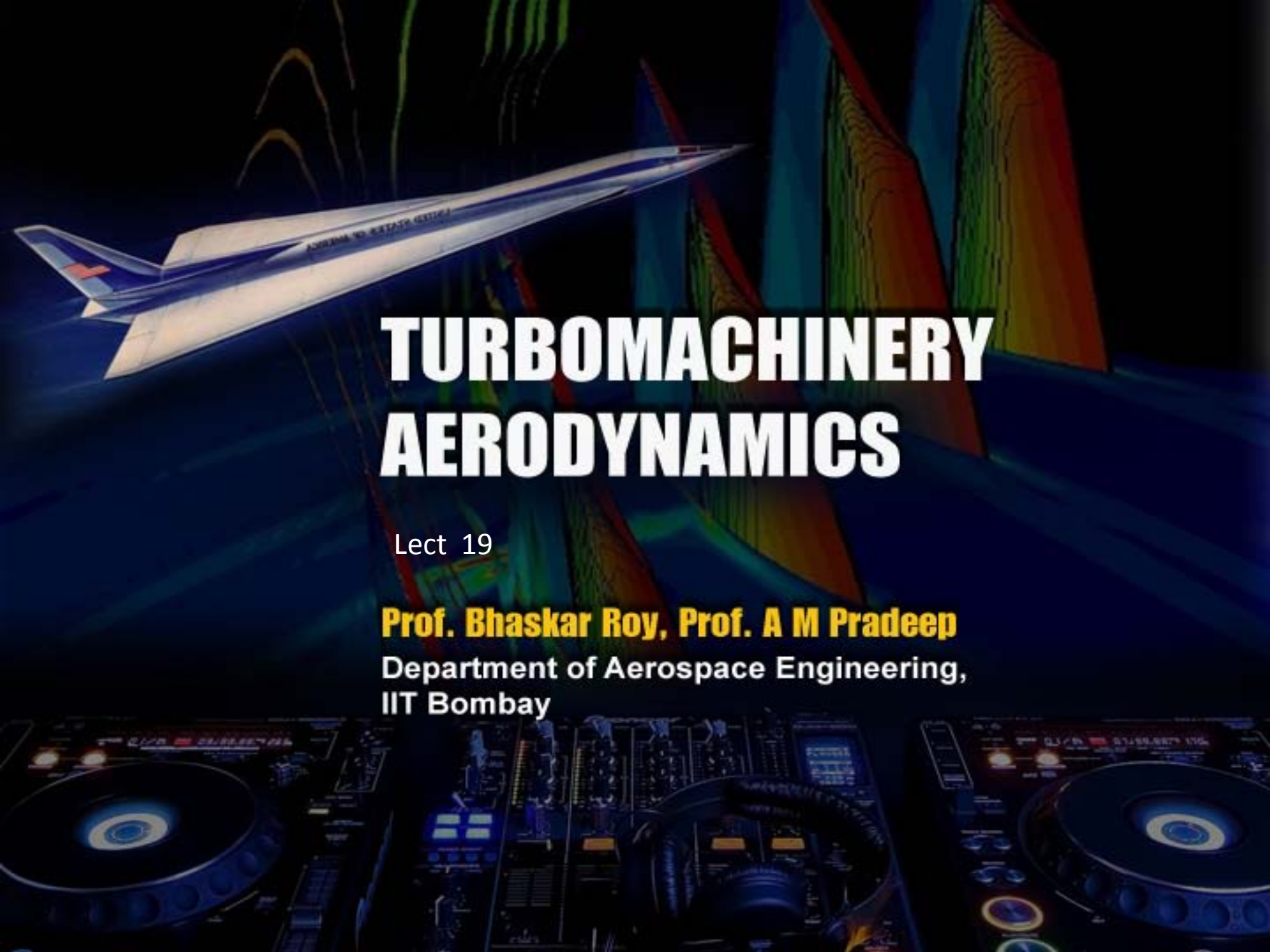

TURBOMACHINERY AERODYNAMICS

Lect 19

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Axial Turbine -----

Fundamental Aerothermodynamics

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Introduction

Gas Turbine engine derives its name from the turbine, which is at the heart of the work producing mechanism of the engine.

