Jet Engine Intake Fan – CFD Snapshot

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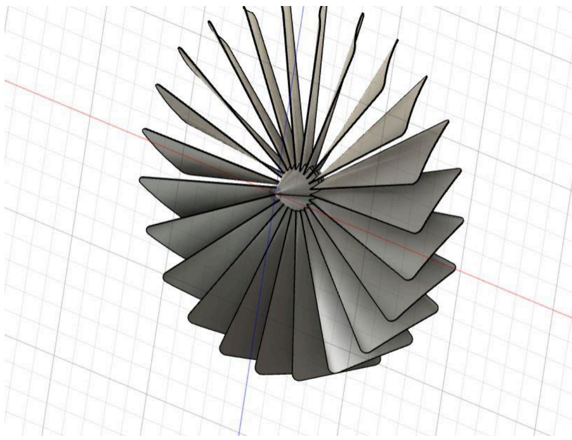
Overview
Custom axial intake fan modeled in Fusion 360 and analyzed in ANSYS Fluent 2025 R1.

Goal: visualize compressible flow behavior around a full-annulus rotor and compare subsonic vs. transonic inflow.

Geometry & Domain

- Full 360° rotor (multi-blade open rotor) with central hub.
- External, unshrouded configuration to highlight wake and swirl development.
- Clean, watertight fluid volume exported from CAD.



Physics & Models

- Steady RANS, compressible; energy equation on; ideal-gas density.
- Turbulence: k-ω SST (turbomachinery standard; robust through adverse pressure gradients).
- Reference frame: single rotating (MRF) region for the rotor.
- Discretization: second-order for flow variables; coupled pressure-based solver.

Boundary Conditions

- Pressure far-field: 1 atm, T≈300 K with two freestream conditions
  - **Case A:** $M_\infty = 0.8$
  - **Case B:** $M_\infty = 1.0$
- No-slip, adiabatic walls on blades and hub.
- Outer domain surfaces: far-field/symmetry.

Meshing Approach

- Unstructured volume mesh with local refinement at leading/trailing edges and in the wake.
- Inflation layers on blades to resolve boundary layer; target y+ ≈ 30–50(wall-function regime).
- Quality checks: skewness within recommended limits; smooth growth ratios.

Convergence & Monitors

- Residual targets ≤ 1e-4 (continuity and momentum); energy/turbulence similar or tighter.
- Monitors tracked for area-averaged static pressure upstream/downstream and mass-flow balance until plateau.

Results & Visual Evidence

- **Velocity Contours (M=0.8):** Attached flow over most of the span with pronounced acceleration in blade passages; thin wakes and orderly helical pathlines indicate effective swirl imparted by the rotor.
- **Static-Pressure Contours (M=0.8):** Peak pressures at leading-edge stagnation; smooth pressure recovery downstream with limited loss zones.
- **Static-Pressure Contours (M=1.0):** Stronger gradients across the blade surfaces; localized shock-like features (shocklets) near mid-chord/outer span; broader wake with higher loss signature.
- **3D Pathlines:** Helical trajectories confirm swirl and mixing; outer-span lines deflect more sharply, consistent with higher local relative Mach numbers and tip-region dynamics.

Interpretation

- The open-rotor (no casing/stator) produces clear compression and swirl but limits achievable pressure ratio and elevates wake losses relative to a shrouded, staged design.
- Transition from M=0.8 to M=1.0 introduces transonic compression on the suction side and increases total-pressure loss in the wakes—qualitatively consistent with axial-fan behavior entering the transonic regime.

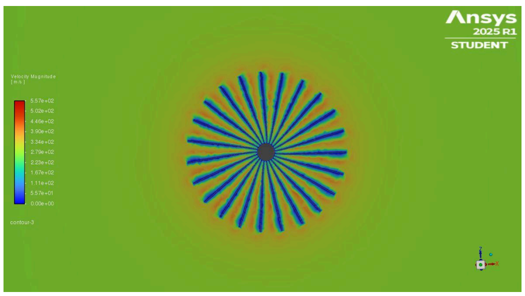
Limitations & Assumptions

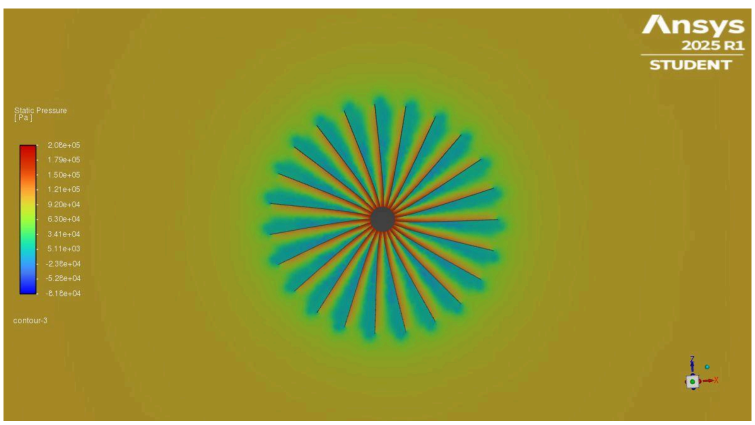
- Steady MRF (no sliding-mesh unsteadiness).
- No inlet bellmouth/casing; no tip-clearance modeling.
- Ideal-gas, adiabatic walls; single rotor with no downstream stator.
- Wall-function y+ target (not fully wall-resolved).

