TURBOMACHINERY AERODYNAMICS

Lect - 6

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3-D Flows in Blade Passages of Axial Flow Compressors

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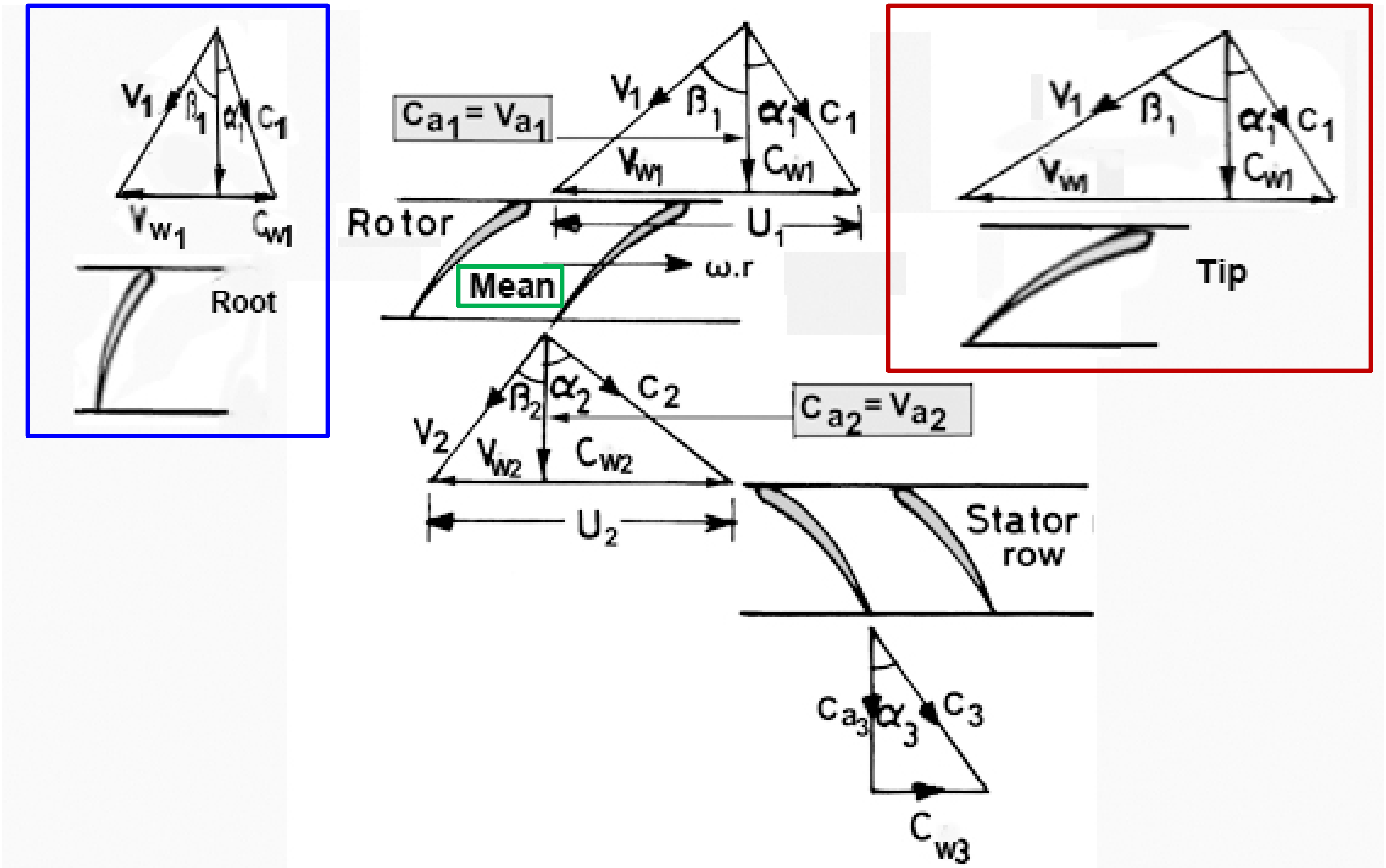
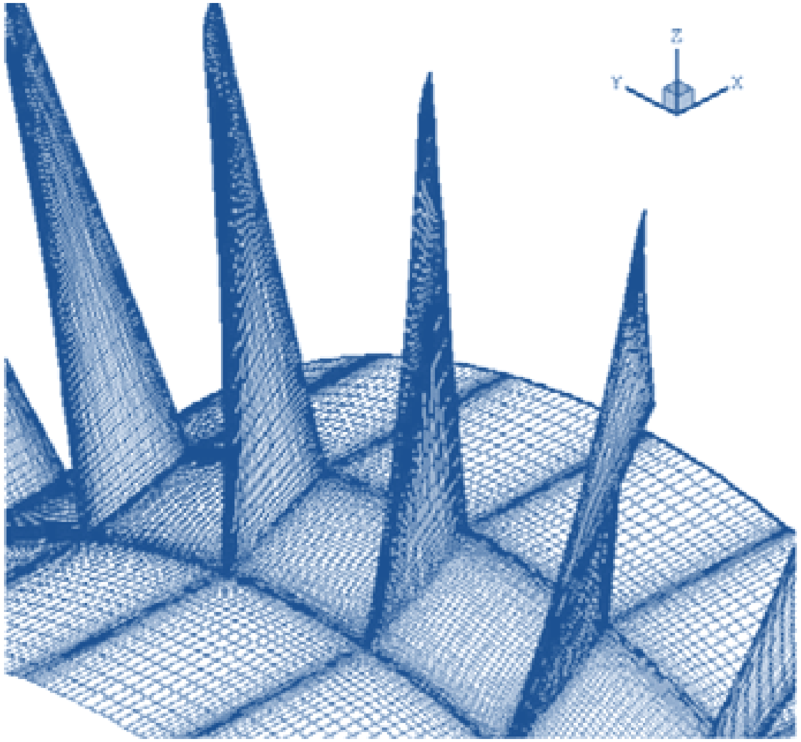
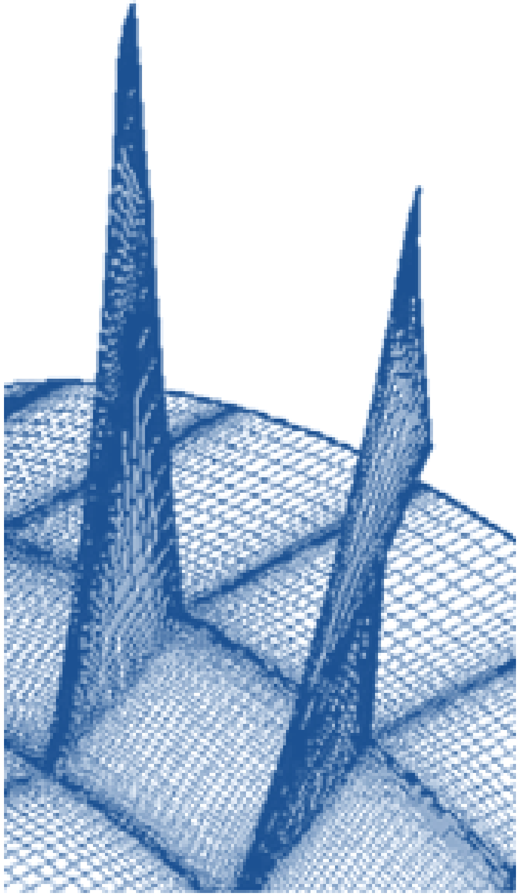
Local flow field decides blade shape