Principle

A fluid with large kinetic energy content is allowed to hit a freely rotating set of blades, certain amount of energy can be extracted from the passing fluid as shaft power

Shaft energy from the turbine is used to run:

i) A compressor, or a fan , which raises the internal energy content of the fluid before it goes into the combustor, for hot thrust

ii) A Fan that produces cold propulsive thrust

iii) A propeller to create the propulsive thrust

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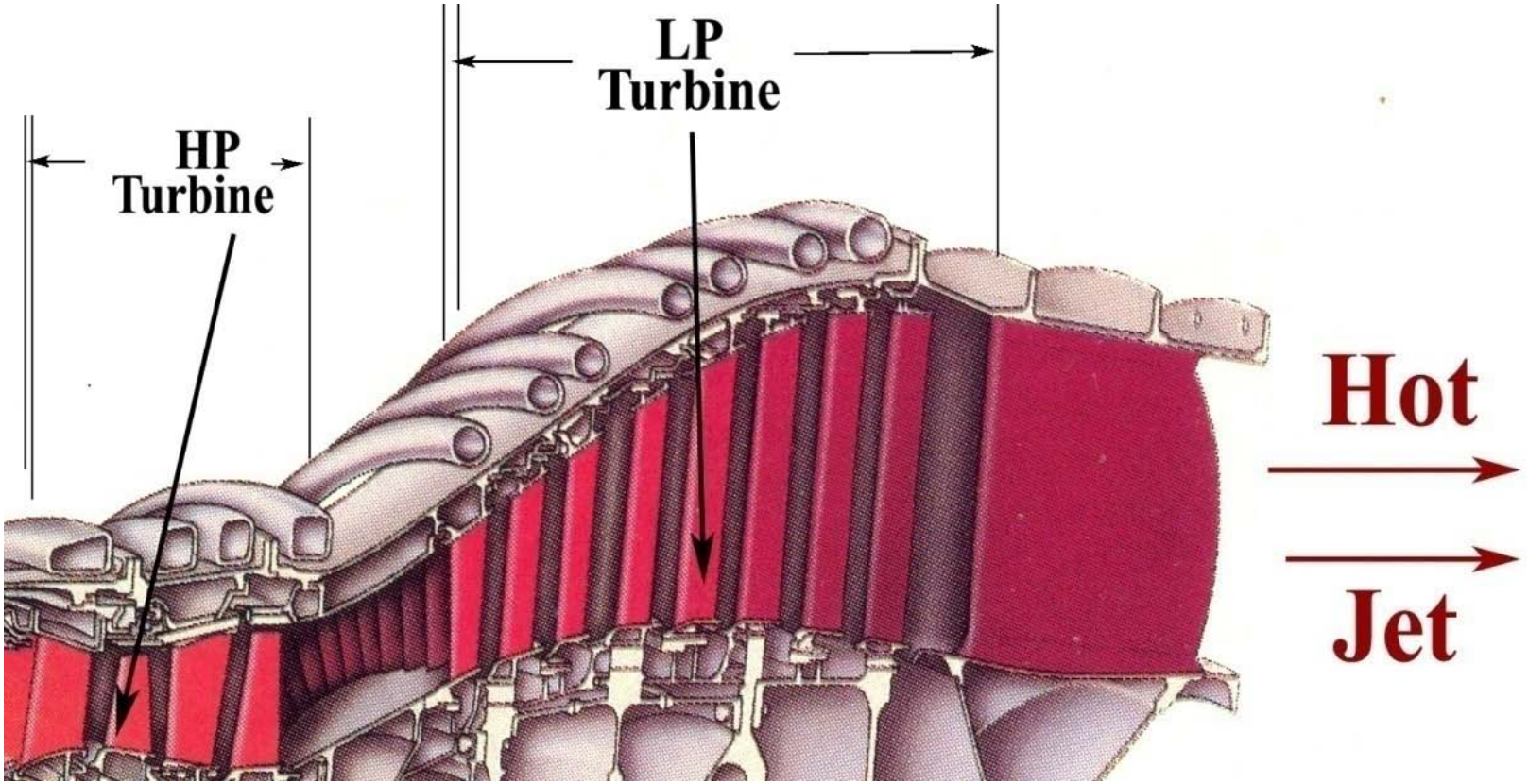
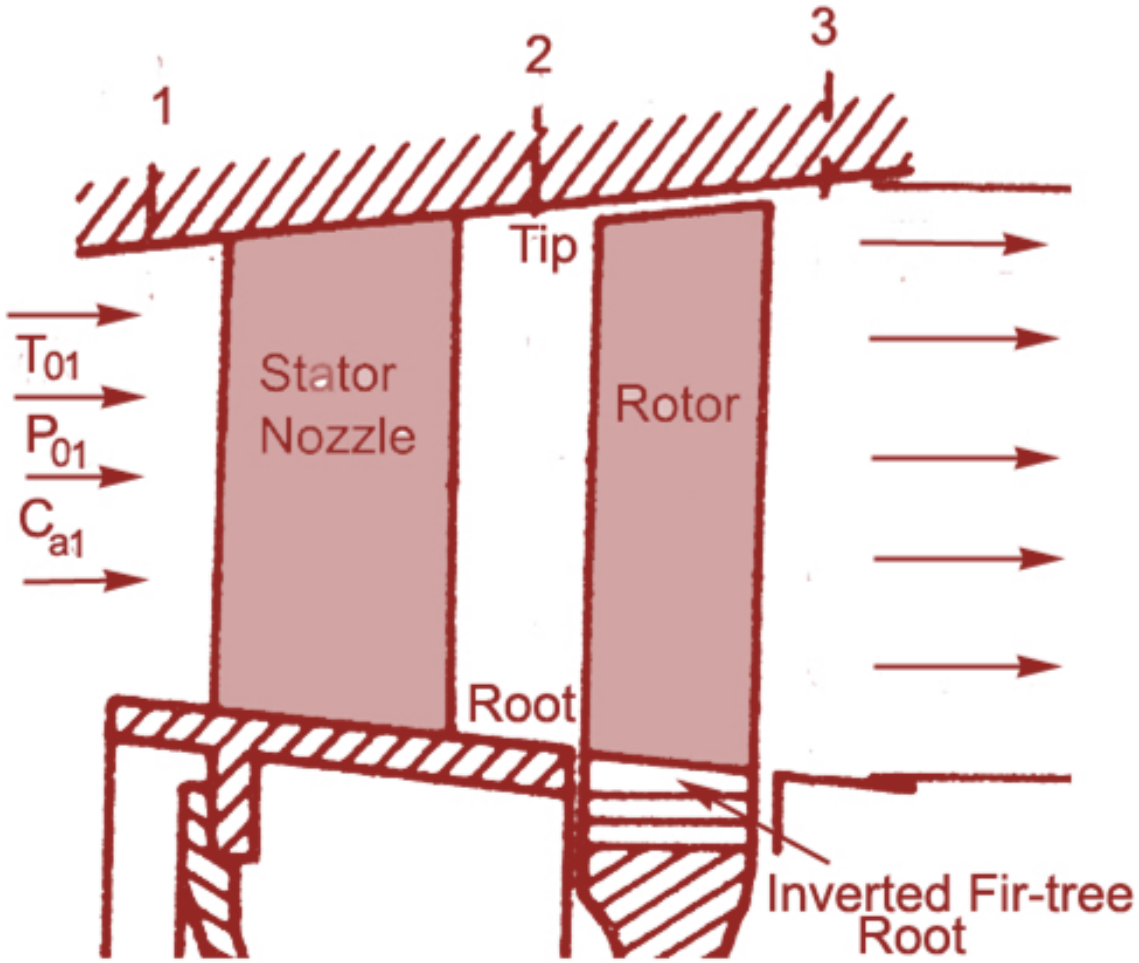
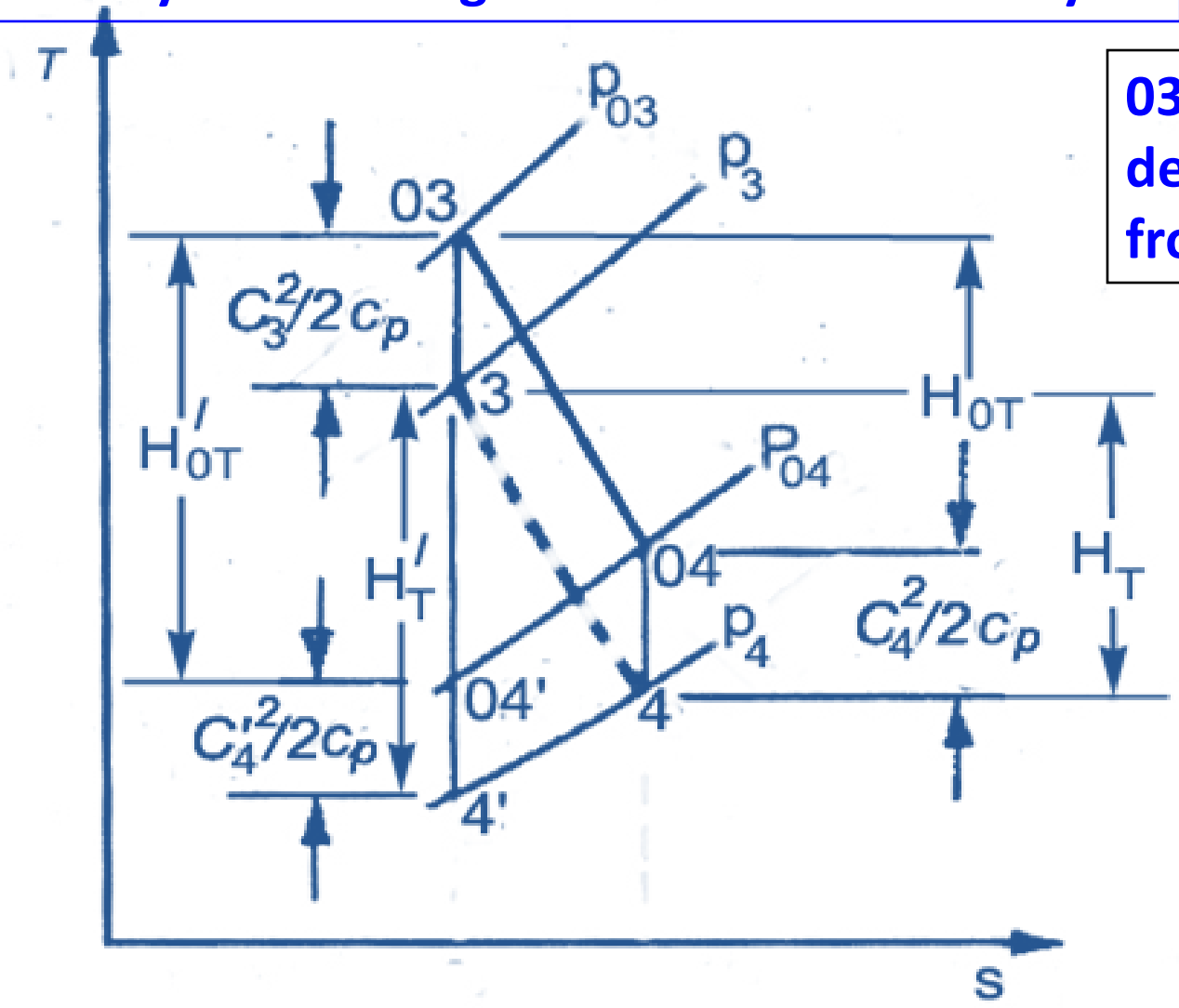


