INDIAN INSTITUTE OF TECHNOLOGY KANPUR

ME401A: Energy System II

Francis Turbine Lab Report

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Group No.: F4

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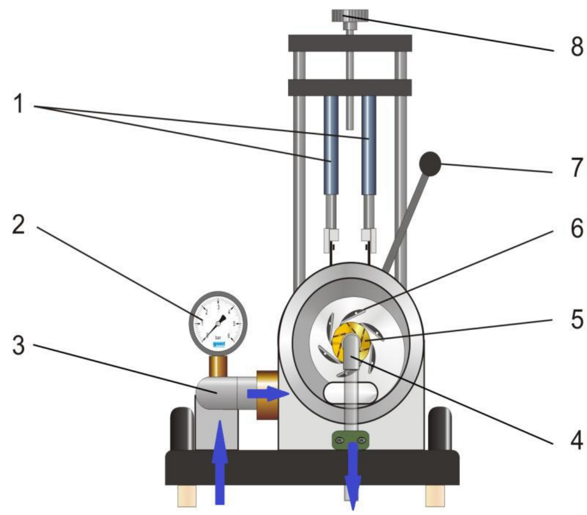
Objective:

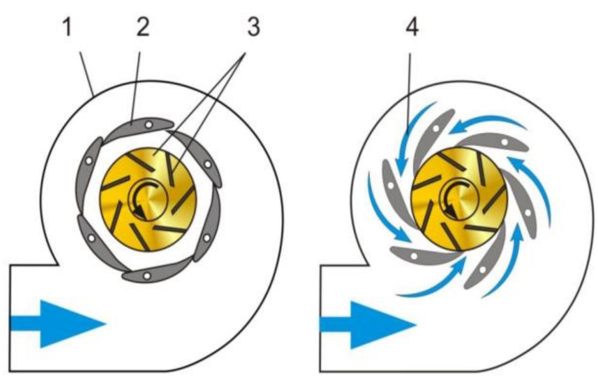
- To understand how Francis Turbine efficiency varies with load for a fixed guide vane position.
- To understand how Francis Turbine efficiency alters with guide vane position.

Introduction:

The Francis turbine is a water turbine developed by James B. Francis. It 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.



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



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

1. **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.

2. **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.
3. **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.

Sample Calculation:

For fifth reading of Table 2 (Vane Position = 10^0)

