Comparison of Full and Partial Admission Flow Fields in the Simplex Turbine

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Outline

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- Flow code description - CORSAIR
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  - Full admission Simplex turbine
  - Partial admission Simplex turbine
- Conclusions
Motivation

- Determine the effects of partial admission flow on:
  - rotor performance as a function of circumferential location
  - unsteady rotor loading
- Provide an efficient technique for determining turbine performance
Flow Code Capabilities - I

- CORSAIR
  - Unsteady time-dependent equations of motion
  - Full Navier-Stokes, thin-layer Navier-Stokes or Euler
  - Variable fluid properties (Cp, gamma)
- Third-order spatial discretization of inviscid fluxes
  - Roe's scheme
- Second-order spatial discretization of viscous fluxes
  - Standard central differences
- Second-order temporal accuracy
- Multi-block O-H grid topology
  - O-grids around airfoils and in tip clearance regions
  - H-grids for remainder of flow field and nozzles
  - Well-suited for medium-to-fine grain parallel simulations
Flow Code Capabilities - II

- **Turbulence models**
  - Highly-modified Baldwin-Lomax model

- **Transition models**
  - Abu-Ghannam and Shaw (natural)
  - Mayle (natural)
  - Modified Roberts' correlation (bubble)

- **Boundary conditions**
  - Steady and unsteady inlet and exit
  - Specified wall temperature or heat flux
  - Film cooling/mass injection
  - Actuator disk
  - Component linking

- **Grid Motion**
  - Arbitrary translation/rotation
  - Blade vibration
Flow Code Capabilities - III

- **MPI and OpenMP used for parallel simulations**
  - decomposition by blade row
  - decomposition by blade passage
  - decomposition by O- and H-grids
  - decomposition by component
  - user specified decomposition

- **Graphical User Interface**
  - Grid generation
  - Flow solver
  - Error checking
  - Design page
  - User's manual/help facility
  - Post-processing

- **Miscellaneous capabilities**
  - Conjugate heat transfer capability
  - Provides unsteady pressure file for stress analysis
  - Provide Fourier decomposition of unsteady pressures
  - Will run on any Unix, Linux or Windows NT platform
CORSAIR Future Directions

- Modifying code for pump geometries
  - incorporating incompressible flow physics
- Incorporate two-phase flow modeling
- Incorporate cavitation modeling
Simplex Turbine Simulations

- **Objective** - determine the effects of partial admission on the rotor unsteady load and performance as a function of circumferential location

- **Full-Admission simulation (FA)**
  - 1 nozzle and 8 rotors modeled
  - 750,000 grid points
  - 8 full cycles (one complete rotor revolution) completed

- **Partial-Admission simulation (PA)**
  - 6 nozzles and 95 rotors modeled
  - 7 million grid points
  - 0.95 revolutions completed
  - PA-IN - in region of nozzle flow
  - PA-OUT - outside the region of nozzle flow
Instantaneous Mach Number

FULL ADMISSION

PARTIAL ADMISSION
Unsteady Rotor Pressure Envelopes (FA)

11.7% Span

50.0% Span

88.3% Span

P/Pr

X/C

Minimum
Maximum
Time-Avg
Unsteady Rotor Pressure Envelopes (PA-OUT)

- 13.3% Span
- 50.0% Span
- 86.7% Span

Legend:
- Minimum
- Maximum
- Time-Avg

X/C vs. P/Pt graphs for different spans.
Unsteady Pressure - 11.7% Span (FA)
Unsteady Pressure - 13.3% Span (PA)
Unsteady Decomposition - 11.7% Span (FA)
Unsteady Pressure - 50.0% Span (PA)

10% Chord S.S.

50% Chord S.S.

90% Chord S.S.

10% Chord P.S.

50% Chord P.S.

90% Chord P.S.
Pressure Decomposition - 50.0% Span (FA)

10% Chord S.S.

10% Chord P.S.

50% Chord S.S.

50% Chord P.S.

90% Chord S.S.

90% Chord P.S.

9/7/01
Unsteady Pressure - 88.3\% Span (FA)

50\% Chord S.S.

10\% Chord S.S.

90\% Chord S.S.

10\% Chord P.S.

50\% Chord P.S.

90\% Chord P.S.
Unsteady Pressure - 86.7% Span (PA)

10% Chord S.S.

50% Chord S.S.

90% Chord S.S.

10% Chord P.S.

50% Chord P.S.

90% Chord P.S.

9/7/01
Pressure Decomposition - 88.3% Span (FA)
Pressure Decomposition - 86.7% Span (PA)
Unsteady Integrated Forces (FA)

- Axial Force
- Radial Force
- Tangential Force
Unsteady Integrated Forces (PA)
Conclusions

- **Full admission simulation performed for the Simplex turbine**
  - models one nozzle and 12 rotors
  - Mach number of flow exiting nozzle low
  - Mach number at rotor exit too high
  - unsteadiness predominantly a nozzle-passing and twice nozzle-passing frequency

- **Partial admission simulation underway for Simplex turbine**
  - models all nozzles and rotors
  - design Mach number obtained at nozzle exit
  - design Mach number obtained at rotor exit
  - unsteadiness at nozzle passing and lower frequencies