Axial Turbine Stage: Gas Angles, Reaction, Loading and Throat Area

Rotor gas angles, degree of reaction, loading coefficient, power and nozzle throat area (choked or not) of an axial gas turbine stage from its velocity triangles.

Input parameters

Unit system: SI

Parameter	Value	Unit
Mean blade speed	300.00	m/s
Axial velocity (constant)	200.00	m/s
Nozzle efflux angle (from axial)	70.000	°
Stage exit swirl angle	0	°
Gas flow	100.00	kg/s
Inlet stagnation temperature	1,126.8	°C
Inlet stagnation pressure	15.000	bar
Nozzle loss coefficient	6.0000	%
Gas specific heat	1.1480	kJ/(kg·K)
Gas ratio of specific heats	1.3333	
Gas constant	0.28700	kJ/(kg·K)

Calculated results

Parameter	Value	Unit
Rotor inlet gas angle	51.284	°
Rotor outlet gas angle	56.310	°
Degree of reaction	8.4174	%
Flow coefficient C_a/U	0.66667	
Temperature drop coefficient $2c_p\Delta T_0/U^2$	3.6633	
Stage stagnation temperature drop	143.60	K
Stage power	16,485	kW
Nozzle exit velocity	584.76	m/s
Relative velocity entering the rotor	319.76	m/s
Relative velocity leaving the rotor	360.56	m/s
Nozzle exit static temperature	1,251.1	K
Nozzle exit static pressure	9.2951	bar
Nozzle pressure ratio	1.6138	
Nozzles choked (1 = yes, 0 = no)	0	
Annulus area at nozzle exit	0.19314	m^2
Nozzle throat area	0.066059	m^2
Relative Mach number at rotor inlet	0.46214	

Notes for this case

- Mean-line stage with constant axial velocity and equal inlet and outlet velocities ($C_1 = C_3$). Throat area ignores the effect of

friction on the critical conditions, as in the textbook.

Formula and method

$$\tan\beta_2 = \tan\alpha_2 - \frac{U}{C_a}, \quad \tan\beta_3 = \tan\alpha_3 + \frac{U}{C_a}, \quad \Lambda = \frac{C_a}{2U}(\tan\beta_3 - \tan\beta_2)$$

$$\psi = \frac{2c_p\Delta T_{0s}}{U^2} = \frac{2C_a}{U}(\tan\beta_2 + \tan\beta_3), \quad T_2 - T_2{}' = \lambda_N \frac{C_2^2}{2c_p}$$

Variables

U	Mean blade speed	m/s
C_a	Axial velocity (constant)	m/s
α_2	Nozzle efflux angle (from axial)	rad
α_3	Stage exit swirl angle	rad
$\dot{m}$	Gas flow	kg/s
T_{01}	Inlet stagnation temperature	K
p_{01}	Inlet stagnation pressure	Pa
λ_N	Nozzle loss coefficient	-
c_p	Gas specific heat	J/(kg·K)
γ	Gas ratio of specific heats	-
R	Gas constant	J/(kg·K)
β_2	Rotor inlet gas angle	rad
β_3	Rotor outlet gas angle	rad
Λ	Degree of reaction	-
ϕ	Flow coefficient C_a/U	-
ψ	Temperature drop coefficient 2c_pΔT₀/U²	-
ΔT_{0s}	Stage stagnation temperature drop	K
P	Stage power	W
C_2	Nozzle exit velocity	m/s
V_2	Relative velocity entering the rotor	m/s
V_3	Relative velocity leaving the rotor	m/s
T_2	Nozzle exit static temperature	K
p_2	Nozzle exit static pressure	Pa
p_{01}/p_2	Nozzle pressure ratio	-
choked	Nozzles choked (1 = yes, 0 = no)	-
A_2	Annulus area at nozzle exit	m²
A_{2N}	Nozzle throat area	m²
M_{V2}	Relative Mach number at rotor inlet	-

Method and standards

Mean-line axial turbine stage design.

Assumptions and limits

- Mean radius only; constant axial velocity.

Report details

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Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/boilers-power-plant/gas-turbines-combined-cycle/axial-turbine-stage

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Reopens the calculator with the inputs of this report.