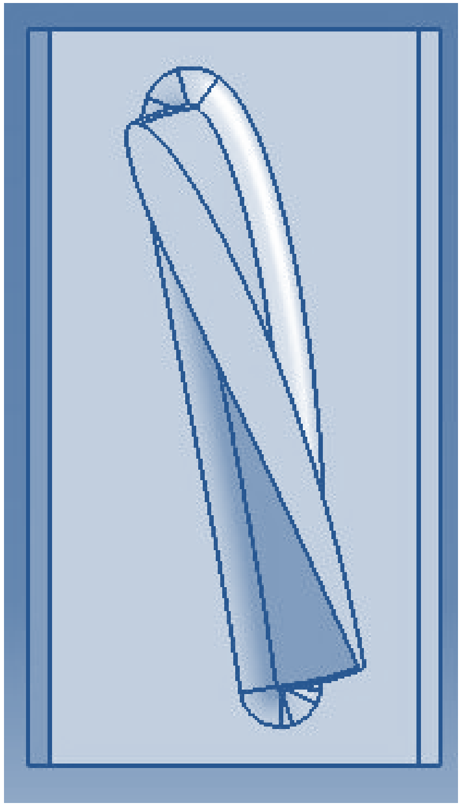


3-D Flows through axial compressor

- Axial flow acquires rotational component on entering the blades
- Axial compressors blades are normally highly twisted
- Airfoils used may significantly vary in camber and stagger settings from hub to tip
- Solidity and spacing between the airfoils vary from root to tip
- As a result of the above, Cp distributions on the blade surfaces vary from root to tip