A Multi-stage 2-spool axial turbine layout



Elemental Turbine stage – Rotor + Stator

Thermodynamic changes in Turbine in a GTE Cycle



03 is the delivery from C.C.

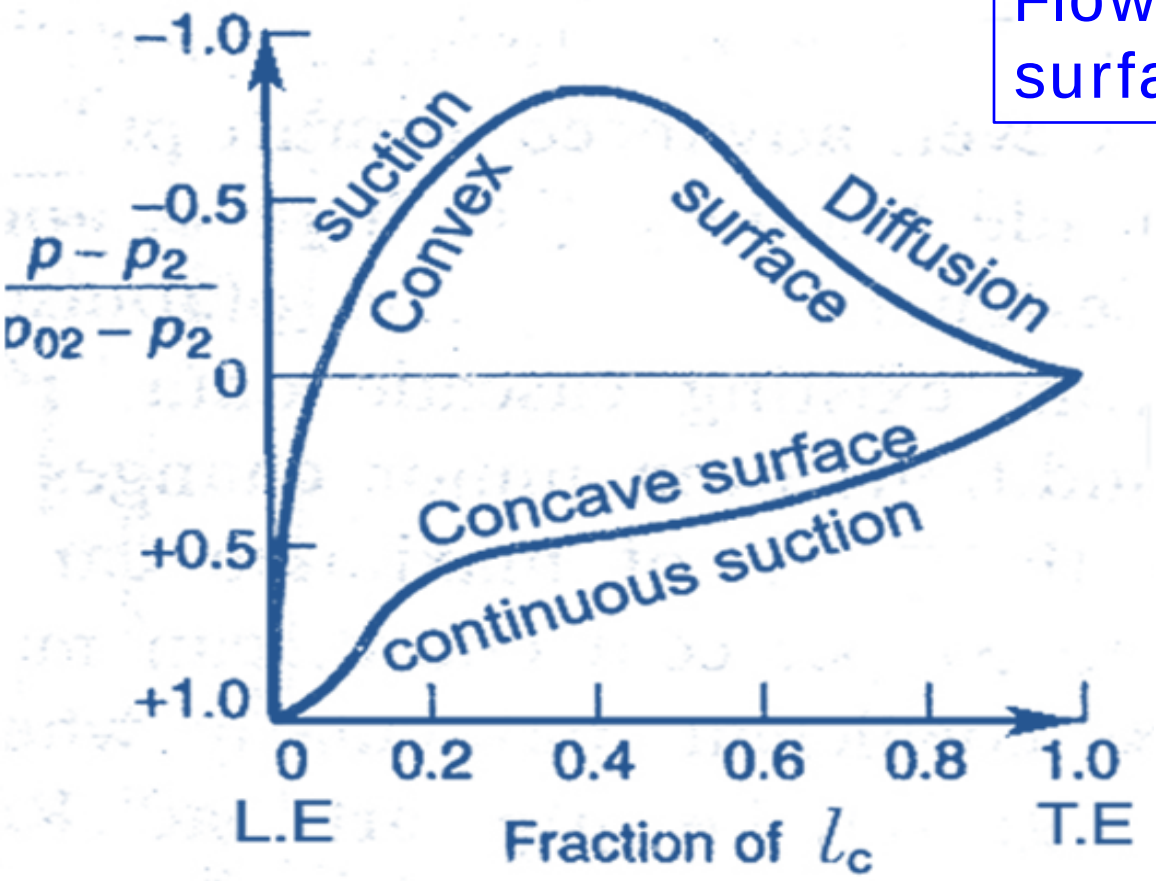
Impulse turbines

High energy flow is accelerated in a stator and made to impinge on the rotor with high momentum and then made to take huge turn through the passage between the blades. The work transfer is through large angular momentum change through the blades.

