Overview

- Corsair algorithms
- Code capabilities
- Sample test cases
- Future plans
- Code validation (partial list)
CORSAIR Algorithms - I

- **Time-dependent equations of motion**
  - Full Navier-Stokes, thin-layer Navier-Stokes or Euler
  - Variable fluid properties \((C_p, \gamma)\) as a function of \(P, T\)

- **Third-order spatial discretization of inviscid fluxes**
  - Roe

- **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 parallel simulations
CORSAIR Algorithms - II

- Turbulence models
  - Highly-modified Baldwin-Lomax model

- Transition models
  - Abu-Ghannam and Shaw
  - Mayle
  - Roberts

- Boundary conditions
  - Steady and unsteady inlet and exit
  - Specified wall temperature or heat flux
  - Film cooling/mass injection
  - Symmetry, part-span shrouds
  - Actuator disk
  - Component linking

- Grid Motion
  - Arbitrary translation/rotation
  - Blade vibration
CORSAIR Algorithms - III

- **Parallel simulations**
  - MPI used for coarse-grain decomposition
    - decomposition by blade row or passage
    - decomposition by O- and H-grids
    - decomposition by component
    - user specified decomposition
  - OpenMP used for fine-grain decomposition

- **Graphical User Interface**
  - Grid generation and flow solver
  - Error checking and user’s manual/help facility
  - Post-processing
• Miscellaneous capabilities
  – Conjugate heat transfer capability
  – Provides unsteady pressure file for stress analysis
  – Comprehensive design page
  – Provide Fourier decomposition of unsteady pressures
  – Will run on any Unix, Linux or Windows NT platform
Full- and Partial-Admission Turbine Simulations

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

  - Simplex supersonic turbine
  - Straight centerline nozzles
  - Full-Admission simulation
    - 1 nozzle and 8 rotors modeled
    - 10 global cycles
  - Partial-Admission simulation
    - 6 nozzles and 95 rotors modeled
    - 1+ revolutions

03/12/2002
Simplex Turbine
Unsteady Pressure – Full Admission – 50% Span

03/12/2002
Unsteady Pressure – Partial Admission – 50% Span

FLOWING PORTION

NON-FLOWING

50% Chord S.S.

10% Chord S.S.

90% Chord S.S.

10% Chord P.S.

50% Chord P.S.

90% Chord P.S.

03/12/2002
Pressure Decomp – Full Admission – 50% Span

03/12/2002
Unsteady Integrated Tangential Force

FULL ADMISSION

FLOW PORTION

NON-FLOWING PORTION

PARTIAL ADMISSION

03/12/2002
Variable Fluid Property RLV-133 Simulations

- **Objective** - determine the differences in loadings and performance predicted with constant and variable fluid property simulations
- **Cp and gamma varies as a function of temperature and pressure**
  - equations for JP, RP, kerosene, oxygen and hydrogen
- **Constant fluid property simulation**
  - 2-nozzle/5-rotor simulation
  - 8 full cycles completed
- **Variable fluid property simulation**
  - 2-nozzle/5-rotor simulation
  - 8 full cycles completed
Instantaneous Mach Number - Midspan

VARIABLE FLUID PROPERTIES

CONSTANT FLUID PROPERTIES

03/12/2002
Instantaneous Entropy Function - Vane Exit

CONSTANT FLUID PROPERTIES

VARIABLE FLUID PROPERTIES

03/12/2002
Instantaneous Entropy Function - Rotor Exit

CONSTANT FLUID PROPERTIES

VARIABLE FLUID PROPERTIES

Tip Clearance Flow

Rotor Wakes
Unsteady pressure – Rotor L.E.

Time-averaged and unsteady pressures similar between 25% and 75% span

\[
P/P_\infty
\]

\[
t \times 10^3 \text{ (sec)}
\]

25% SPAN

50% SPAN

-------- CONSTANT SPECIFIC HEATS
-- -- -- -- VARIABLE SPECIFIC HEATS
Unsteady pressure – Rotor L.E.