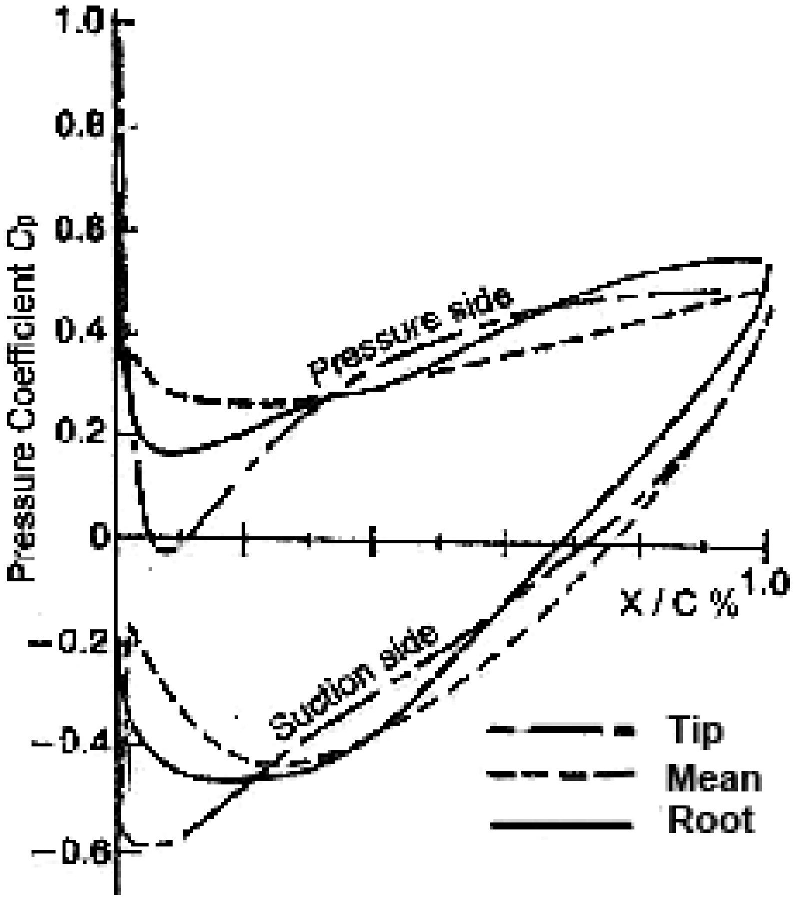


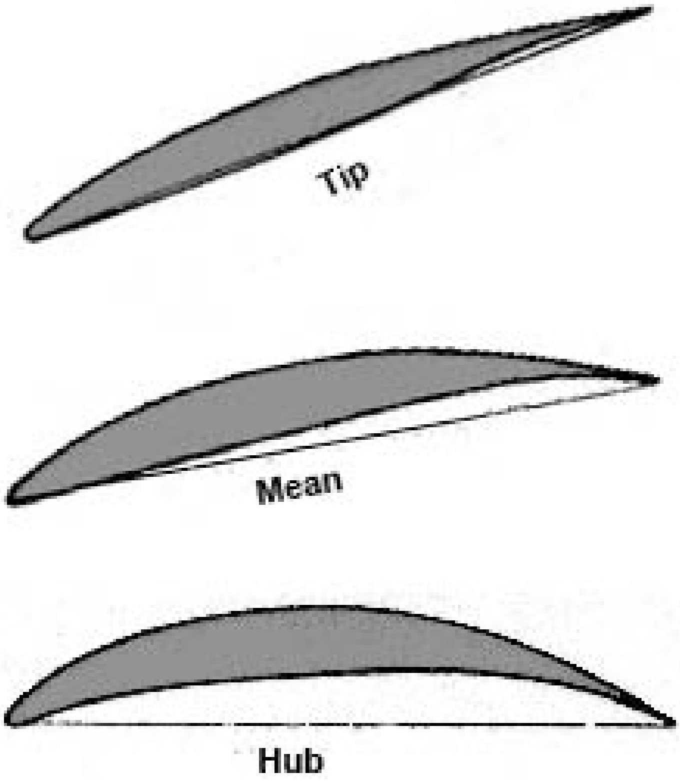


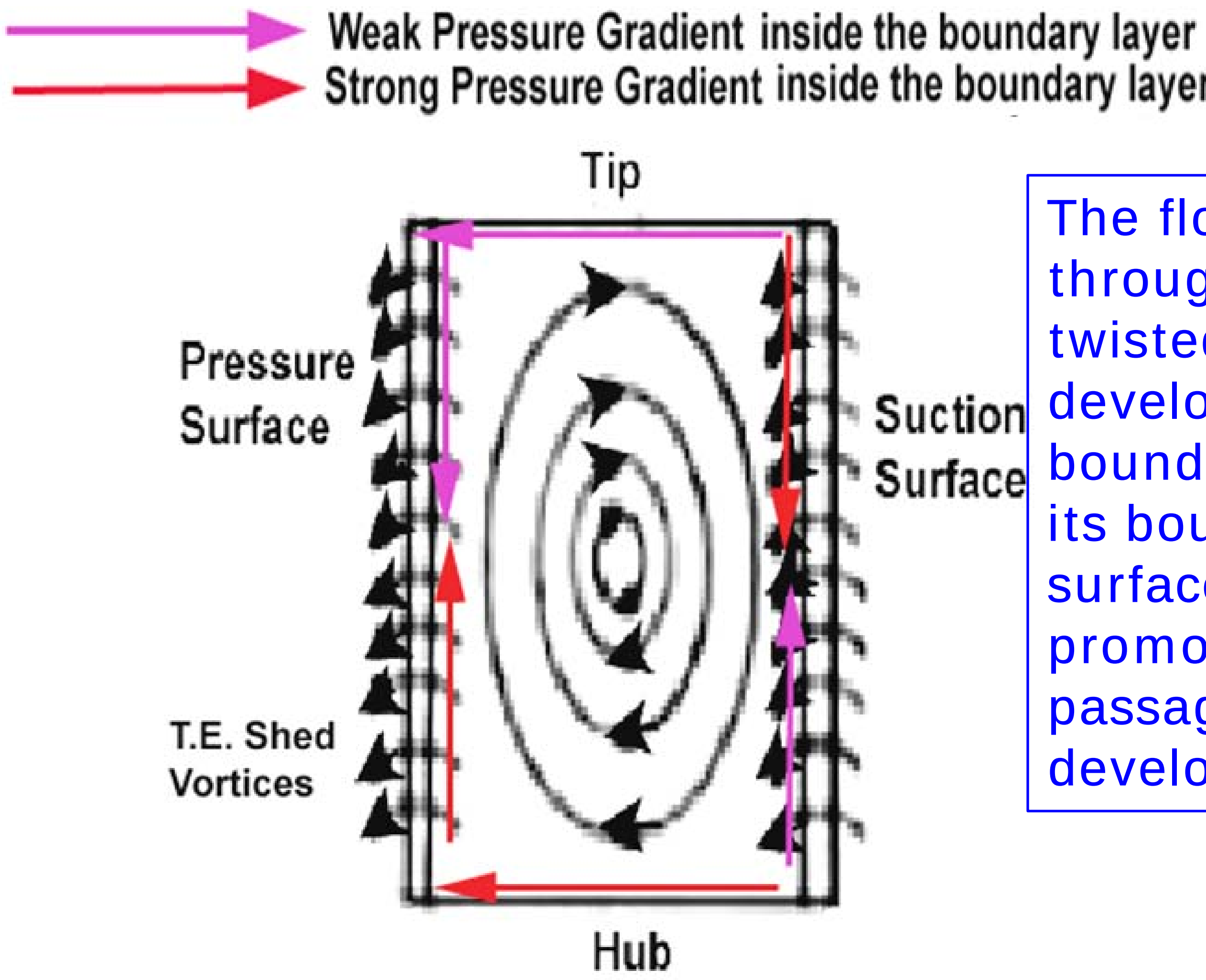
Top View

Fabricated Blades

3-D blade shapes


1.0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Pressure Coefficient Cp
X / C %
1.0
Pressure side
Suction side
Tip
Mean
Root


Tip
Mean
Hub



The flow, in passing through the curved, twisted blades, develop asymetric boundary layers on its bounding surface, which promote strong passage vortex development

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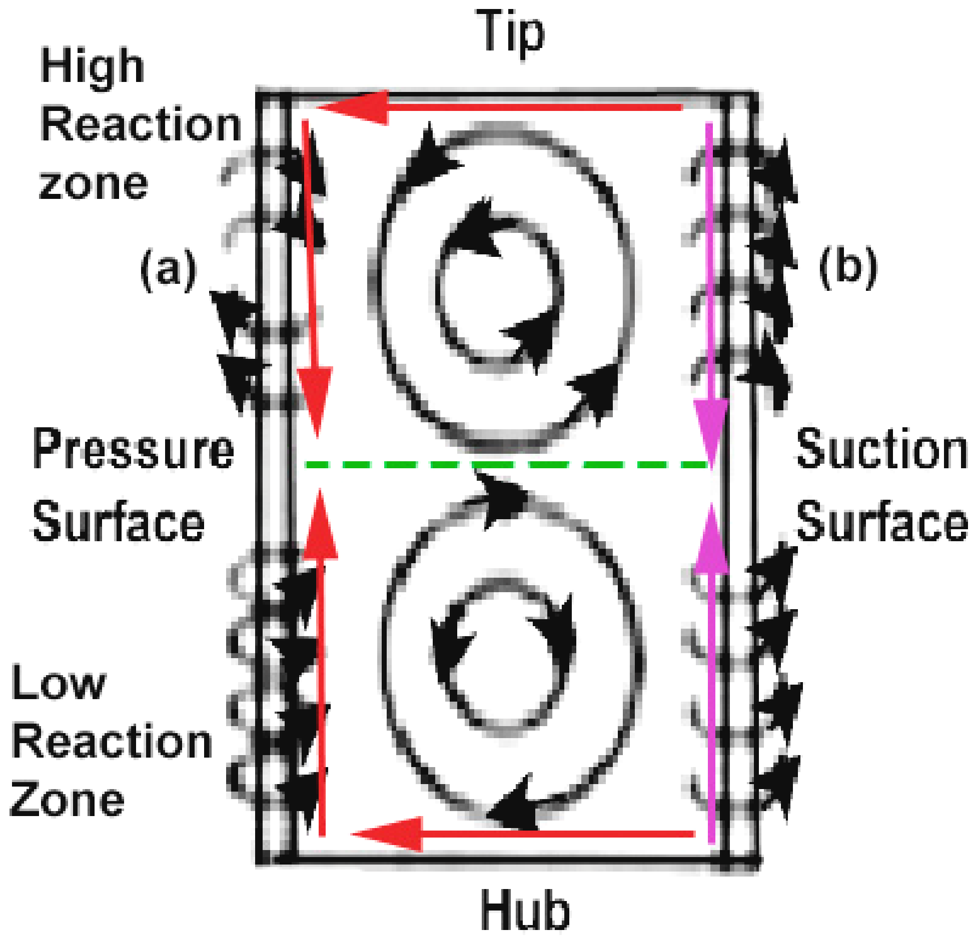

