Chapter 5:
Random Vibration

ANSYS Mechanical Dynamics
Random Vibration Analysis

Topics covered:
- Definition and purpose
- Overview of Workbench capabilities
- Procedure
A. Definition and Purpose

What is random vibration analysis?

- A spectrum analysis technique based on probability and statistics.
- Meant for loads such as acceleration loads in a rocket launch that produce different time histories during every launch.

Reference: Random vibrations in mechanical systems by Crandall & Mark
• Transient analysis is not an option since the time history is not deterministic (sample is not repeatable).
• Instead, using statistics the sample time histories are converted to *Power Spectral Density function (PSD)*, a statistical representation of the load time history.

*Image from “Random Vibrations Theory and Practice” by Wirsching, Paez and Ortiz.*
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Image from “Random Vibrations Theory and Practice” by Wirsching, Paez and Ortiz.
Random Vibration Analysis

Statistical Representation

- A Random Vibration analysis computes the probability distribution of different results, such as displacement or stress, due to some random excitation.

- The analysis follows a modal analysis.

- An internal combination is done to compute the combined effect from each mode and their interactions.

![Gaussian (normal) Distribution](image)
Power Spectral Density

- The Power Spectral Density is the mean square value of the excitation for a unit frequency band.
  - The area under a PSD curve is the variance of the response (square of the standard deviation).
  - The units used in PSD are mean square/Hz (e.g. an acceleration PSD will have units of $G^2/Hz$).
  - The quantity represented by PSD may be displacement, velocity, acceleration, force, or pressure.

Random Vibration curve by MIL-STD-202
Random Vibration Analysis

Common Uses

• Commonly used for
  – Airborne electronics
  – Acoustic loading of Airframe parts
  – Jitter in alignment of optical equipment
  – Relative deformation in large mirrors
Workbench Capabilities

• **Input:**
  – Natural frequencies and mode shapes from a modal analysis
  – Single or multiple PSD excitations applied to ground nodes

• **Output:**
  – $1\sigma$ results can be contoured like any other analysis.
  – Response PSD at one DOF (one point in one direction)
Procedure:

Random Vibration
Random Vibration

Procedure

• Drop a Modal (ANSYS) system into the project schematic.
Procedure

- Drop a Random Vibration system onto the Solution cell of the Modal system.
Random Vibration

Procedure

- Create new geometry, or link to existing geometry.
- Edit the Model cell to bring up the Mechanical application.
Preprocessing

- Verify materials, connections, and mesh settings.
  - This was covered in Workbench Mechanical Intro.
• Add supports to the model.
  – Displacement constrains must have a magnitude of zero.
Random Vibration
Solution Settings

- Choose the number of modes to extract.

- If needed, upper and lower bounds on frequency may be specified to extract the modes within a specified range.
Random Vibration

Postprocessing

- Review the modal results before proceeding.
Random Vibration

Preprocessing

- Insert an Acceleration, Velocity, or Direction PSD base excitation.
- Set the Boundary Condition, Load (Tabular) Data, and Direction.
Random Vibration

Postprocessing

- Insert Directional Deformation, Velocity, or Acceleration.
  - the direction and sigma value may be chosen here
  - note that results are always reviewed with scaling set to 0.0
Postprocessing

- Stress (normal, shear, equivalent) and Strain (normal, shear) results can also be reviewed.
Postprocessing

- Response PSD can be plotted at one DOF (one point in one direction, either absolute or relative to base excitation).
• In workshop 5A, you will determine the displacements and stresses in a girder assembly due to an acceleration PSD.

**WS5A: Random Vibration (PSD) Analysis of a Girder Assembly**