Problem continued

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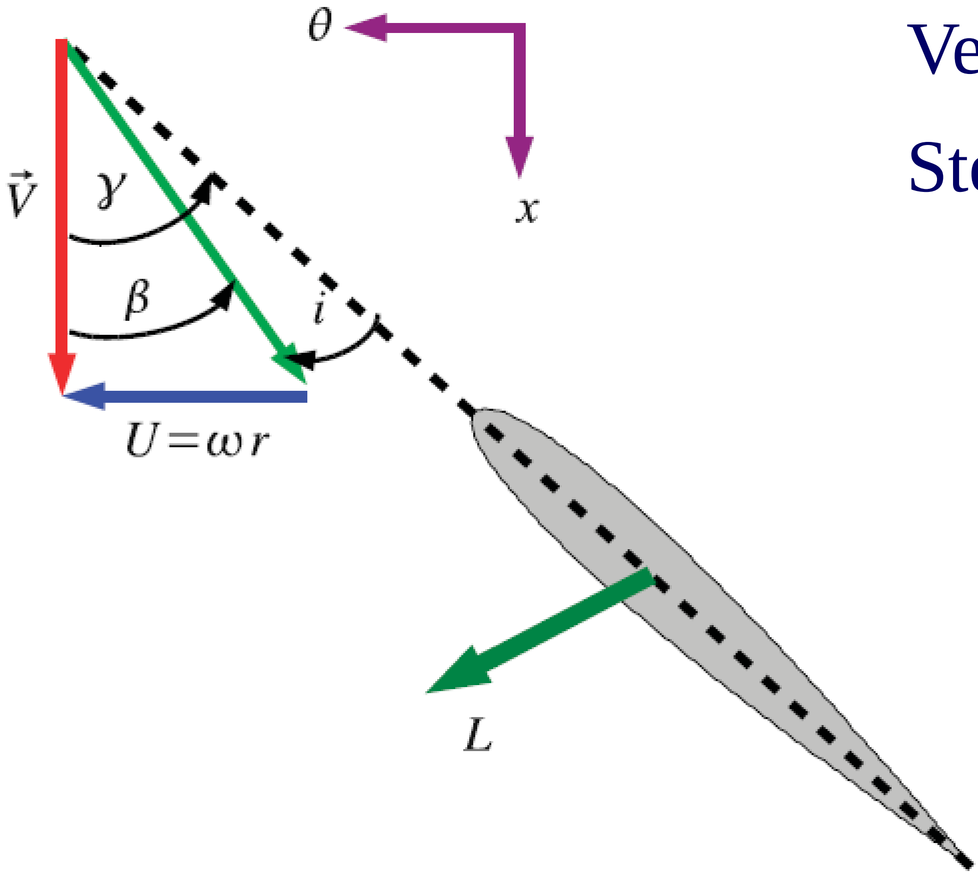

Velocity triangle.

Steps to follow:

- *Get V, U and W magnitudes and directions.*
- *Get blade setting angle gamma at different locations*
- *Find lift force and tangential force on blade per unit span at different locations.*
- *Use the per unit span-wise power estimates to get overall power produced.*

Lecture 6

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Different Turbomachines and their operation

- *Radial flow turbomachines*
- *Centrifugal flow turbomachines*
- *Hydraulic turbines*

Classification of Turbomachinery

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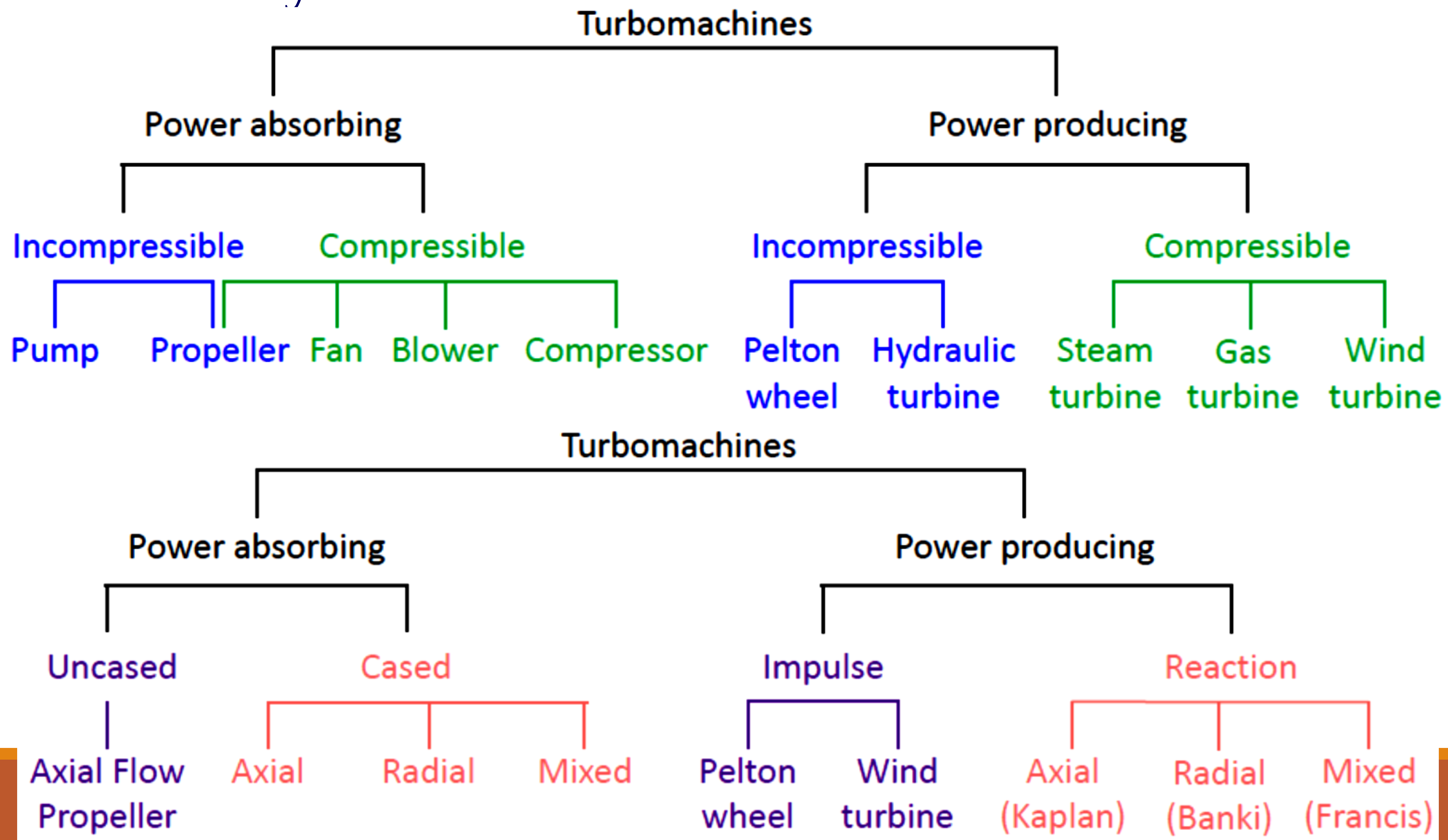
Two ways of classification.



