MEEN-414/646 Module 3
DESIGN OF A SINGLE STAGE TURBINE COMPONENT
A Parameter Study

Problem Definition

To drive a compressor, a single stage power generation gas turbine needs to be designed, Fig. 1 shows a schematic of the turbine.

The preliminary design data are:

Medium: Air to be considered as perfect gas
Turbine mass flow: $\dot{m} = 3.5 kg/s$
Stage inlet pressure: p_1 1.6 *bar*
Turbine inlet temperature: $T_1 = 800.0\,K$
Stage pressure ratio: $\pi = 1.2$
Stage flow coefficient: $\varphi = 0.4$
Degree of reaction: $r = 50\%$
Stage isentropic efficiency: $\eta = 0.85$

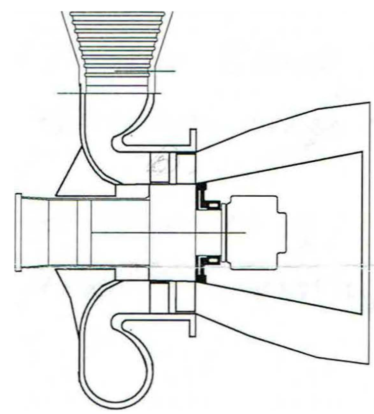

Figure 1: Schematic of the turbine to be designed

Under variation of the mean diameter $D_m = 0.2 - 0.45\ m$ with increment of $\Delta D_m = 0.05 m$ (outer loop) and the axial velocity component varying $V_{ax} = 50.0 - 100.0\ m/s$, $\Delta V_{ax} = 1\,m/s$ (inner loop)

Determine:
1) The turbine frequency as a function of the stage power and plot
2) Stage blade height as a function of power and plot
3) Blade height as a function of frequency and plot
4) Stage specific load coefficient as a function of frequency and plot
5) Stage power as a function of stage load coefficient and plot

For $D_m = 0.35\ m$, $\lambda = 2.0$, $c_{stator} = c_{rotor} = 40mm$, $\sigma = chord/spacing = 1.4$ and corresponding angles, α_2, α_3, β_2, β_3, design the complete stator ring with the blades and the complete rotor with the shaft with compressor side having a flange and the diffuser side a bearing.
Use the blade design subroutine that you have developed and SOLIDWORK for complete design.

MEEN-414/646 Module M4-Design of Radial Compressor

Distributed 02/23/2016,
Part I Aero-Thermo: Collected Tuesday 03/01/2016
Part II Hardware Design Tuesday 03/08/2016
umber of participants: 2/group

The sketched radial compressor has dry air as the working medium. Air enters the compressor axially and leaves it radially. The compressor has the following given data

Sin le stage radial com ressor data see Figure 1

Design point mass flow	$\dot{m}_D = 3.5\ kg/s$
Inlet temperature	$T_{in} = 300K$
Inlet total pressure	$p_{01} = p_{02} = 1.0$ bar
Reference pressure ratio	$\pi_{ref} = 3.0$
Angular velocity	$\omega = 3{,}000.0\ rad/s$
Design efficiency	$(\eta_{is})_{Design} = 0.86\%$
Inlet mean diameter at 2:	$D_{m_2} = 160.0mm$
Exit diameter at station 3:	$D_3 = 300.00mm$
Inlet Blade height	$B_{h_2} = 100.00mm$
Exit blade height	$B_{h_3} = 40.00mm$
Absolute flow angle	$\alpha_2 = 90^o$

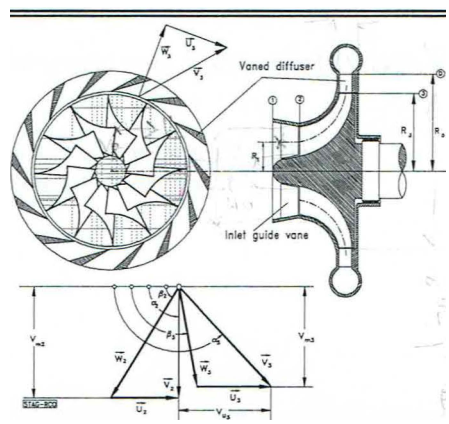

Figure 1: Schemetic of Radial Compressor

Note: The above dimensions and angular velocity are just guiding numbers, you are free to make changes to arrive at a reasonable design.

Project Execution

Aero-thermo design

Write computer program to determine the design and off-design performance at the given ω. With the given equations for $\pi = f(\dot{m}/\dot{m}_D)$ and $\eta_{is} = f(\dot{m}/\dot{m}_D)$, a step-by-step procedure is given below:

Step 1: Includes the given data and the calculation of rotational velocities at the mean sections
Step 2: The variation loop of mass flow from $\dot{m} = 2.5\text{-}4.5\ kg/s$ builds the mass flow ratio $\dot{m}/\dot{m}_D$
Step 3: With the ratio above go to $\pi = f(\dot{m}/\dot{m}_D)$ and get the efficiency $\eta_{is} = f(\dot{m}/\dot{m}_D)$ from below

$a_0 = -0.3844$, $a_1 = 3.0222$, $a_2 = -1.7778$,

$$\eta_{is} = a_0 + a_1 \dot{m}/\dot{m}_D + a_2 \dot{m}/\dot{m}_D^2, \quad \pi = \eta_{is} * \pi_{ref}$$

and get the actual $\pi = f(\dot{m})$ and $\eta_{is} = f(\dot{m})$

Step 4: Calculate all temperatures, enthalpies, kinetic energies, power, all velocities and Mach numbers
Step 5: Generate 9 diagrams and place them in three rows as specified below:

Row 1: $\pi = f(\dot{m})$, $Power = f(\dot{m})$, $\eta = f(\dot{m})$

Row 2: $\varphi = f(\dot{m})$, $\omega = f(\dot{m})$, $\beta_3 = f(\dot{m})$
Row 3: $\alpha_3 = f(\dot{m})$, V_2, $W_2 = f(\dot{m})$ (nine diagram), V_3, $W_3 = f(\dot{m})$

Radial Compressor design, geometry, complete aero-thermodynamics design, all angles, stage characteristics should be listed in a table. Now you have learned how a compressor is working at one constant rpm, generally a compressor performance map has many performance curves. Now we go to hardware design as specified below.

Part II:
Solid Mechanic Design a Team work

For the given inlet condition (T,p), the design mass flow, the design efficiency, the geometry, design radial compressor that fulfils $\lambda = -1.0$.

Step 1: Take all design parameters and design the compressor using solid work or any other 3-D design tool you are familiar with.
Step 2: Design completely the impeller
Step 3: Design the shaft of the compressor with the bearings in interaction with step 2 group
Step 4: Design the compressor casing, inlet and exit in cooperation with Step 2 and 3
Step 5: System integration of steps 2 though 4

If question arises stop by my office or sed me an email.