Time-averaged and unsteady pressures different in endwall regions

\[ \frac{P}{P_{\infty}} \]

\[ \Delta P_{1/2}^{0.040} \]

\[ f \times 10^{-3} \ (\text{Hz}) \]

\[ t \times 10^3 \ (\text{sec}) \]

25% SPAN

50% SPAN

-------- CONSTANT SPECIFIC HEATS
--- --- --- VARIABLE SPECIFIC HEATS

03/12/2002
Pumps and Inducers

Objective – Extend the code to pump and inducer geometries; enable flange-to-flange predictions

COMPUTATIONAL GRID

INSTANTANEOUS PRESSURE
Current Work and Future Plans

- General fluid properties
  - Reformulate equations without perfect gas assumption
  - Tabular fluid properties or compute based on equation of state
- "All-speed" version of Corsair
  - Sensors to switch between incompressible (pre-conditioning) and compressible physics
  - Dual time stepping for time accuracy
- Two-phase flows
- Cavitation modeling
## CORSAIR Validation - I

<table>
<thead>
<tr>
<th>Test Case</th>
<th>Flow</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTRC LSRR Turbine (1 and 1.5-stage)</td>
<td>subsonic</td>
<td>Steady and unsteady pressure, wake data, exit traverse data, hot streak data, tip clearance data</td>
</tr>
<tr>
<td>Langston Cascade</td>
<td>subsonic</td>
<td>Steady pressure, loss distributions, flow angle distributions, Stanton No. distributions</td>
</tr>
<tr>
<td>PW F119 2-stage counter-rotating turbine</td>
<td>transonic</td>
<td>Steady and phase-resolved unsteady pressure, efficiency, film cooling</td>
</tr>
<tr>
<td>SSME 2-stage turbine</td>
<td>subsonic</td>
<td>Steady and phase-resolved unsteady pressure</td>
</tr>
<tr>
<td>GE LSRT 2-stage turbine</td>
<td>subsonic</td>
<td>Steady pressure data, phase-resolved unsteady momentum thickness and shape factor</td>
</tr>
<tr>
<td>Test Case</td>
<td>Flow</td>
<td>Notes</td>
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<tr>
<td>----------------------------------------</td>
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<td>-----------------------------------------------------------------------</td>
</tr>
<tr>
<td>NASA CERTS single-stage turbine</td>
<td>high</td>
<td>Steady pressure data, exit traverse of flow angle, total pressure and total temperature</td>
</tr>
<tr>
<td>UTC Carrier centrifugal compressor</td>
<td>subsonic</td>
<td>Steady pressure data, surface flow visualization</td>
</tr>
<tr>
<td>NASA Ames NACA 0012 pitching airfoil</td>
<td>transonic</td>
<td>Lift, drag and moment histograms (blade vibration, plunging and pitching)</td>
</tr>
<tr>
<td>VKI cascade</td>
<td>subsonic</td>
<td>Steady and unsteady pressure data, Strouhal number (vortex shedding)</td>
</tr>
<tr>
<td>Test Case</td>
<td>Flow</td>
<td>Notes</td>
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<td>------------------------------</td>
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<td>----------------------------------------------------</td>
</tr>
<tr>
<td>ABLE boundary layer analysis</td>
<td>subsonic</td>
<td>Boundary layer thickness, momentum thickness, skin friction</td>
</tr>
<tr>
<td>Roberts' cascade; PAK-B cascade</td>
<td>subsonic</td>
<td>Steady pressure data (transition models)</td>
</tr>
<tr>
<td>Circular cylinder</td>
<td>subsonic</td>
<td>Flow visualization, time-averaged separation location</td>
</tr>
<tr>
<td>Flat plate</td>
<td>subsonic</td>
<td>Analytical (laminar) and empirical skin friction</td>
</tr>
</tbody>
</table>