Engineering and Architecture School
UniversityZaragoza

Rotating Machinery MSc

MODULE 1

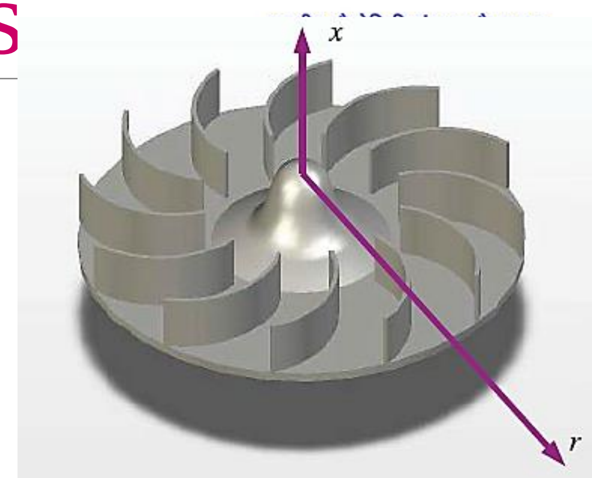
Principles of turbomachinery

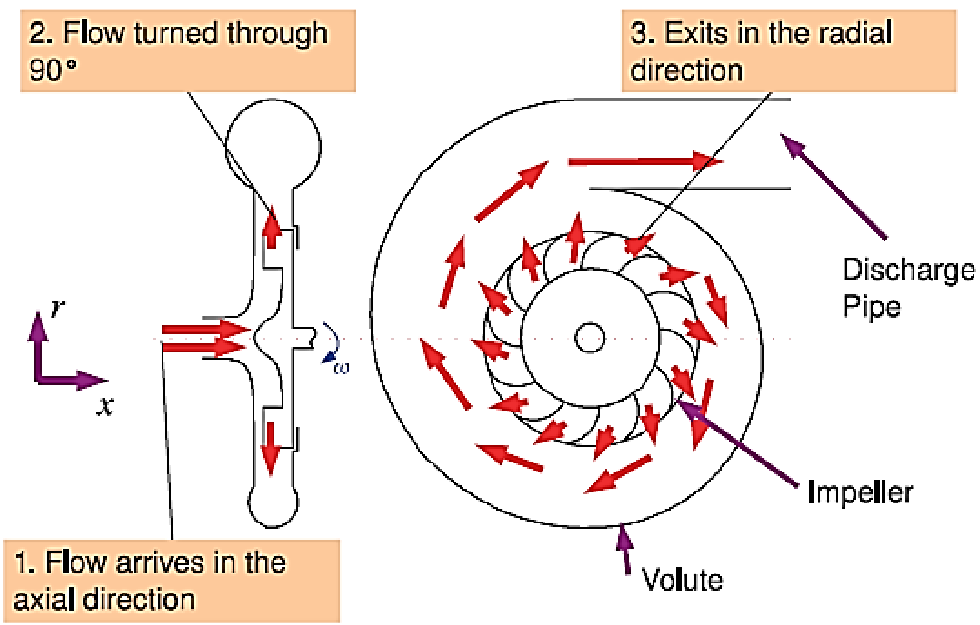
Author: Francisco Alcrudo

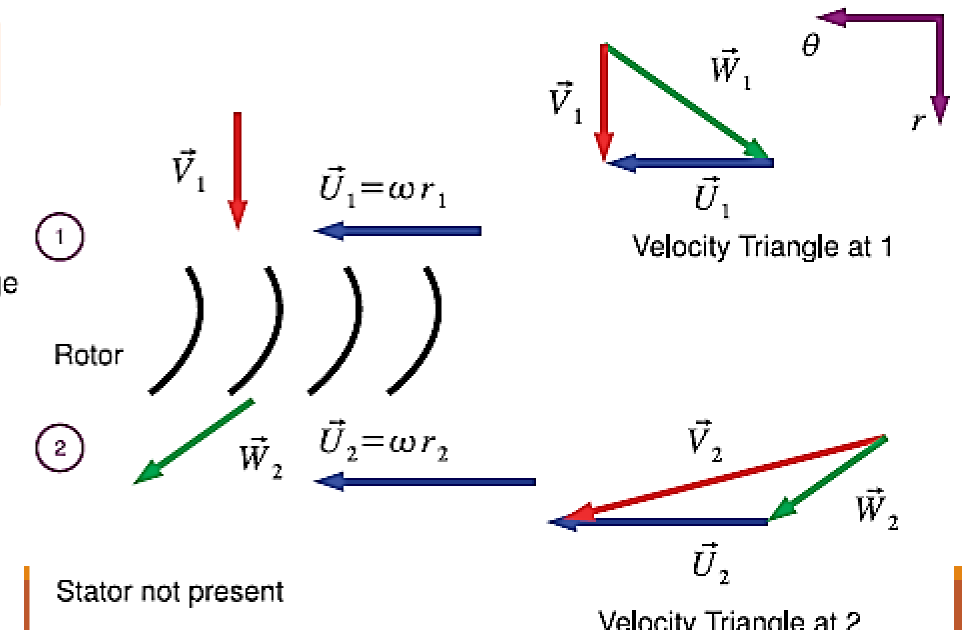
Radial Flow Turbomachines

Radial flow pump

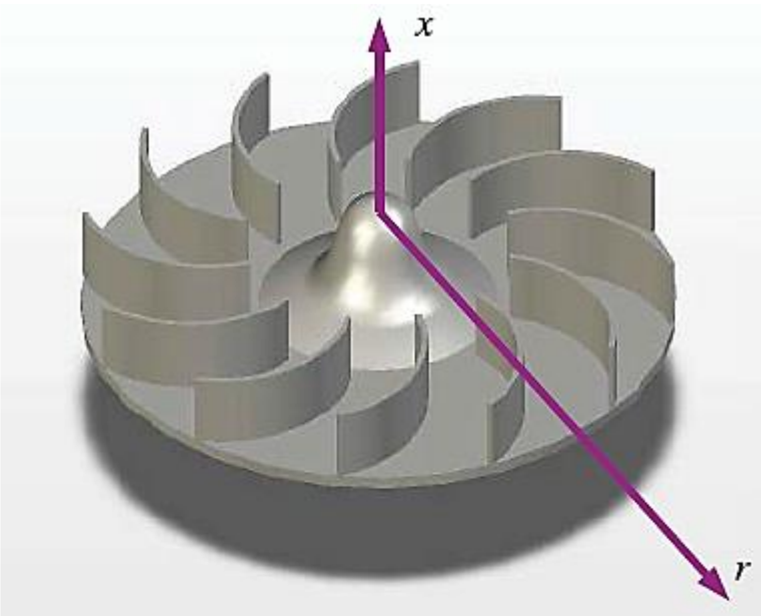
- *Volute collects the fluid and acts as a diffuser*
- *For large head built up stator between rotor and volute is employed*







