Heat Transfer, Prof. A. Shojaie, Fall 2021

Sharif University of Technology

Course Project **Due Date: Bahman 15**

Dear all,

One of the most important pieces of equipment in the power plant industry is turbines. According to **Fig. 1**, turbines are used for the expansion of high-pressure and high-temperature gas streams leaving the combustion chamber to generate mechanical power. All steam power plants and gas generators are taking advantage of turbines to meet the electricity requirement in the residential and industrial areas.

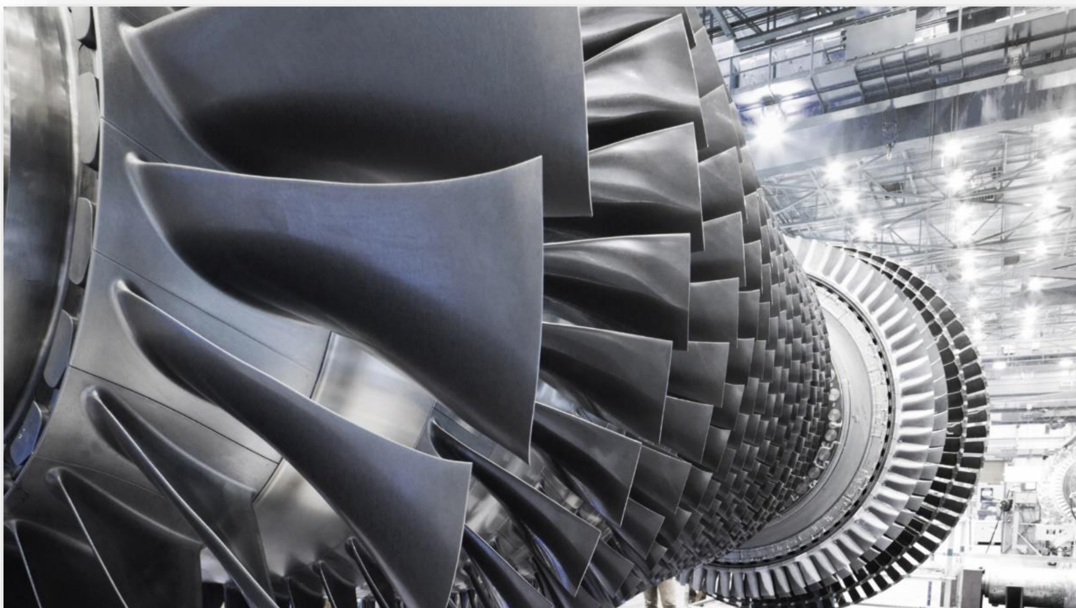

Fig. 1: Gas Turbine Generator

According to **Fig. 2**, turbines mostly consist of two parts, **a)** nozzles blades (stators) **b)** rotor blades. At the stator, the total enthalpy of gas is converted to the kinetic energy. Therefore, rotor meets a high velocity stream and starts rotating and generating mechanical power. In steam and gas turbine power plants, so many turbine stages (stator and rotor) are used to reduce the pressure of the fluid as much as possible. One of the most decisive factors affecting the efficiency and the power output of power plants is TIT (**T**urbine **I**nlet **T**emperature). When gas stream leaves the combustion chamber or the furnace, its temperature and pressure are high enough that impinge on the turbine blades. Much more TIT will culminate in an efficient gas generator with the higher power output. But since turbine blades cannot tolerate a temperature as high as possible, a constraint is imposed on turbomachinery engineers that have to deal with. Because when the temperature rises enough, the material cannot resist it and blade deformation will occur and the power output of the plant is going to fall drastically.

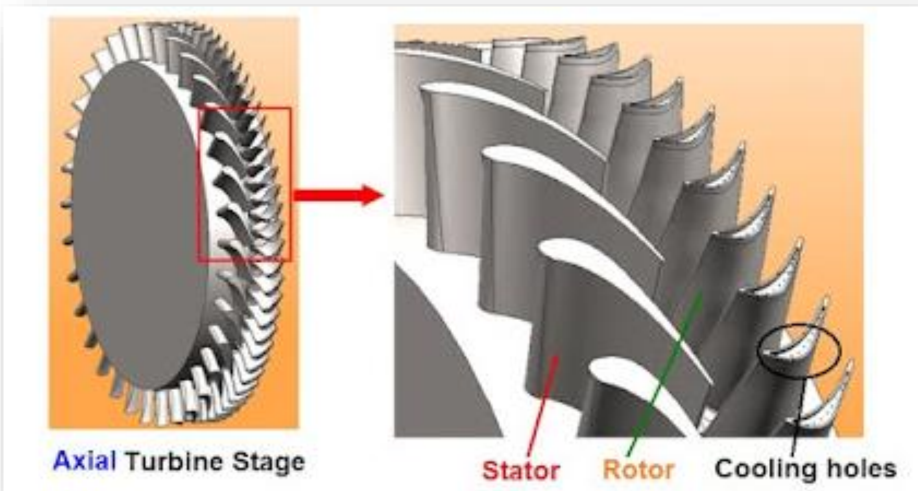

Fig. 2: Axial Turbine Schematic

Thanks to the single-crystal technology, nowadays, the maximum TIT that has been reached is about 1600 °C. To keep high the efficiency of turbines, and prevent from deformation of the stator and rotor blades so many techniques have been proposed. One of the useful and conventional approaches that have been put into practice in power generation cycles is flowing a fraction of pressurized air from the intermediate sections of the compressor to cool down the turbine's blades. This technique is called the air cooling method.

