Axial Compressor Stage: Velocity Triangles, de Haller and Reaction

Blade and air angles, de Haller number, degree of reaction and stage pressure ratio of an axial compressor stage from blade speed and temperature rise.

Input parameters

Unit system: SI

Parameter	Value	Unit
Mean blade speed	280.00	m/s
Axial velocity	160.00	m/s
Air angle entering the rotor (0 = axial)	25.000	°
Stage stagnation temperature rise	25.000	K
Work-done factor	88.000	%
Air specific heat	1.0050	kJ/(kg·K)
Ratio of specific heats	1.4000	
Stage inlet stagnation temperature	86.850	°C
Stage inlet stagnation pressure	1.8000	bar
Stage isentropic efficiency	90.000	%

Calculated results

Parameter	Value	Unit
Whirl velocity change	101.97	m/s
Whirl velocity leaving the rotor	176.58	m/s
Rotor inlet relative angle	52.081	°
Rotor outlet relative angle	32.878	°
Air angle leaving the rotor	47.820	°
Rotor deflection	19.203	°
de Haller number (keep at or above 0.72)	0.73175	
Degree of reaction	55.145	%
Flow coefficient C_a/U	0.57143	
Stage loading $c_p\Delta T_0/U^2$	0.32047	
Stage pressure ratio	1.2364	
Stage exit stagnation pressure	2.2255	bar
Stage exit stagnation temperature	385.00	K
Relative velocity entering the rotor	260.36	m/s
Relative Mach number at rotor inlet	0.69962	

Notes for this case

- Mean-line design with constant axial velocity (C_a1 = C_a2). Reaction from 1 − (C_w1 + C_w2)/2U assumes the stage outlet velocity equals the inlet velocity (a repeating stage).

Formula and method

$$\Delta T_{0s} = \frac{\lambda U(C_{w2} - C_{w1})}{c_p} = \frac{\lambda U C_a(\tan\beta_1 - \tan\beta_2)}{c_p}, \quad \tan\beta = \frac{U - C_w}{C_a}$$

$$\frac{V_2}{V_1} = \frac{\cos\beta_1}{\cos\beta_2}, \quad \Lambda = 1 - \frac{C_{w1} + C_{w2}}{2U}, \quad \frac{p_{03}}{p_{01}} = \left(1 + \frac{\eta_s \Delta T_{0s}}{T_{01}}\right)^{\gamma/(\gamma-1)}$$

Variables

U	Mean blade speed	m/s
C_a	Axial velocity	m/s
α_1	Air angle entering the rotor (0 = axial)	rad
ΔT_{0s}	Stage stagnation temperature rise	K
λ	Work-done factor	-
c_p	Air specific heat	J/(kg·K)
γ	Ratio of specific heats	-
T_{01}	Stage inlet stagnation temperature	K
p_{01}	Stage inlet stagnation pressure	Pa
η_s	Stage isentropic efficiency	-
ΔC_w	Whirl velocity change	m/s
C_{w2}	Whirl velocity leaving the rotor	m/s
β_1	Rotor inlet relative angle	rad
β_2	Rotor outlet relative angle	rad
α_2	Air angle leaving the rotor	rad
$\beta_1 - \beta_2$	Rotor deflection	rad
V_2/V_1	de Haller number (keep at or above 0.72)	-
Λ	Degree of reaction	-
ϕ	Flow coefficient C_a/U	-
ψ	Stage loading c_pΔT₀/U²	-
p_{03}/p_{01}	Stage pressure ratio	-
p_{03}	Stage exit stagnation pressure	Pa
T_{03}	Stage exit stagnation temperature	K
V_1	Relative velocity entering the rotor	m/s
M_{V1}	Relative Mach number at rotor inlet	-

Method and standards

Mean-line axial compressor 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-compressor-stage

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Reopens the calculator with the inputs of this report.