Radial and centrifugal impeller



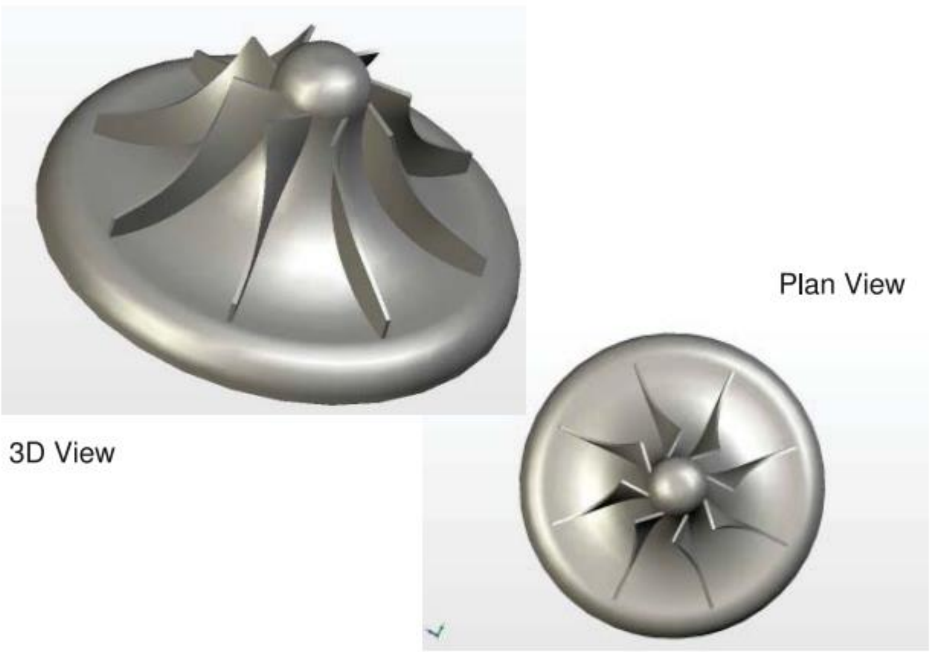


Figure 4.3: Centrifugal Impeller

Radial impellers

