Overview

- **NASA Gearbox Noise**
  - Effects of bearings on noise transmission

- **Student Research**
  - Journal bearing impedance measurements (J. H. Gyurko)
  - Sound Intensity in Reverberant Environments (A. Barnard)
  - Sound transmission through joints between spacecraft structures
  - Structural Condition Monitoring with Structural Intensity (S. Conlon)
Rotorcraft Transmission Noise Path Model, Including Distributed Fluid Film Bearing Impedance Modeling

Investigators: S.A. Hambric, E. Smith, R. Bill, A. Hanford, R. Campbell

Students: M. Shepherd

Sponsor: NASA
Source: gear mesh transmission error

Receiver: Panel vibrations, and subsequent sound radiation

Transmission Path: through bearings
Project Goals

- Develop steady state, time-harmonic FE/BE approach for simulating gear mesh noise transmission through bearings and housings
  - Bearing types:
    - Rolling element
    - Traditional fluid-film (journal)
    - NASA’s wave bearings (modified journal)

- Validate against measurements taken in NASA-GRC’s test rig
Shafts and housing coupled using bearing impedances

Conclusion: housing should not be considered rigid for shafting analysis
Measurements vs. Simulations

**Exp**
- 484 Hz
- 879 Hz
- 1221 Hz

**FE**
- 484 Hz
- 887 Hz
- 1238 Hz
- Compare vibration transmission through rolling element and journal (including wave) bearings

(3) 898/314 N

(1) 864/326 N
Measuring Impedances of Journal Bearing Films

Advisors: S.A. Hambric and K.M. Reichard

Researcher: J. Harrison Gyurko (Ph.D. Acoustics pending)

Sponsor: ARL Penn State
Goals

- Measure distributed stiffness and damping of fluid film in a journal bearing
  - Verify simulation codes
Pair of shakers drives bearing vertically or horizontally

Journal bearing test setup

Cross section of test bearing assembly

Proximity probes measure bearing displacement

Oil feed

Pressure transducers
Results

Static Pressures

Stiffness and Damping (Vertical Direction)
Next Steps

• Investigate:
  – Several static loading conditions (light to heavy loading)
  – Different excitation frequencies
  – Different shaft speeds
Sound Intensity in Reverberant Environments

Advisor: S.A. Hambric

Researcher: Andrew Barnard (Ph.D. Acoustics pending)

Sponsor:
**Objective**
Measure underwater narrowband radiated sound power and directivity in a reverberant tank

**Process**
1. Measure sound intensity map of source in reverb environment
2. Spatial FFT to wavenumber domain
3. Separate incident and reflected waves using measured pressure and particle velocity
   - Note: Currently only separable geometries (planes, cylinders, spheres)
4. Reject reflected waves
5. Filter evanescent waves
6. Inverse spatial FFT to spatial domain
7. Compute radiated power and directivity

**Benefits**
1. Low cost narrowband measurements in the lab (instead of in the field)
2. Less restrictive than NAH in regards to standoff distance from the source
3. Computationally straightforward
Thin walled aluminum shell

- Hologram resolution
  - z-axis: 5.82 cm
  - θ-axis: 20 degrees
- Over-scanned each end by 1 cylinder length
- Resulted in 1314 scan points

ARL Reverb Tank
4 degree of freedom scanning intensity measurement system measures acoustic pressure and particle acceleration
In general, raw intensity over-predicts and supersonic intensity under-predicts.

SIRE is within ±2 dB of T60 method in 1/3 octaves.

Evanescent nearfield effects

Destructive interference
- Spherical SIRE intensity map of dipole source
- SIRE effectively extracts dipole patterns from reverberant measurements
Structure-borne power through joints between composite and metal structures

Advisors: S.A. Hambric and S.C. Conlon

Researcher: Ben Grisso (Ph.D. Post-Doctoral Student)

Sponsor: United Launch Alliance
Goals

• Help develop design procedures that minimize structure-borne sound through launch vehicle panels

• Measurements on two sets of 4’ x 6’ panels
  – Set 1: honeycomb core with Aluminum facesheets (S. Conlon thesis panels)
  – Set 2: honeycomb core with Composite facesheets and end doublers (from Boeing)

• Simulations using classical (and simple) analytic methods
Test Setup

Gantry wide enough to hold two 4’ x 8’ panels

National Instruments data acquisition system

Aluminum core/facesheet panel
Conductance (Input Power)

Impedance Head (conductance measurement)

Shaker
Single Panel Measurements

Conductance (power input)

Energy

Dip caused by peak in radiation efficiency
Effects of bolting on conductance

Averaged Point Mobility - Panel Two

Conductance (s/kg) vs. Frequency (Hz)

- Panel Two - Bolted
- Panel Two - Unattached
- Inf. Plate Theory
Coupling loss factors comparable to internal loss factors

Internal (induced) loss factors exceed coupling loss factors
Next Steps

- Test panels with composite facesheets
– Vibration and acoustic scattering of submerged shell structures (Sabih Hayek)
– Composite structural acoustics (Kevin Koudela)
– Gear dynamics (Bill Mark)
– Machine lubrication (Liming Chang)
– Machine tools dynamics (Eric Marsh)
– Mechanics of flexible structures (Eric Mockensturm)
– Nonlinear dynamics (Gary Gray)