AE 204 FLUID MECHANICS

CENTRIFUGAL PUMP EXPERIMENT / EXP5

2024

OBJECTIVE

The primary objective of this experiment is to measure the performance of a centrifugal pump and compare the results to the manufacturer’s specifications. Secondary objectives are to familiarize the student with the characteristics of a centrifugal pump. Additional objectives may be specified by the instructor.

THEORY

The most common machine for causing liquids to flow through piping systems is the centrifugal pump. The centrifugal pump is well suited to situations requiring moderate to high flowrates and modest increases in head (or pressure). Typical applications include municipal water supply systems, circulating water heating and cooling system for buildings, pumps in dishwashers and clothes washing machines and the cooling water circulating pump in an automobile engine. For very high pressure, low flow applications, positive displacement pumps are more suitable. Positive displacement pumps move fluids with pistons, gears or vanes and flowrate is a function of rotational speed and has little if any dependence on the pressure rise. A common application of a positive displacement pump is that used to supply high pressure oil for hydraulic actuators such as those on a large earth moving machines.

by Dr. BEGÜM KÜTÜK

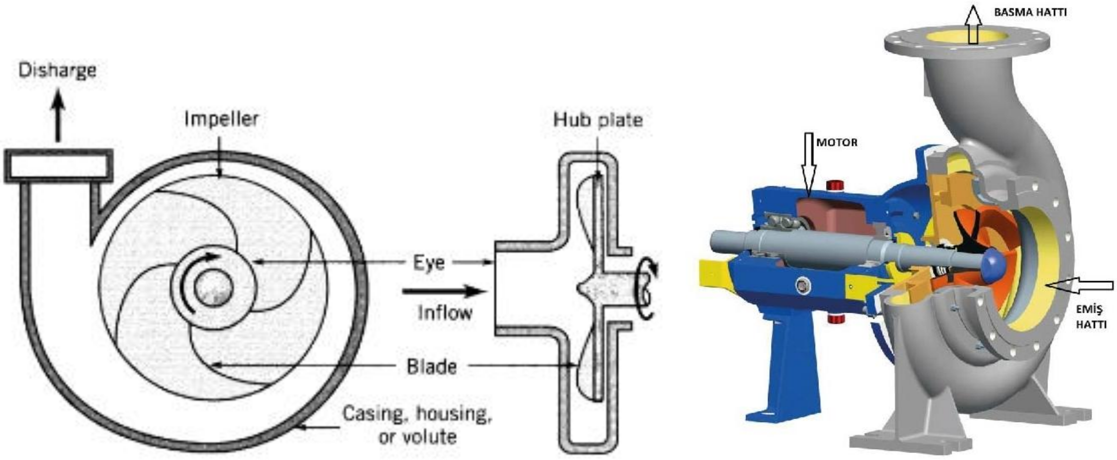

Figure 1. Cutaway sketch of typical centrifugal pump and 3D view of the pump.

A sketch of a typical centrifugal pump is shown in Figure 1. Fluid which flows into the impeller at the inner radius is given significant angular momentum and kinetic energy as it flows radially outward. After the fluid leaves the outer radius of the impeller, it is diffused or slowed down resulting in a significant increase in pressure.

The actual head rise (H) produced by a centrifugal pump is a function of the flowrate (Q). It is possible to determine the head-flow relationship by appropriate selection of the geometry of the impeller blades. Normally, pumps are designed so that the head decreases with increasing flow since such a design results in a stable flowrate when the pump is connected to a piping system. A typical head flow curve for a pump is shown in Figure 2.

