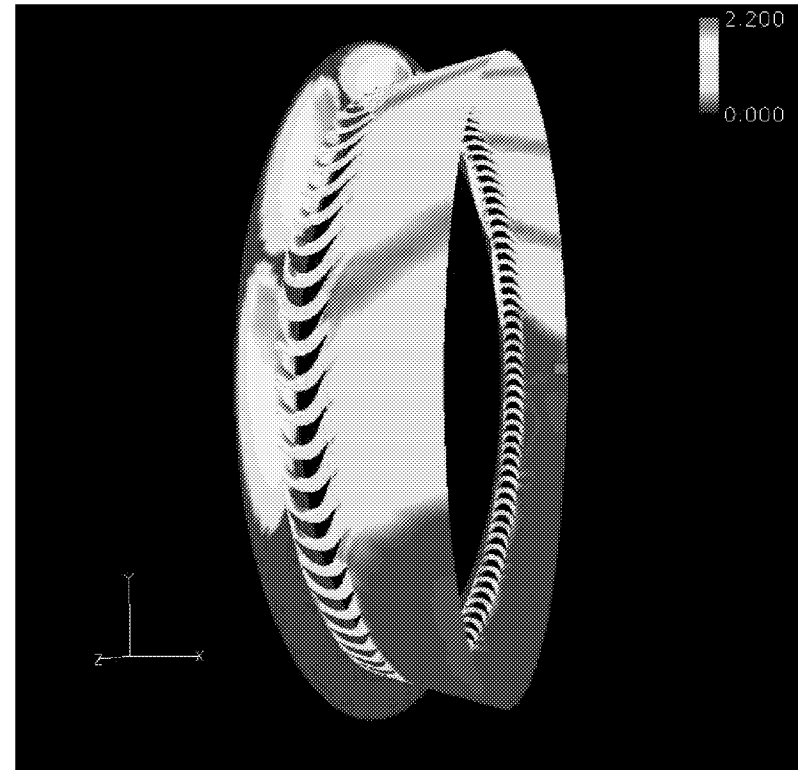
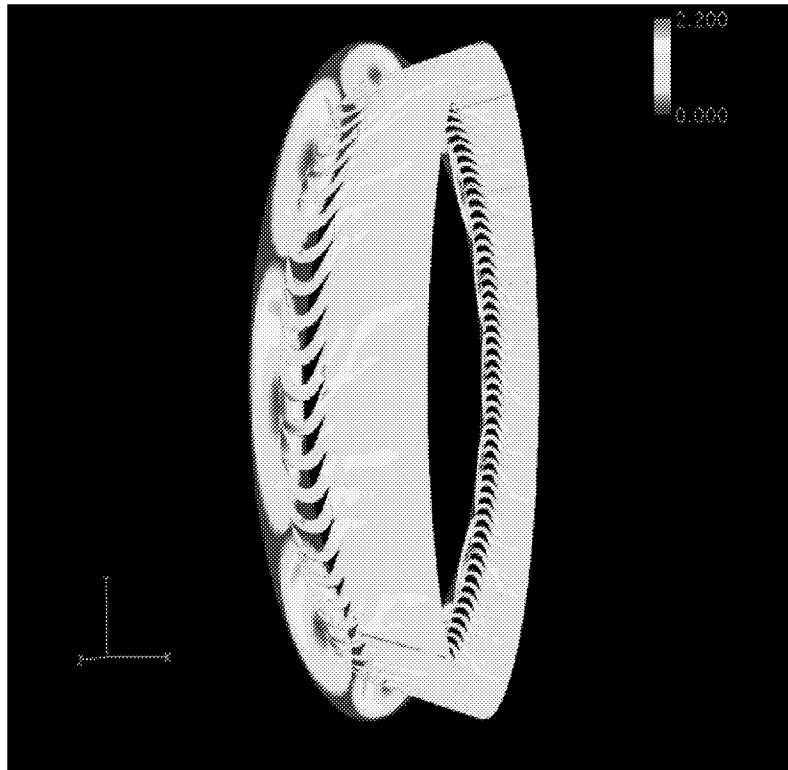


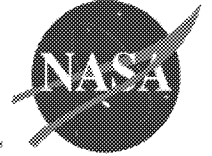
Comparison of Full and Partial Admission Flow Fields in the Simplex Turbine



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MSFC, AL 35812

10 September 2001

Outline



- **Motivation**
- **Flow code description - CORSAIR**
 - Capabilities
 - Future directions
- **Results**
 - 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 (C_p , γ)
- **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



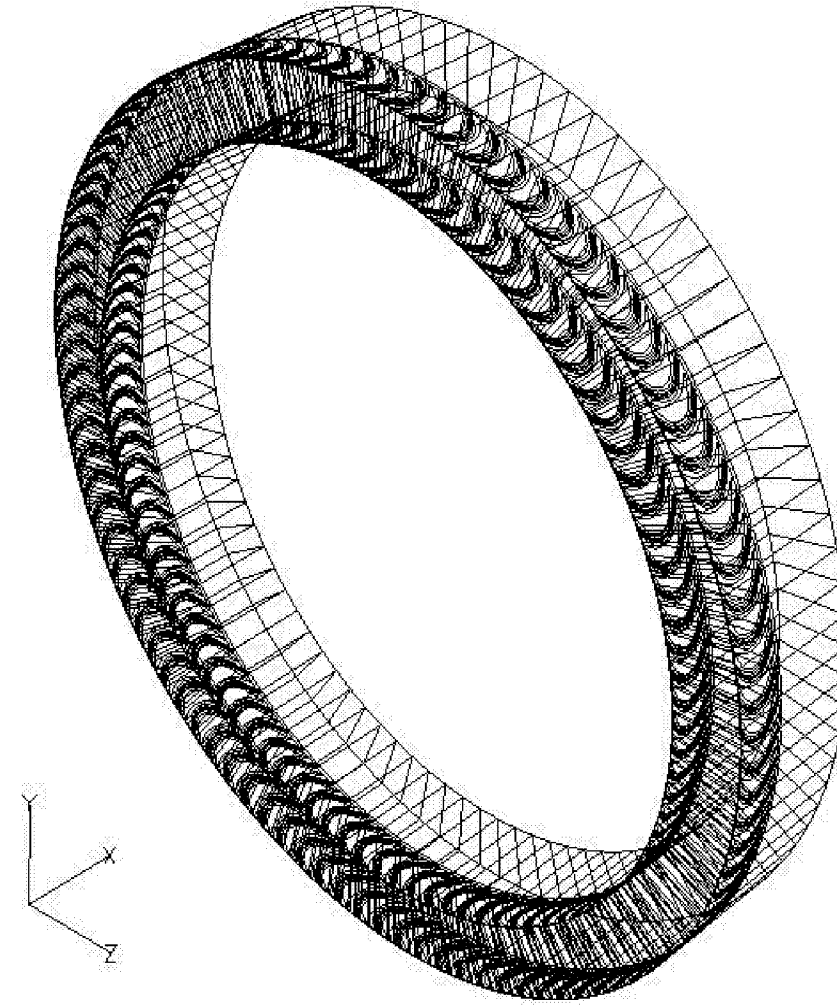
- **Modifying code for pump geometries**
 - incorporating incompressible flow physics
- **Incorporate two-phase flow modeling**
- **Incorporate cavitation modeling**

Simplex Turbine Simulations

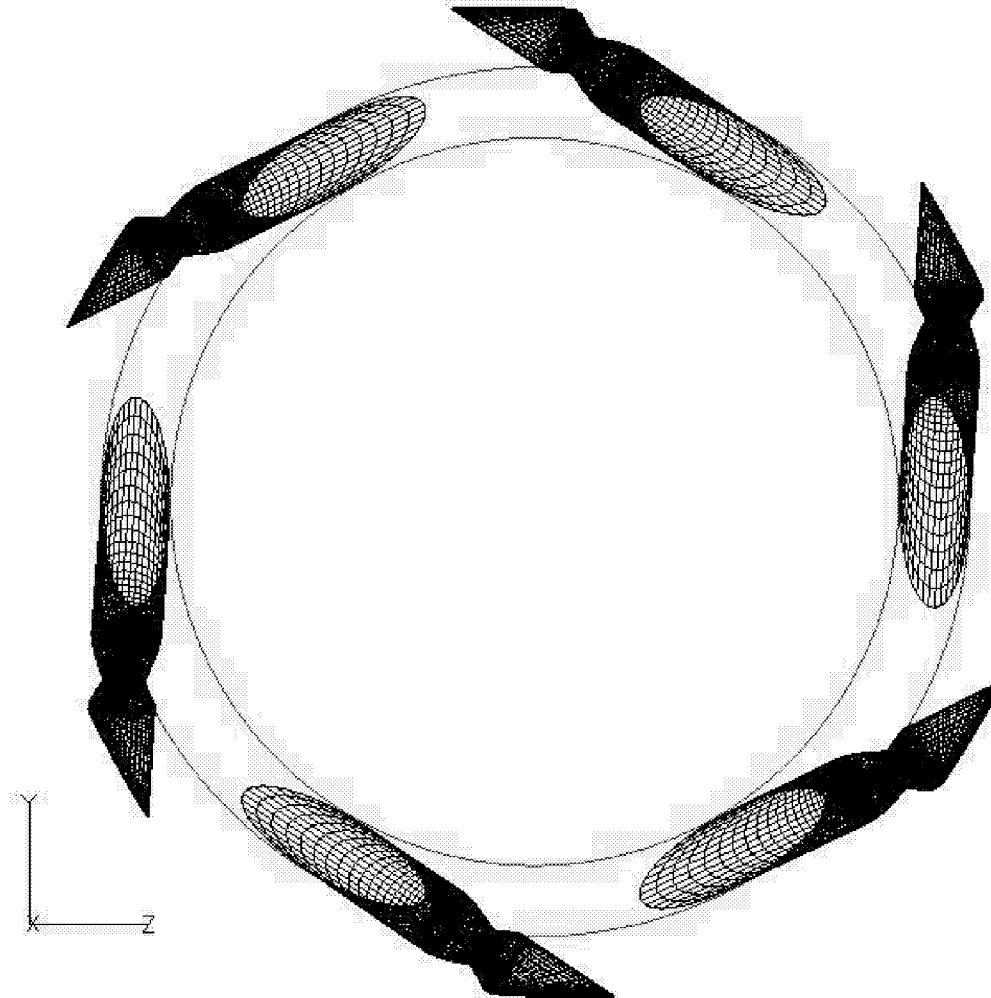


- **Objective - determine the effects of partial admission on the rotor unsteady load and performance as a function of circumferential location**
- **Full-Admission simulation (FA)**
 - 1 nozzle and 8 rotors modeled
 - 750,000 grid points
 - 8 full cycles (one complete rotor revolution) completed
- **Partial-Admission 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