Input flow rate = Volume/Time

$$= \frac{10}{15.50 \times 1000} \frac{m^3}{sec}$$

$$= 6.45 \times 10^{-4}\ m^3/sec$$

Input hydraulic power (P_i) $= 0.3 \times 10^5 \times 6.45 \times 10^{-4}$

$= 19.35$ W

Torque at the shaft $= 1.4 \times \left(\frac{0.05}{2}\right)\ N.m$

$= \mathbf{0.035\ N.m}$

Power (P_{av}) at the turbine $= Torque \times Angular\ velocity$

$= 0.035 \times 63.34$

$= \mathbf{2.355\ W}$

Efficiency $= \frac{P_{av}}{P_i} \times 100\ \%$

$= \left(\frac{2.355}{19.35}\right) \times 100\ \%$

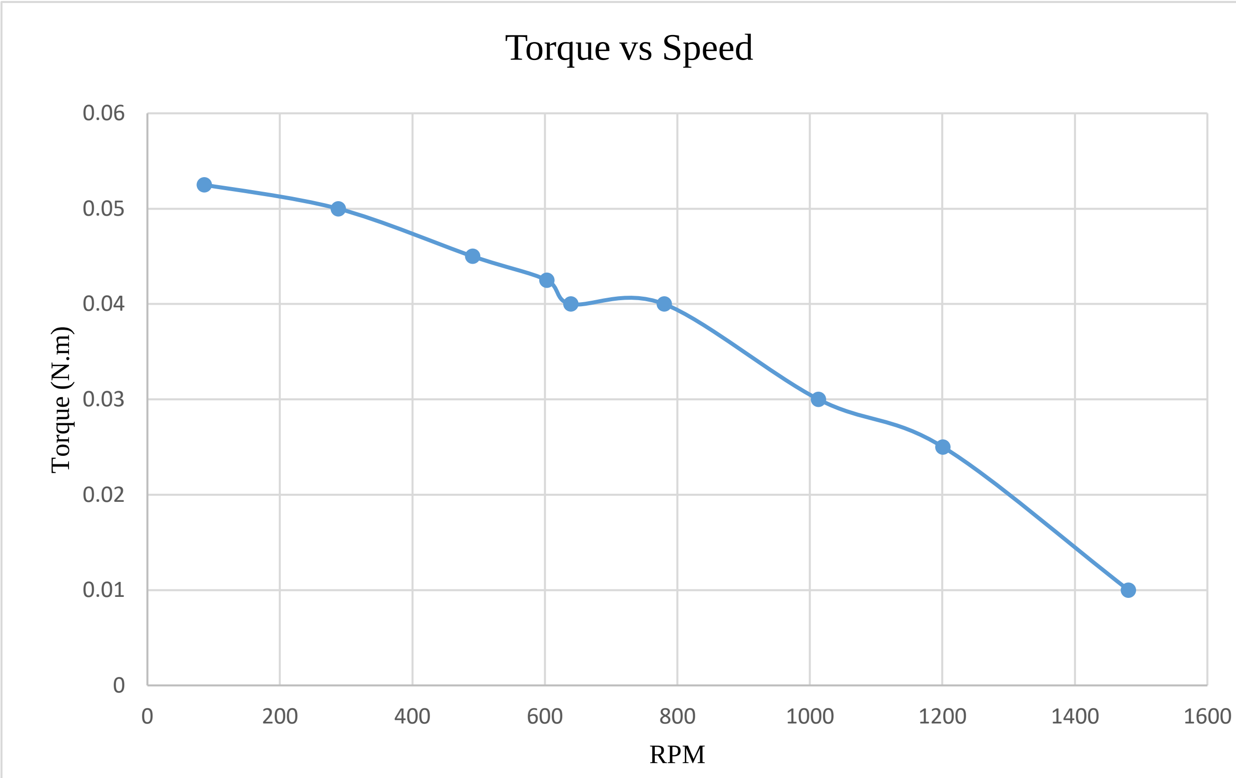
$= \mathbf{12.17}\ \%$

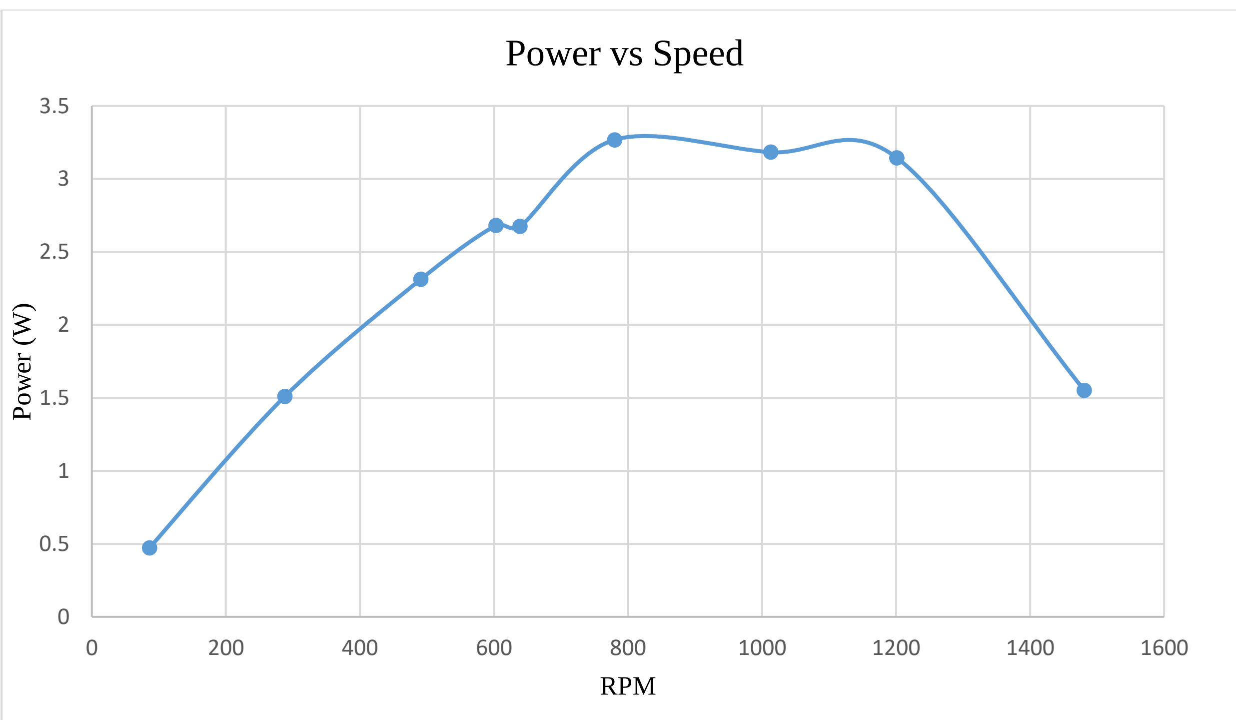
Results and Discussion:

The following results are obtained by changing the load on the turbine for a particular angle of guide vane. On increasing the load from minimum load to maximum by using dynamometer and measures the power generated by Francis turbine. The following results and graph are obtained from the recorded data.

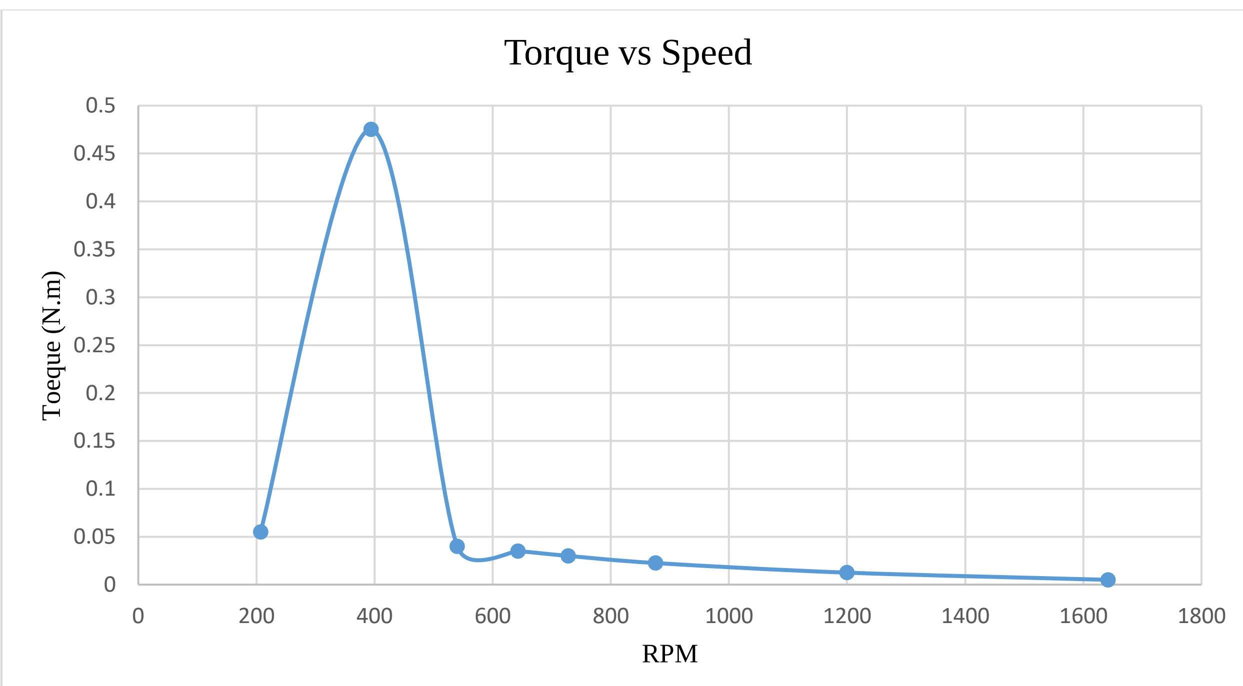
For the vane position 15^0, graphs have not followed the similar trends as it followed for the vane position 5^0 and 10^0 and the reason for that may be due to human errors and malfunctioning of the dynamometer.

