# AEEM 4063 – Air-Breathing Propulsion

# Project 2: Turbomachinery Design

## Reports Due: November 20th, 2022

## Team Presentations: November 22nd & 29th, 2022

Your team has been tasked with conducting the preliminary aerodynamic design of a single-spool, multi-stage axial compressor and a multi-stage axial turbine to drive the compressor for a modern high-bypass ratio (BPR) engine. The maximum thrust design point is static sea-level take-off conditions. The engine has a BPR = 7 and a total mass flow rate entering the engine at takeoff of 520 kg/s. The goal of this design is to meet the requirements with the fewest number of stages to minimize weight and cost of the turbomachinery design.

The performance engineering team has specified that the compressor must have:

* A compressor pressure ratio of 18 and a polytropic efficiency no lower than
* Flow enters the compressor after passing through the fan with and
* It is assumed that advanced design methods can be used to handle a new de Haller criteria - No compressor stage shall violate )
* Use Figure 5.10 to approximate the work done factor for each stage
* Tip Mach number relative to the blade cannot exceed

The performance engineering team has specified that the turbine must have:

* Turbine inlet temperature
* Polytropic efficiency
* Flow coefficient
* Blade loading coefficient cannot exceed

For the preliminary aerodynamic design of the compressor and turbine, calculate:

1. Rotational speed and annulus dimensions
2. Determine the number of stages for the compressor and turbine
3. Calculate angles and pressure ratio for each stage at the mean radius (mean-line design)
4. Calculate the velocity triangle parameters at the root and tip of for each stage based on free vortex design
5. Generate a table showing all the design parameters for each stage, including the requirements shown above are satisfied
6. 3D print one of your compressor or turbine blades at the UC CEAS 3D Printer Farm (<https://ceas.uc.edu/research/centers-labs/3d-print-farm/tutorials.html>). You can utilize the root, mean, and tip inlet and outlet angles with a representative airfoil shape. You can print a single blade, sector, or scaled-down full disk. Be sure to print a hub for the blade so that there is a reference for the blade angles. Bring your blade to class when you present to pass around to your colleagues.

Section 5.7 in your book may be used as a guide, but you do not need to stick precisely to the same limitations and assumptions. The information provided here may be incomplete. If so, you may ask me for clarification or make assumptions and clearly state what the assumptions are. For example, you may choose to use IGV’s, you may have to set limits on tip speeds, and you have flexibility to choose the mean radius for the design (constant or varying).

Write a report summarizing the design procedure you followed, the results of the preliminary design, and any figures and tables that illustrate the design parameters and that they satisfy all of the requirements laid out. Include a short discussion of at least 500 words on each the compressor and turbine design.

Your team will need to present the results of your turbomachinery design to the class on one of the two class periods reserved for presentations. The presentations should be 5 minutes with 1-2 minutes for questions. Each team member will be expected to present a portion of the work. The presentations should justify the design decisions made and demonstrate that the requirements were satisfied. Presentations should

Please submit:

1. Example hand calculations in a math typeset format (MS Eq. Editor or Latex) in a clear and easy to follow format.
2. Be sure to label all axes, include units, include legends for what is being plotted, and label all figures with a caption that explains what is being plotted.
3. Source code or spreadsheet used for conducting the design calculations. For cod, use a code report generator or submit clearly organized and commented.
4. A description of the team member contributions to the project.