In certain blade shapes the flow, in passing through the blades, develop two passage vortices

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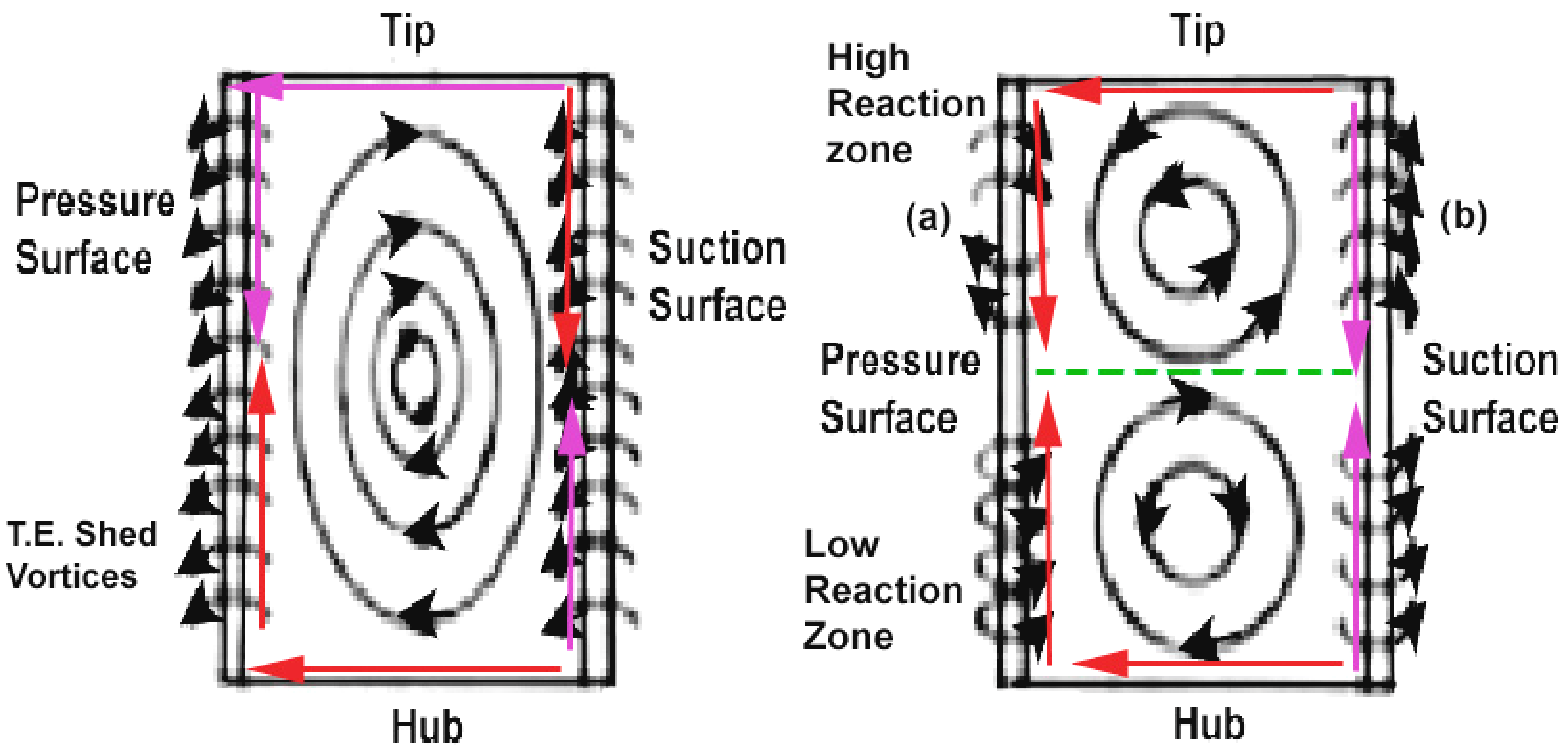
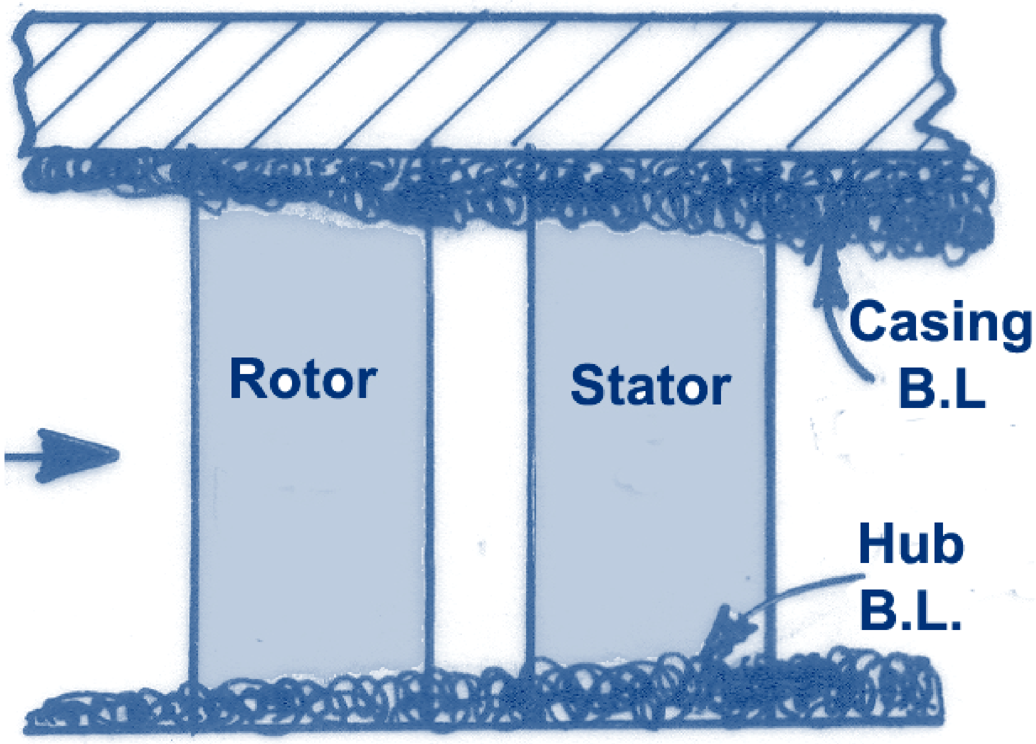
Weak Pressure Gradient inside the boundary layer
Strong Pressure Gradient inside the boundary layer