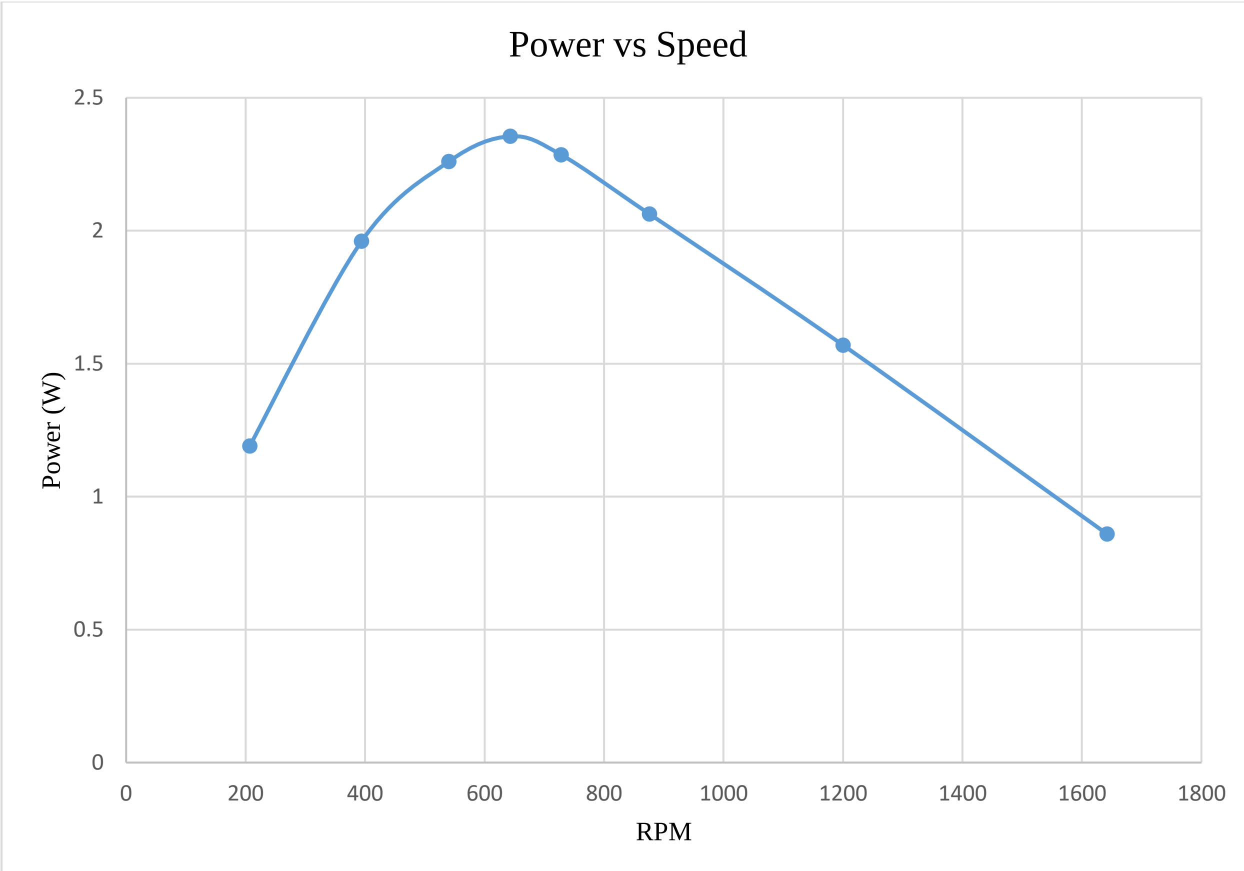
For Table 1 (Vane Position 5^0):