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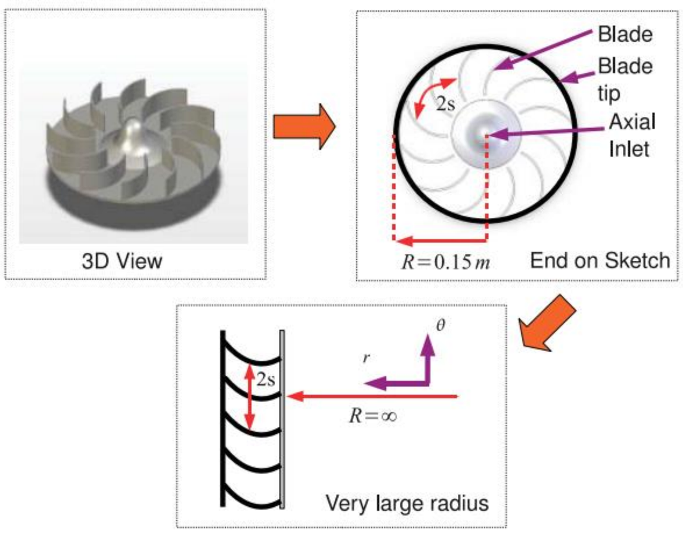
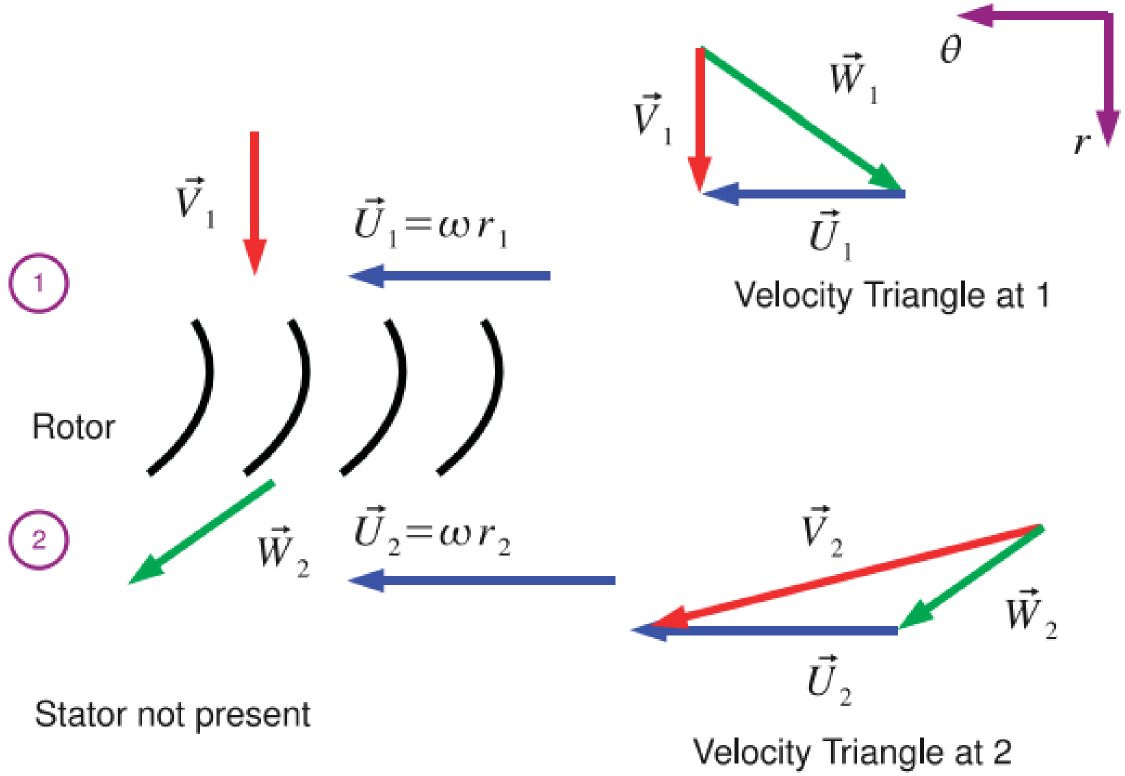
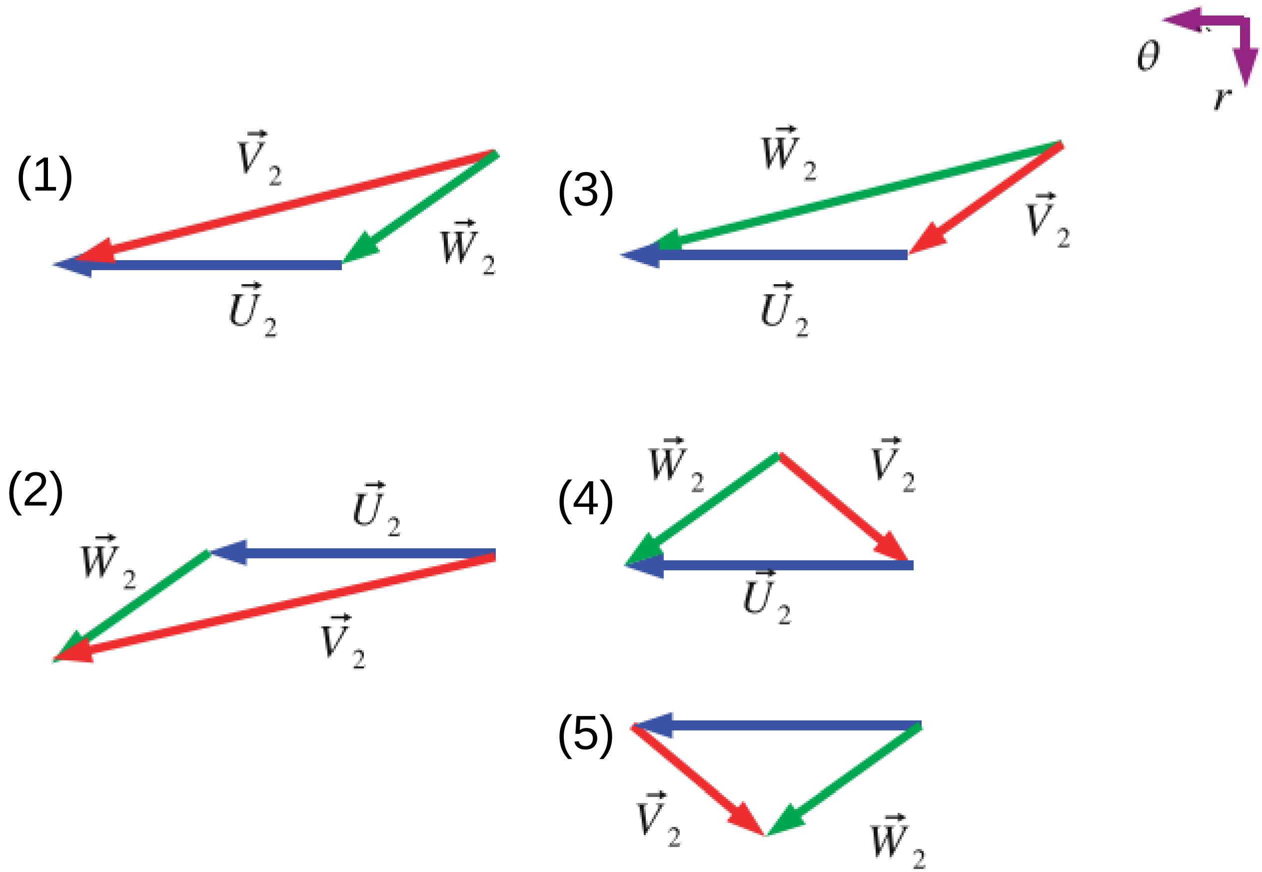


