Title: - Francis Turbine

Objective:

- To understand how Francis Turbine efficiency varies with load for a fixed guide vane position.
- To understand how Francis Turbine efficiency alters with guide vane position.

Apparatus required:

Francis turbine setup, Tachometer, Stopwatch

Theory:

The Francis turbine is a water turbine developed by James B. Francis .1t is an inward-flow reaction turbine that combines radial and axial flow concepts. It converts potential energy of water into mechanical energy which is used to generate power. Advantage of Francis turbine is high speeds can be achieved with low heads.

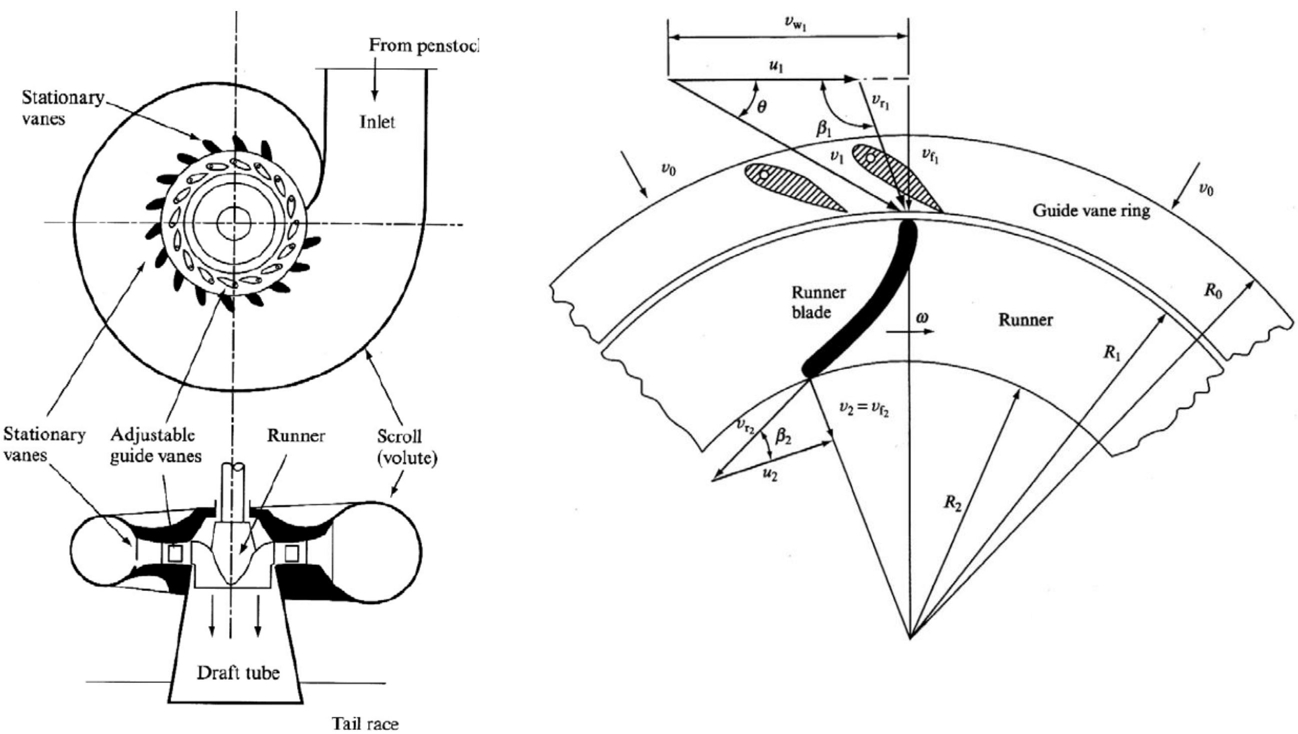
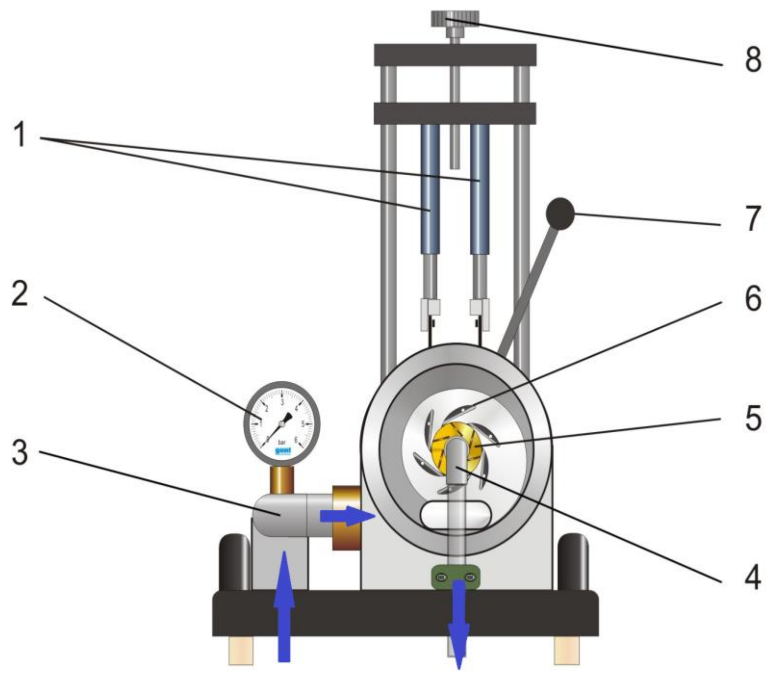


