluid to flow in a horizontal pipe, a driving force is required. One way of providing this driving force is to use a centrifugal pump. The pump provides energy to the fluid in the pipe and drives the flow. We can apply conservation of energy to the fluid in the pipe using the Bernoulli equation. In steady-state conditions, this equation is given by:

$$\frac{p_1}{\rho g} + \frac{u_1^2}{2g} + z_1 + h_p = \frac{p_2}{\rho g} + \frac{u_2^2}{2g} + z_2 + h_L \qquad (1)$$

where p is the pressure in the fluid
u is the velocity of fluid in the pipe
z is the elevation of the fluid
h_p is the pump head provided
h_L is the head loss due to pipe friction and minor losses

Figure 1 shows a typical piping system which uses a centrifugal pump to drive water flow in a pipe. Points 1 and 2 are the free surface of water in the storage tank. The system head of the centrifugal pump can be determined by energy conservation between points 1 and 2.

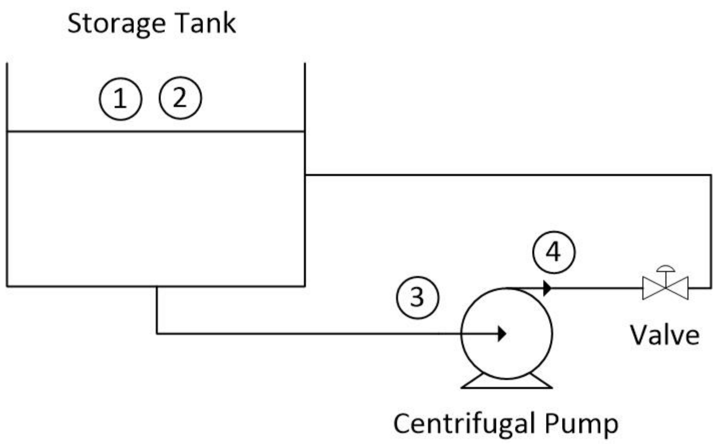


Figure 1: Schematic diagram of the pump experiment displaying energy levels for Bernoulli equation.

In the above system, the pressure at points 1 and 2 is atmospheric as the storage tank is open to the atmosphere. The velocity of water on the free surface can be approximated to be zero. The change in elevation between points 1 and 2 is also zero. Applying all the above conditions into (1), the Bernoulli equation becomes:

$$h_p = h_L = f\left(\frac{L}{D}\right)\left(\frac{u^2}{2g}\right) + \sum K\left(\frac{u^2}{2g}\right) \tag{2}$$

where f is the Darcy friction factor
L is length of pipe
K is the minor loss coefficient at each irregularity in the pipe

Note that, as the pipe diameter changes, the velocity and the velocity head term on the right hand side of (2) will be different in different sections of the pipe.

Point 3 is the suction side of the pump and point 4 is the discharge side of the pump. Points 3 and 4 can be used to determine the pump head using the Bernoulli equation. Assuming the suction and discharge pipe have the same diameter, then the velocity at points 3 and 4 will be the same. Also, the change in elevation between the suction and discharge side is negligible. The Bernoulli equation thus reduces to:

$$h_p = \frac{p_4 - p_3}{\rho g} \tag{3}$$

PART 1 – ELEMENTS OF A CENTRIFUGAL PUMP

EXPERIMENTAL NOTES

- Do not overtighten screws on equipment as this may damage the thread.
- If bolts do not screw in easily, it is likely that the bolt is not aligned properly. Undo screw and realign to prevent cross threading.
- The pumps used in this experiment are purely for dismantling and reassembly only. They should not be used for any other purpose.

EXPERIMENTAL APPARATUS

Figure 2 shows the centrifugal pump. The setup consists of 2 sets of flanges, 1 centrifugal pump, 1 gate valve and PVC pipe fittings.

Figure 2: Evaluation of a centrifugal pump experiment setup.

EXPERMENTAL PROCEDURE

This practical exercise is to take apart a centrifugal pump and identify its components.

Using the tools provided, progress through the disassembly of the centrifugal pump and take photos of the various parts as they are disassembled.