Looking at the flow from the rear of the blade passage

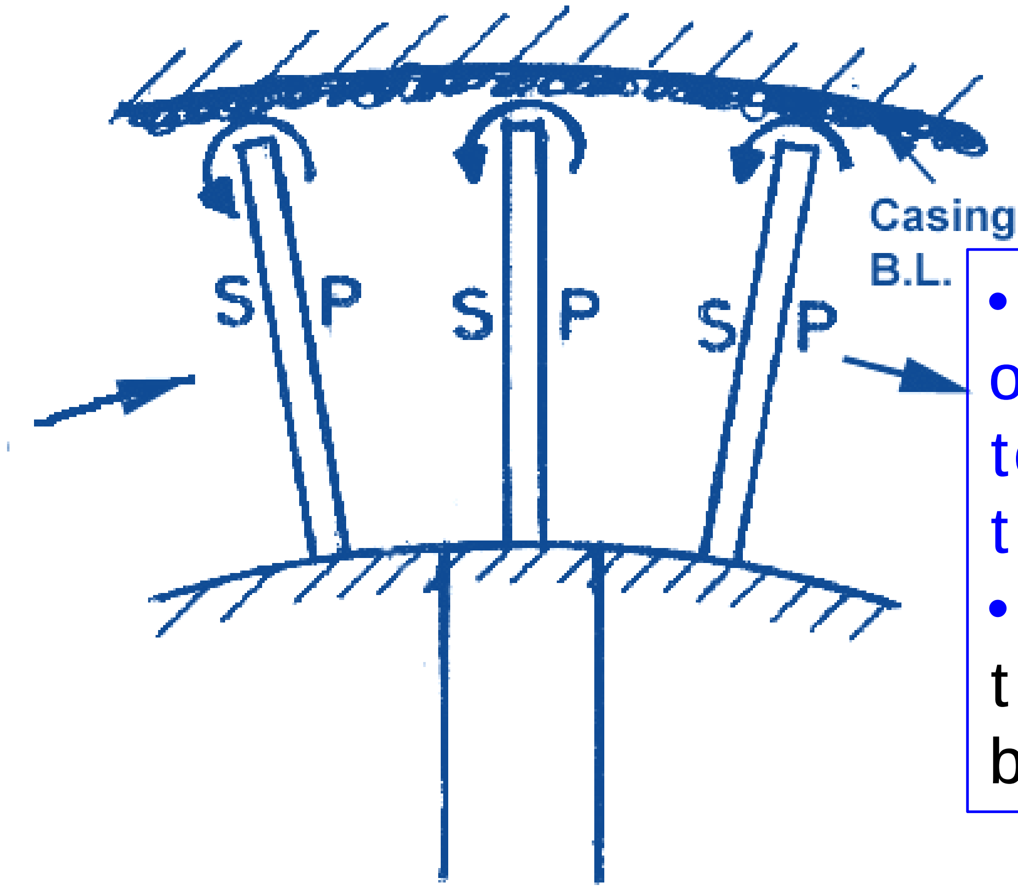




Boundary layer development at casing and hub (due to adverse pressure gradient of main flow) further contributes to 3-D flow development