Figure 1 & 2- Schematic View and Velocity Diagram of Francis Turbine

Francis turbine is a reaction turbine in which the working fluid comes to the turbine under immense pressure and the energy is extracted by the turbine blades from the working fluid. A part of the fluid energy is converted to mechanical energy because of pressure changes occurring in the blades of the turbine, determined by the expression of Degree of reaction. The remaining part of the energy is extracted by the volute casing of the turbine. The components of Francis turbine are shown in the figure below. The water enters radially through the stationary guide vane and then exists axially after passing through the runner.

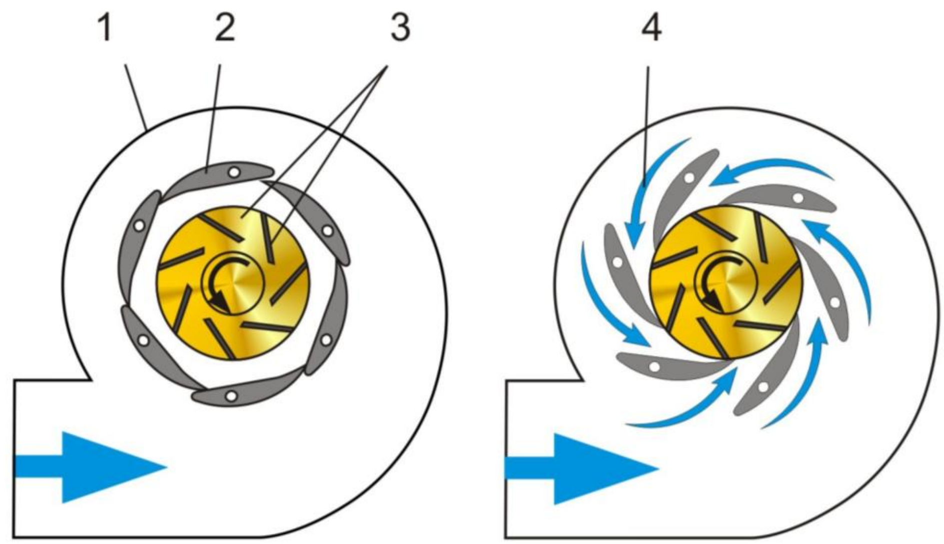
Experimental Setup:



1-Spring balance
2- Manometer
3- Water inlet
4- Water outlet
5- Impeller
6- Guide vanes
7- Adjustment of guide vanes
8- Adjustment of the band brake

Figure 3- Different Parts of Experimental Setup

Different Position of Guide Vane



1- Spiral casing
2- Guide Vane
3- Rotor with blades
4- Water flow

Closed   Open

Spiral Casing- The fluid enters from the penstock (pipeline leading to the turbine from the reservoir at high altitude) to a spiral casing which completely surrounds the runner. This casing is known as scroll casing or volute. The cross-sectional area of this casing decreases uniformly along the circumference to keep the fluid velocity constant.

Guide Vane- The basic purpose of the guide vane is to convert a part of pressure energy of the fluid to the kinetic energy and then to direct the fluid on to the runner blades at the angle appropriate to the design. Moreover, they are pivoted and can be turned by a suitable governing mechanism to regulate the flow while the load changes.

Runner(Rotor with Blade)- Runner blades are the heart of any turbine.It consist moving blades on its periphery. During operation, the fluid strikes on the blade and the tangential force of the impact causes the shaft of the turbine to rotate, producing torque. For a mixed flow type Francis Turbine, the flow in the runner is not purely radial but a combination of radial and axial. The flow is inward, i.e. from the periphery towards the centre.

Procedure:

1. Start the main power supply for the setup and turn on the pump.

2. The pump draws the water from the bottom tank and which acts as input head to the turbine. Thus the water flows through the turbine and shaft power is developed at output of the turbine.

3. Set the guide vane angle to particular degree and take the reading.

4. Note down the input pressure and find the volumetric flow rate by measuring the time taken to fill 10 liters of water. The product of input pressure and volumetric flow rate gives the input power.

5. Load is applied to the turbine shaft using a band brake. The force is measured from the spring balance and multiplied with the radius to get the torque.

6. The RPM of the shaft is measured using digital tachometer which indicates the yd speed using the reflection from the silver-strip on the output shaft. Therefore torque times rotational speed gives the output power.

7. Efficiency of the turbine if found from input by output and plot the performance curves. Repeat steps 5 and 6 for different loads.

