SEA

É. Savin

What is it all about?

Course description

Bibliography

Advanced structural dynamics and acoustics

Introduction à l'Analyse Statistique Énergétique (SEA)

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Outline

Random loads

Launcher structure excited by jet noise

Aircraft structure excited by turbulent boundary layer

Random loads

Bridge excited by wind

Offshore oil rig excited by swell

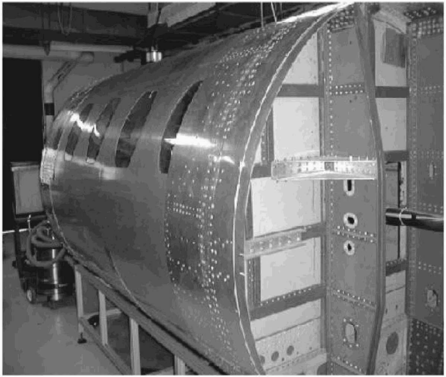
Random loads

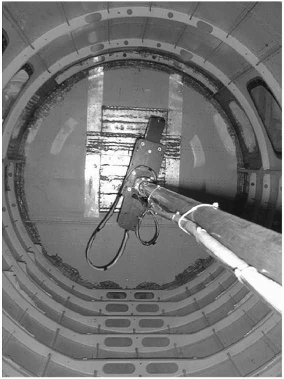
Earthquakes

Tank excited by road unevenness

Frequency ranges of vibration

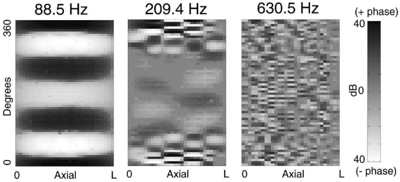
- Cessna Citation fuselage: 9+19 stringers, 22 stiffeners.
- $L = 2.55$ m, $R = 0.81$ m, thickness = 0.8–1.2 mm.



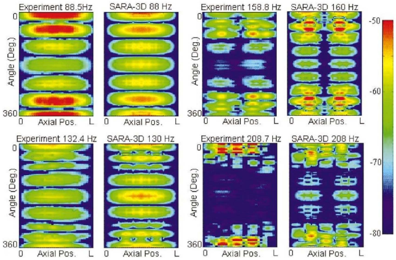


Herdic *et al.* *JASA* **117**(6), 3667 (2005)

Frequency ranges of vibration



Phase of the radial celerity

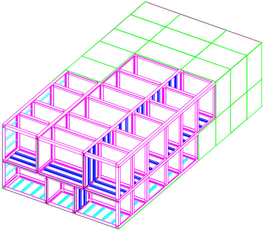


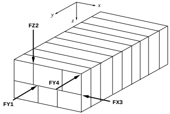
Ampl. of the radial celerity

Loading: a point force at the junction of a frame and stiffener.

Frequency ranges of vibration

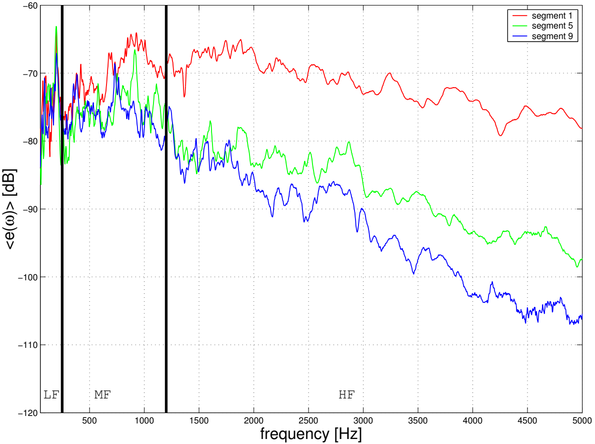
- Structure: 200 plates, 400 stiffeners, 54 cavities.
- $L = 5.3$ m, width $= 2.5$ m, height $= 1.4$ m, $M = 825$ kg.





