MEEN 646 – Aerothermodynamics of Turbomachinery

Module V:

CFD, Pressure Distribution

Prepared by:

Dung Tran

Jitaditya Mondal

Submission Date: 03/22/2016

Introduction

In this module, the CFD (Computational Fluid Dynamics) analysis of turbine and compressor blades are covered. The following post analysis were done:

- Coefficient of pressure ($\frac{p_1-p_x}{p_1}$) along suction and pressure surfaces
- Velocity distribution in the cascade channel
- Pressure distribution in the cascade channel

Alongside, an attempt has been made to optimize the chord spacing ratio to reduce total pressure loss. The software used for this module were:

- CFX for obtaining coefficient of pressure, temperature and pressure distribution.
- Solidworks for C/S optimization

Turbine

For the turbine, CFD was done for the stator. Stator cascade consisted of two parallel blades. These blades were imported from Solidworks and had the following characteristics.

Thickness ratio ($\frac{t_{max}}{c}$)	0.015
Chord spacing ratio ($\frac{c}{s}$)	1
Deflection	100^0
Chord length	38 mm

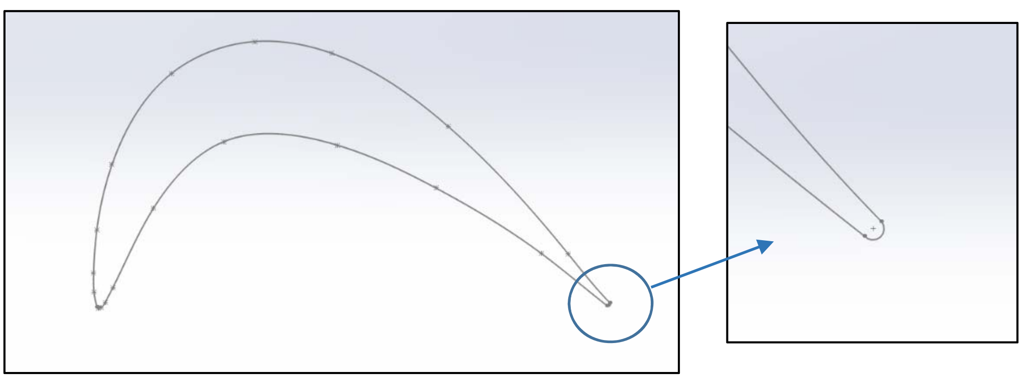

Figure 1: Blade in Solidworks

Mesh settings were chosen as follows:

- Advanced sizing function: Proximity and curvature
- Relevance center: Medium
- Smoothing: High
- Transition: Slow
- Span angle center: Coarse
- Element size: 0.0018

To capture boundary layer, the element size around the boundary layer was finer and set to 0.001

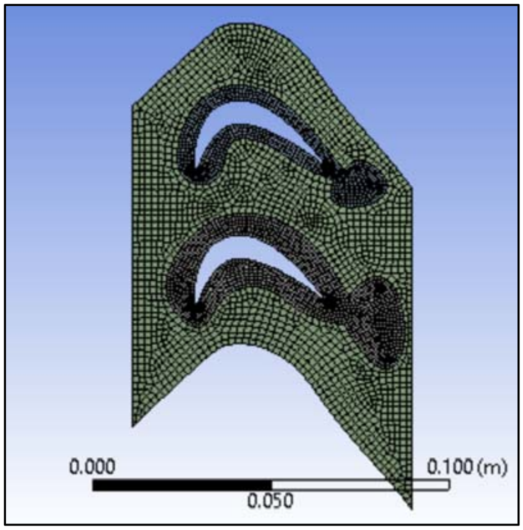

Figure 2: Mesh for turbine blade

The following boundary conditions were set:

- Inlet velocity was to 25 m/s. Additionally, inlet velocity was made parallel to camberline of the turbine blade (72^0)
- Outlet reference pressure was set to 101 KPa.
- Periodic boundary conditions were imposed at the edges
- Since the blade was only 30 mm in height, the hub and tip boundary conditions were set to free slip wall to remove effect of secondary and endwall effects.

Using these boundary conditions, the simulation was run. Results of CFD are presented below.