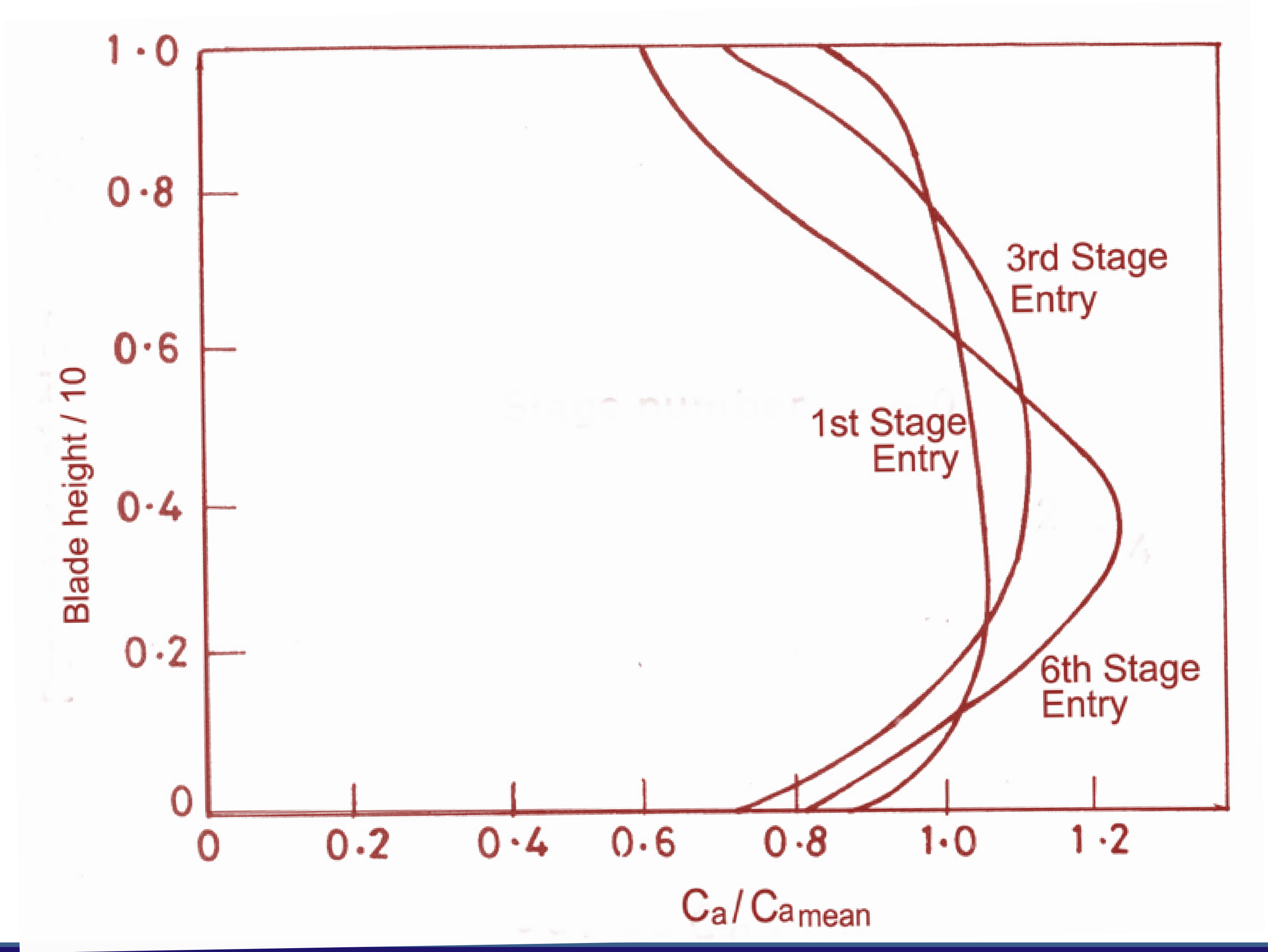
End-wall Boundary layer development

Scrubbing



- Tip cross flow is opposite in motion to the rotation of the rotor blades
- Blade tip scrubs through casing boundary layer

Change of inlet velocity profile through stages

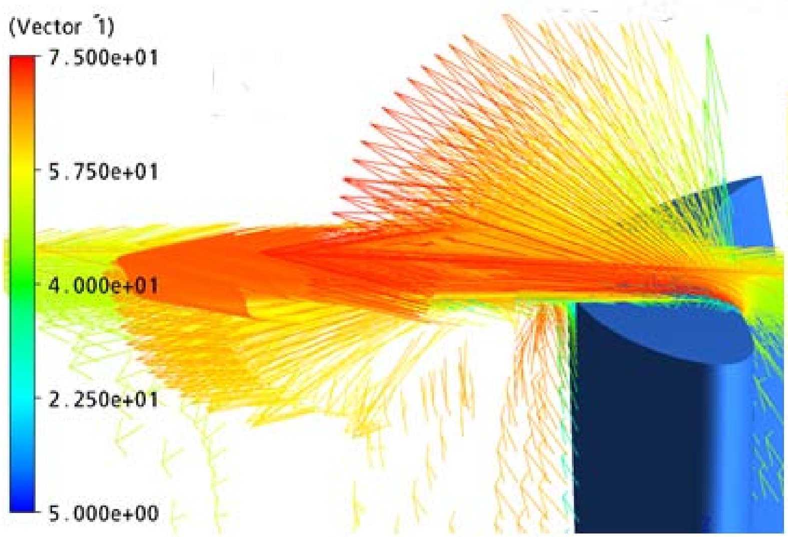


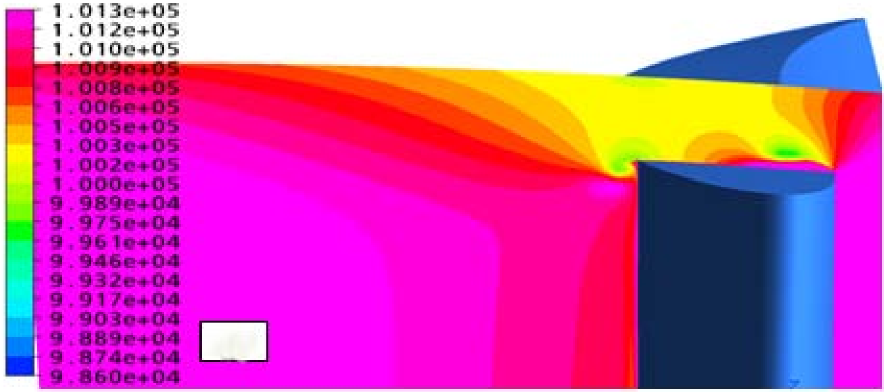
- Flow entering the stages downstream of the first stage becomes more and more non-axial

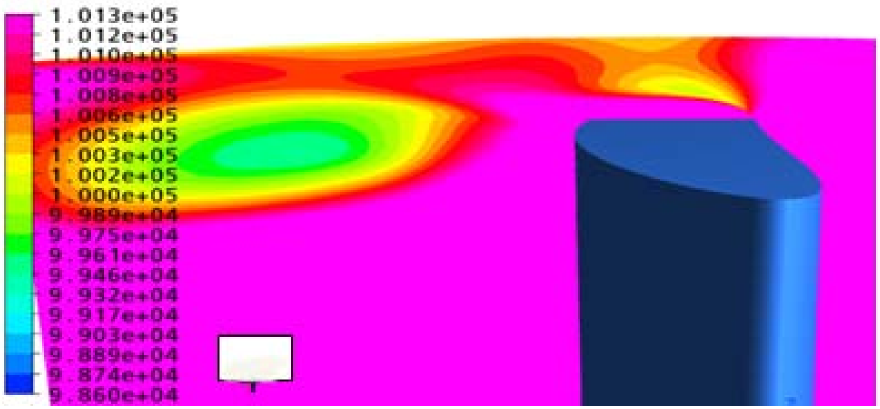
- Boundary layers are developed at the two ends of the blades – casing and hub ends