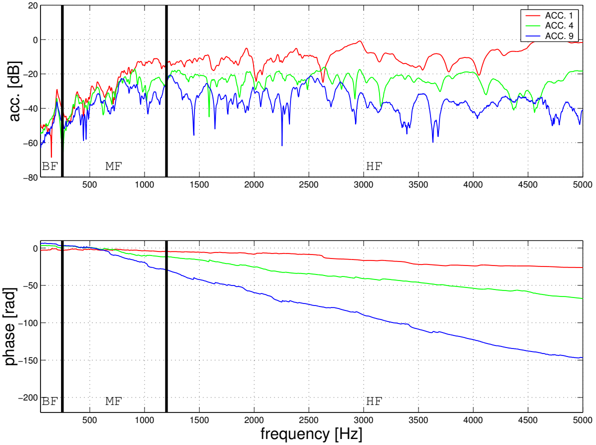
Savin *AIAA J.* **40**(9), 1876 (2002)

Frequency ranges of vibration



Estimated mechanical energies $\mathcal{E} = m\langle v\rangle^2$;
$$dB_{\mathrm{ref}} = 10 \times \log_{10}(1\,\mathrm{kg.m^2/s^2}).$$

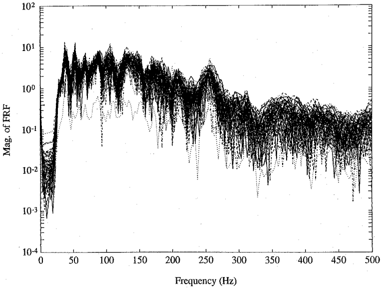
Frequency ranges of vibration



Measured vertical accelerations along the structure;

$$dB_{\text{ref}} = 20 \times \log_{10}(1\,\text{m/s}^2).$$

Frequency ranges of vibration



Measured FRF amplitudes of 99 "identical" Isuzu Rodeo trucks: acoustic pressure at driver's ear for a mechanical excitation applied to the left front wheel.

Kompella-Bernhard *Noise Control Engrg. J.* **44**(2), 93 (1996)

Course description

- At **low frequencies** the dynamic response of a built-up structure is physically well represented by component mode synthesis (Structural dynamics and vibration courses).
- At **higher frequencies** this representation is mathematically sound, but numerically and above all **physically** meaningless. These issues have critical relevance in both internal and external structural acoustics (Fluid-structure interaction, Structural acoustics, Boundary element method courses).

Course description

- SEA is to date the only one engineering approach capable of dealing with them, but it is based on (very) restrictive hypotheses. The objectives of the course are twofold:
  1. introduce the basic SEA concepts,
  2. discuss the underlying assumptions and limitations.
- Use of a **probabilistic framework** (Stochastic dynamics course).

Course description

- **Prerequisites**: structural dynamics, structural acoustics, fluid-structure interaction, random vibrations, elastic wave propagation:
  - Vibrations, analyse modale (É. Balmès, M. Corus);
  - Méthodes fréquentielles en vibrations (A. Barbarulo);
  - Interaction fluides-structures (J.-S. Schotté);
  - Propagation des ondes élastiques (B. Tie);
  - Apprentissage statistique (D. Clouteau, F. Gatti).

  but all lectures are self-contained!!!
- **Lecture notes & slides**: on demand `eric.savin@{centralesupelec,onera}.fr`.
- **Grading**: final exam, homework.

Agenda 2021–2022
All lectures start at 13:45 PM

22 Sep **Lecture #1**: primer on random vibrations & energetics of the single-dof oscillator.

29 Sep **Lecture #2**: fundamental coupled problems:

1. 2-dofs system [after R.H. Lyon, G. Maidanik, *JASA* **34**(5), 623 (1962)],
2. single-dof oscillator in an acoustic fluid [after P.W. Smith Jr., *JASA* **34**(5), 640 (1962)].