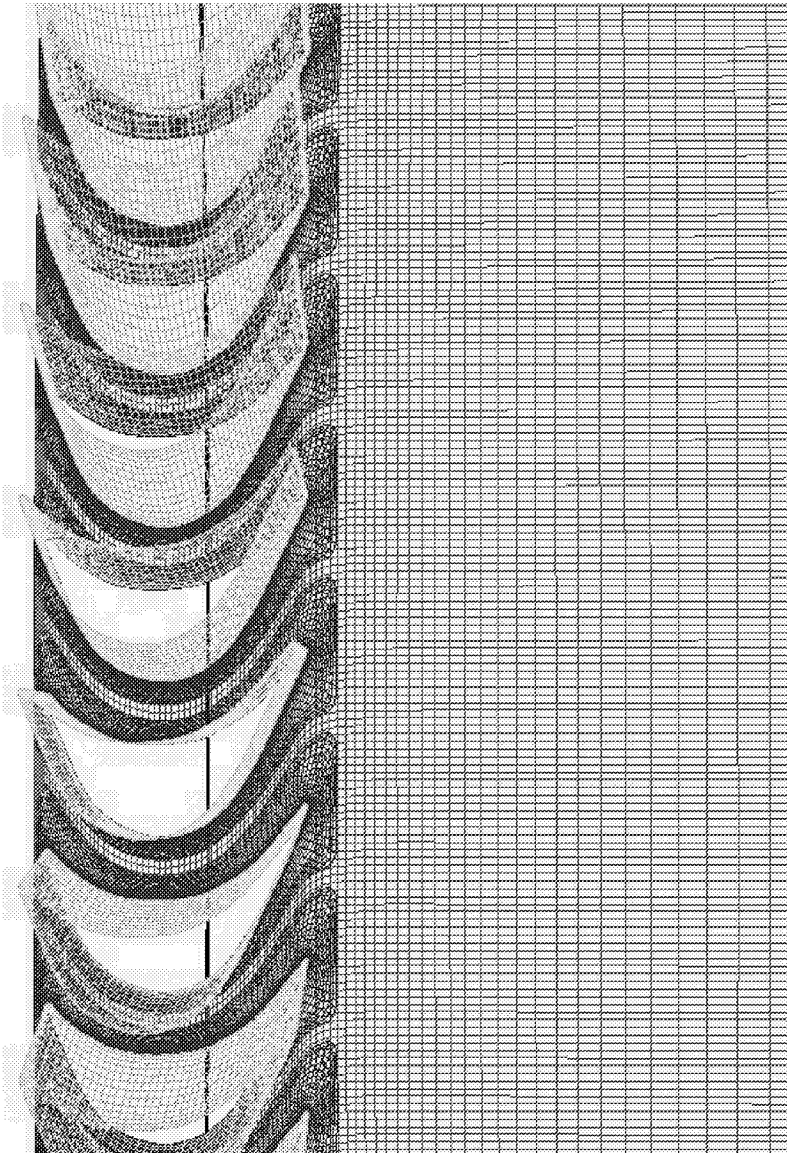
Simplex Turbine Rotors



Simplex Turbine Nozzles



Computational Grids - Rotor



Nozzle/Rotor Interface - Mach Number (PA)



Instantaneous Mach Number - Nozzle

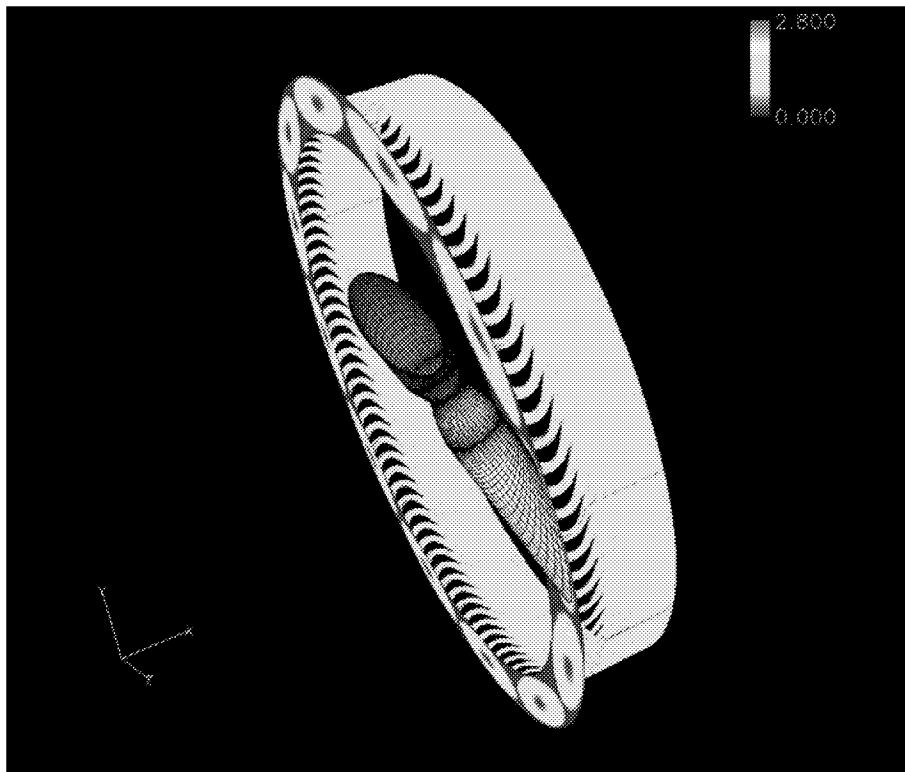


FULL ADMISSION

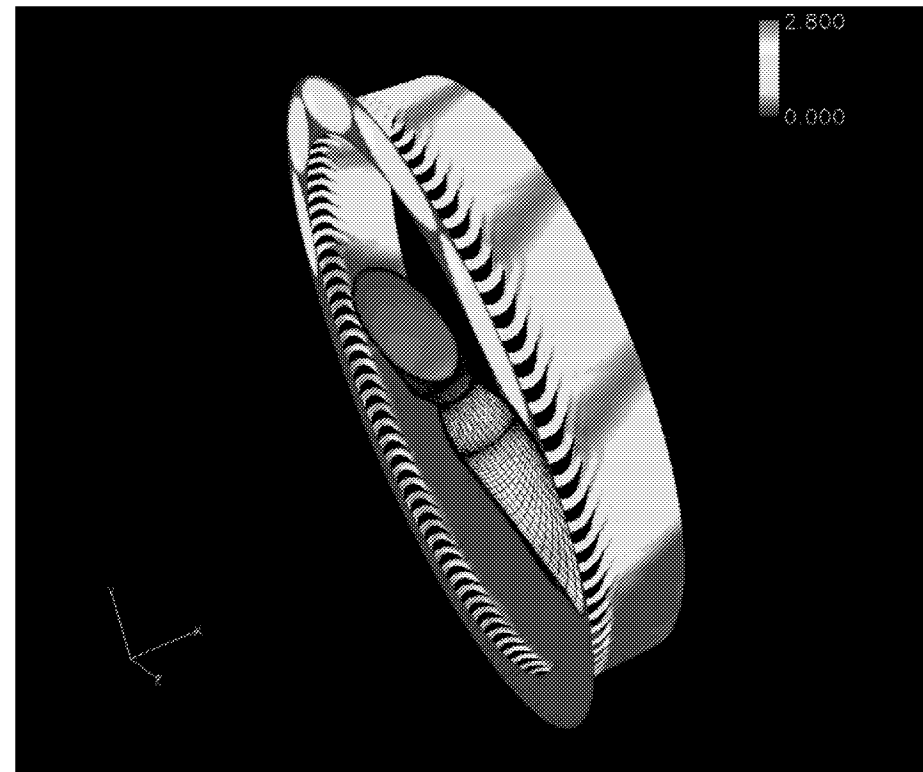


PARTIAL ADMISSION

Instantaneous Mach Number - Nozzle

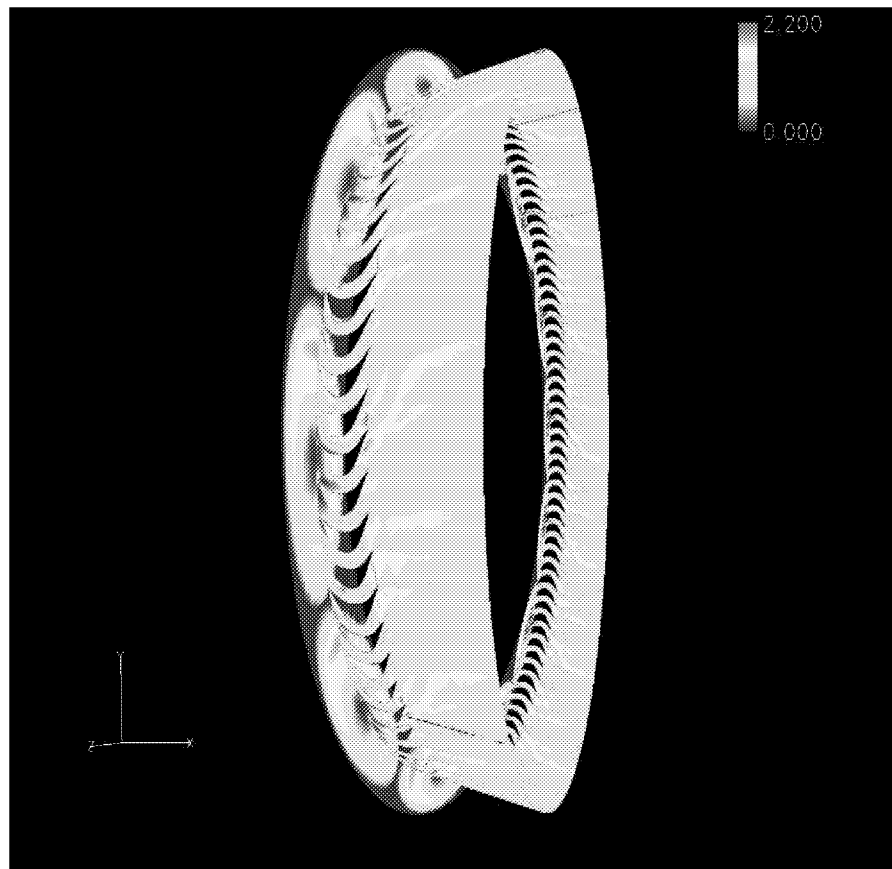
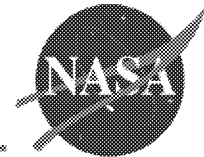