Figure 4.4: The Cascade View for a Radial Impeller

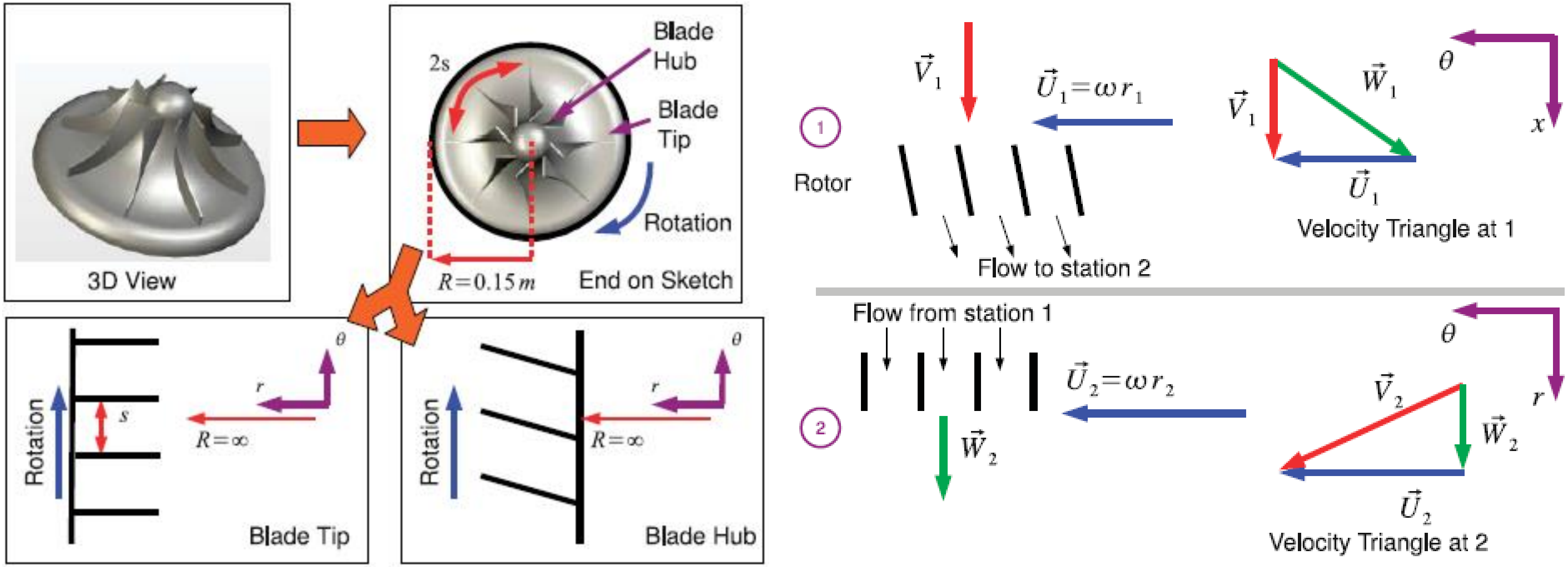



θ
r
(1)
$\vec{V}_2$
$\vec{W}_2$
$\vec{U}_2$
(3)
$\vec{W}_2$
$\vec{V}_2$
$\vec{U}_2$
(2)
$\vec{U}_2$
$\vec{W}_2$
$\vec{V}_2$
(4)
$\vec{W}_2$
$\vec{V}_2$
$\vec{U}_2$
(5)
$\vec{V}_2$
$\vec{W}_2$

Radial Flow Turbomachines

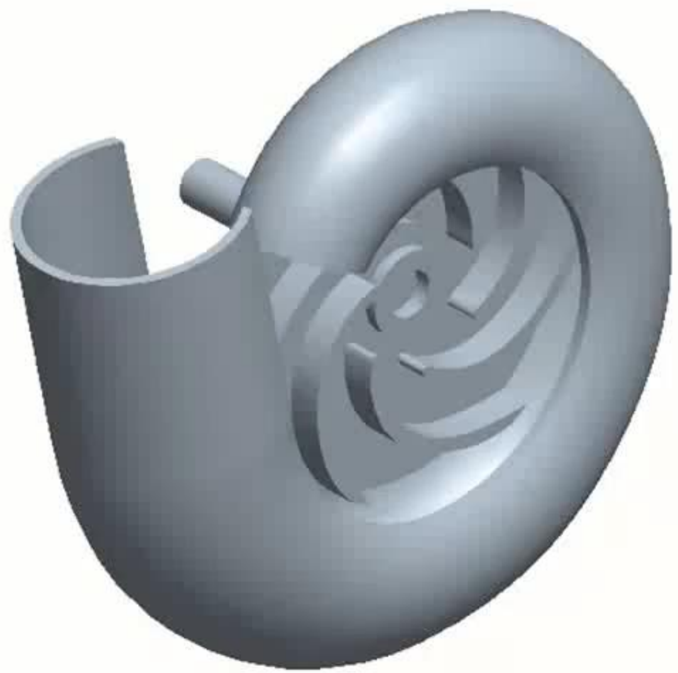
Centrifugal pump

- *Note the change in impeller shape and co-ordinates at inlet and exit. (axial inlet, radial outlet).*