06 Oct **Lecture #3**: tutorial class #1.

13 Oct **Lecture #4**: energetics of continuous system vibrations.

20 Oct **Lecture #5**: energetics of coupled system vibrations; structural-acoustics bases, inertial and radiation effects.

Agenda 2021–2022

All lectures start at 13:45 PM

27 Oct	**Lecture #6**: tutorial class #2.
17 Nov	**Lecture #7**: structural-acoustics (cont'd): infinite and finite plates coupled to the air.
24 Nov	**Lecture #8**: SEA formulation, hypotheses, shortcomings, parameters. Industrial applications.
01 Dec	**Lecture #9**: tutorial class #3.
08 Dec	**Lecture #10**: external Neumann problem for the Helmholtz equation.
TBA	**Final exam**.

Other graduate courses

- **M.I.T. 13.811**: Advanced structural dynamics and acoustics [available on MIT OCW].
- **U. of Adelaide MECH ENG 7030**: Advanced vibrations.
- **K.T.H. SD2170**: Energy methods.
- **U. of Illinois TAM 514 ONL**: Elastodynamics and Vibrations.
- **Boston U. ENG ME 515**: Vibrations of complex mechanical systems.
- **Shandong U. Postgraduate**: Mechanical vibration.
- *etc.*

History

- M. Heckl 1930–1996, R.H. Lyon 1929–2019, G. Maidanik 1925–2010, D.U. Noiseux 1920–2009, P.W. Smith, Jr. 1923–2010, E.E. Ungar 1926–, W. Westphal 1928–???...
- Bolt, Beranek & Newman Inc., Cambridge Acoustical Associates Inc., Harvard Acoustical Research Lab., MIT Acoustics and Vibration Lab. (Cambridge MA), Naval Ship Research and Development Center (Bethesda MD)...
- Apollo program 1961–1975, acoustic signature of ships and submarines, aeroacoustics, underwater acoustics...

Further reading...

- H. Benaroya, S. M. Han, M. Nagurka: *Probabilistic Models for Dynamical Systems*. CRC Press, Boca Raton FL (2013).
- J. S. Bendat, A. G. Piersol: *Random Data: Analysis and Measurement Procedures*, 4th Ed. Wiley, Hoboken NJ (2010).
- C. F. Coe, W. J. Chyu: "Pressure-fluctuation inputs and response of panels underlying attached and separated supersonic turbulent boundary layers", *AGARD Symposium of Acoustic Fatigue, 26-27 September 1972, Toulouse*; 20 pages (1972).
- G. M. Corcos: "Resolution of pressure in turbulence", *J. Acoust. Soc. Am.* **35**(2), 192-199 (1963).
- F. Fahy, P. Gardonio: *Sound and Structural Vibration: Radiation, Transmission and Response*, 2nd Ed. Academic Press, London (2006).
- M.C. Junger, D. Feit: *Sound, Structures, and their Interaction*, 2nd Ed. Acoustical Society of America, Melville NY (1993).

Further reading...

- A. Le Bot: *Foundation of Statistical Energy Analysis in Vibroacoustics*. Oxford University Press, Oxford (2015).
- R.H. Lyon, R.G. DeJong: *Theory and Applications of Statistical Energy Analysis*, 2nd Ed. Butterworth-Heinemann, Boston MA (1995).
- G. Maidanik: "Vibrational and radiative classifications of modes of a baffled finite panel", *J. Sound Vib.* **34**(4), 447-455 (1974).
- R. Ohayon, C. Soize: *Structural Acoustics and Vibration*. Academic Press, London (1998).
- J. J. Shynk: *Probability, Random Variables and Random Processes. Theory and Signal Processing Applications*. Wiley, Hoboken NJ (2013).
- P.W. Smith Jr., R.H. Lyon: *Sound and Structural Vibration*. NASA CR-160, March 1965.