Structures/Motion Lab (1998-1999)
20-263-571, Sections 001, 002, 003

CENTRIFUGAL PUMP TEST LAB

OBJECTIVE:

The objective of this experiment is to determine the performance characteristics of a centrifugal pump. This is accomplished by determining the capacity and efficiency of a centrifugal pump when operating under the assigned conditions.

EXPERIMENT:

Apparatus:

A 1.375 inch inside diameter pipe is connected from a water tank to the inlet of the centrifugal pump. A pressure gage is located just before the pump inlet to measure vacuum or suction pressure at the inlet of the pump. Connected to the 1.375 inch diameter discharge pipe of the pump are a discharge pressure gage, fluid flow meter, and head valve before the discharge pipe returns to the tank.

The pump is driven by an AC electric motor. A mechanical variable pitch speed controller is connected to the motor to vary the speed of the pump. ***Caution: Do not turn the variable pitch speed control knob unless the motor is operating.*** *This could result in belt damage when the motor is started.*

Between the variable speed controller and the pump is a torque transducer that consists of an intermediate shaft that is instrumented with a full-bridge strain gage torque sensor. The knob on the top of the torque transducer engages/disengages the brushes in the sensor in order to minimize wear when no data is being taken. The brushes are engaged when the knob is in the up position. ***When the pump test is started, be sure that the torque transducer is disengaged (knob in the down position).*** *The housing of the torque transducer also contains a passive magnetic pick-up speed sensor that is connected to a pulse counter for pump RPM measurement.*

Procedure:

The group is to perform two constant speed, variable head tests. Test RPM will be prescribed by the lab instructor (3400 RPM).

- *Before starting the motor, connect the magnetic pick-up to the pulse counter and the torque transducer to a strain indicator.*

- *Balance the strain indicator to zero at zero load. Indirectly calibrate the torque sensor using the precision calibration resistors provided (50 kohm or 60 kohm resistor depending on torque sensor serial number) to simulate the load (torque) noted on the specification sheet. Note: Since the pump operation is to be counter-clockwise (negative), the precision calibration resistor is to be connected across the green and black terminals of the strain indicator. (The shaft will rotate CCW when viewed from the inlet side of the pump.)*
- *Close the head valve on the discharge pipe and start the motor. Check to see if the pump discharge pressure increases. If there is no pump discharge pressure in ten seconds, the pump is probably dry and must be primed. To prime the pump, open the cap on the flowmeter and add water to fill the pump. Close the flowmeter cap and start the pump again.*
- *Allow the pump to operate a few minutes before taking any data. During this time period, open and close the discharge valve and observe the suction and discharge pressure gages.*
- *Begin each of the two tests with the head valve open. Use the variable pitch speed control knob to set the motor shaft speed as prescribed by the instructor. There are 60 teeth on the gear (inside the torque sensor housing) that passes through the flux of the magnetic pick-up. Determine the number of teeth per second that is equivalent to the prescribed shaft RPM, set the pulse counter gate to one second, and adjust the variable pitch speed control knob until the prescribed shaft speed is obtained.*
- *Before taking data make sure the head valve is open. Vary the head of the pump by gradually opening the head valve over several increments (10-15) until the head valve is fully closed. At each increment (including the fully closed initial head valve position) record:*
    - *Suction pressure*
    - *Discharge pressure*
    - *Strain indicator reading (torque)*
    - *Flow capacity*
- *The two tests are to be constant speed tests at the same RPM. However, the data for one of the tests will not be at constant speed. As the head valve is opened, the load is reduced and the motor speed increases. The results for this test are to be corrected to constant speed in the final calculations. To ensure constant speed tests the following procedure is to be followed:*
    - *Test 1: At each head valve position increment adjust the variable pitch speed control knob to maintain constant speed.*
    - *Test 2: Do not adjust the variable pitch speed control knob to maintain constant speed. Record the actual RPM at each head valve position increment.*

RESULTS:

For the data taken for the two tests:

- *Calculate dynamic head, hydraulic horsepower, input horsepower, and pump efficiency for both tests. (Show complete sample calculations for one head valve position in the appendix of the report).*
- *In the test where the pump RPM varied (Test 2), the final determinations of head, flowrate, hydraulic horsepower, and input horsepower must be adjusted (using dimensional analysis pump equations) to values that correspond to the initial pump RPM. Stated otherwise, the data should be corrected to represent a constant RPM test.*
- *Performance curves for pumps generally depict efficiency (percent), total dynamic head (ft), and power input (HP) as functions of capacity (GPM) for a particular speed. Graph total dynamic head, horsepower unit, and pump efficiency as functions of capacity for both tests on the same graph.*
- *From the results of the graphs determine the maximum efficiency of the pump and the specific speed of the pump. The specific speed of a homologous series of pumps is defined as the speed of some one unit of series of such a size that it delivers unit discharge at unit head (at conditions of maximum efficiency).*

DISCUSSION:

The discussion should include a comparison of the two test methods and a judgement of validity of test procedure 2. Also included should be a commentary regarding the calculated specific speed and expected specific speed for this size pump.

References:

1. *Olsen, R.M.,* **Essentials of Engineering Fluid Mechanics, Second Edition**, *International Textbook Company, 1968, 448 pp.*

Theoretical Background

For the Centrifugal Pump Test, the following equation governs the input-output characteristics of the system.

$$Z_1 + U_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2\,g} + W_s = Z_2 + U_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2\,g} + Q + h_f$$

where:

- $Z_{1,2} =$ *Elevation at points 1 and 2*
- $U_{1,2} =$ *Internal Energy at points 1 and 2*
- $P_{1,2} =$ *Pressure at points 1 and 2*
- $\gamma =$ *Specific weight of fluid*
- $V_{1,2} =$ *Average free stream velocity at points 1 and 2*
- $W_s =$ *Work applied to pump as shaft work per unit force*
- $Q =$ *Net heat flow from fluid to surroundings*
- $h_f =$ *Friction loss between points 1 and 2 (units of head)*

Note that, historically, the similar terms on the two sides of the equation are often combined and given the generic designation "head". For example, the following terms are sometimes used:

Pressure Head $= \frac{P_2 - P_1}{\gamma}$

Potential Head $= Z_2 - Z_1$

Based upon assumptions concerning the operating condition, the above equation reduces to:

$$W_s = \frac{P_2 - P_1}{\gamma}$$

Specific Speed Definition:

Specific speed is a means of comparing pumps of similar design and/or style. The concept of specific speed is based an attempt to represent the speed in RPM of a geometrically similar pump (virtual pump) that has been reduced in size so as to develop one (1) foot of head at a flow of one (1) GPM. Note that, while the units should be in RPM or dimensionless, specific speed does not have correct units.

$$N_s = \frac{N\,Q^{0.5}}{H^{0.75}}$$

where:

- $N =$ *Speed of test in RPM*
- $Q =$ *Flow at maximum efficiency*
- $H =$ *Head at maximum efficiency*

Speed Corrections:

When a test is conducted at one speed but the results need to be extrapolated to another speed, generally for comparative purposes, the following corrections can be used:

- *Flow*

$$Q_2 = Q_1 \left(\frac{N_2}{N_1} \right)$$

- *Head*

$$H_2 = H_1 \left(\frac{N_2}{N_1} \right)^2$$

- *Hydraulic HP*

$$HP_2 = HP_1 \left(\frac{N_2}{N_1} \right)^3$$

- *Input HP*

$$HP_2 = HP_1 \left(\frac{N_2}{N_1} \right)^3$$

- *Efficiency*

$$\eta_2 = \eta_1$$