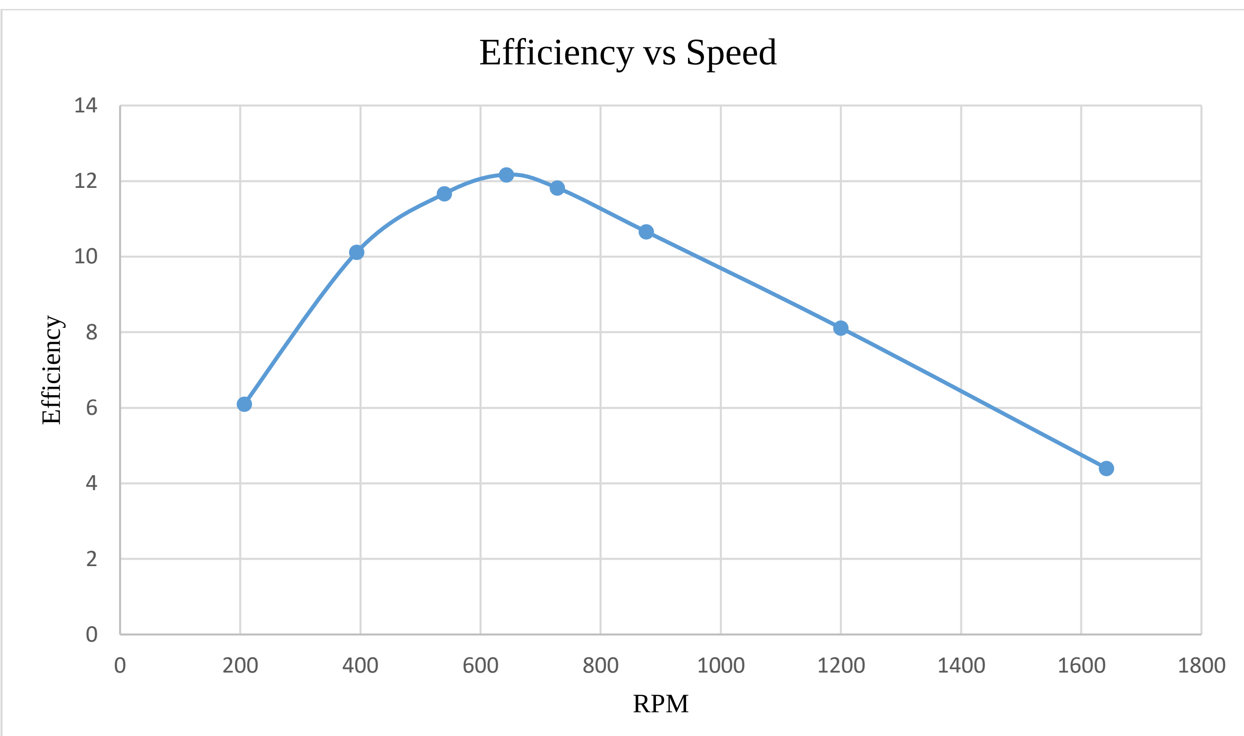




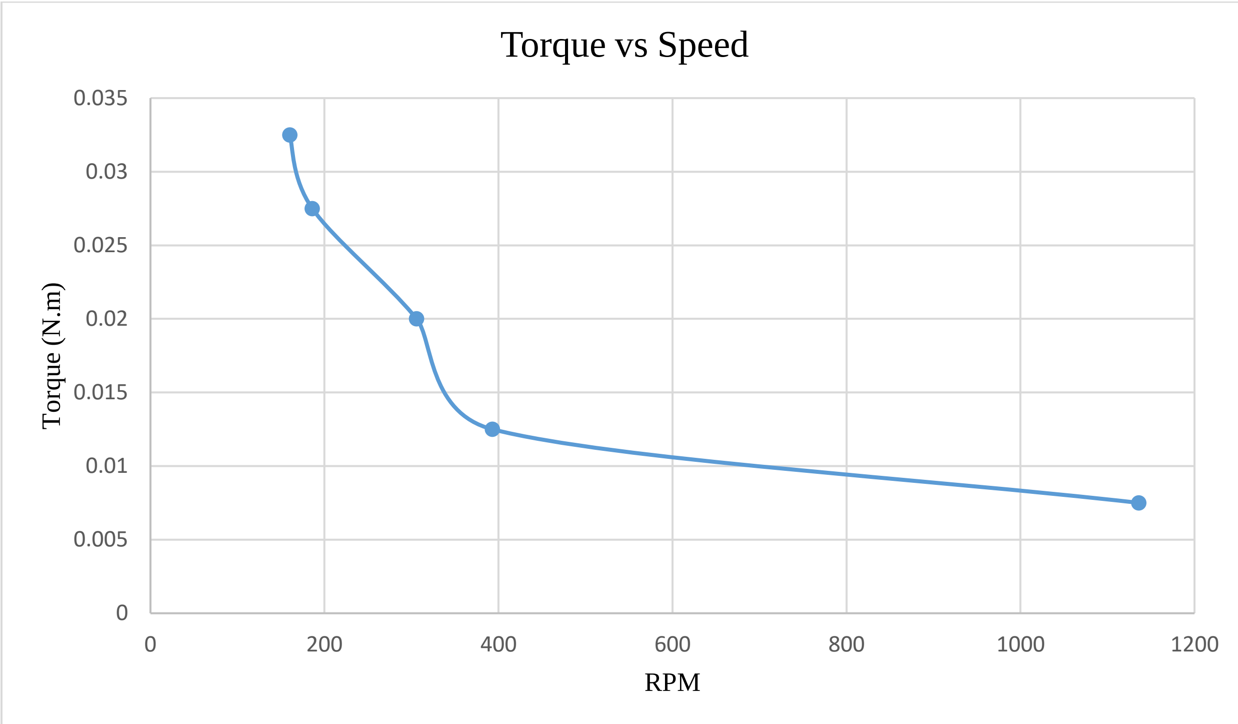
For Table 2 (Vane Position 10^0):

