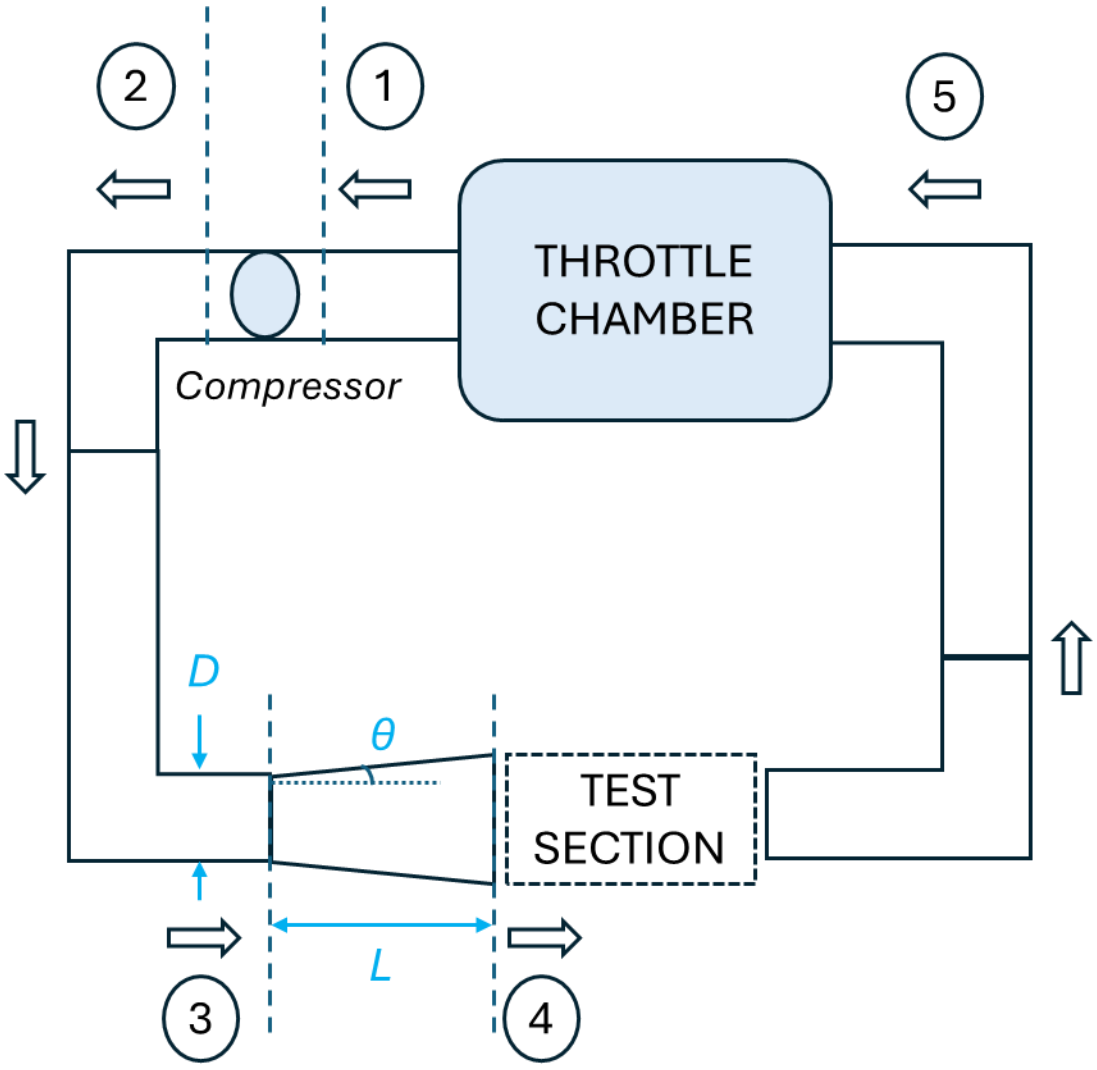
ME302: 2024-25 - II

COURSE PROJECT [Total Marks = 20]

The course project is to be done in a group of 2 or 3

A turbomachine component, which is being designed for a future gas turbine engine by company **X**, is to be tested at a smaller scale in a laboratory for performance analysis. The project is given to research laboratory **Y,** which has a closed loop testing facility for high pressure flows, shown below.



