

**Benha University Faculty of Engineering- Shoubra**

**Mechanical . Eng. Department 4thyear Mechanical Power Eng.**

**Sheet No (3) Turbo-machinary A**

1. At inlet to the rotor in a single-stage axial-flow turbine the magnitude of the absolute velocity of fluid is 610 m/s. Its direction is 61° as measured from the cascade front in the direction of the blade motion. At exit of this rotor the absolute velocity of the fluid is 305 m/s directed such that its tangential component is negative. The axial velocity is constant, the blade speed is 305 m/s, and the flow rate through the rotor is 5kg/s. (a) Construct the rotor inlet and exit velocity diagrams showing the axial and tangential components of the absolute velocities, (b) Evaluate the change in total enthalpy across the rotor, (c) Evaluate the power delivered by the rotor, (d) Evaluate the average driving force exerted on the blades, (e) Evaluate the change in static and stagnation temperature of the fluid across the rotor, assuming the fluid to be a perfect gas with *cp* = 1148 J/(kg • K). (f) Calculate the flow coefficient and the blade-loading coefficient. Are they reasonable?
2. A small axial-flow turbine must have an output power of 37 kW when the mass flow rate of combustion gases is 0.5kg/s, and the inlet total temperature is 410 K. The value of the gas constant is 287 J/ (kg • K) and γ = 4/3. The total-to-total efficiency of the turbine is 80%. The rotor operates at 50,000 rpm, and the mean blade diameter is 10 cm. Evaluate (a) the average driving force on the turbine blades, (b) the change in the tangential component of the absolute velocity across the rotor, and (c) the required total pressure ratio across the turbine.
3. A turbine stage of a multistage axial turbine is shown in Figure 6.3. The inlet gas angle to the stator is -36.8°, and the outlet angle from the stator is 60.3°. The flow angle of the relative velocity at the inlet to the rotor is 36.8° and the flow leaves at -60.3°. The value of the gas constant is 287 J/ (kg • K) and γ = 4/3. (a) Assuming that the blade speed is 220 m/s, find the axial velocity, which is assumed constant throughout the turbine, (b) Find the work done by the fluid on the rotor blades for one stage, (c) The inlet stagnation temperature to the turbine is 950 K, and the mass flow rate is m = 400kg/s. Assuming that this turbine produces a power output of 145 MW, find the number of stages, (d) Find the overall stagnation pressure ratio, given that its total to total isentropic efficiency is 0.85. (e) Why does the static pressure fall across the stator and the rotor?
4. A single-stage axial turbine has a total pressure ratio of 1.5 to 1, with an inlet total pressure 300 kPa and temperature of 600 K. The absolute velocity at the inlet to the stator row is in the axial direction. The adiabatic total-to-total efficiency is 80%. The relative velocity is at an angle of 30° at the inlet of the rotor and at the exit it is -35°. If the flow coefficient is 0.9, find the blade velocity. Use compressible flow analysis with *cp =* 1148 J/ (kg • K), γ=1.33 and *R =* 287 J/ (kg K).
5. An axial turbine has a total pressure ratio of 4 to 1, with an inlet total pressure 650 kPa and total temperature of 800 K. The combustion gases that pass through the turbine have γ=1.33, and *R =* 287 J/ (kg • K). (a) Justify the choice of two stages for this turbine. Each stage is normal stage and they are designed the same way, with the blade-loading coefficient equal to 1.1 and the flow coefficient equal to 0.6. The absolute velocity at the inlet to the stator row is at angle 5° from the axial direction. The adiabatic total-to-total efficiency is 91.0%. Find, (b) the angle at which the absolute velocity leaves the stator, (c) the angle of the relative velocity at the inlet of the rotor, (d) the angle at which the relative velocity leaves the rotor, (f) Draw the velocity diagrams at the inlet and outlet of the rotor, (g) What are the blade speed and the axial velocity? A consequence of the design is that each stage has the same work output and efficiency. Find, (h) the stage efficiency and (i) the pressure ratio for each stage.