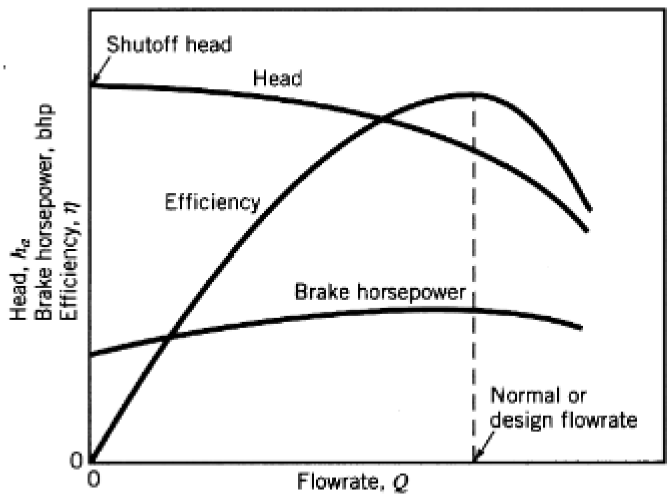

Figure 2. Typical performance curves for centrifugal pump [2].

If the mechanical energy equation is applied between two points in a piping system on opposite sides of the pump, the result is:

$$H_P + \frac{V_1^2}{2g} + \frac{P_1}{\gamma} + z_1 = \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + z_2 + h_l$$

H_p is the pump head, and h_l is the total head loss in the associated piping. If section 1 is located at the pump inlet and section 2 at the pump outlet, the h_l term in the mechanical energy equation is zero. If there is include piping, either upstream or downstream, the h_l term may be greater than zero.

For a given pump operating at a given rotational speed, there is only one operating point where the geometry of the impeller blades is optimum. This fact combined with other losses results in an efficiency which is a function of the flowrate. The efficiency is defined as the ratio of the fluid work to the shaft power input to the pump:

$$\eta = \frac{\gamma Q H_p}{P_{shaft}}$$

$P_{hyd} = \gamma Q H_p$ $\quad$ $P_{shaft} = V_m I_m cos\theta$ $\quad$ V_m: $Motor\ voltage\ (V)$

