Multistage Axial Turbine Aerodynamic Design

Case Study 1C

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OBJECTIVES

☐ Apply *aerodynamic design programs* to multistage axial turbine cases with design and test performance known.
  - AT1DP
  - AT3DP
  - BLADE3DR

☐ Demonstrate their validity.

☐ Investigate aerodynamic design philosophy behind.

☐ 1\(^{st}\) Case
  - NASA 2-stage axial turbines for aviation gas turbines for Mach 2.5 flight
    (NASA TM X-148, 1959)
AT3DP GEOMETRY DESIGN (2/2)
BLADE FINAL DESIGN – AT3DP : STATOR 1 GEOMETRY (1/2)
BLADE FINAL DESIGN – AT3DP : STATOR 1 CFD PERFORMANCE (3/3)
BLADE FINAL DESIGN – AT3DP : ROTOR 1 GEOMETRY (1/2)
BLADE FINAL DESIGN – AT3DP : ROTOR 1 CFD PERFORMANCE (1/3)
BLADE FINAL DESIGN – AT3DP : Rotor 1 CFD PERFORMANCE (3/3)
BLADE FINAL DESIGN – AT3DP : STATOR 2 GEOMETRY (1/2)
BLADE FINAL DESIGN – AT3DP : STATOR 2 GEOMETRY (2/2)
BLADE FINAL DESIGN – AT3DP : STATOR 2 CFD PERFORMANCE (1/3)
BLADE FINAL DESIGN – AT3DP : STATOR 2 CFD PERFORMANCE (3/3)
BLADE FINAL DESIGN – AT3DP : ROTOR 2 GEOMETRY (1/2)
BLADE FINAL DESIGN – AT3DP : ROTOR 2 CFD PERFORMANCE (1/3)
BLADE FINAL DESIGN – AT3DP : ROTOR 2 CFD PERFORMANCE (2/3)
BLADE FINAL DESIGN – AT3DP : ROTOR 2 CFD PERFORMANCE (3/3)
BLADE FINAL DESIGN – AT3DP : STAGE CFD PERFORMANCE
BLADE FINAL DESIGN – AT3DP : CFD PERFORMANCE (1/6)
BLADE FINAL DESIGN – AT3DP : CFD PERFORMANCE (3/6)
BLADE FINAL DESIGN – AT3DP : CFD PERFORMANCE (5/6)
Starting with AT1DP to AT3DP (through BLADE3DR check), it was successfully demonstrated to complete aerodynamic design of a two-stage axial turbine.

- Traditional throughflow design/analysis programs can be replaced by AT3DP which will provide,
  - Higher accuracy of flow analysis by 3D compressible flow solver with turbulent viscous body forces
  - Significantly shorter time of design iterations
  - Directly linked to Final Full CFD and CAD

- Thanks to
  - Efficiently interacting 3D blade design logic ← Meridional contours, blade metal angle and thickness
  - Fast 3D CFD solver with viscous effects indirectly considered

Simplified CFD of AT3DP predicts aero performance exceeding targets.

- Higher isentropic efficiency will be required due to the absence of rotor tip leakage.
- A little larger choked flow was chosen on purpose.

Next step will be the final full CFD which includes rotor tip leakages and a complete leading/trailing-edge modeling (but no further demonstrations).