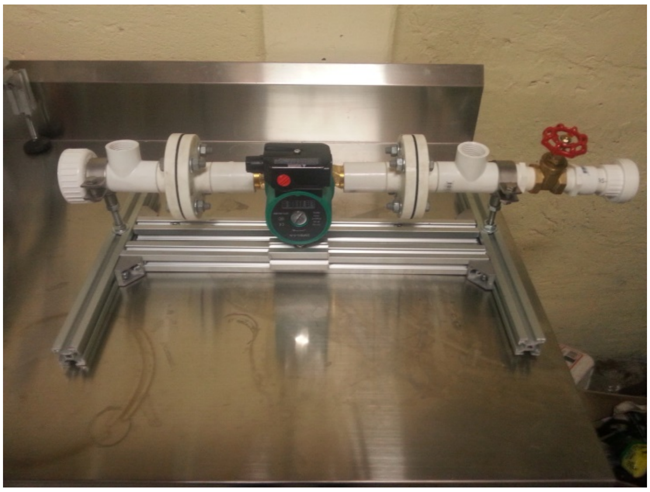
Tools Required

The tools required for this exercise are:

- 1x Allen Key
- 1x Shifter
- 1x 10mm Spanner

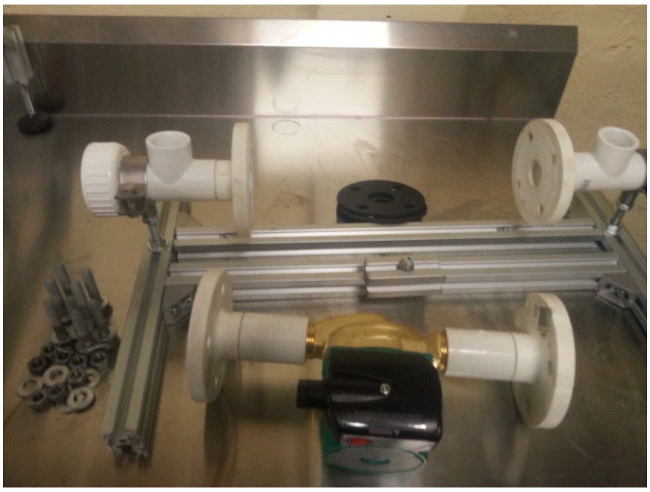
Disassembly of centrifugal pump

1. Ensure equipment and tools are acceptable for use.



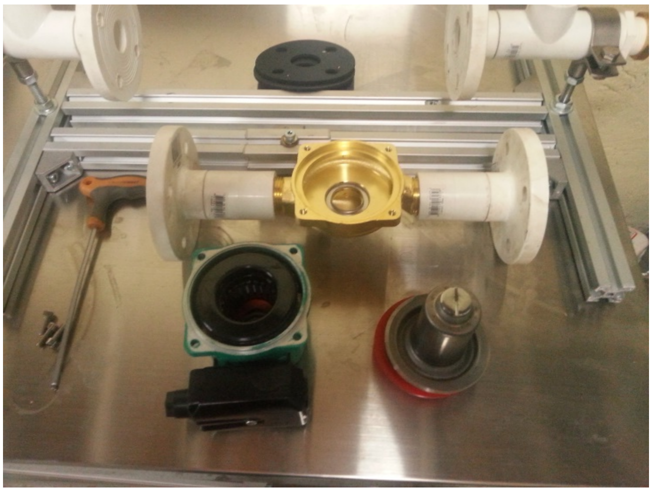
2. Remove flange bolts nuts from each side, keeping bolts in position. When all nuts are removed, remove all but 1 bolt from each side. Hold the pump steady and remove the remaining bolts.

3. Remove pump from setup and use the Allen key to remove the 4 bolts connecting the motor to the pump housing.

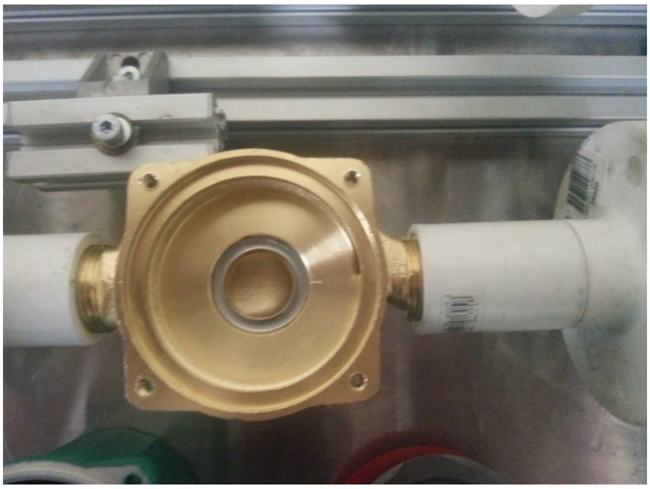


4. The demonstrator will then remove the rotor from the motor and take photos of each piece.

   Important note: This step should be performed only by the demonstrator. The impeller blade is very sharp and you risk cutting your fingers if you disassemble the pump.