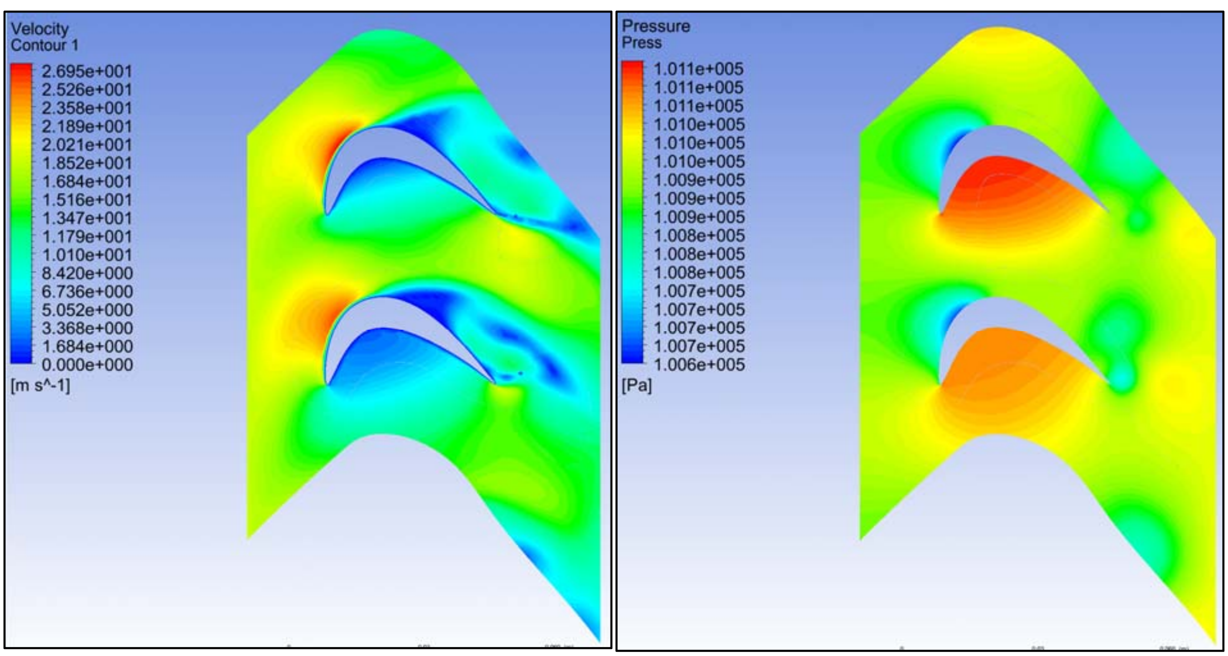

Figure 3: Velocity contour (on left) and Pressure distribution (on right) for turbine blades

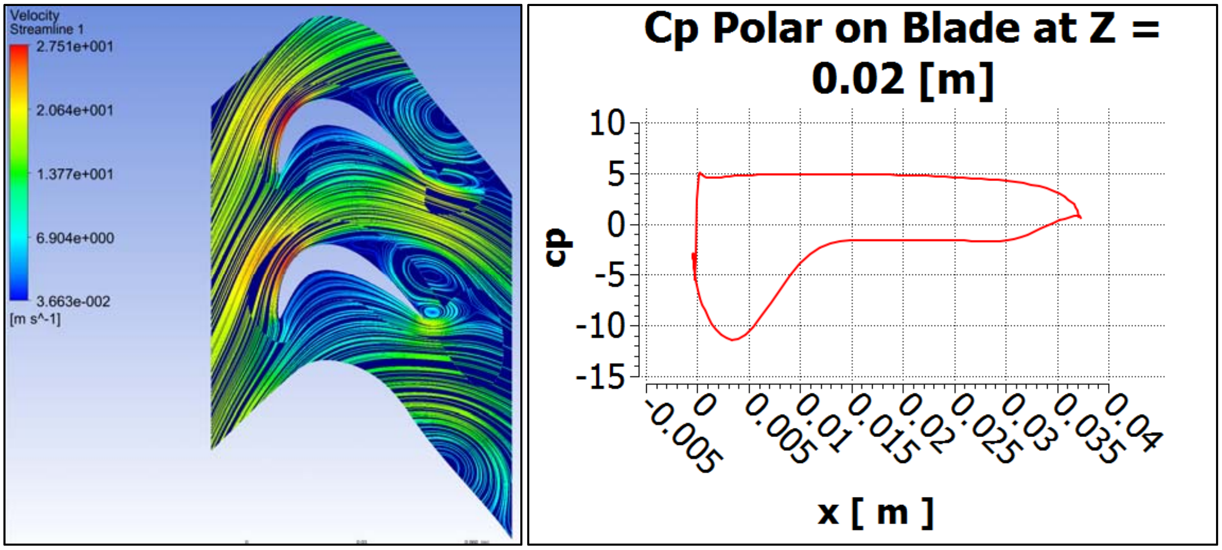

Figure 4: Velocity streamline (on left) and pressure coefficient (on right)