FULL ADMISSION

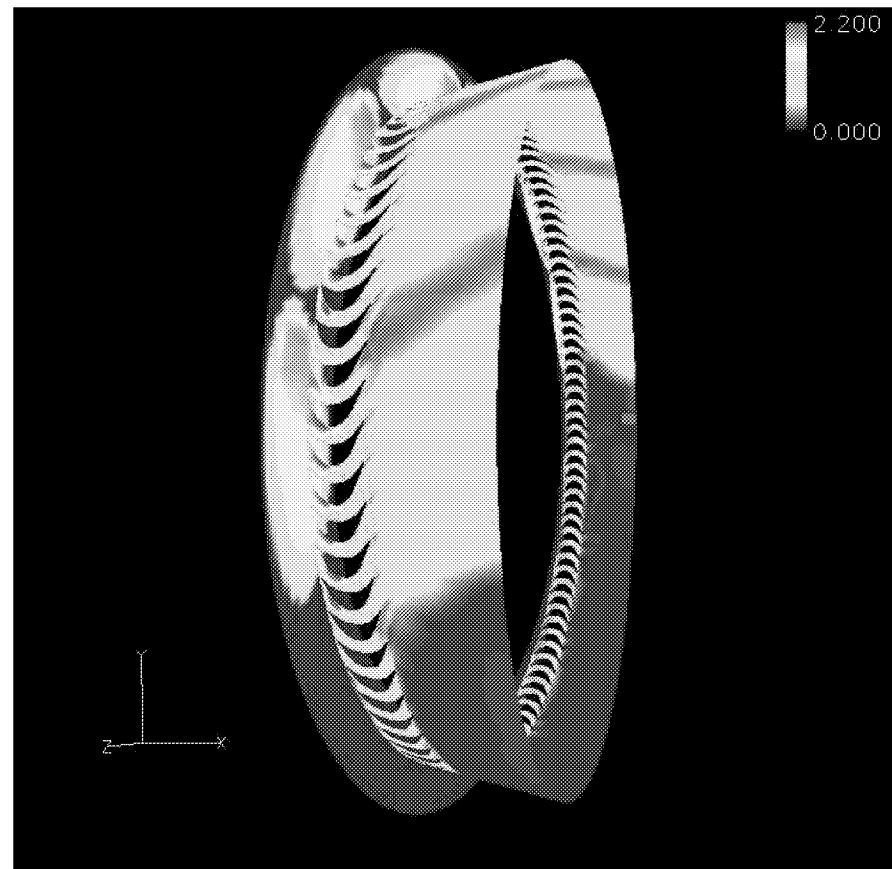


PARTIAL ADMISSION

Instantaneous Mach Number

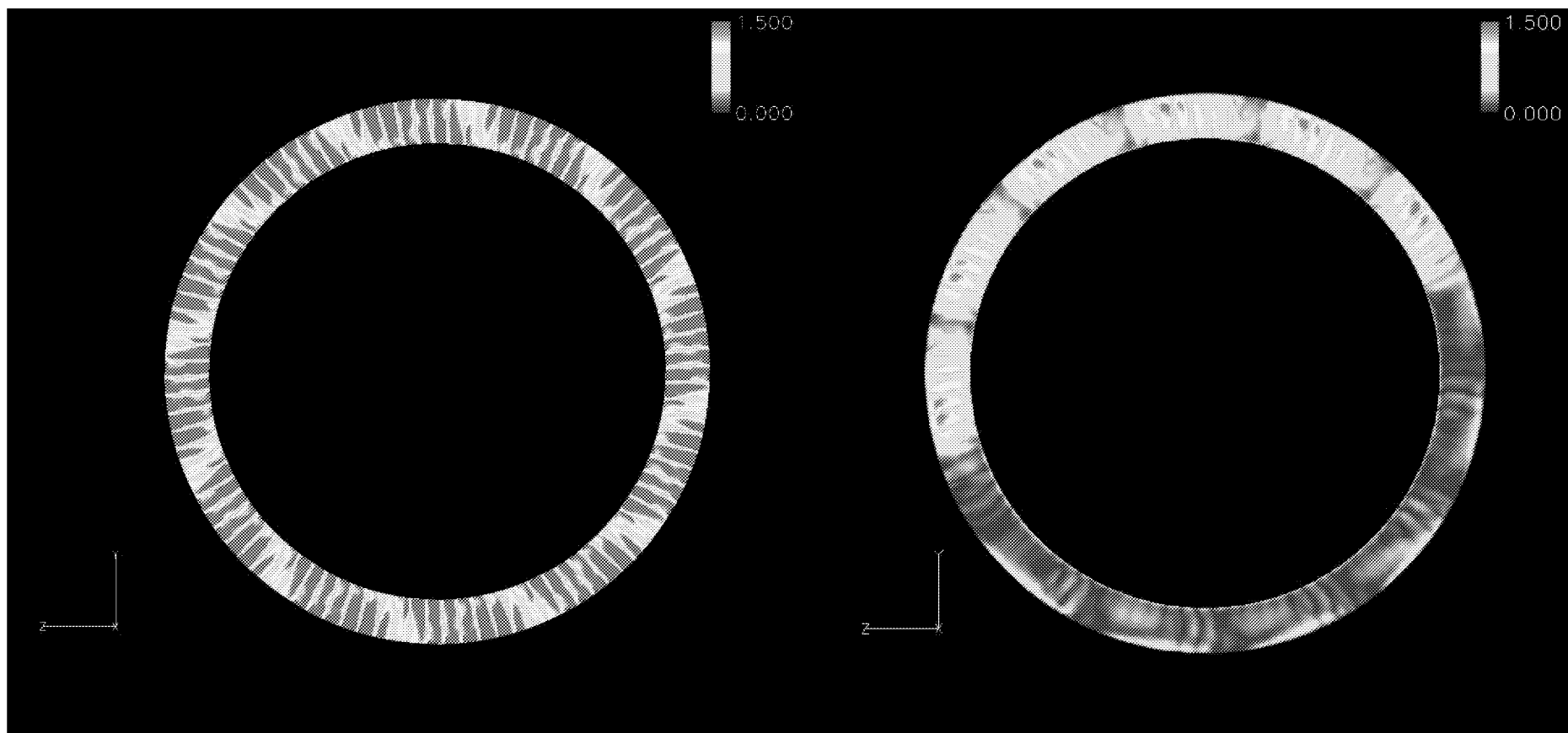
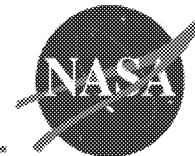


FULL ADMISSION



PARTIAL ADMISSION

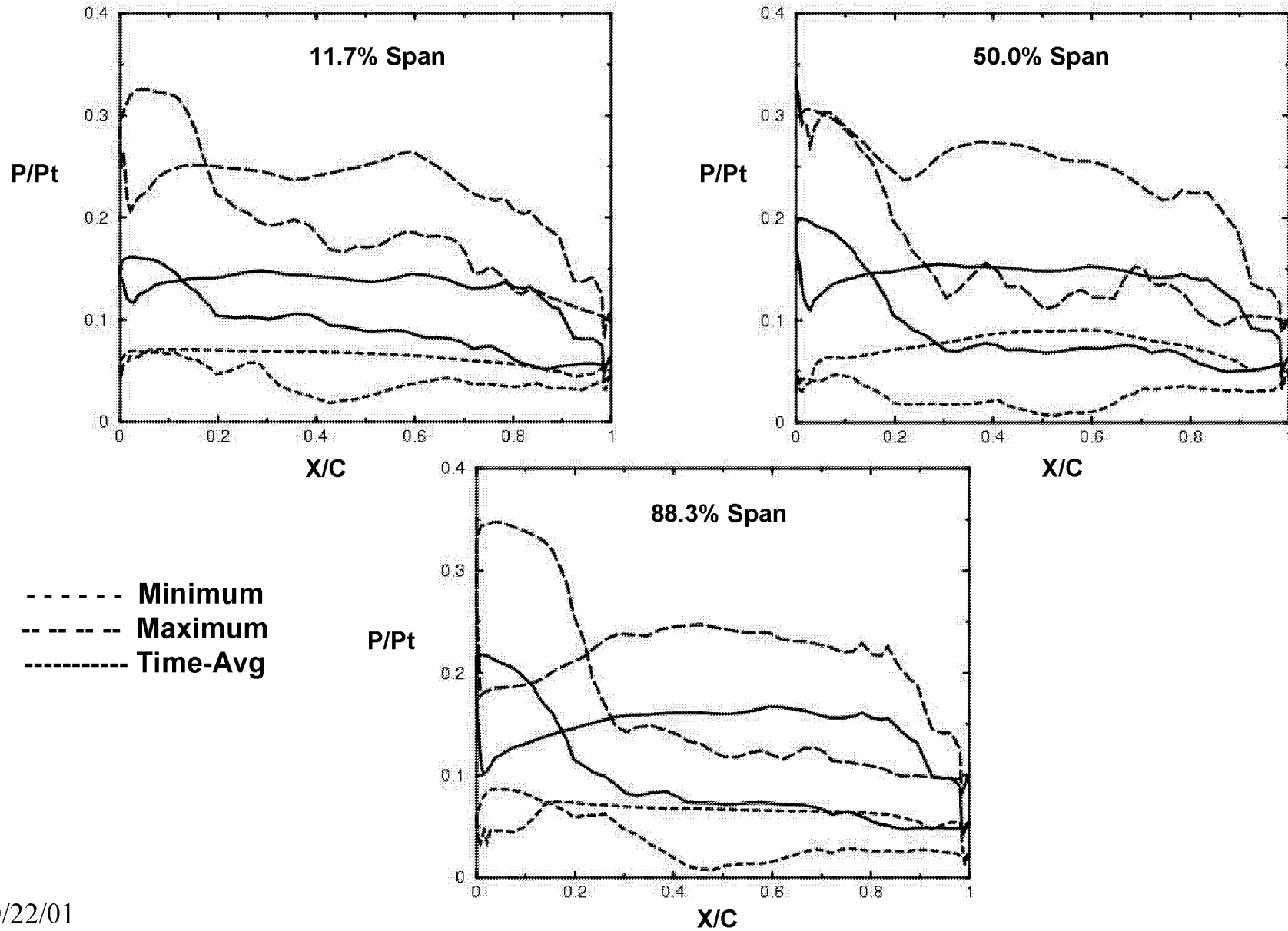
Instantaneous Mach Number - Rotor Exit



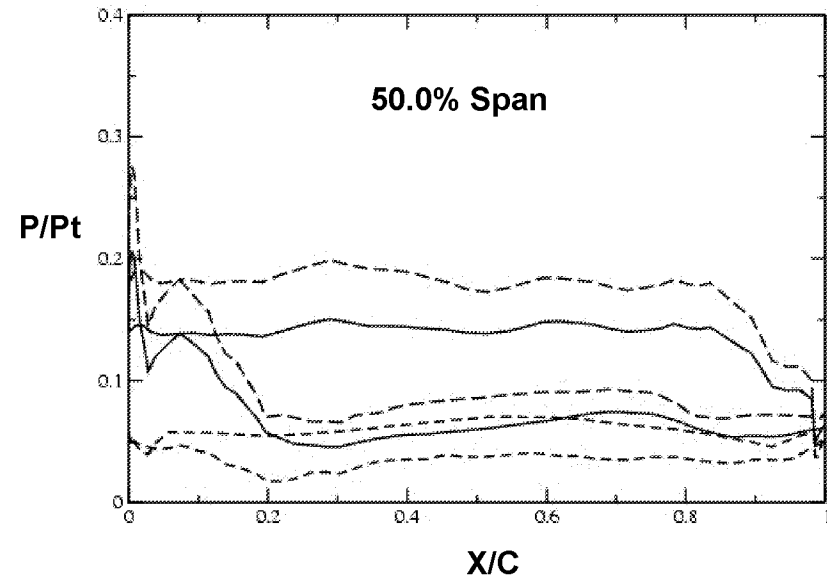
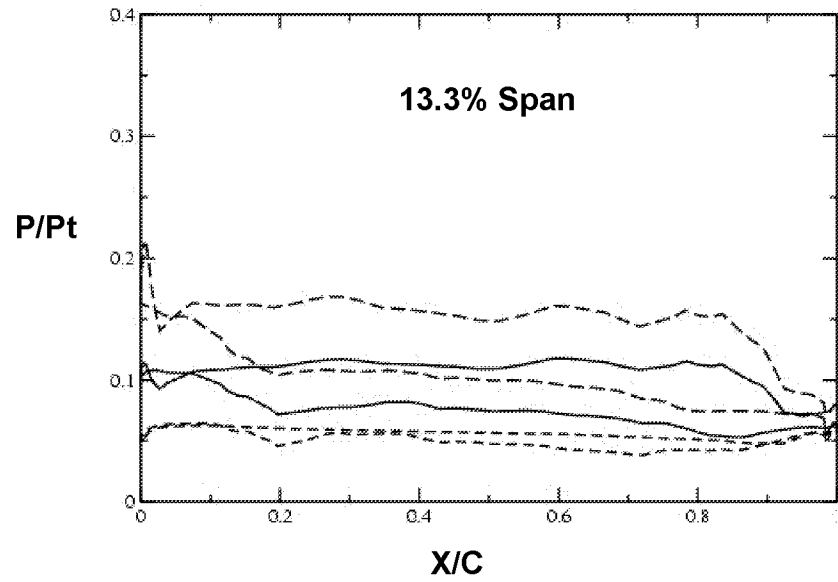
FULL ADMISSION

PARTIAL ADMISSION

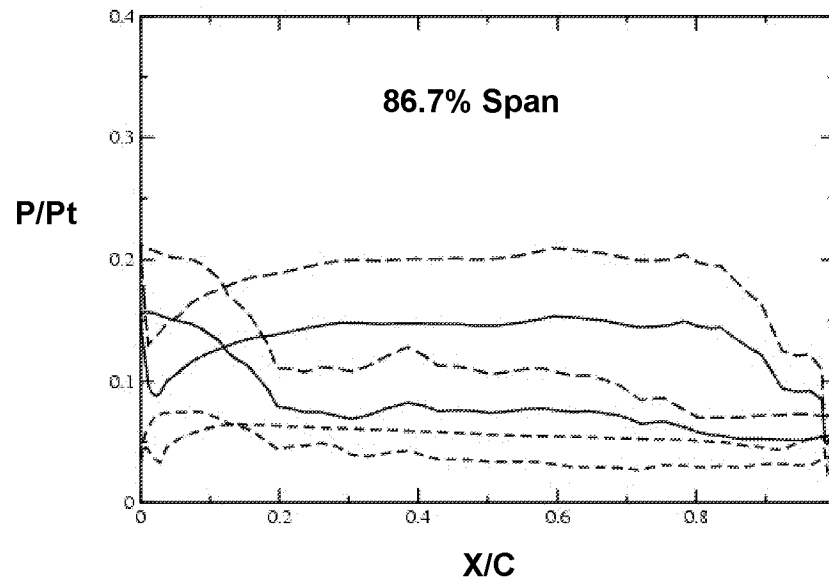
Unsteady Rotor Pressure Envelopes (FA)