5. Discuss the water flow path with the demonstrator. Why does water move in this direction?



PART 2 – EVALUATION OF A CENTRIFUGAL PUMP

EXPERIMENTAL NOTES

The pump must not be plugged in unless the system has been filled with water and the pump primed. Running the pump dry can cause premature equipment failure.

Barrel unions should screw easily and not be over tightened. If they are not aligned correctly, the thread can be damaged and it will cause the equipment to leak.

All threaded PVC fittings (excluding barrel unions) require Teflon tape to be applied before installation. Teflon tape is used to seal gaps between the solid fittings to stop leaks.

EXPERIMENTAL APPARATUS

The experimental apparatus consists of a water tank, centrifugal pump, pressure gauges, flow meter and a throttling valve as shown in Figure 3. Once you have checked that the setup is complete, the experiment can be run according to the experimental methodology below.

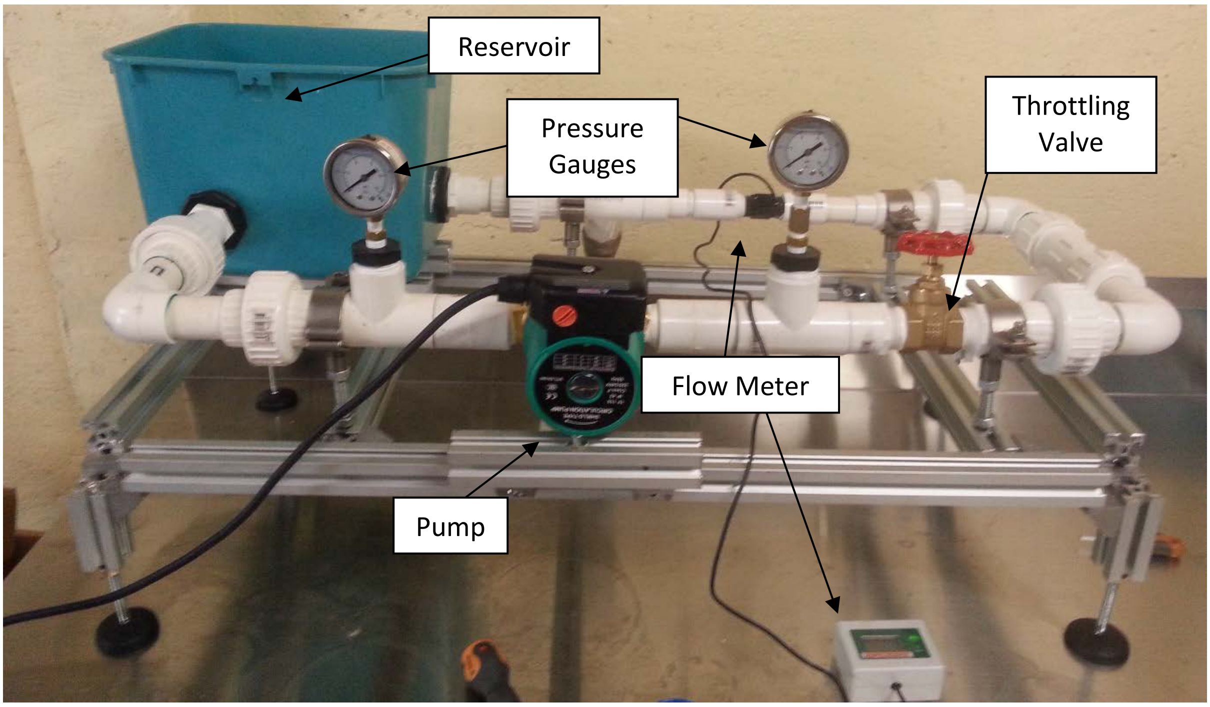


Figure 3: Evaluation of a centrifugal pump experiment setup.