At this project, you are called to model and study heat transfer of Trent XWB (Rolls-Royce Trent series) high-pressure turbine numerically. At the end of the project, you should say whether such a technique is acceptable to implement in or not.

The simplified schematic of one blade is shown in **Fig. 3**. In this typical view of a turbine blade, a routing air keeps the base temperature of the turbine at. Also, notice that the maximum allowable temperature of the blade fabricated from Inconel is about.

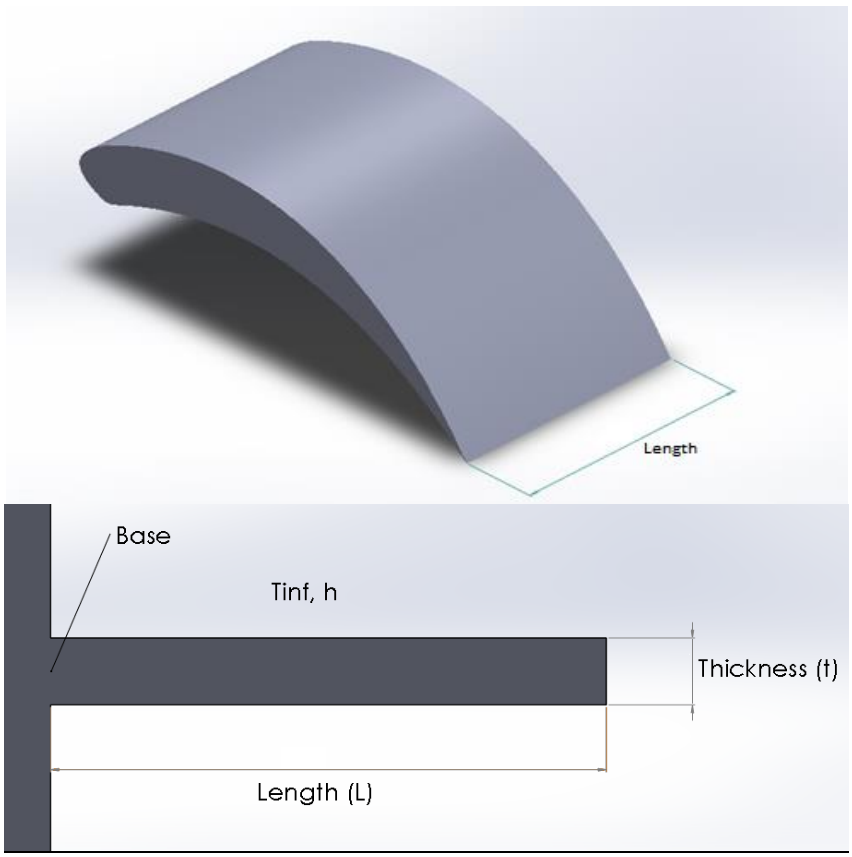

Fig. 3: Schematic of the Project

All the information you need through the project is presenting in below (**Table 1**). Please, generate a fine 2-D mesh and based on the requirements, show this method is satisfactory or not.

Table 1: Required Information

$T_\infty\ (K)$	$T_{Base}\ (K)$	$h\ (\frac{W}{m^2K})$	$Length\ (mm)$	$Thickness\ (mm)$	$Ac\ (mm^2)$	$k\ (\frac{W}{mK})$	$max.\,Allowable\ Temp.\,(K)$
1600	673	800	50	6	600	20	1350

Requirements:

a) If the tip of the blade is assumed to be at the convection condition, find the temperature distribution along the blade at the steady-state operation mode.
(Continue your iteration till your error criteria are going to less than 0.01 ℃)

b) Redo the part (a), but the tip is at the insulation condition and compare your result with the previous one.

c) It is required to see what will happen when the gas generator starts to ignite. At this part that is so interesting too (visit youtube.com, and search for "running of the gas turbine"), assume that a gas generator is at the starting stage. The blades are at 400 K. The TIT will be heightened when time is passing. At such a transient condition, regarding the convergence criteria, when the tip of the blade is at the convection condition, plot the contour of temperature along the blade at t = 0, 30 min, 45 min, 1 h, and 2 h when the TIT is varying with time as follows:

$$T_{\infty}(K) = 400 + 1200\exp[-t(h)]\{-10\,t(h) + \exp[t(h)] - 1\}$$

d) Do you think that the cooling method is a promising option to introduce to all the gas turbine designers?

Best Wishes

از غم و درد مکن ناله و فریاد که دوش / زده‌ام فالی و فریادرسی می‌آید (حافظ)