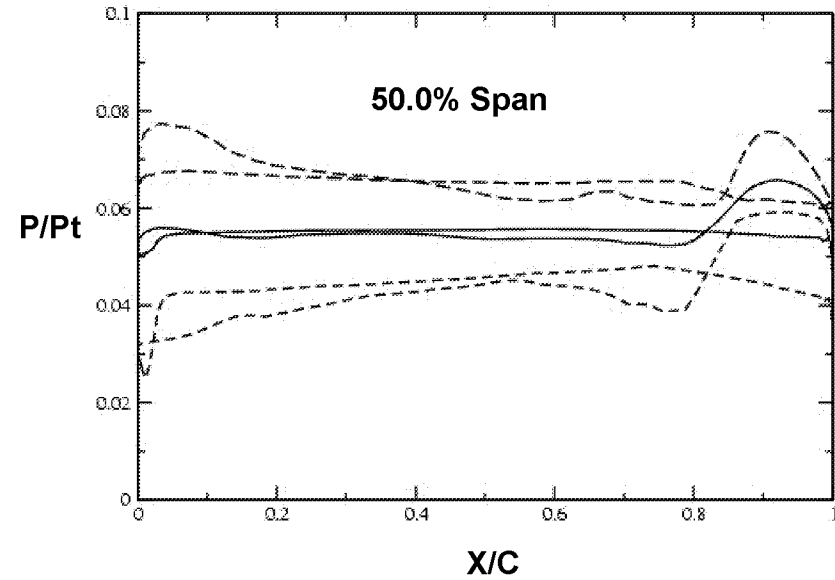
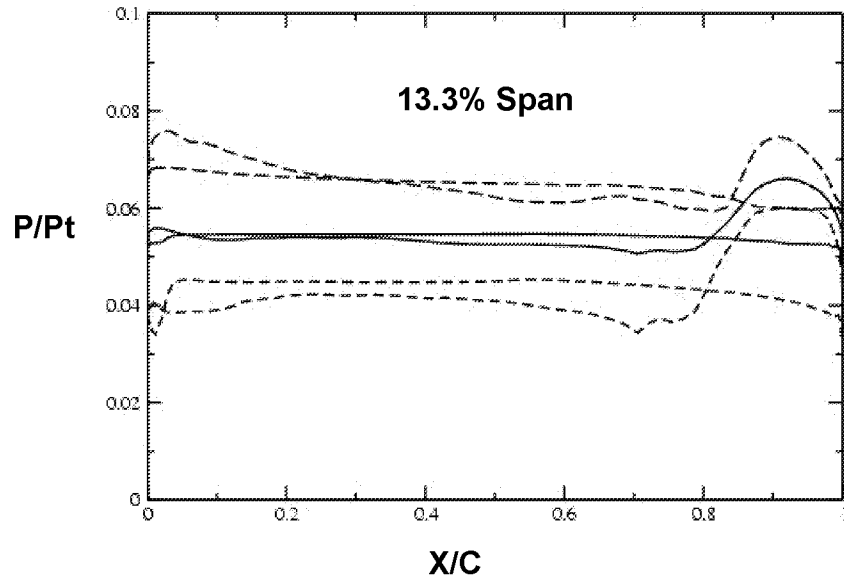
Unsteady Rotor Pressure Envelopes (PA-IN)



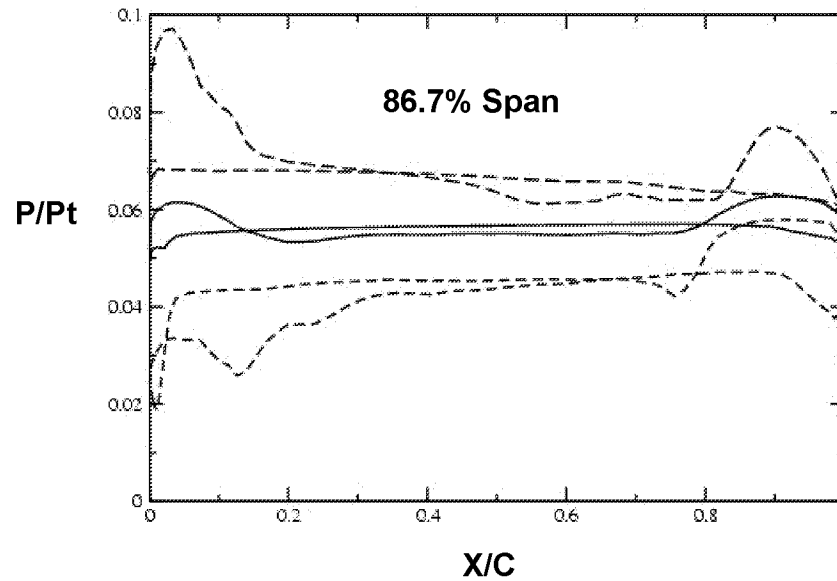
----- Minimum
- . - . - . Maximum
----- Time-Avg



Unsteady Rotor Pressure Envelopes (PA-OUT)

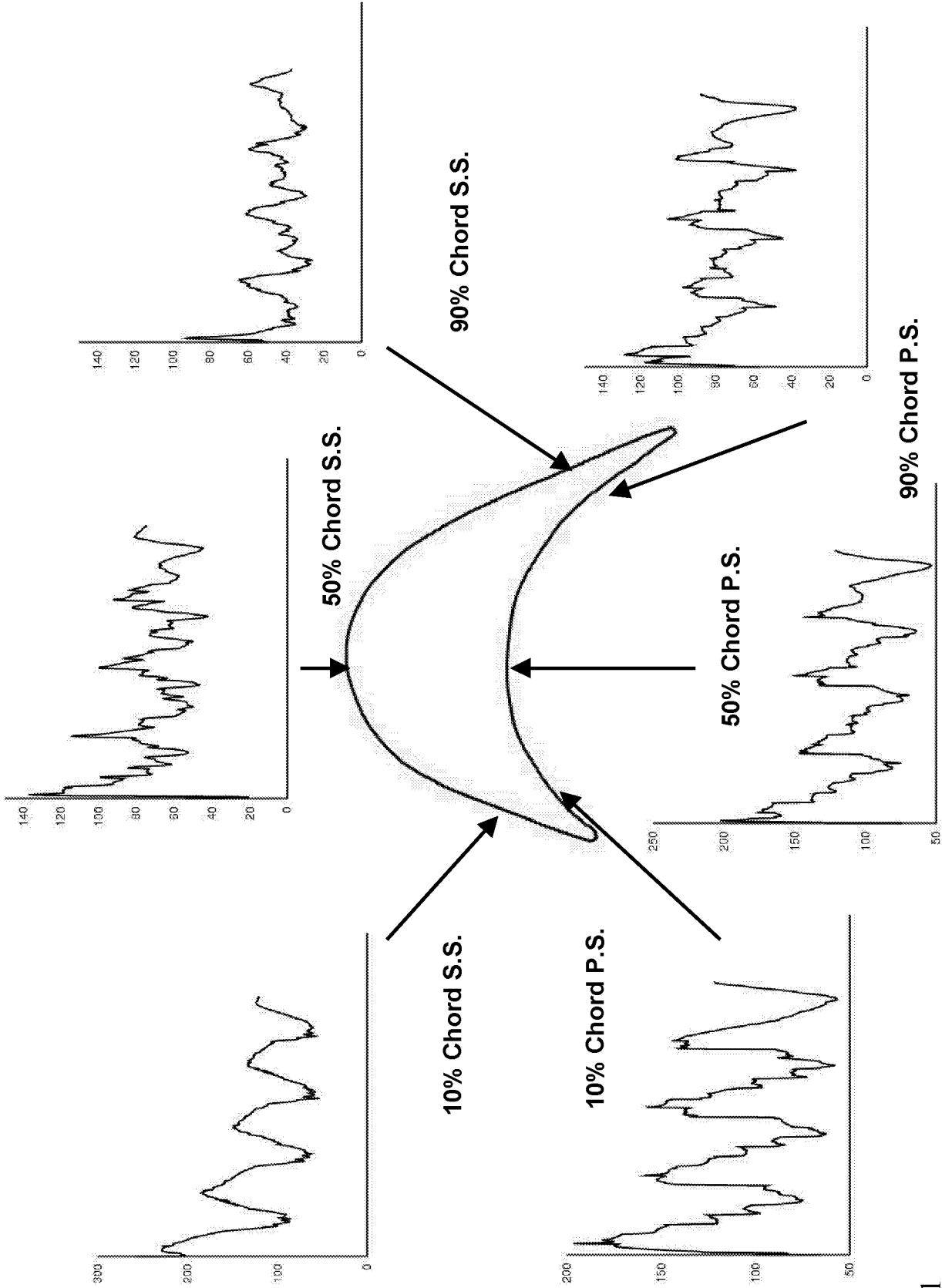


----- Minimum
- . - . - . Maximum
----- Time-Avg

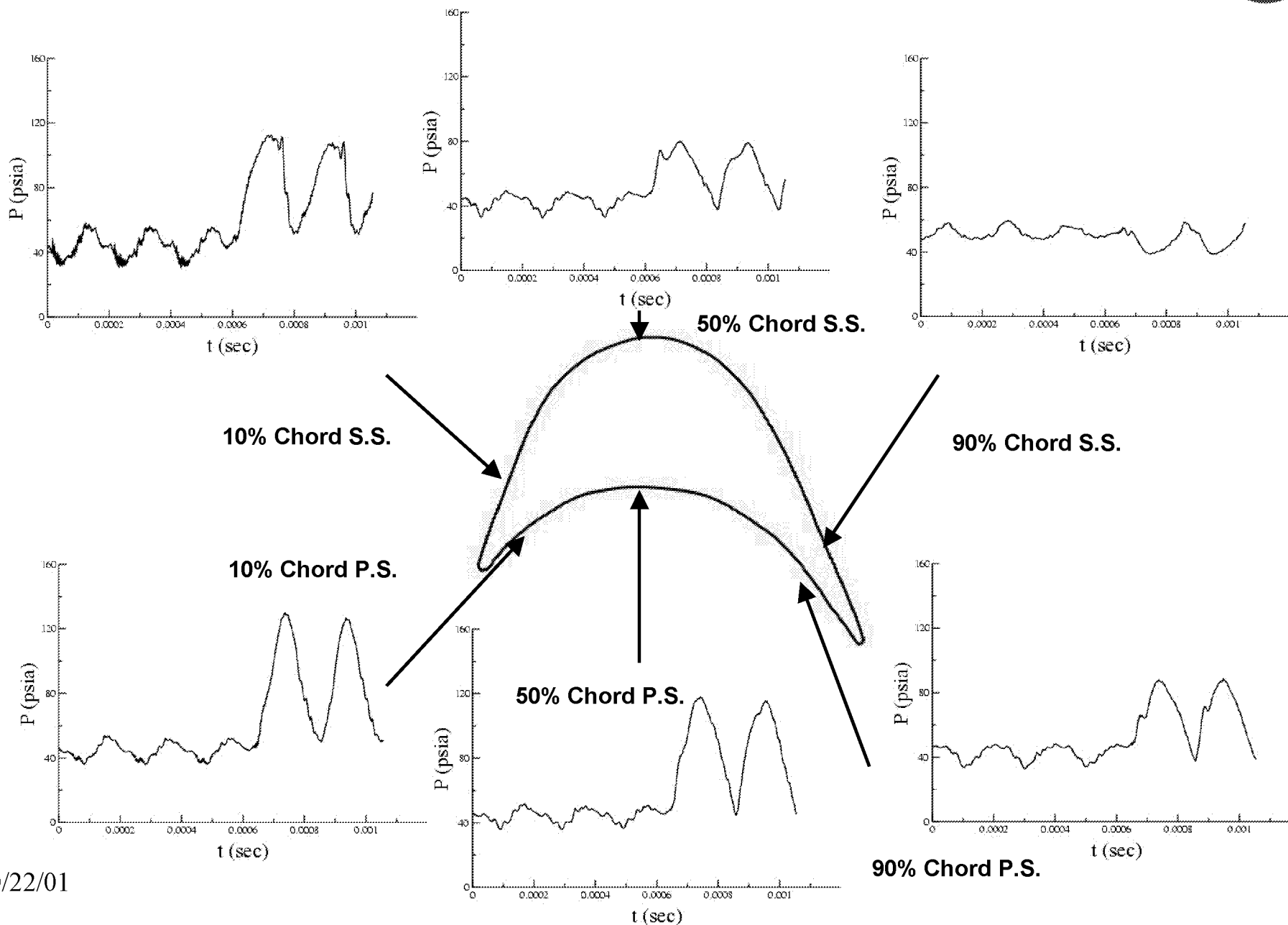
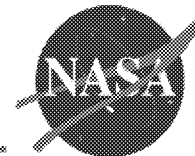