EXPERMENTAL PROCEDURE

Pre-start-up Checks

1. Check the flow direction arrow on the pump and flow meter to ensure they are installed correctly.

2. Ensure the electrical outlet is switched off and the pump power cord is not connected.

3. Ensure the drain valve is closed.

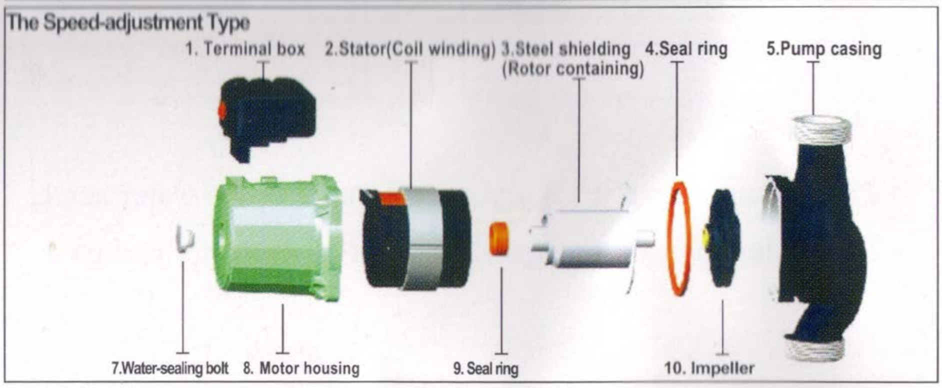
4. Open the throttling valve by turning it anti-clockwise (do not over tighten)

5. Fill the reservoir with approximately 5 - 8L of water

6. Ensure there are no leaks in the system

7. Prime the pump by unscrewing the water-sealing bolt (see figure below) and then retightening it when water is flowing through the pump.

N.	Description	N.	Description
1	Terminal box	6	Water-sealing bolt
2	stator(Coil winding)	7	Motor housing
3	Steel shielding(Rotor containing)	8	Seal ring
4	Automatic switch	9	Seal ring
5	Pump casing	10	Impeller



Turning on pump and experiment initiation

1. Ensure all pre-start-up checks have been completed.

2. Plug the pump into the electrical socket and turn on switch.

3. Set pump to setting III and leave running to remove air from the system.

4. When the pump outlet pressure and flow stabilise, progress to the next step.

5. Cycle through each of the pump settings (I, II & III) and record the maximum flow rate and minimum pressure differential (please take extra care when switching between different speed settings and do not break the plastic dial).

6. Close the valve completely by turning it clockwise (do not over tighten) and ensure the flow meter is reading 0 L/min.

7. Cycle through the settings again and note the maximum pressure of each setting at a flow of 0 L/min.

8. Turn off the pump at the power switch.

Experimental Run

1. Open the valve completely.

2. Turn on the pump.

3. By gradually closing the valve, record at least 10 pairs of flowrate and pressure differential data points for each of pump settings I, II and III (starting with the valve fully open and ending with it fully closed).

4. When all data is recorded, turn off the pump.

Shutting down equipment

1. Open valve completely.

2. Turn off pump at the switch.

3. Remove pump plug from GSO.

QUESTIONS

1. Make a sketch of the system, showing all system elements, pipe lengths & diameters and regions where minor losses will be considered.

2. For each setting, plot the experimental data of h_p versus Q for the centrifugal pump (where h_p is in m and Q is in L/min).

3. Construct the pump curves by generating, for each setting, a curve of best fit to the experimental data in the form of

$$h_p = a + bQ^c$$

where h_p is in m and Q is in L/min. Add these curves to the plot in Question 2 and report the values of a, b and c for each pump setting.

4. What is the purpose of the throttling valve?

5. What are the implications of having the throttling valve prior to the pump inlet? Explain in terms of NPSH.

6. Using reasonable estimates of friction factors (for a smooth pipe) and minor loss coefficients, construct a curve of theoretical system head for the case of the valve being fully open.

7. For the 3 experimental runs with the valve fully open, how do your estimates of system head loss compare to the experimentally-obtained values?

8. In relation to Question 7, what might be the cause of any discrepancy?