Problem

Consider the design of a single-stage turbine with axial inlet and exhaust flow. The flow coefficient is specified as $\phi = 0.8$, and the power coefficient is fixed at $\psi = 1.6$. From experience, we expect at this condition a turbine component efficiency of $\eta_t = 0.93$. The combustor exit temperature is $T_{t4} = 1800\,K$, and the flow should be choked at the stator exit.

(a) Calculate the degree of reaction and the flow angles, and draw the velocity triangles to scale.

(b) Calculate the absolute entering velocity V_b, the axial velocity w, the rotor velocity ωr and the total temperature drop ΔT_t. Taking the estimated efficiency into account, calculate the pressure ratio π_t.

(c) The Zweiffel coefficient Ψ_Z should be 0.8. Calculate the axial solidities σ_x of stator and rotor, and sketch a few stator and rotor blades in cross section (use velocity triangle results to set some of the angles).

Concept questions

(1) If the blade speed you calculate seems excessive, suggest possible changes to the design parameters and point out pros and cons.

(2) What would happen to π_t if the engine were throttled such that the temperature T_{t4} is reduced? State your assumptions.

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