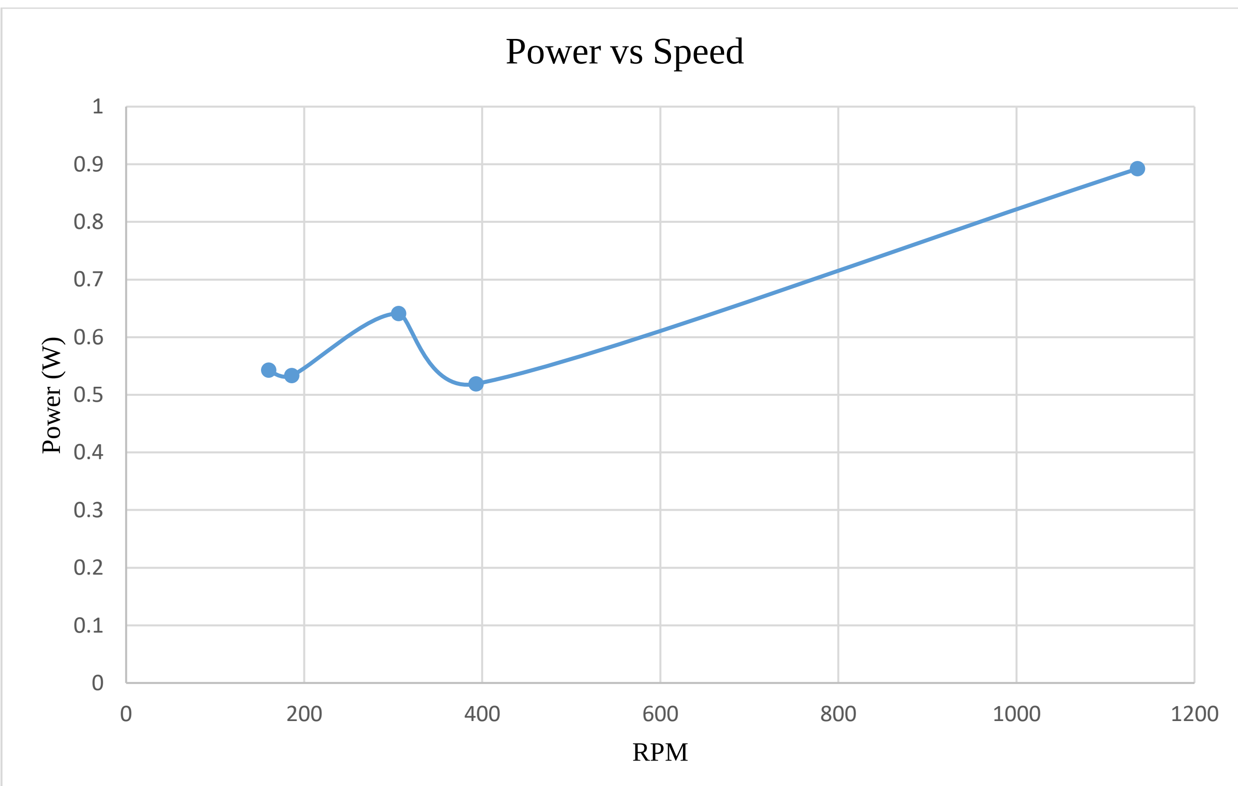



Power vs Speed
Power (W)
RPM
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
1400
1600
1800


Efficiency vs Speed
Efficiency
RPM
14
12
10
8
6
4
2
0
0
200
400
600
800
1000
1200
1400
1600
1800

For Table 3 (Vane Position 15^0)





Conclusion:

From the above results, it can be concluded that torque is almost inversely proportional to the speed and average power generated on the shaft by turbine first increases and after a maxima it starts decreasing with the speed. And similarly overall efficiency first increases and after a certain maxima starts decreasing. And maximum overall efficiency decreases with increasing vane angle.