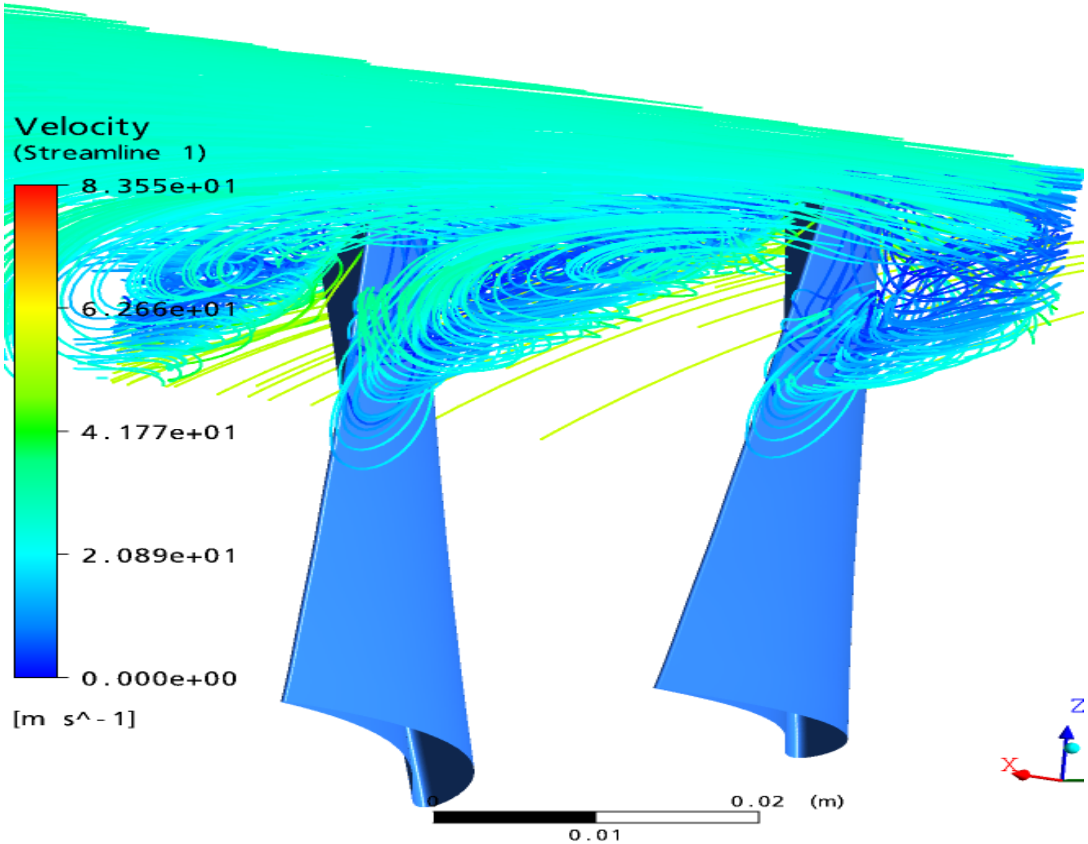
- The growing end wall boundary layers also act as “blockage” and reduces the main flow rate