Compressor

For the compressor, CFD was done for the stator. Stator cascade consisted of two parallel blades. Chord spacing ratio was set to 1. The following boundary conditions were set:

- Inlet velocity was to 60 m/s. Additionally, inlet velocity was made parallel to camberline of the turbine blade (17.5^0).
- Outlet reference pressure was set to 101 KPa.
- Periodic boundary conditions were imposed at the edges
- Since the blade was only 30 mm in height, the hub and tip boundary conditions were set to free slip wall to remove effect of secondary and endwall effects.

The compressor blade had the following characteristics:

Thickness ratio ($\frac{t_{max}}{c}$)	0.01
Chord spacing ratio ($\frac{c}{s}$)	1
Deflection	20^0
Chord length	38 mm

Using the above boundary conditions, mesh properties were chosen similar to that of the turbine blade. The mesh size was se to 0.0015 but around the boundary layer, it was set to 0.0008. The following mesh was obtained.

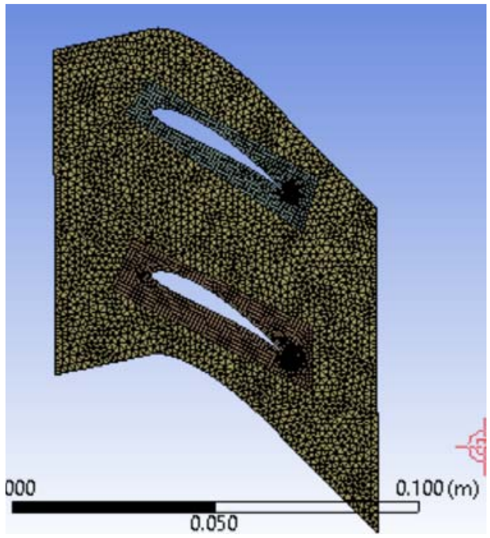

Figure 5: Mesh for compressor blade

On running the CFD, the following pressure and velocity distributions were obtained.

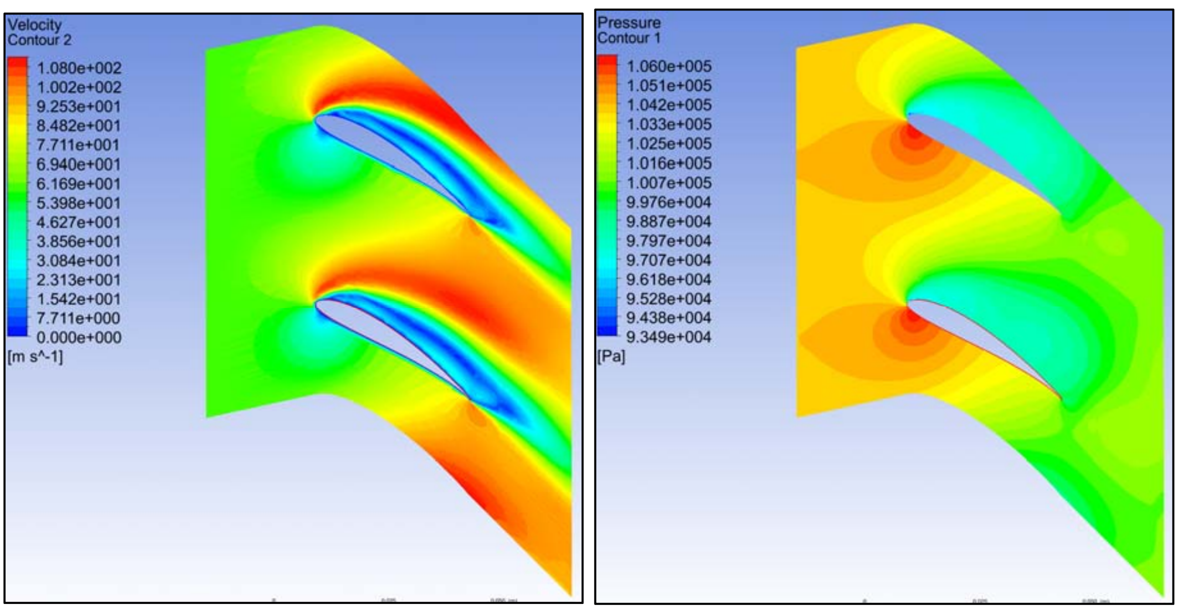

Figure 6: Pressure contour (on left) and velocity contour (on right) for compressor blades

