Spotlight on ...

Aeroacoustics

CFD METHODOLOGIES including LARGE-EDDY SIMULATION for NOISE PREDICTION

STAR South East Asian Conference 2013
Industries & Applications

**Aerospace**
- High Lift Devices
- Landing Gear
- ECS
- Jet and turbo noise

**Building Environment**
- HVAC ducting
- Fan noise

**Power Generation**
- Pipe / duct / cavity resonances
- Compressor / turbine / combustor

**Marine**
- Propeller noise
- Cavitation
- Hull/propeller/rudder interaction

**Automotive**
- Wing mirror
- Sunroof noise
- HVAC systems
- Turbo chargers
- Cooling fans
- Exhaust systems
- Interior transmission

**Electronics cooling**
- Fan noise
- Air conditioning
STAR-CCM+ Aeroacoustics Capabilities

Aeroacoustics

Simulation Options

Steady state

Unsteady

Compressible Non-reflective

Direct

Flow & Propagation

Broadband Correlations

CURLE (Surface)
PROUDMAN (volume)
GOLDSTEIN (2D-axisymmetric)

Synthesized

LEE Analogy
LILLEY Analogy
FW-H Tonal blade passing

Turbulence

LES
DES

Direct Simulation of Noise Propagation

FW-H Propagation

Steady-state and Transient Post-Processing

Mesh Frequency Cut-off

Point & Surface FFTs

Direct export to Acoustics and SEA codes

Point & Surface Inverse FFTs

Non-conformal mapping to structures codes

Band Stop & Pass Filters and Finite Impulse Response (FIR)

Uniform grid mapping and Export to MATLAB

Wave-number analysis including Cross Spectral Analysis for Phase and Coherence
HVAC, ECS, Duct ventilation and discharge
ECS and electronic rack cooling

Debatin, K, ECCOMAS CFD 2006

- Elbow with flow straightener
- Inlet Bulk Velocity
- Outlet Pressure on all holes on each shelf
- Plenum
- Restrictor
ECS and electronic rack cooling

Debatin, K, ECCOMAS CFD 2006
ECS and electronic rack cooling

Debatin, K, ECCOMAS CFD 2006

[Graph showing data and analysis]

[Image of electronic rack cooling equipment]
ECS and electronic rack cooling

Debatin, K, ECCOMAS CFD 2006

[Graph showing frequency vs. sound level]

Noise Source Localization + Flow Field + = Smoothened Restrictor

Image of electronic rack cooling equipment
External Aeroacoustic Excitation and Internal Noise Transmission (also, see later)

Surface FFT (dB) at 500Hz (top) and 1000Hz (bottom)

AIAA2012-2205
AIAA2012-2206
SAE2013-01-0640
Turbo compressor Noise

GT2012-70028
HVAC – blower, distributor, ducts, flaps

Solution Time 0.1 (s)

SAE13-01-0856
Pipe network singing

AIAA2012-2171
Sunroof/side-window buffeting – real vehicle effects

- Wall compliance effects
  - Full FSI of compliant walls (above right)
  - Correlations for wall compliance (below right)
- Leakages

SAE2013-01-1012
Acoustic Transmission Loss - mufflers

Pure Acoustical Transmission Loss
- Including porous media
- In the presence of flow

Production geometry test by InDeSa

Idealised geometry test by CD-adapco
Aerospace: Airframe and Jet noise
Trailing edge self noise @ Re ~ $2 \times 10^5$
Propeller noise – vortex wake interaction
Hydroacoustics

- Sound propagation in compressible liquid media
- Multi-phase phenomena (bubble growth/collapse)
- Hull boundary layer noise with LES (Re~$10^7$-$10^8$)
Focus on Transient and Aeroacoustics

- LES-type turbulence model
  - DES (options of Spalart-Allmaras, k-ε, k-ωSST)
  - DES advection scheme blending
  - Full LES (wall resolved)
- Advanced wall treatment
  - y+ insensitive
- Non-reflecting boundaries for ideal gases
- Acoustic far-field damping in compressible liquids
- Full Compressibility
  - Interaction between the flow and acoustics
    - Especially for cavity/duct resonances
- Efficient implicit transient solver
  - 2nd order space and time discretisation
- Spectral Analysis
  - FFT and iFFTs at points and surfaces
  - Auto and Cross spectra – coherence and phase
  - Frequency and Wave Number Fourier analysis
Direct Propagation in STAR-CCM+

- Mesh requirement
  - 20 cells per acoustic wavelength ($\lambda = c / f$)
  - In ambient air, you need cells of ~15mm to propagate a signal at 1000Hz
  - Domain size = 1000D, (~10 $\lambda$)
  - Double precision code

- Ideal-gas non-reflective in/outflow boundaries

- Compressible liquid far-field acoustic reflecting-avoidance treatments
STAR results capture the acoustic sources for propagation via:

- *Ffowcs Williams-Hawkins* (far-field propagation of compact sources)

STAR offers coupling to 3rd party propagation codes:

- *FFT, ACTRAN*
- *LMS, Virtual.Lab.Acoustics*
- *ESI, VA-One*

Aero-VibroAcoustics:

- *Using FVS in STAR-CCM+
- *Export to SEA and FEA*
Introduction to 1D (line) WaveNumber Analysis

\[ \Phi_c(k, \omega) = \omega / c_0 \]
\[ k_c = \omega / U_c \]
\[ k_0 = \omega / c_0 \]

Bremner and Wilby AIAA-2002-2551
1D wave number analysis on attached and separated zones
2D wave number analysis at discrete frequencies

**Convective ridge**

**Acoustic circle**

Acoustics 2D wavenumber, by3D no freq averaged, 977Hz

Acoustics 2D wavenumber, by3D no freq averaged, 1953Hz

Acoustics 2D wavenumber, by3D no freq averaged, 2930Hz

Acoustics 2D wavenumber, by3D no freq averaged, 3906Hz

Acoustics 2D wavenumber, by3D no freq averaged, 4980Hz
Separating the acoustic content
Total and acoustic power input to vibration analysis
Summary

- Widely applicable modelling for flow noise prediction
- Continued investment towards
  - answering current needs
  - driving future expectations

in Aeroacoustics
and towards
AeroVibroacoustics

THANK YOU for your KIND ATTENTION
Questions on ... 

Aeroacoustics?