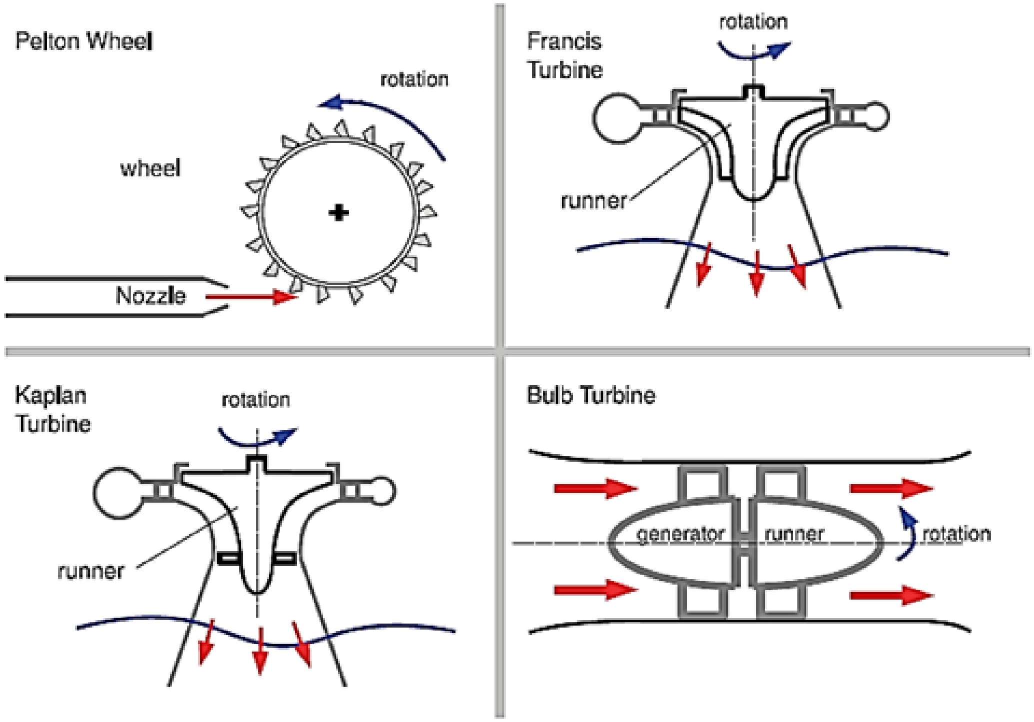


Centrifugal Pump Working

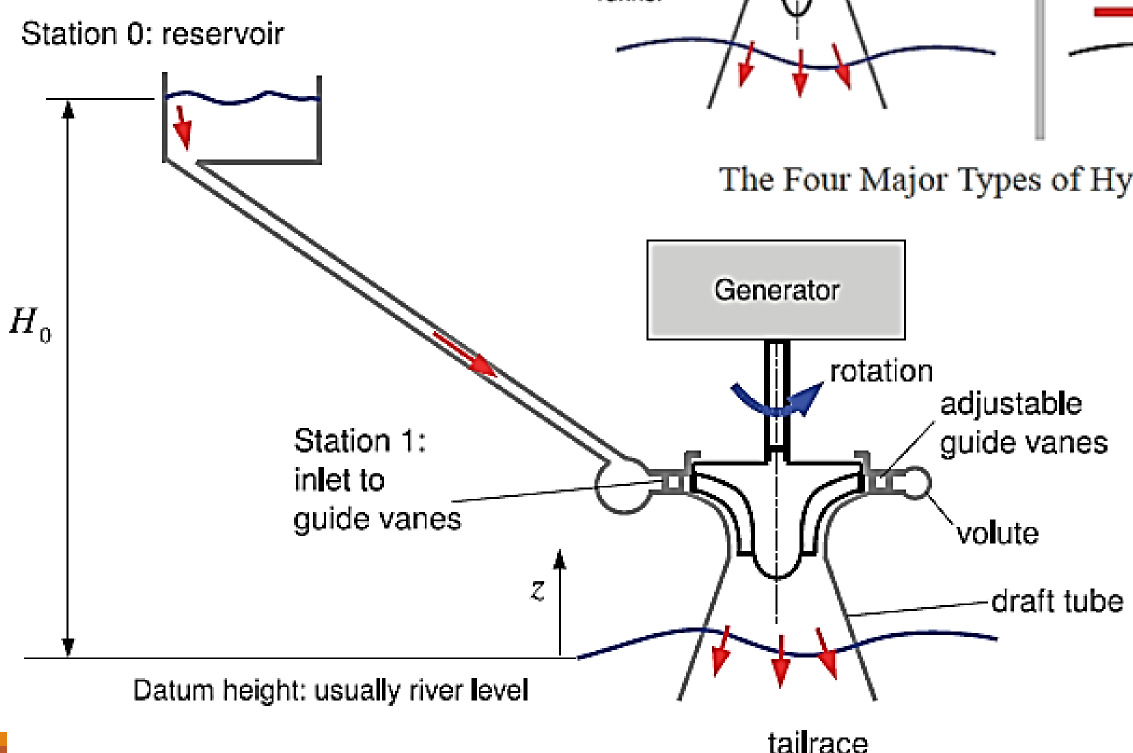
CENTRIFUGAL PUMPS



Hydraulic Turbines

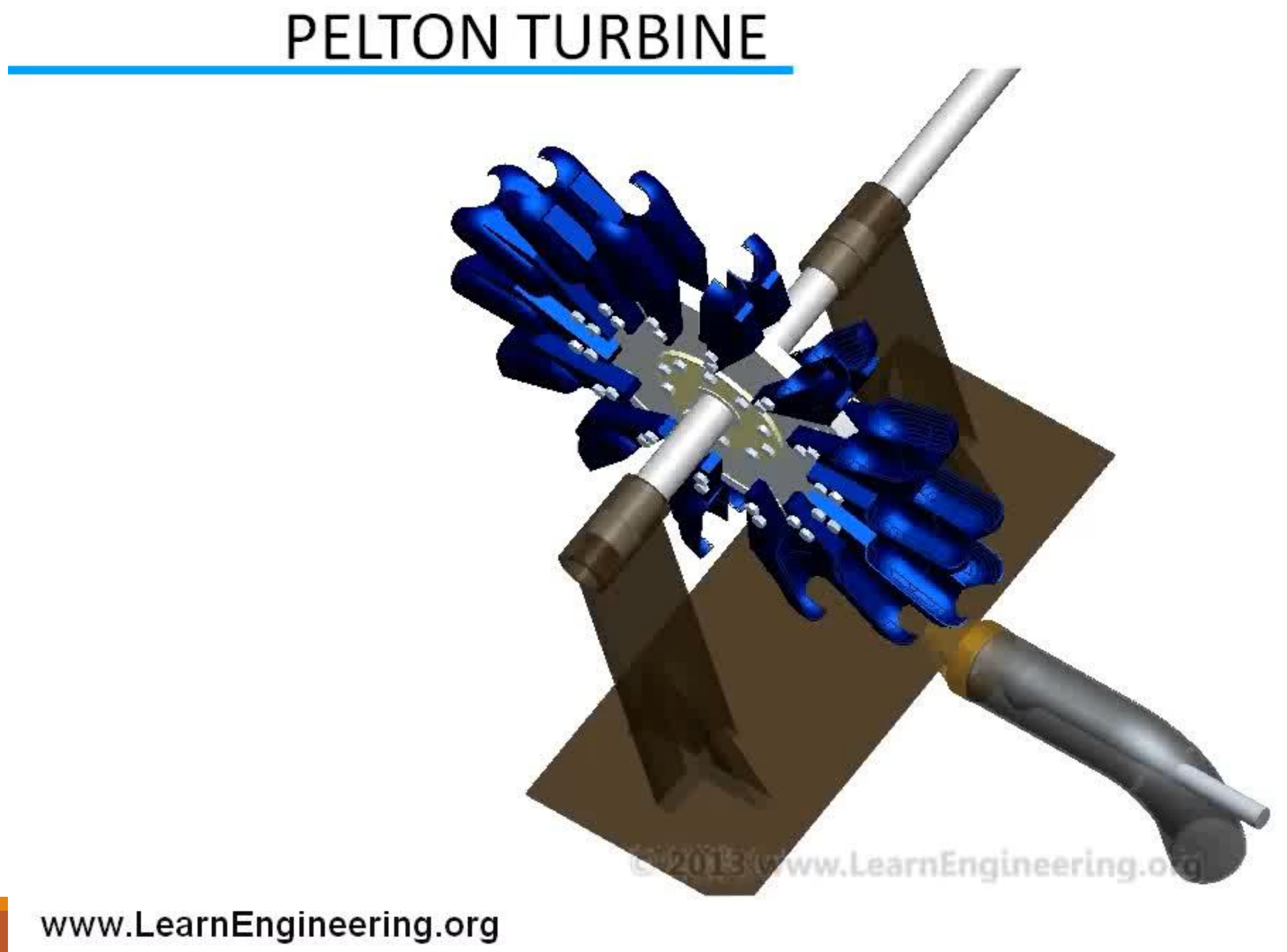


The Four Major Types of Hydraulic Turbine

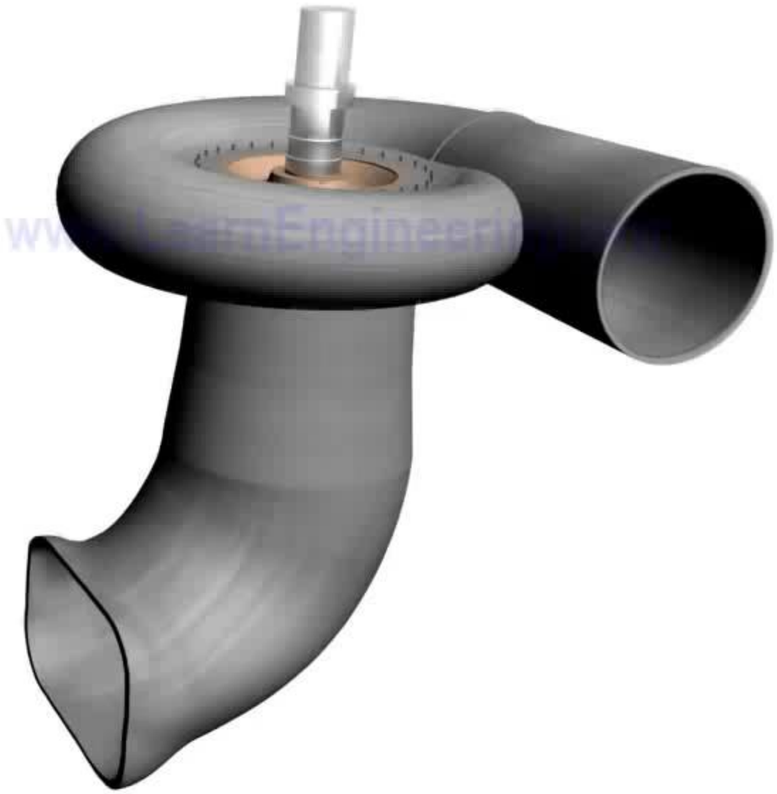


Schematic of Hydro-Electric Scheme

Pelton Turbine



Francis Turbines



Kaplan Turbine

Comparison of Pelton, Francis & Kaplan Turbines

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Lecture 7

Applications of Equations of Motion

- *Conservation of Mass*
- *Conservation of Momentum*
- *Cascade of Blades*
- *Conservation of Energy & Rothalpy*

Applications of Equations of Motion

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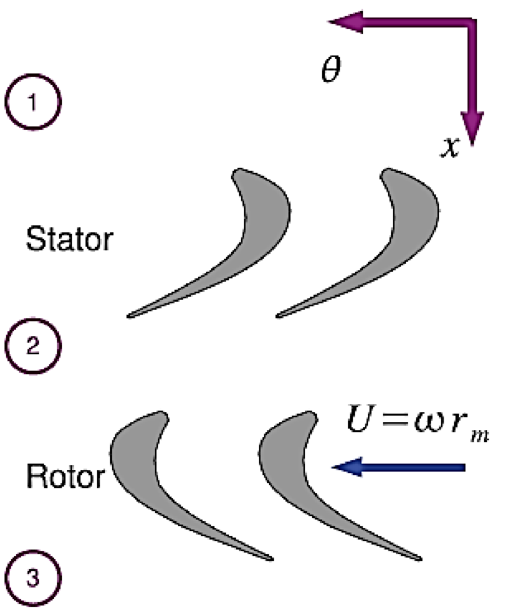
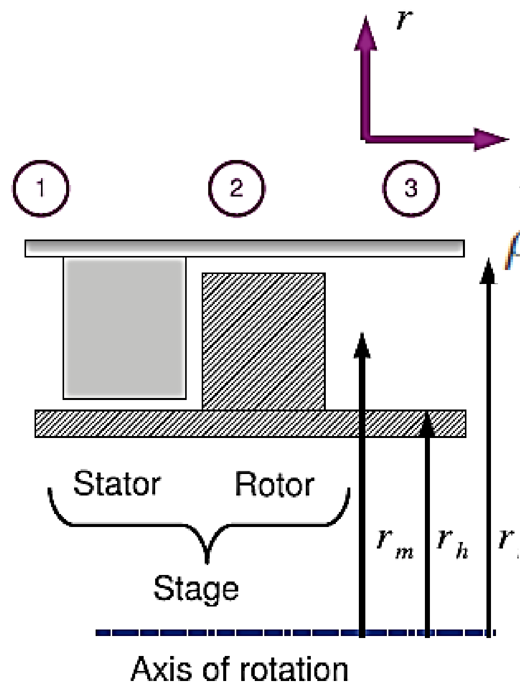
Conservation laws when applied to turbomachines give insight into energy interaction mechanism.

Conservation of Mass:





- ***Applying continuity to axial flow turbomachines*** *we can write*

$$\rho_1 A_1 V_{1x} = \rho_2 A_2 V_{2x} = \rho_3 A_3 V_{3x}$$

  - Note that area is perpendicular to axial velocity component & is given by

$$A = \pi(r_t^2 - r_h^2) = \pi(r_t + r_h)(r_t - r_h)$$

$$A = \pi(2r_m)(b) = 2\pi r_m b$$

$$\boxed{2r_m = r_t + r_h \qquad b = r_t - r_h}$$

Example An industrial turbine operates at an 8.8:1 pressure ratio and a mass flow of $77\,kg/s$ using air as the working fluid. The exhaust temperature is at $43°\,C$ and the inlet temperature to the machine is around $1000°\,C$. The mean blade radius is $0.4\,m$. The machine is to be designed for a constant axial velocity of $200\,m/s$. Estimate the blade heights at entry and exit of the turbine.

