PELTON WHEEL TURBINE LAB

PURPOSE: The main purpose of this lab is to measure the power output of a Pelton Wheel turbine and to compare this to the theoretical power output. Another purpose of the lab is to check turbine scaling laws.

PROCEDURE: Set the driving pressure at a low level. Measure the flow rate through the turbine. Set the brake at some level and measure the brake load using the load cell and the rotor speed using a tachometer. Repeat for various brake settings. Set the driving pressure at a high level and repeat the experiment.

REPORT: Using the measured data, calculate the brake torque and the bucket speed. Then calculate the brake power output of the turbine. Next calculate the power coefficient C_P and speed coefficient C_S. Plot the actual and theoretical C_P versus C_S curves. Comment on the plots. Are the scaling laws adequate?

MEASUREMENTS

The brake power output of the turbine is:

$$\mathbf{P} = T\ \omega$$

where T is the torque on the rotor and ω is the rotational speed of the rotor. The torque is:

$$T = L\ d$$

where L is load measured by the brake load cell and d is the moment arm of the cell from the rotor axis. The rotor speed ω is measured using a tachometer.

The theoretical power is a function of the bucket speed V_B and the jet speed V_J. The bucket speed is:

$$V_B = R\ \omega$$

where R is the distance out to the bucket from the rotor axis. The jet speed is:

$$V_J = k\ \sqrt{2\Delta P/\rho}$$

where ΔP is the jet driving pressure: this is measured using a pressure gage. The volumetric flow rate Q is measured using a V Notch Weir.

PELTON WHEEL TURBINE THEORY

The power output of the turbine is:

$$\mathbf{P} = T\ \omega$$

where T is the torque on the rotor and ω is the rotational speed of the rotor. The torque is:

$$T = \Delta\ (\dot{M}\, V_T\, R)$$

where $\dot{M} = \rho Q$ is the mass flow rate through the turbine and V_T is the tangential flow speed. The tangential flow speeds at the inlet and the outlet are:

$$V_{IN} = V_J \qquad V_{OUT} = (V_J - V_B)\ K\ \text{Cos}\beta + V_B$$

where β is the bucket outlet angle. So power becomes:

$$\mathbf{P} = \dot{M}\ (V_J - V_B)\ (1 - K\ \text{Cos}\beta)\ V_B$$

The outlet angle β of the lab turbine is 165°.

SCALING LAWS FOR TURBINES

For turbines, we are interested mainly in the power of the device as a function of its rotational speed. The simplest way to develop a nondimensional power is to divide power **P** by something which has the units of power. The power in a flow is equal to its dynamic pressure P times its volumetric flow rate Q:

$$P \; Q$$

For a Pelton Wheel turbine, the dynamic pressure P is approximately equal to the driving pressure ΔP. So, we can define a power coefficient $C_{\mathbf{P}}$:

$$C_{\mathbf{P}} = \mathbf{P} \mathbin{\boldsymbol{/}} [P \; Q] = \mathbf{P} \mathbin{\boldsymbol{/}} [\Delta P \; Q]$$

To develop a nondimensional version of the rotational speed of the Pelton Wheel turbine, we can divide the tip speed of its buckets $R\omega$ by the jet speed V_J. So, we can define a speed coefficient $C_{\mathbf{S}}$:

$$C_{\mathbf{S}} = R\omega / V_J$$

DATA SHEET FOR TURBINE

JET PRESSURE = FLOW RATE =

RUN	BRAKE LOAD	ROTOR RPM

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