The flow is driven by a compressor and inlet stagnation pressure, p_{01}, can be controlled by the operator. The throttle chamber is positioned to reduce the end stagnation temperature and pressure to the inlet conditions. For testing an article in the facility, the test-section and the upstream diffuser are re-designed and fabricated. The inlet of the diffuser is shown as station 3 and the outlet is shown as station 4. The pipe diameter, D = 0.6 m, and the available length for diffuser, L = 1.5 m. The running facility has the following constraints:

1. Maximum allowable pressure in any part of the facility = 250 kPa (structural requirement).
2. p_{05} >= p_{01}, else constant inlet conditions will not be maintained, and the closed-loop flow will not happen.

The length parameter of the actual prototype, *l_prototype* = 0.2 m. For the model to be representative of real conditions, the Mach number and Reynolds number are to be matched. The target engine conditions for the operation of the component are Mach number = 0.55 and Re (based on *l*) = 3.0*10^6. The company has left it to the laboratory researchers to select the geometric scaling for the model.

Part (a)

For experimental study, the larger the scale, the easier the instrumentation is. Defining *scale* = *l_model/l_prototype*, find the maximum scale (between 0 and 1) which can be tested, meeting the requirements of the company and the constraints of the facility operation. Also report the corresponding inlet stagnation pressure, p_{01}, and the compressor operating point, and indicate the compressor operating point on p_0 *ratio* vs *mdot_ref* curve.

Assume the facility to be adiabatic, which implies that the stagnation temperature remains constant at T_{02} beyond station 2. Use the following data for your analysis:

1. Assume test section inlet diameter, D_4, = 2**l_model* (for sufficient gap)
2. Compressor operation points are tabulated in a file and both .txt and .xlsx files are provided (*mdot_ref = Mass flow rate at some reference condition, T0 ratio = T_{02}/T_{01}, p0 ratio = p_{02}/p_{01}*)
3. $Actual\ mass\ flow\ rate\ (mdot)\ =\ mdot_{ref}\left(\frac{p_{01}}{101.325\ kPa}\right)\sqrt{\frac{293\ K}{T_{01}}}$
4. Inlet stagnation temperature is fixed at 293 K (T_{01} = 293 K)

5. Consider air as an ideal gas with R = 287 J/Kg.K , γ = 1.4 and speed of sound, $a = \sqrt{\gamma RT}$. The viscosity value required for calculating the Reynolds number, $Re = {\rho_4 C_4 l_{model}}/{\mu_4}$, can be assumed to be 1.83 x 10^-5 Pa-s.
6. $\Delta p_{023} = p_{02} - p_{03} = 1.5\%$ of p_{02}
7. For the diffuser, neglect viscous effects and losses as semi-angle, θ, is expected to range from negative values (which corresponds to a nozzle) to low positive, where losses are low.
8. $\Delta p_{045} = p_{04} - p_{05} = 5\%$ of p_{04}

Part (b)

Given that the R&D facility for the project is developed successfully, laboratory **Y** is interested in doing further research by modifying only the test section and the diffuser upstream of the test section. However, any research activity requires industrial funding to cover the fabrication, operation and maintenance costs. Think and specify three different experimental research studies that can be carried out in the facility along with potential benefiting company/companies. For each activity, describe in a short paragraph how the research work can be useful in technological advancement and attract the interest of the company/companies. You may put figures or sketches to better express your thoughts.

Expected documents for submission:

1. **Project report in .pdf format (For those who use LATEX, all LATEX files in a .zip file are to be additionally provided)**
2. **MATLAB code/Python code/MS Excel files used**

PS:

1. **3 bonus marks will be awarded to those who use LATEX for documenting the project report, but only if the LATEX files get successfully executed by the TA's in charge.**
2. **The reports will be checked for originality using Turnitin, to ensure that no group has copied from each other.**
3. **The MATLAB code/Python code/MS Excel files will be executed by the TA's to check if the code is working**