At entry to the turbine: $p_1 = 8.8\,bar = 8.8 \times 10^5\,Pa$ and $T_1 = 1000 + 273 = 1273\,K$

At exit from the turbine: $p_2 = 1.0\,bar = 1.0 \times 10^5\,Pa$ and $T_2 = 473 + 273 = 730\,K$

The corresponding densities are therefore:

$$\rho_1 = \frac{p_1}{RT_1} = \frac{8.8 \times 10^5}{287 \times 1273} = 2.41\,kg/m^3$$

$$\rho_2 = \frac{p_2}{RT_2} = \frac{1.0 \times 10^5}{287 \times 710} = 0.49\,kg/m^3$$

$$\dot{m} = \rho A V_x = \rho 2\pi r_m b V_x \implies b = \frac{\dot{m}}{\rho 2\pi r_m V_x}$$

$$b_1 = \frac{77}{2.41 \times 2\pi \times 0.4 \times 200} = 0.06\,m$$

$$b_2 = \frac{77}{0.49 \times 2\pi \times 0.4 \times 200} = 0.31\,m$$

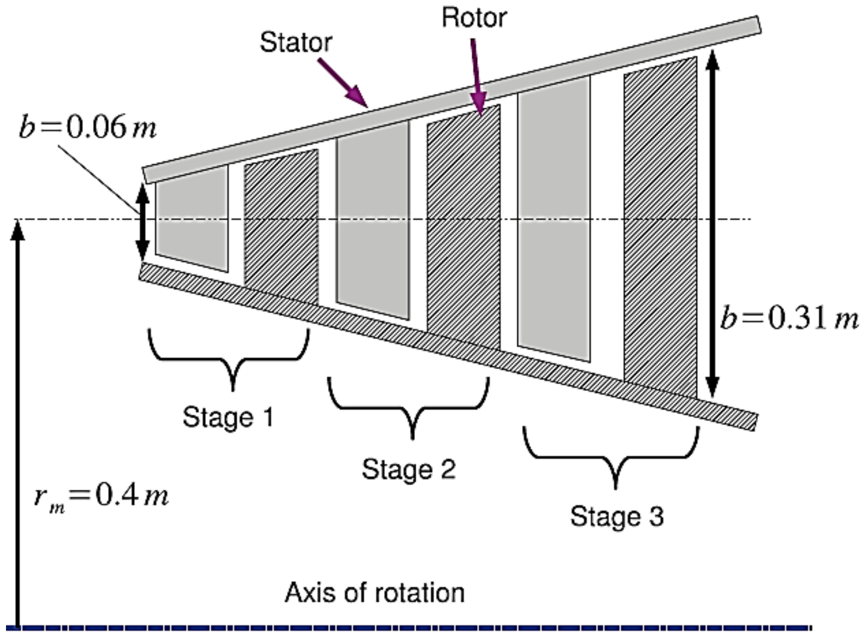


Figure 5.1: Meridional View of a Gas Turbine

Application of Continuity to Radial Flow Turbomachines

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For Radial flow turbomachines

$$\rho_1 A_1 V_{1r} = \rho_2 A_2 V_{2r} \implies \rho_1 2\pi r_1 b_1 V_{1r} = \rho_2 2\pi r_2 b_2 V_{2r}$$

For Centrifugal Flow Turbomachines

$$\dot{m}_1 = \rho_1 A_1 V_{1x} = \rho_1 2\pi r_{1m} b V_{1x}$$

$$\dot{m}_2 = \rho_2 A_2 V_{1r} = \rho_2 2\pi r_2 b V_{2r}$$

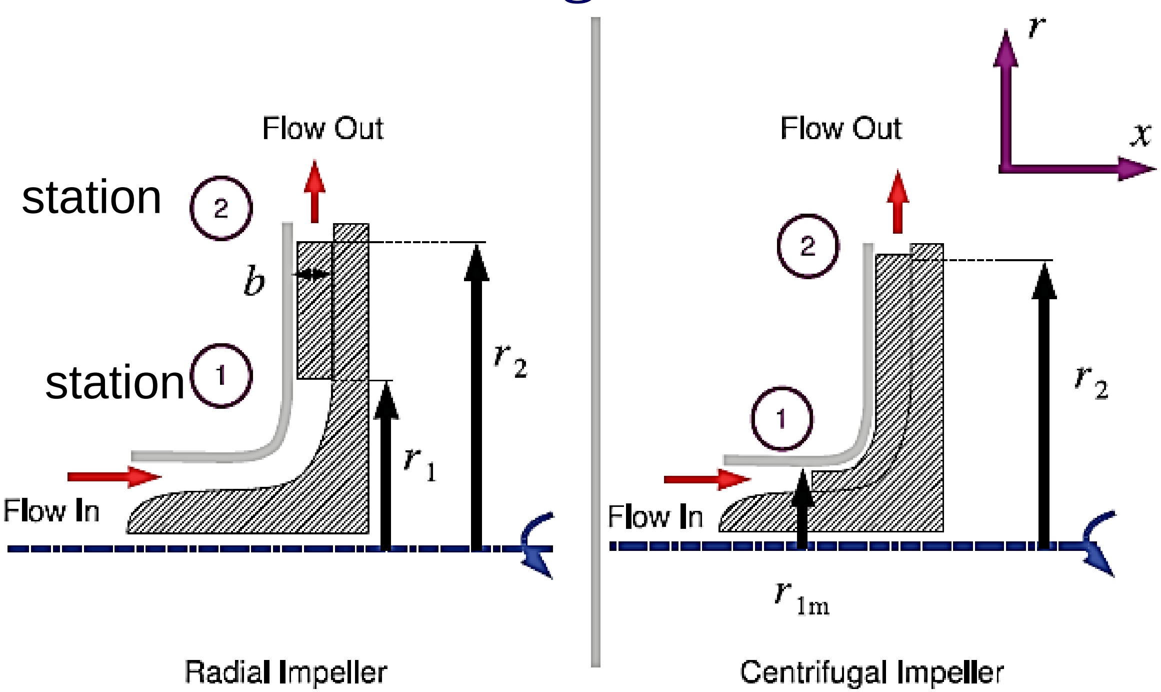

Figure 5.2: Meridional Views of Radial and Centrifugal Machines

❖ *Most useful application of these equations is to find flow velocities given the mass flow rate and geometry.*