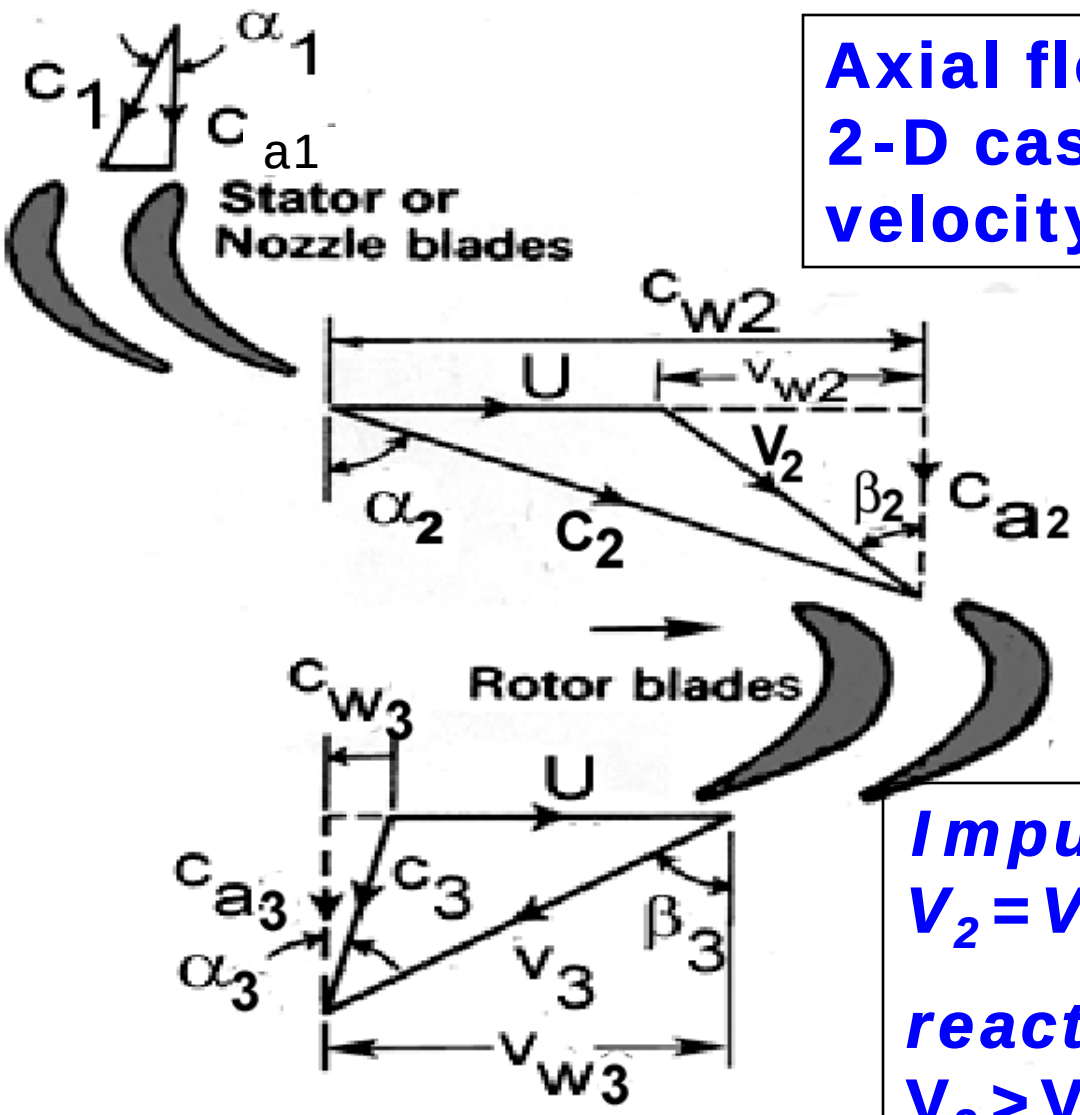
Reaction turbines

The flow is accelerated through the rotor blade passage which is an converging curved nozzle passage; Jet effect creates a reaction force as per Newton's 3rd law of motion. This work is in addition to the work done by large turning.