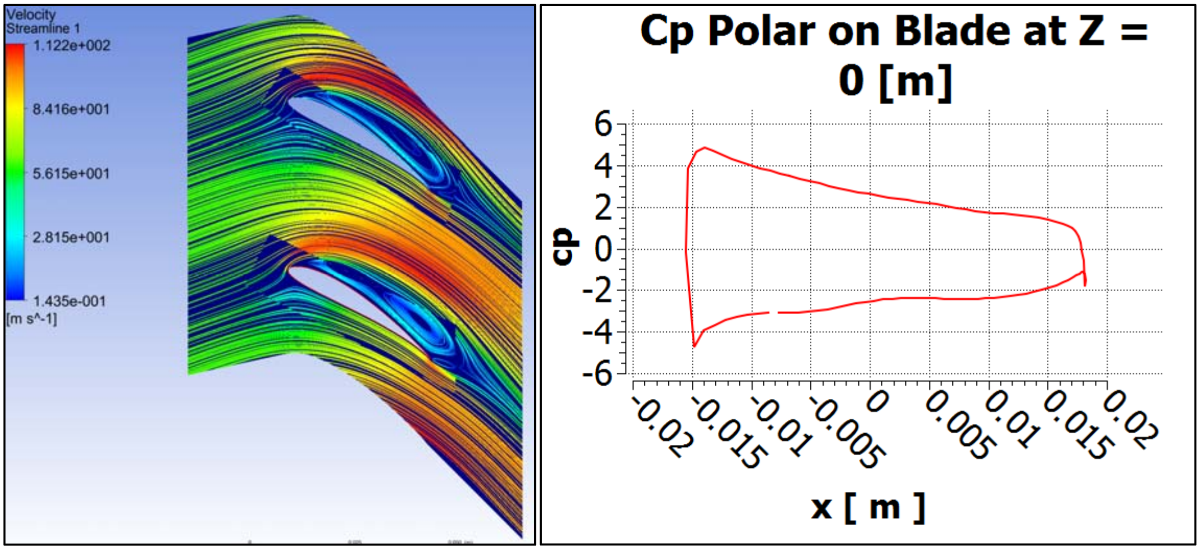

Figure 7: Velocity streamline (on left) and pressure coefficient (on right)

Chord spacing ratio optimization

For optimizing chord spacing ratio, simulation was run on Solidworks. Solidworks provided the ability to quickly change blade spacing and automatically update the flow pattern. Pressure loss was found by finding the average total pressure at the inlet and the average total pressure at the outlet. This was done by extracting 3D pressure point data to excel and averaging them. Then the pressure loss percent was found using:

$$\frac{(P_{0_1} - P_{0_2})}{P_{0_1}} * 100$$

The following graph was obtained when the case of 0.9, 1, 1.1 and 1.2 were run. From the graph we can see, the optimum pressure ratio occurs at 1.1.

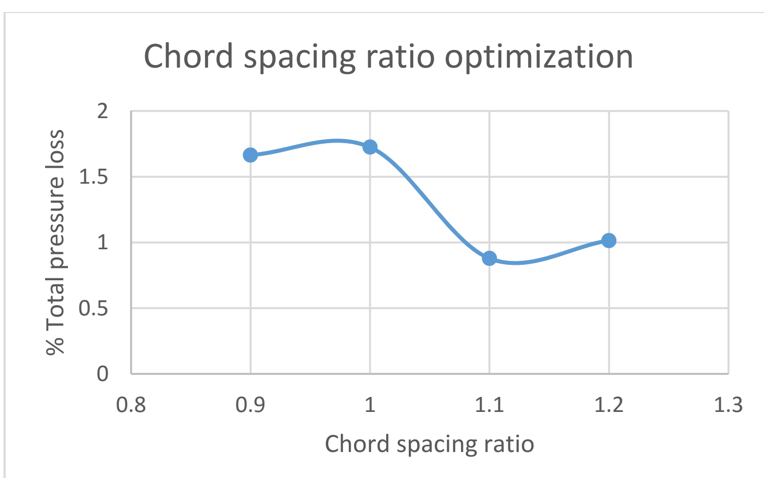

Figure 6: Chord spacing ratio optimization