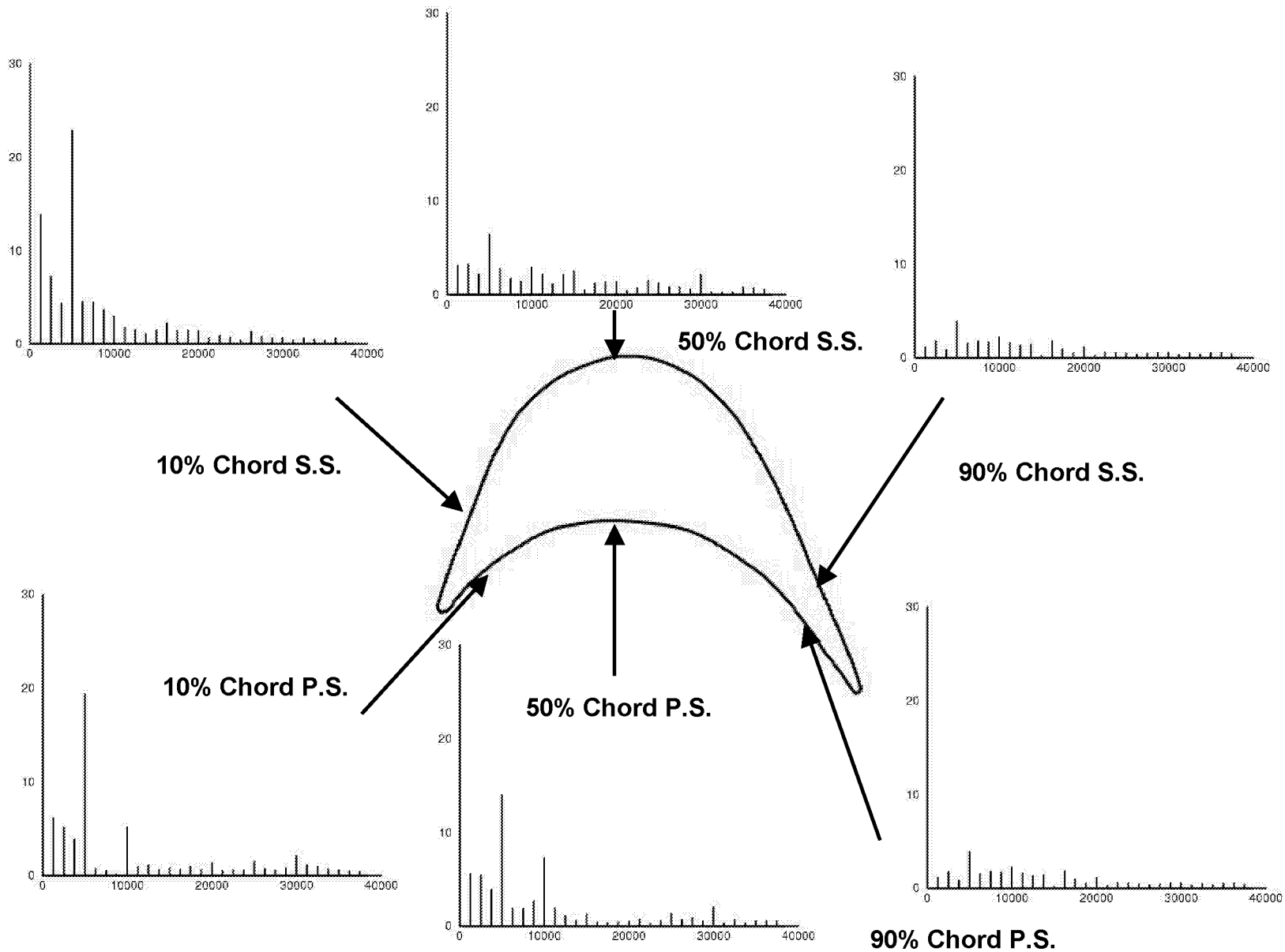
Unsteady Pressure - 11.7% Span (FA)



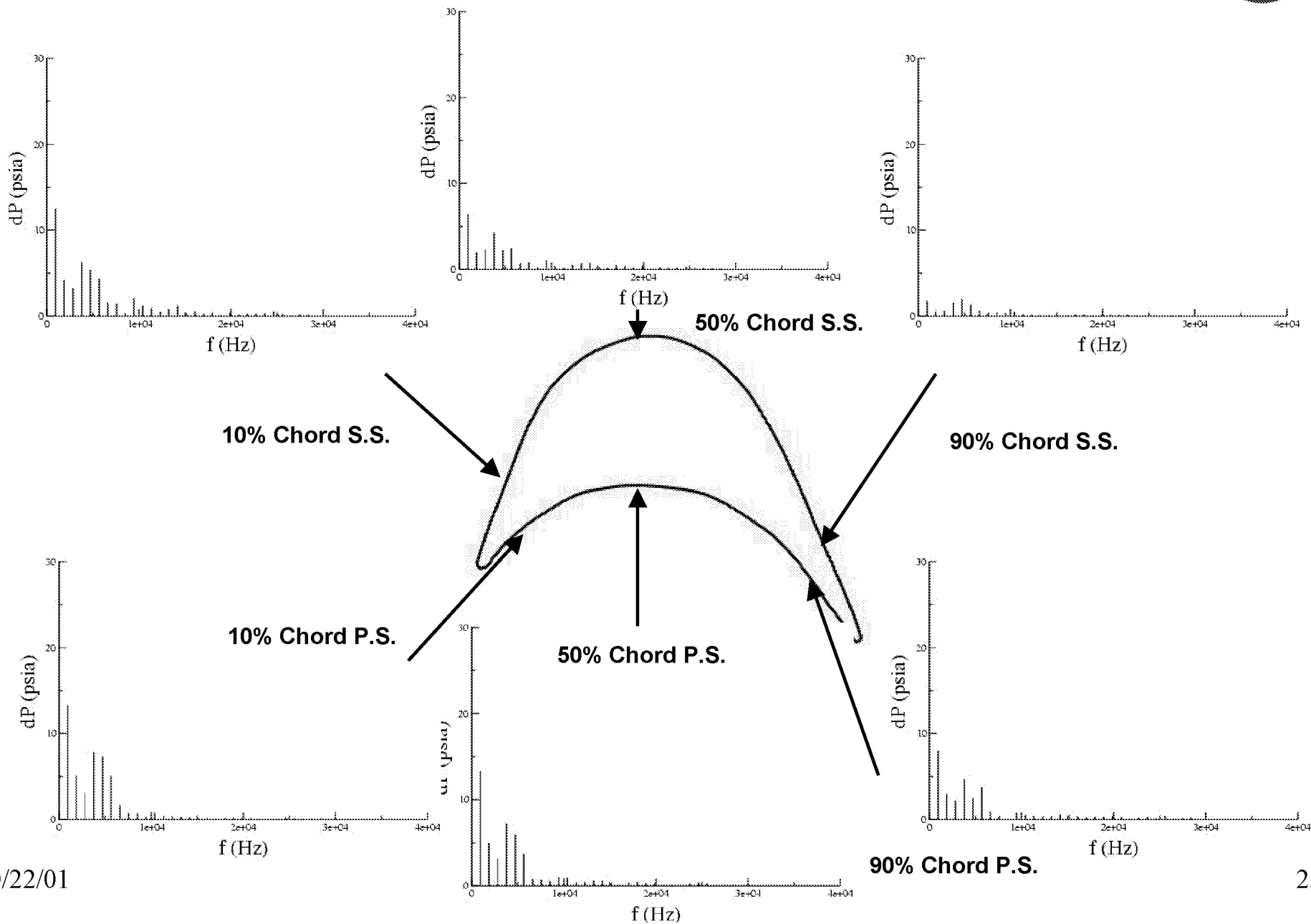
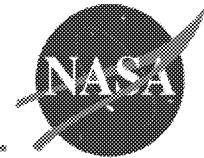
Unsteady Pressure - 13.3% Span (PA)



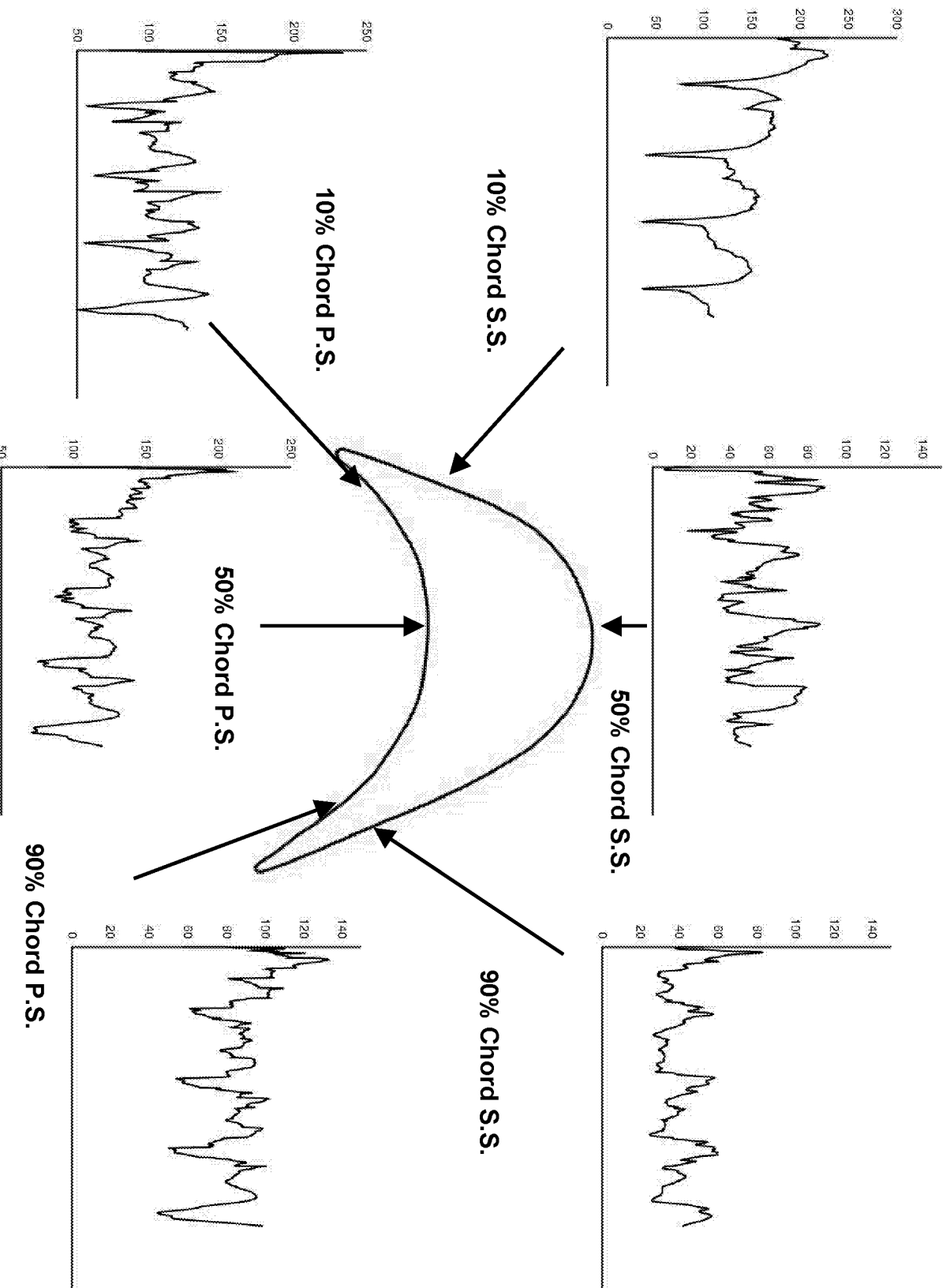
Unsteady Decomposition - 11.7% Span (FA)

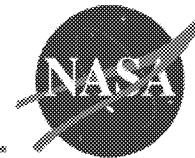


Unsteady Decomposition - 13.3% Span (PA)