I_m: $Motor\ current\ (A)$

$cos\theta$: $Motor\ power\ constant, take$ 0.85

DESCRIPTION OF APPARATUS

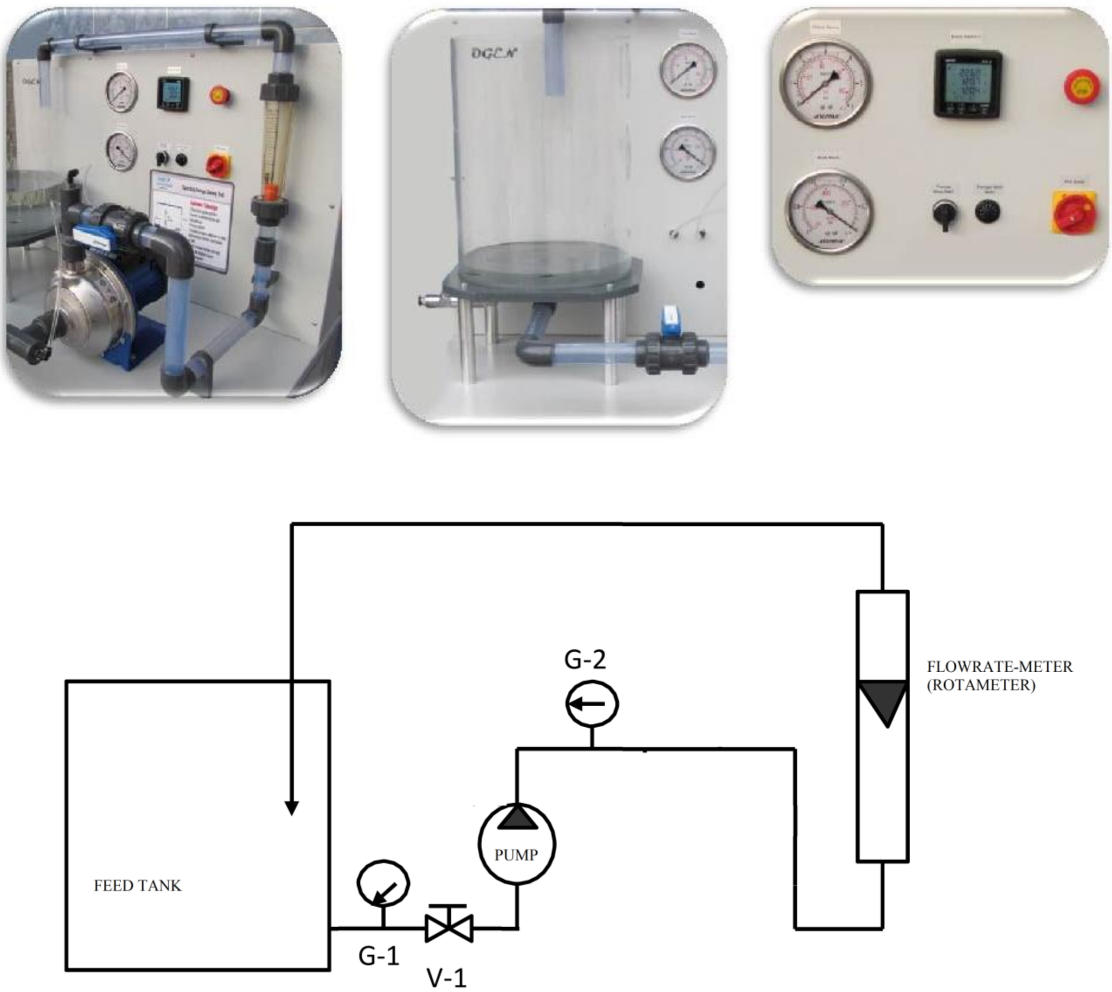

Figure 3. Experimental setup with (a) pressure-flowrate measurement module, (b) acrylic tank, (c) flow control unit (d) experiment scheme

PROCEDURE

1. Open the valve (V-1).
2. Start the pump by turning the main switch number to 1.
3. Starting from flowrate of 4 m^3/h, take each new data 0.5 m^3/h lower than the previous one and fill in the table with flowrate versus pressure head (G-2 minus G-1). Write also the motor current and motor voltage values.
4. If the flow is completely cut-off, the maximum pump pressure head is reached (shut-off head). Write it also as your last value on the table.

REFERENCES

1. https://sfsu.app.box.com/s/cwun0avysjn2eqm32u4kez74sfrhi8xf, Access date: Mar 27th, 2024.
2. Munson, B.R. et al., Fundamentals of Fluid Mechanics, 7th Ed., 2013.

CENTRIFUGAL PUMP EXPERIMENT / LAB 5 DATA SHEET DATE:

STUDENT NAME, SURNAME: SIGNATURE:

TABLE 1

Data No	Q, Volumetric flow rate (m^3/h)	Q (m^3/s)	G-1 (bar)	G-2 (bar)	H_p (m)	Motor Current, I_m, (A)	Motor Voltage, V_m, (V)	P_{shaft} (W)	P_{hyd} (W)	η (%)
1	4.0									
2	3.5									
3	3.0									
4	2.5									
5	2.0									
6	1.5									
7	1.0									
8	0.5									
9	0.0 (Shut-off)									

Calculation steps:

1. Do necessary calculations and fill the table 1.
2. Calculate head developed by the pump (H_p), (b) shaft and hydraulic powers (P_{shaft} and P_{hyd}), (c) efficiency of the pump (η).
3. Using the calculations and data taken, plot for the impeller, H_p-Q, η-Q and P_{shaft}-Q characteristics on the same graph paper. Take g =9.81 m/s^2.

LAB RULES:
•Each group should submit one report.
•Each group should write each part by their own and get together with their group members to merge all of them.
•Reports are due to <u>next Monday</u>. They must be submitted to the corresponding assistant **till 17:00** on the next Monday.
•Students must sign the data sheet from the lab assistant at the end of each experiment and the signed sheet must be attached with the report. Reports without the signed data sheet will not be graded.
•Students are advised to read the detail of each experiment sheet before coming to the corresponding lab class.

LAB REPORT FORMAT (<u>HANDWRITTEN EXCEPT COVER PAGE, TABLES AND PLOTS</u>):
The lab report (no longer than 15 pages – all included –) should include the followings (unless otherwise specified):

1. Objective	2. Theory	3. Procedure	4. Results
5. Sample calculation	6. Necessary plots	7. Discussion on results, errors and graphs	8. Conclusion