Flow across blade tip



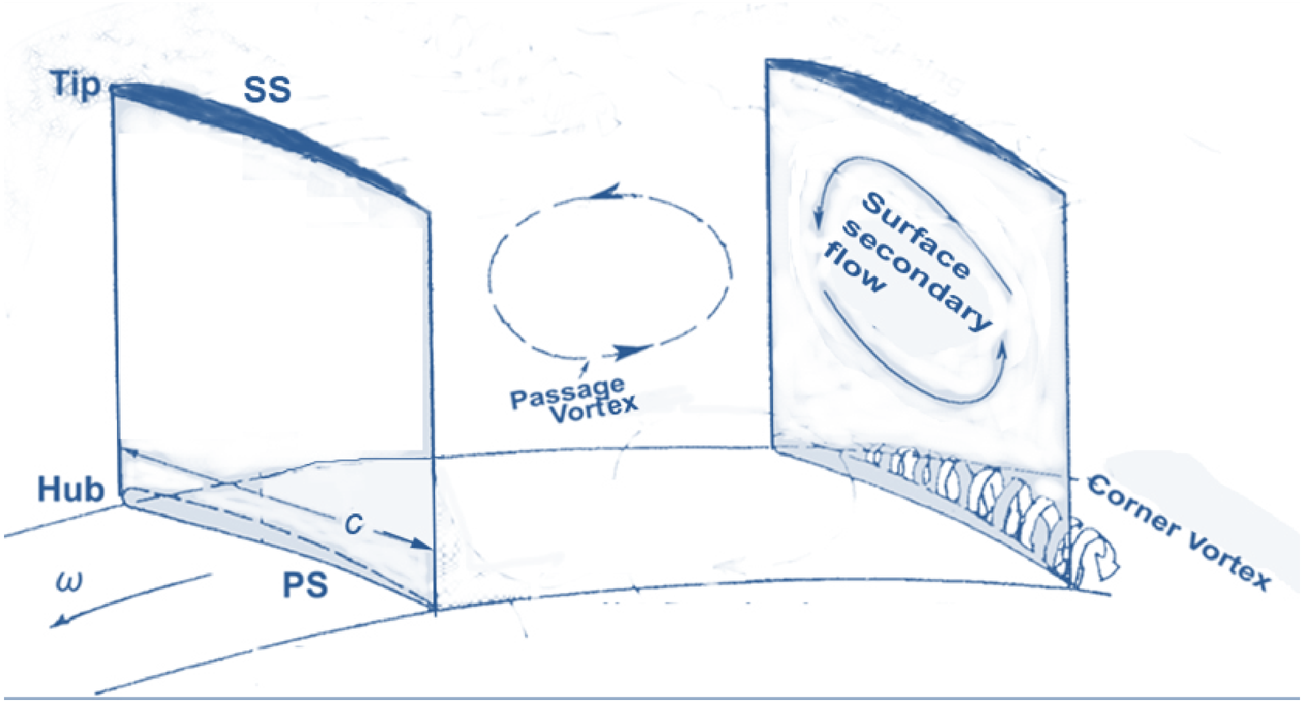






Passage vortex development across blade passage

3-D Flow development in rotor blades



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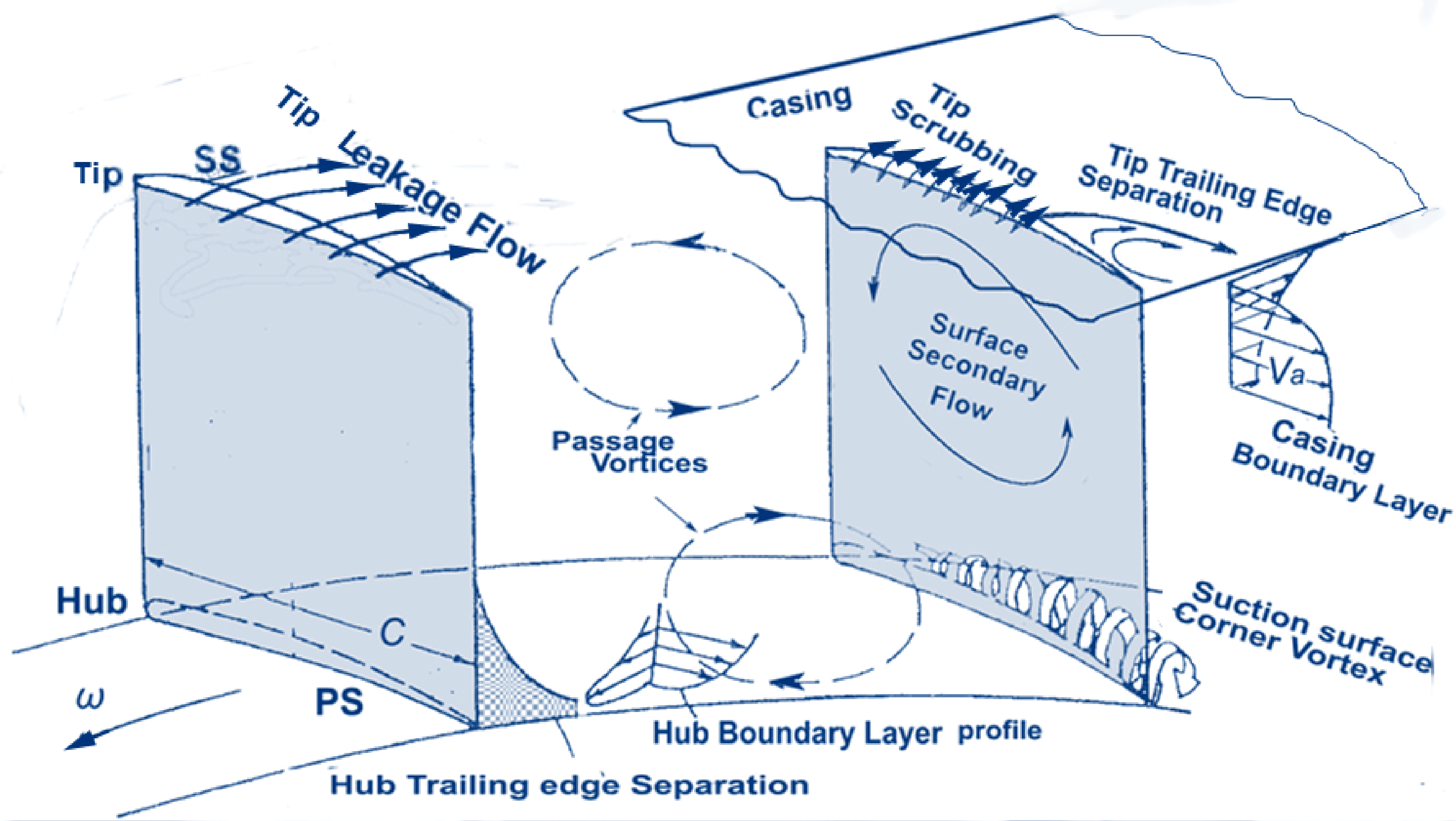
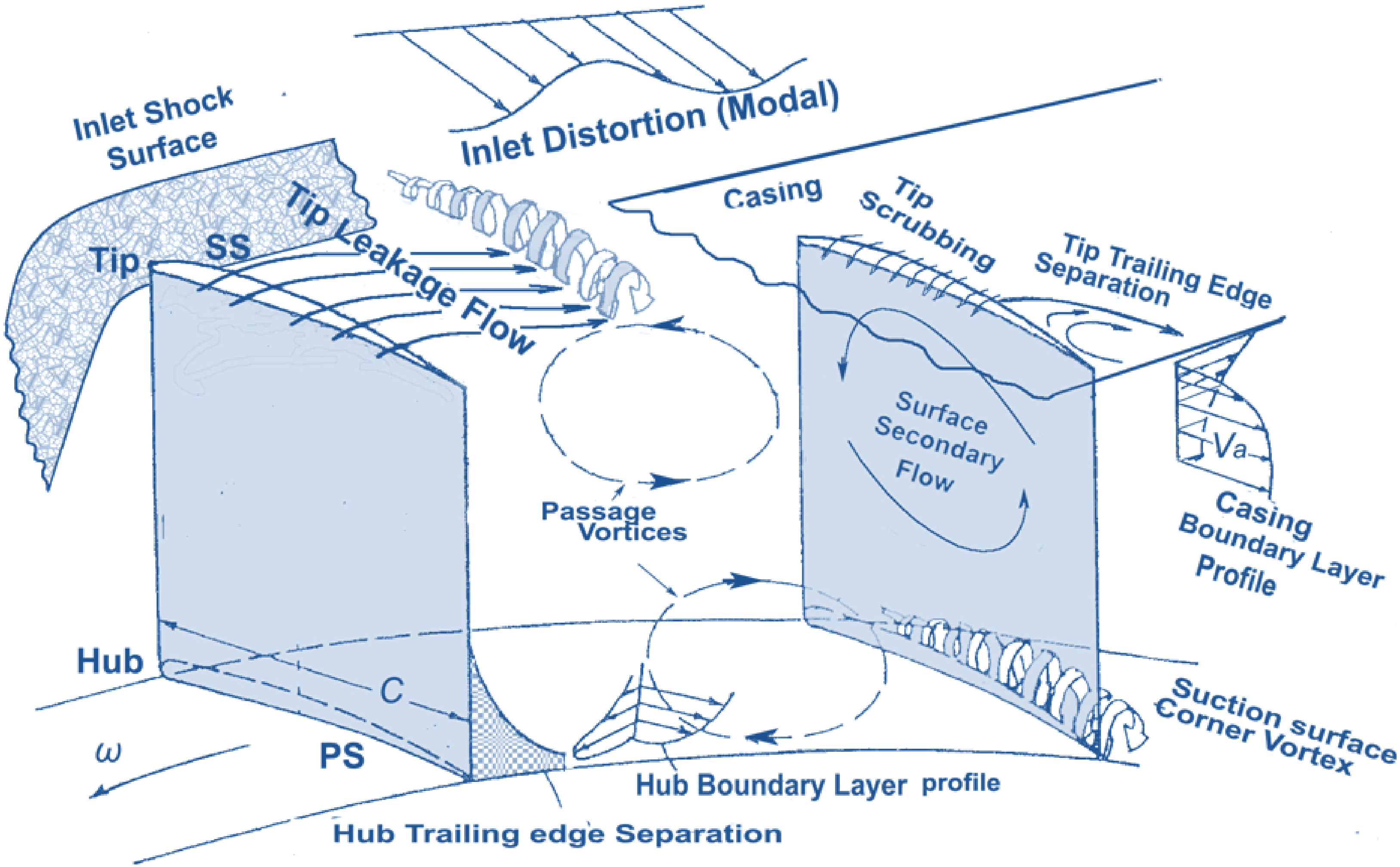
3-D Flow development in rotor blades



3-D Flow development in rotor blades



Next Class -----

3-D Flow Analysis –
Simple Radial Equilibrium theory