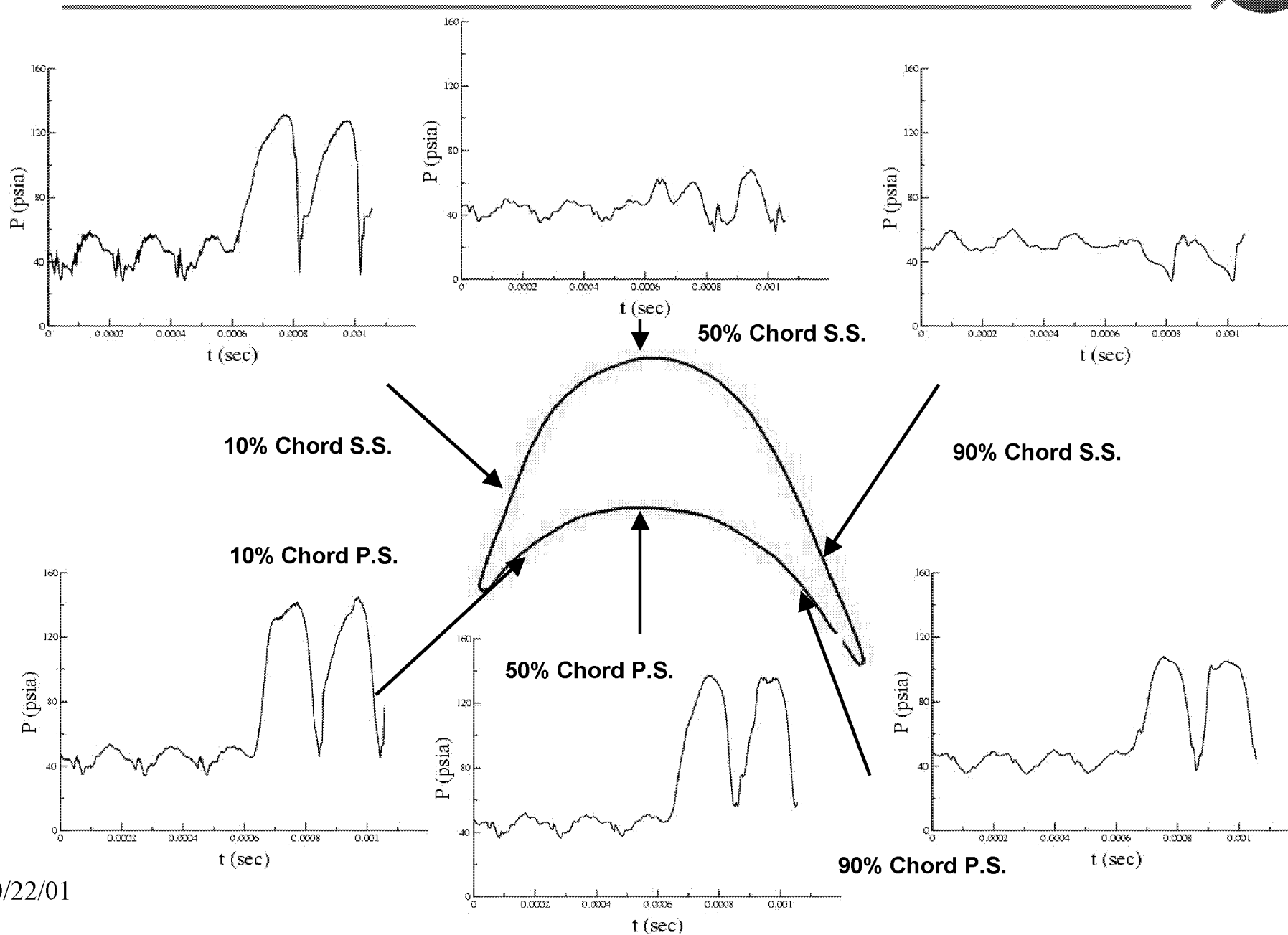


Unsteady Pressure - 50.0% Span (FA)

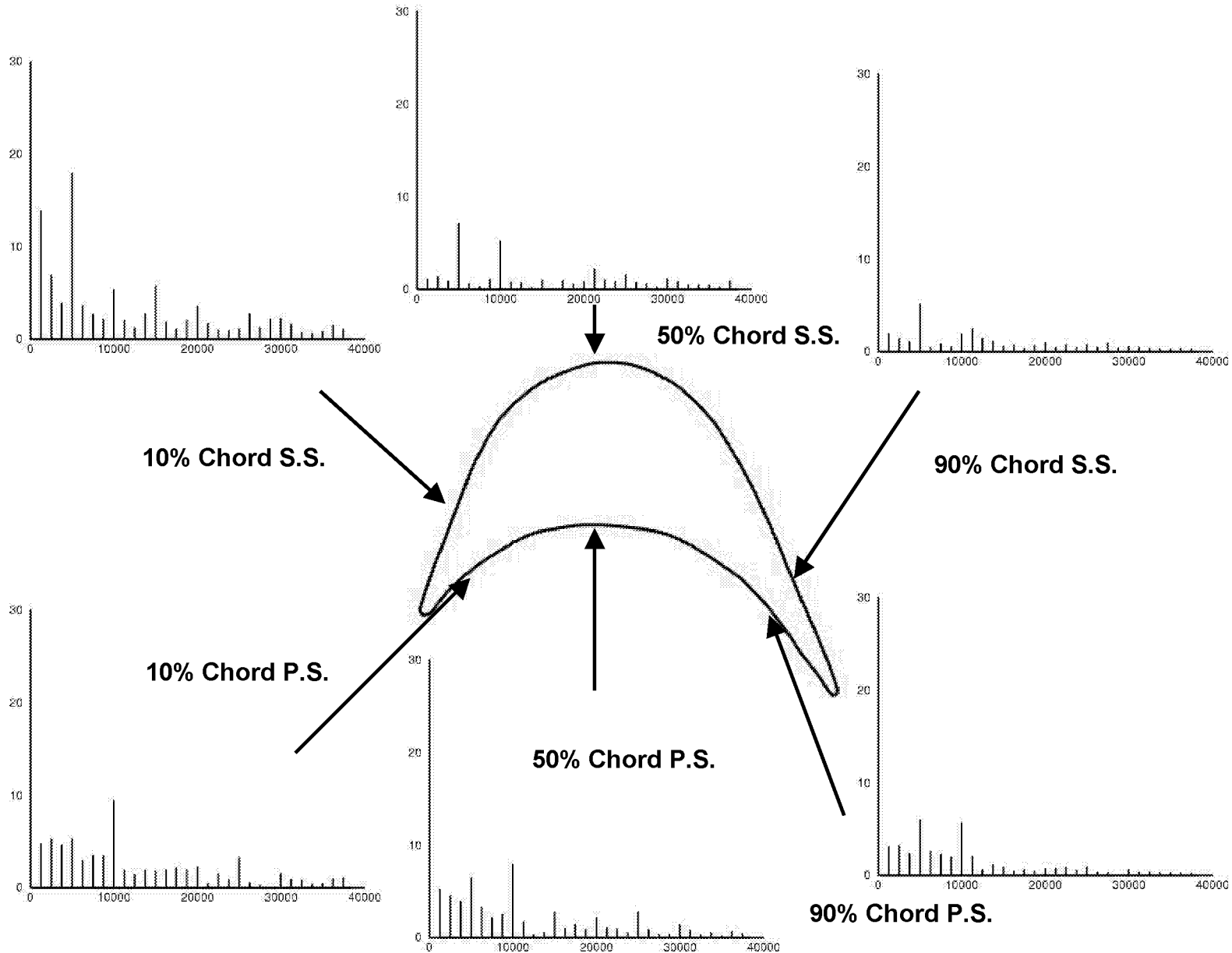




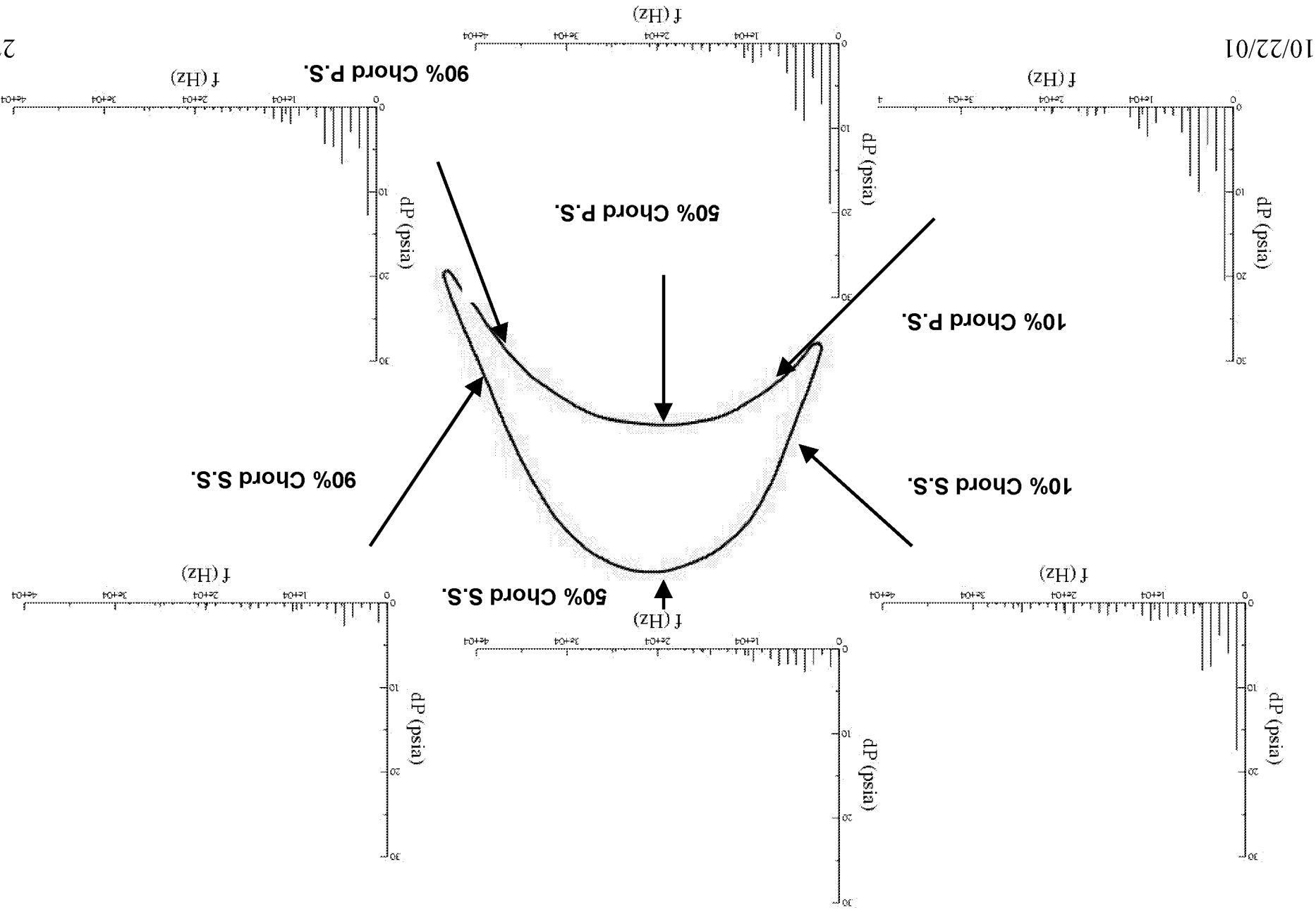
Unsteady Pressure - 50.0% Span (PA)



Pressure Decomposition - 50.0% Span (FA)



Pressure Decomposition - 50.0% Span (PA)