8. Repeat the entire procedure (from step 3-7) for three different guide vane angle setting.

Sample Calculation

1. **Input Hydraulic power P_{hyd} :**

The hydraulic power is a function of volumetric flow rate and head- P_{hyd}= f (Q, H)

Thus the hydraulic power is given by,

$$P_{hyd} = \rho.g.H.\dot{Q}$$

The head can be written in terms of pressure and hence the formula becomes,

$$P_{hyd} = \frac{p.\dot{Q}}{1000*60} * 10^5 \quad [W]$$

Where p is pressure at inlet in bar and Q (volume flow rate) in l/min

2. **Torque M at the Shaft:**

Torque (M) = Force (F) * Lever arm radius

Force (F) = (T_1-T_2) [N]

Where Lever arm D = 0.05 m

3. **Power P_{av} at the turbine shaft:**

Power = Torque * angular velocity

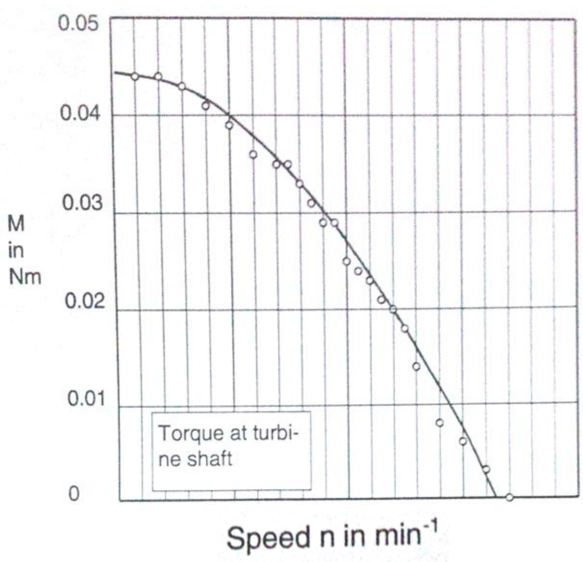
$$P_{av} = \frac{M * 2\pi N}{60} \quad [W]$$

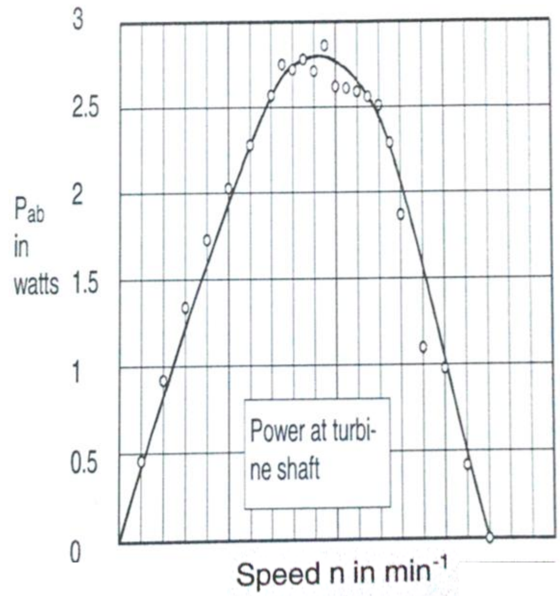
4. **Efficiency:**

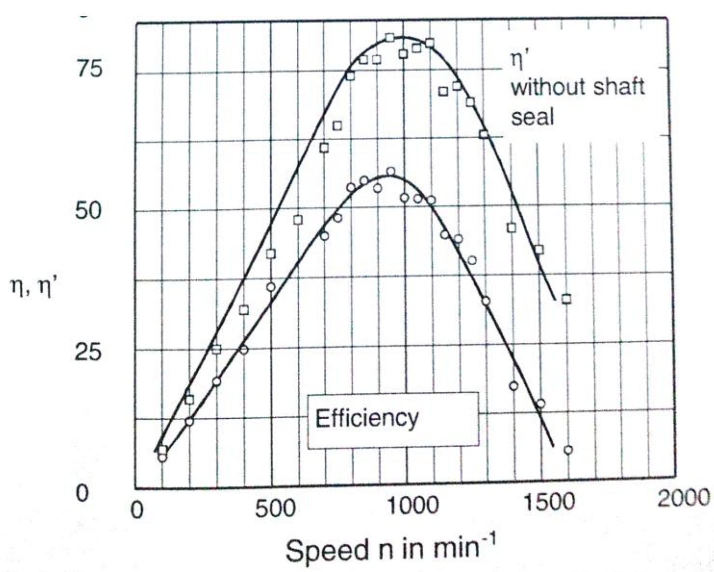
$$\eta = \frac{Shaft\ Power\left(P_{av}\right)}{Hydraulic\ Power(P_{hyd})} = \frac{T.\omega}{\rho g \dot{Q} H}$$

Efficiency can be enhanced still further if allowance is made from the outlet for the internal friction torque of approximately 0.012 N-m.

Performance Curves:







Data Sheet

Title: Francis Turbine

Date : **Roll No. :**

Name :

1) Vane Position: **Pressure:** **Volume:** **Time:**

Reading No.	Vane Position 1:						
	T_1 (N)	T_2 (N)	Speed (RPM)	Force F (N)	Torque M (N-m)	Power (W)	Efficiency (η)
1							
2							
3							
4							
5							
6							

REPORT

In your laboratory reports must have the followings;

- Cover page
- Experimental Setup
- Working Principle
- All the necessary calculations using measured data.
- Discussion of your results and a conclusion.