Flow over the blade surfaces



Axial flow turbine 2-D cascade velocity diagram

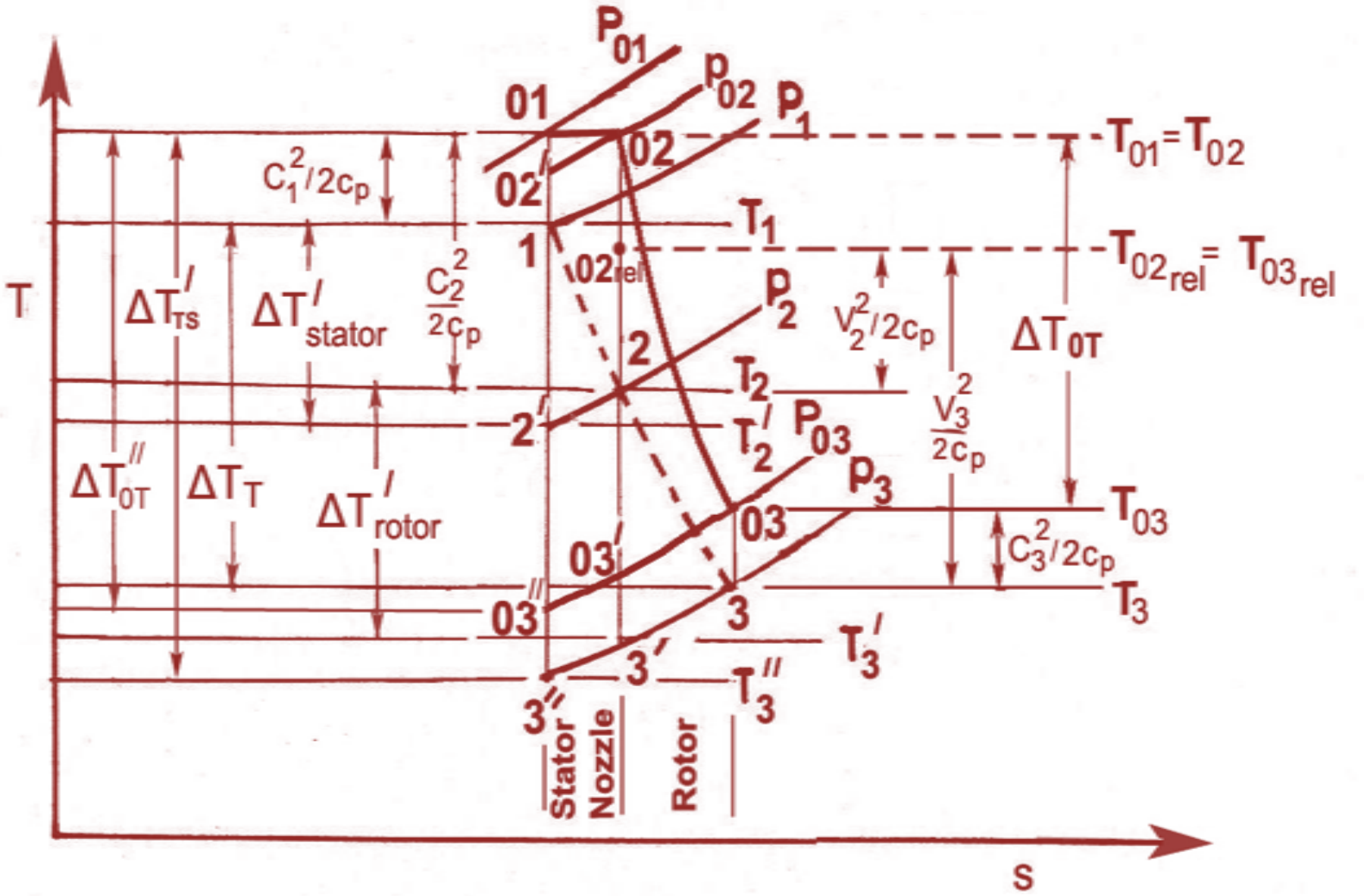


Impulse turbines

$V_2 = V_3$

reaction turbines

$V_3 > V_2$


T
S
P_{01}
P_{02}
P_1
P_2
P_{03}
P_3
01
02'
02
1
02rel
2'
2
03'
03''
03
3'
3''
3
$T_{01}=T_{02}$
T_1
$T_{02rel}=T_{03rel}$
T_2
T_2'
T_{03}
T_3
T_3'
T_3''
$C_1^2/2c_p$
$C_2^2/2c_p$
$V_2^2/2c_p$
$V_3^2/2c_p$
$C_3^2/2c_p$
$\Delta T_{ts}'$
$\Delta T_{stator}'$
$\Delta T_{rotor}'$
ΔT_T
$\Delta T_{0T}''$
ΔT_{0T}
Stator
Nozzle
Rotor

Isentropic Efficiencies

Total-to-total **efficiency**,

$$\eta_{0T} = \frac{\Delta T_{0T}}{\Delta T'_{0T}}$$

Static-to-static **efficiency**,

$$\eta_T = \frac{\Delta T_T}{\Delta T'_T} = \frac{\Delta T_T}{\Delta T'_{Stator} + \Delta T'_{Rotor}}$$

Total-to-static **efficiency,**

$$\eta_{TS} = \frac{\Delta T_{0T}}{\Delta T'_T} = \frac{\Delta T_{0T}}{\Delta T'_{Stator} + \Delta T'_{Rotor}}$$

Total-to-total* isentropic efficiency of the *rotor only

$$\eta_{0\text{-}Rotor} = \frac{\Delta T_{0\text{-}Rotor}}{\Delta T'_{0\text{-}Rotor}} = \frac{T_{02} - T_{03}}{T_{02} - T'_{03}}$$

Specific Work (per unit mass flow) Done

$$H_{Th} = U\left(C_{W_2} + C_{W_3}\right)$$

Next Class :

Detailed 2-D Turbine Aerodynamics