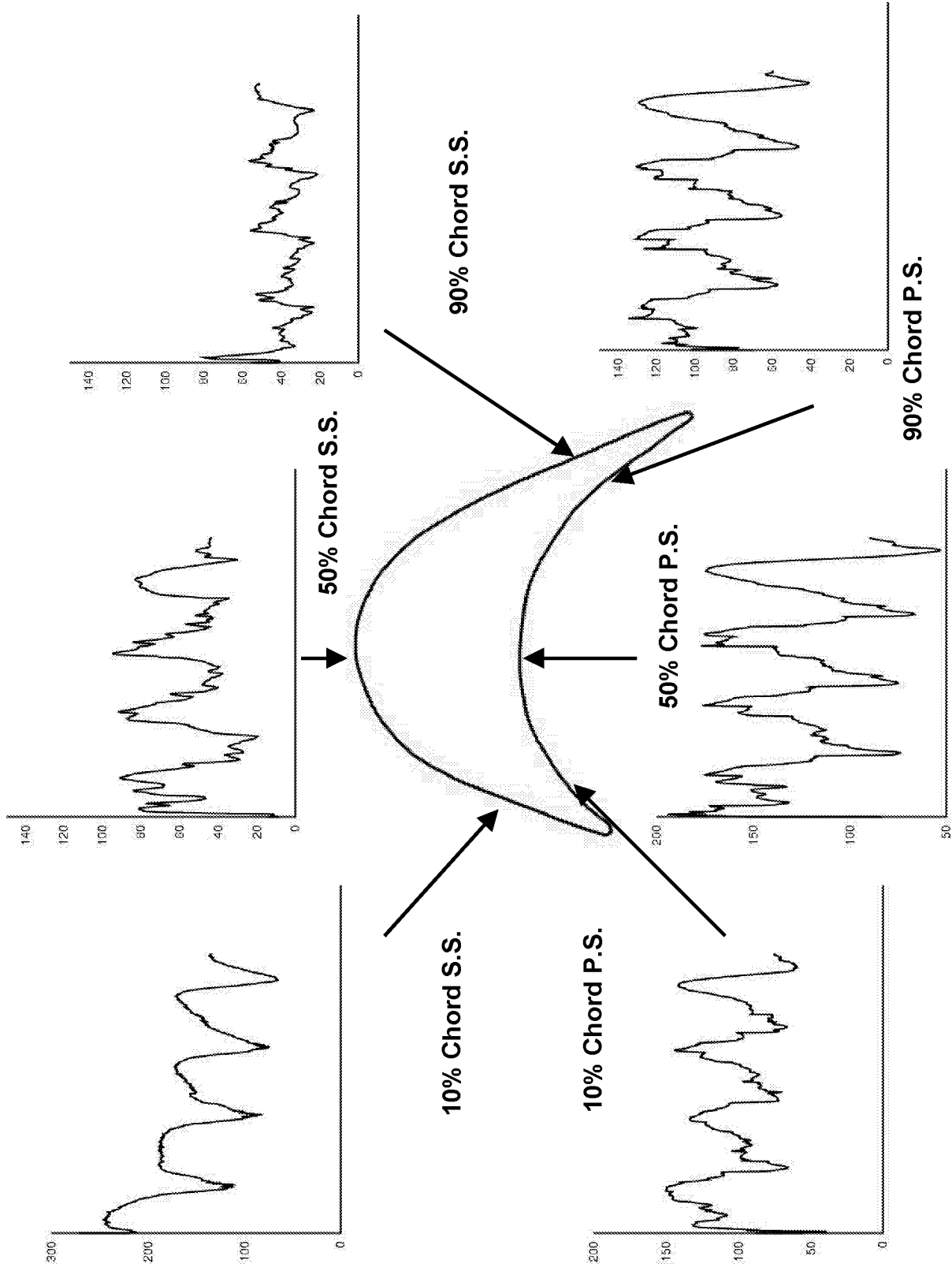


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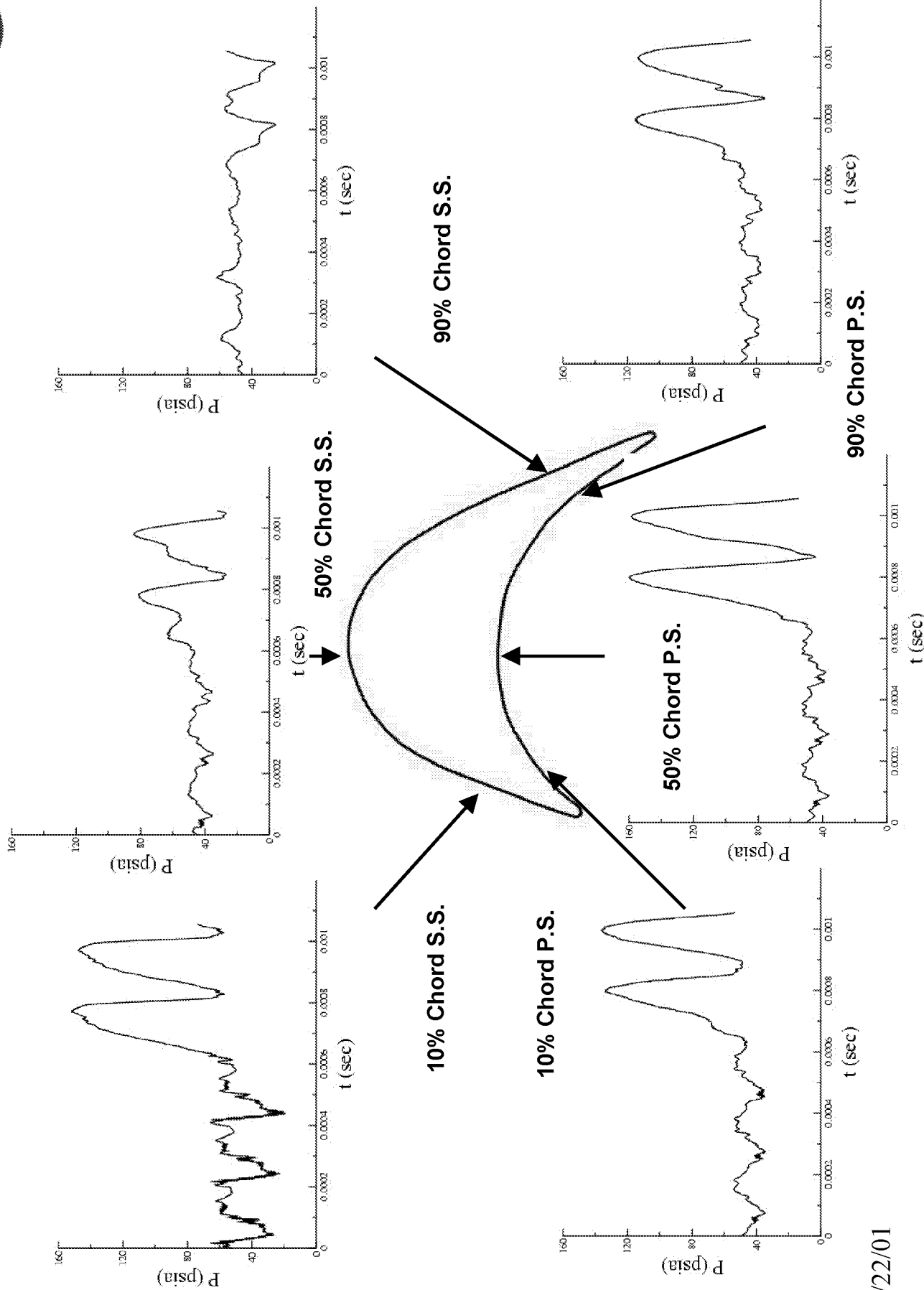
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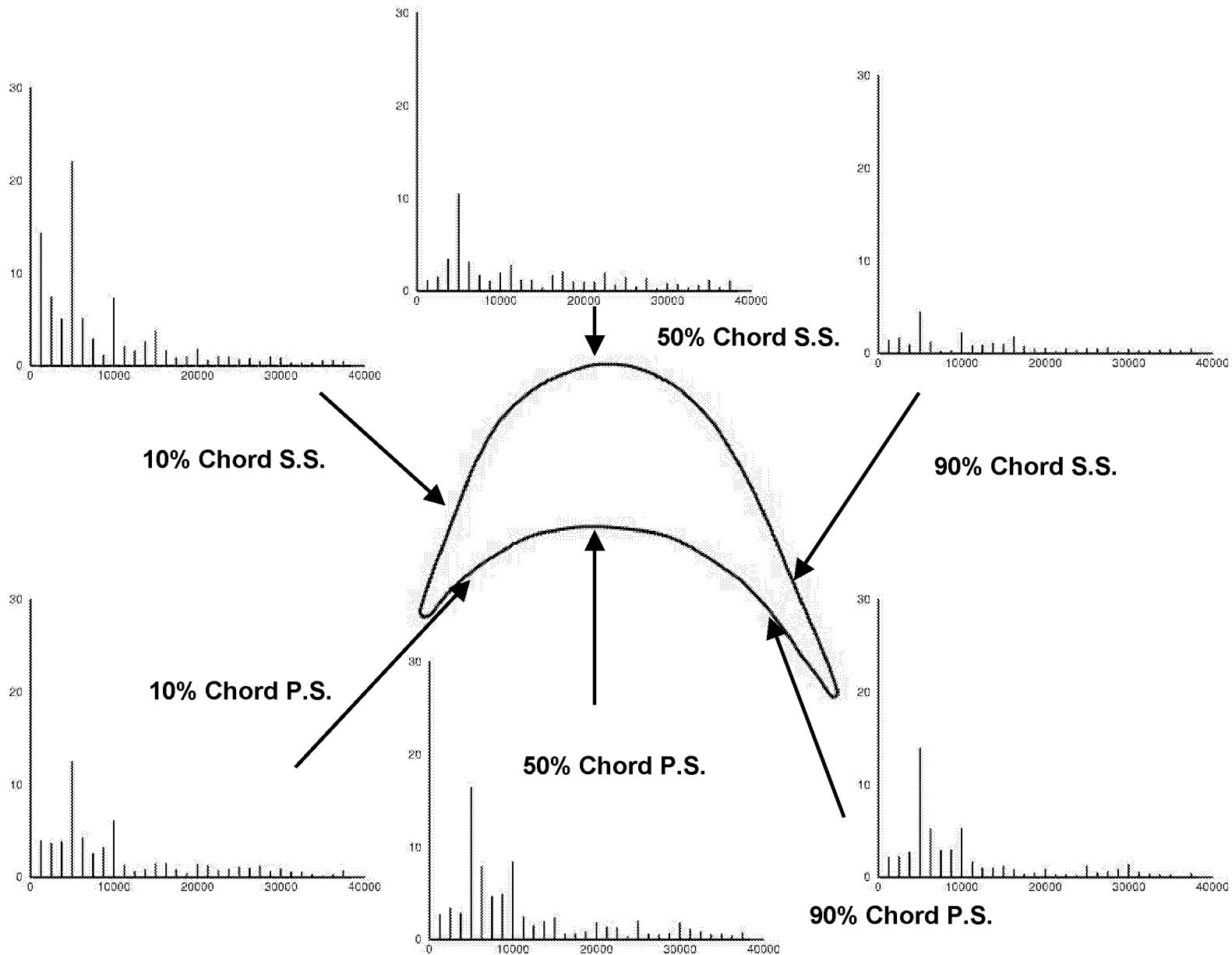
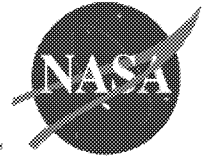
Unsteady Pressure - 88.3% Span (FA)



