

S.A. Hambric

ACS 519 - Fluid Structure Interaction
Spring 2009

Instructor: Stephen A. Hambric
Office: Garfield Thomas Water Tunnel
Hours: By appointment
email: sah19@arl.psu.edu
Phone: (814) 863-3030

Fluid-structure interaction (FSI): when waves in fluids meet waves in structures and how they interact

Class prerequisites: Fundamentals of Acoustics and EMCH 524 (PDEs, complex numbers) or equivalent

My Motivation: That at the end of this course you understand the basic mechanisms of fluid-structure interaction and that you can apply your method(s) of choice (analytical, numerical, experimental) to solve structural-acoustics problems;

not:

that you can derive all the formulations we go through in this course from memory, but rather have a fundamental understanding of them

Your Motivation: Why are you here? Complete the Angel survey before the next class.

Focus of Course:

We will discuss:

Waves in fluids: compressional waves in fluids and gases (which will be referred to as fluids in this course), ...

Waves in structures: compressional, shear, and bending waves in plates, shells, and beams.

The interaction between wavetypes in fluids and structures.

This will be a practically oriented course motivated by noise control applications:

How and why is noise generated? Many mechanisms are responsible depending on structure and fluid properties and system operating conditions.

I will try to balance theory and practical applications, and expose you to many problem classes and solution approaches. This broad exposure may come at the expense of detailed derivations. Recommended textbooks and other materials I provide may be referred to for more details if desired.

Analytical and numerical (FEA, BEA, SEA) approaches to problems will be presented. Whatever the approach, some understanding of the dominant mechanisms of an FSI problem is the goal. The assumptions behind the approach (usually many) and ranges of validity with respect to the input and output parameters must be well understood.

You will not have all the answers to all fluid-structure interaction problems at the end of this course:

This is an evolving, R&D field.

No one, not even the masters in the field, can explain all the noise mechanisms in complex fluid-structure systems.

The more you learn about structural-acoustics, the less certain you are about the validity of its theory

But... there is lots and lots of room for improving understanding and developing new methods

Grading

Structural-acoustics is about 10% theory and 90% applications. Since this is a research area, this course will be conducted accordingly. The course grade will be composed of:

10% short homeworks;
60% projects (2 analytical/numerical applications); and
30% final (term paper).

The projects will help you to understand the fundamentals of fluid-structure interaction by solving relatively simple test problems involving flat plates interacting with surrounding acoustic spaces. You will use analytical and numerical methods and examine their ranges of applicability (and inapplicability).

The term paper will require you to research a structural-acoustic topic in the open literature and report on it. If you can do this well by the end of the semester, I will consider the course a success.

Outline

Basics

Overview, Assumptions
Kirchoff-Helmholtz Integral Equation, General FSI formulation, Rayleigh Integral Equation
Pressure and power radiated from a baffled piston and radiation efficiency and loss factor definitions
Structural wavetypes, thin and thick plate flexural waves
Definitions and discussion of dispersion relationships, coincidence frequencies
Structural vibrations and resonant modes

Application - SS Flat Plate (Analytical Solutions)

Modal radiation resistances - *Wallace paper*
Project 1 - Analytic solutions to radiating SS flat plate problem
Forced response - modal approach
Structural-acoustic loss factors
Damped forced response, convergence to infinite plate theory
Transmission loss of elastic plates

High Frequency Modeling Methods (Statistical Energy Analysis [SEA])

Some background (energies, power inputs, 1/3-octave frequency bands)
Introduction to SEA - *Burroughs paper*
Application - Double panel transmission loss - *Price/Crocker paper*
Project 2 - SEA for double panel transmission loss

Low Frequency Modeling Methods (Finite and Boundary Element Methods)

Basic approaches and fluid-structure coupling
FE for structures and fluids - *Everstine survey paper*
BE for fluids
Fluid-structure coupling - FE/FE and FE/BE
Cavity backed flexible panel - *Pretlove paper*

Structural-Acoustics of Cylindrical Shells

Structural vibrations and modes
External fluid loading (reactive and resistive)
Forced vibration and radiation of externally fluid-loaded cylindrical shells
Interior fluid acoustics
Fluid-filled pipe modeling with finite elements

Advanced topics

Structural-acoustics in wavenumber space
Structural-acoustic analysis for spatial random excitation fields
Structural-Acoustic inverse problems

Text Books

Most textbooks emphasize analytical approaches heavily, with only cursory treatments of numerical methods (FEA, BEA, SEA). We will examine analytical *and* numerical methods here.

Class notes and journal articles will be used for much of this course, but several textbooks are nice to have as permanent references for structural-acousticians:

Fahy and Gardonio - *Sound and Structural Vibration, 2nd Edition* - (REQUIRED) A good book, with heavy emphasis on formulating and solving problems in wavenumber space. Also, a nice survey of transmission loss analysis of building partitions. *But:* seems to be biased toward in-air problems (fluid loading effects are not treated extensively)

Junger and Feit - *Sound, Structures, and their Interaction* - (OPTIONAL) Excellent book for heavy fluid (water) applications. Junger and Feit have developed much of the theory used in Navy applications today. Highly recommended for future Naval structural-acousticians. *But:* hard to understand for the beginner.

Cremer, Heckl, and Ungar - *Structure-Borne Sound* - (OPTIONAL) The definitive structural-acoustics book. Cremer and Heckl wrote the original book in German and Ungar translated it into English. A comprehensive treatment of waves and vibrations in structures with some discussion of radiation into fluids.

Ross - *Mechanics of Underwater Noise* - (OPTIONAL) A general underwater acoustics book written by the former head of the David Taylor Research Center Acoustics Department. Filled with understandable explanations of very complicated underwater acoustics problems. Excellent summary of a lot of the early Navy acoustics R&D work.

Leissa – *Vibrations of Plates* and *Vibrations of Shells* (OPTIONAL) Two book set of modes of vibration of plates and shells – cheap and indispensable for the practicing structural-acoustician

Blevins – *Formulas for Natural Frequency and Mode Shape* - (OPTIONAL) Tables of mode shapes and frequencies for a wide variety of structures

Finally, please download PDFs of my tutorials on Structural Acoustics (originally published in Acoustics Today magazine) from www.hambricacoustics.com