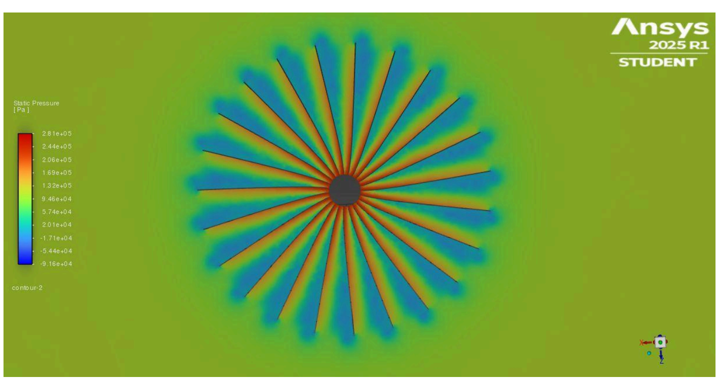
Next Steps

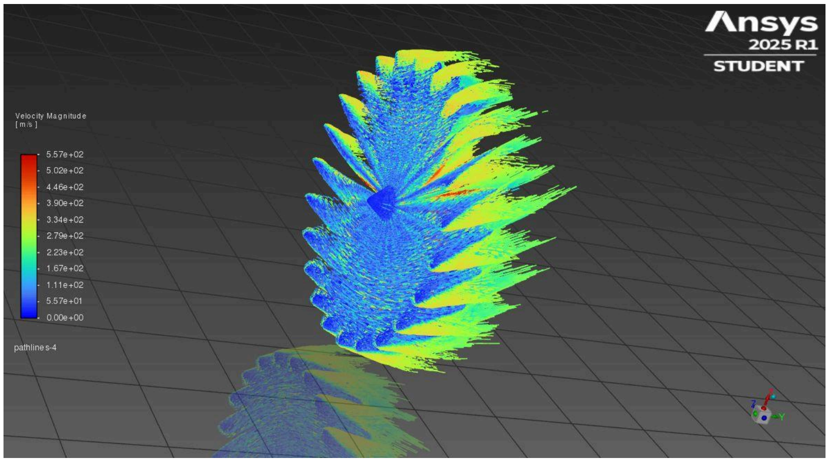
1. Add annulus and inlet contraction; include tip clearance.
2. Use a sliding-mesh transient to capture rotating shocks/unsteadiness at M≈1M\approx1.
3. Switch to a periodic sector (e.g., one blade passage) to concentrate cells and refine the boundary layer (y+<1y^+<1) or apply scalable wall functions consistently.
4. Extract quantitative metrics: area-averaged Δps\Delta p_s, stage pressure ratio, torque, and efficiency; map vs. flow coefficient and RPM.
5. Run a parametric design sweep (stagger, chord, solidity, twist) to study shock strength and loss trends.

CFD Figures








Ansys
2025 R1
STUDENT
Velocity Magnitude
[m/s]
5.57e+02
5.02e+02
4.46e+02
3.90e+02
3.34e+02
2.79e+02
2.23e+02
1.67e+02
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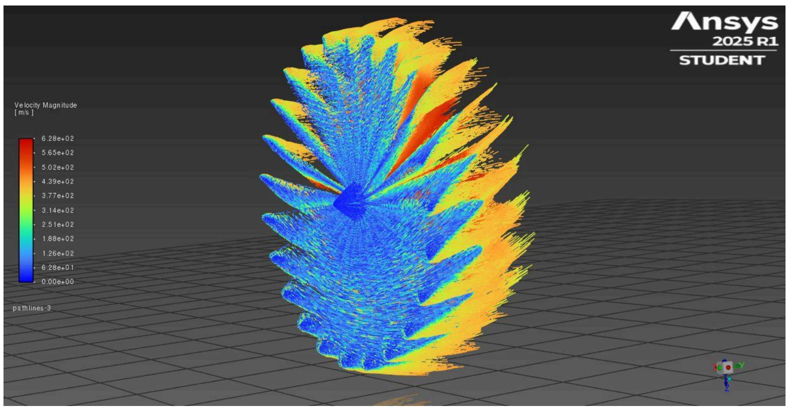
0.00e+00
pathlines-4


Ansys
2025 R1
STUDENT
Velocity Magnitude
[m/s]
6.28e+02
5.65e+02
5.02e+02
4.39e+02
3.77e+02
3.14e+02
2.51e+02
1.88e+02
1.26e+02
6.28e+01
0.00e+00
pathlines-3