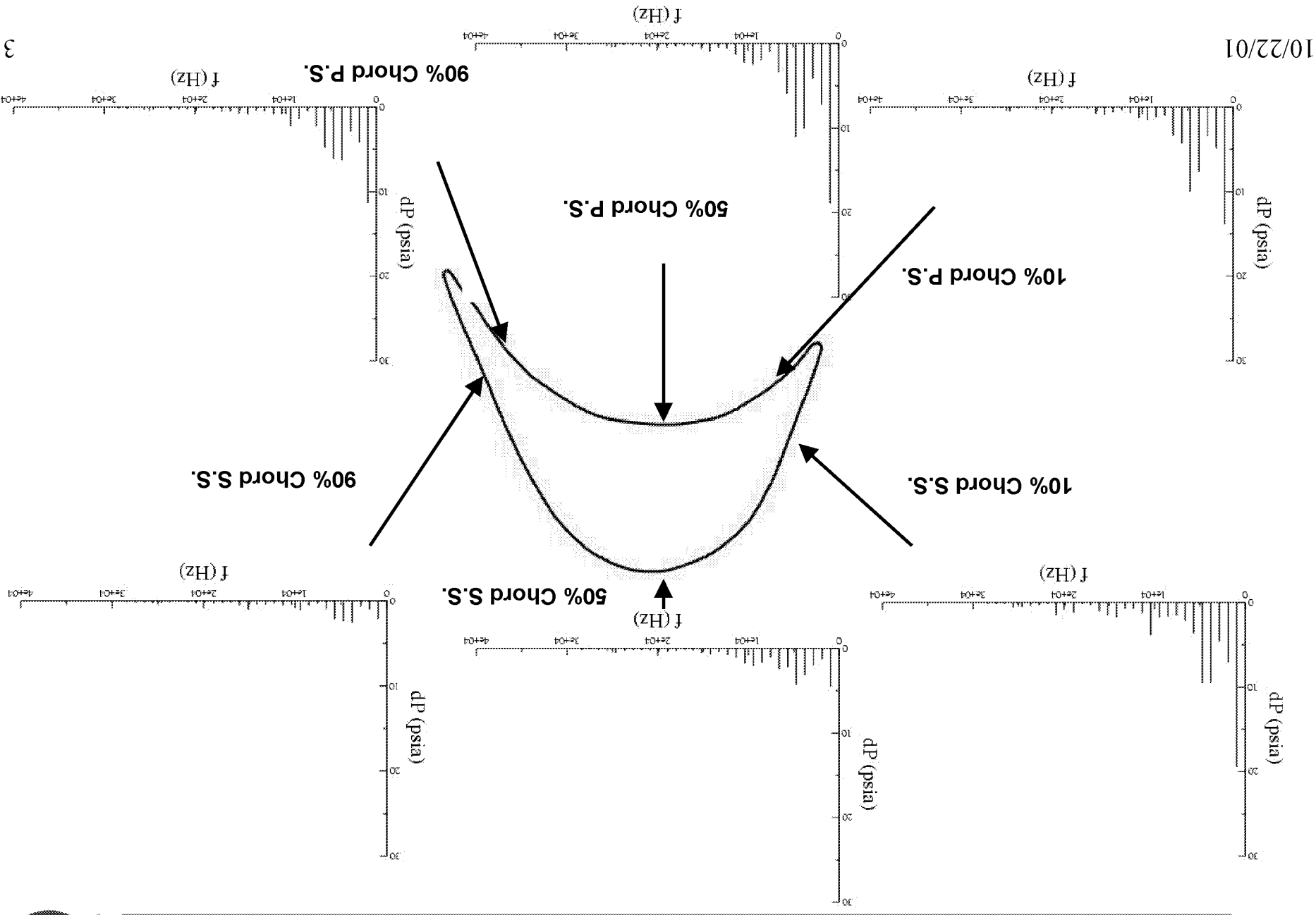
Unsteady Pressure - 86.7% Span (PA)



Pressure Decomposition - 88.3% Span (FA)



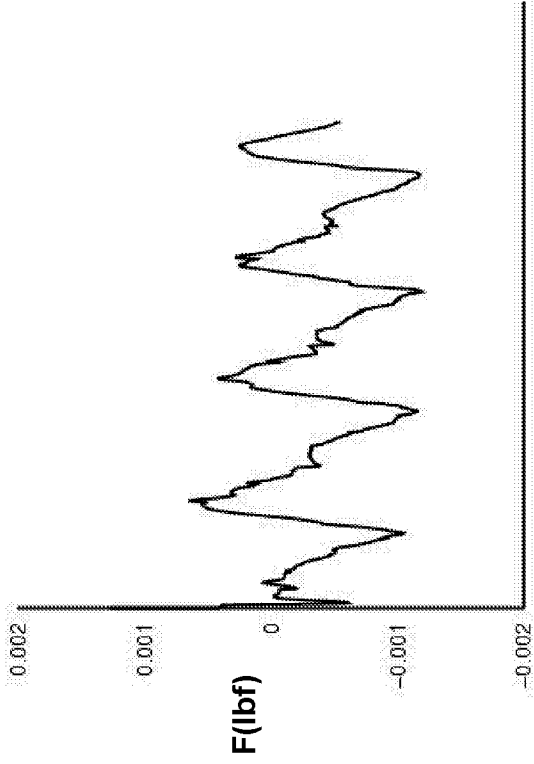
Pressure Decomposition - 86.7% Span (PA)



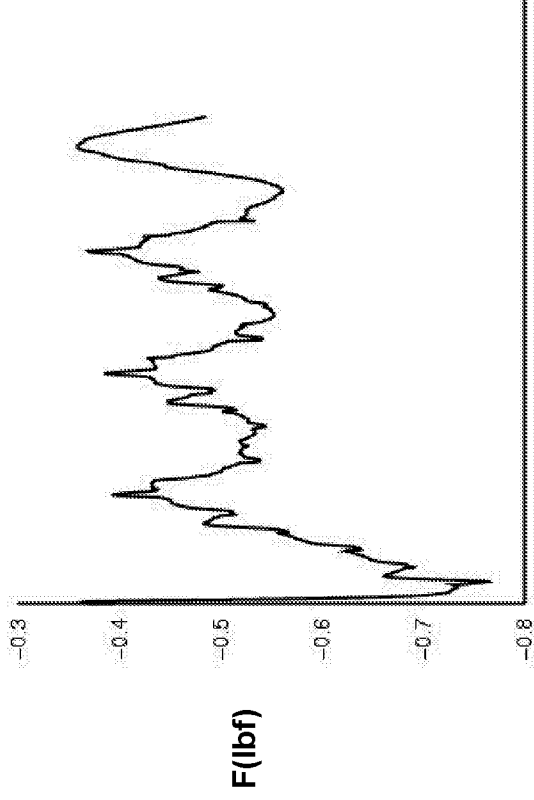
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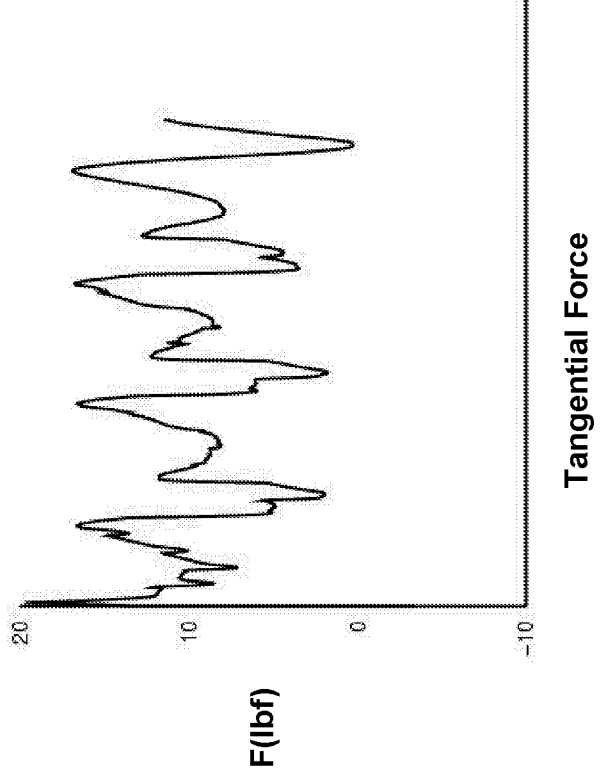
Unsteady Integrated Forces (FA)



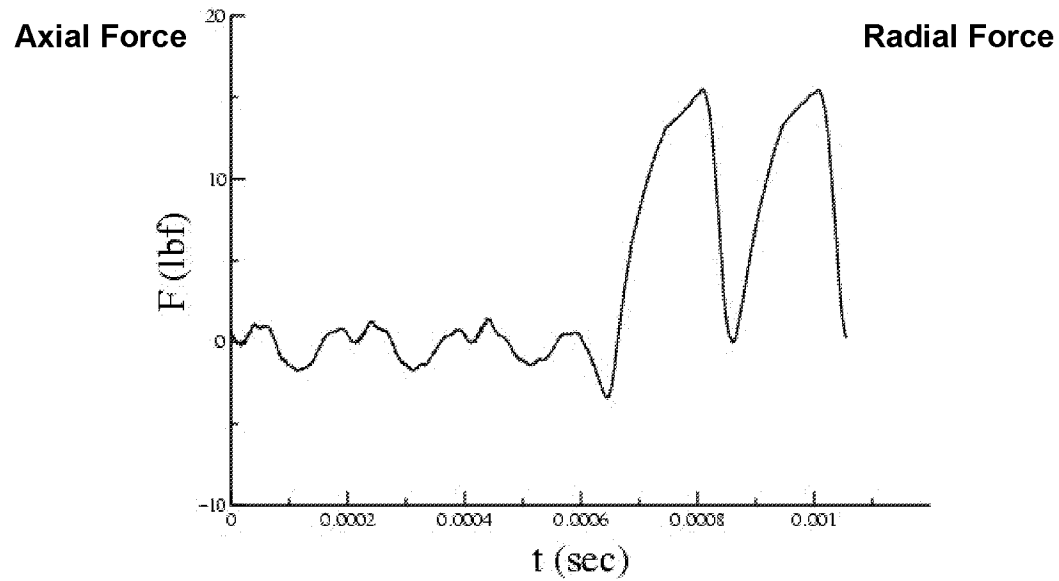
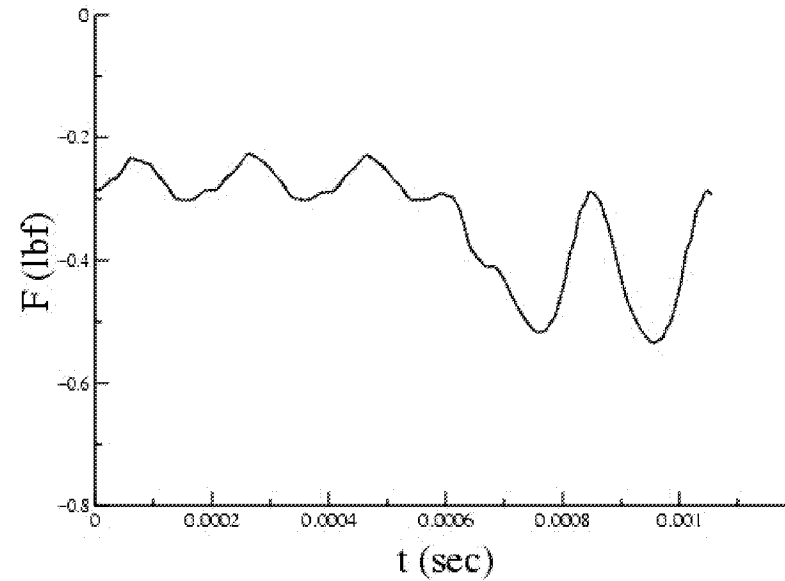
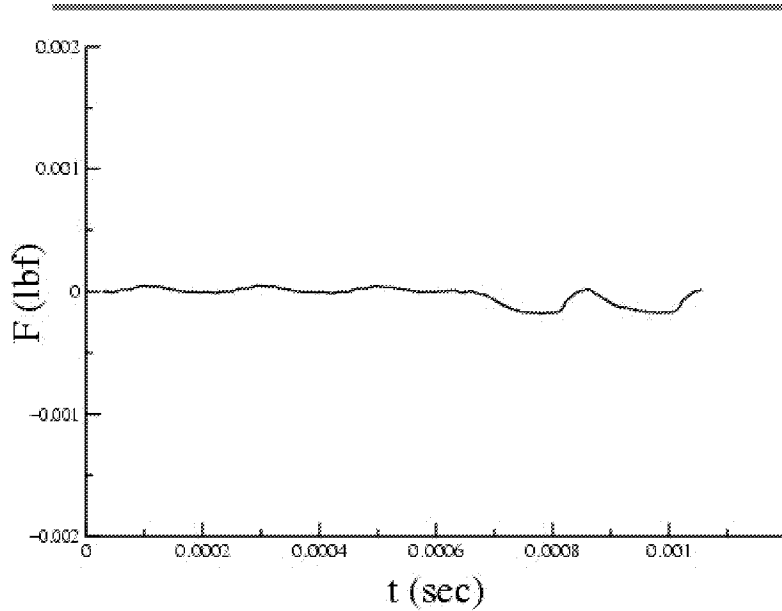
Axial Force



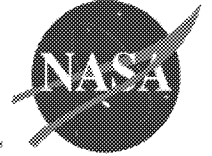
Radial Force



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