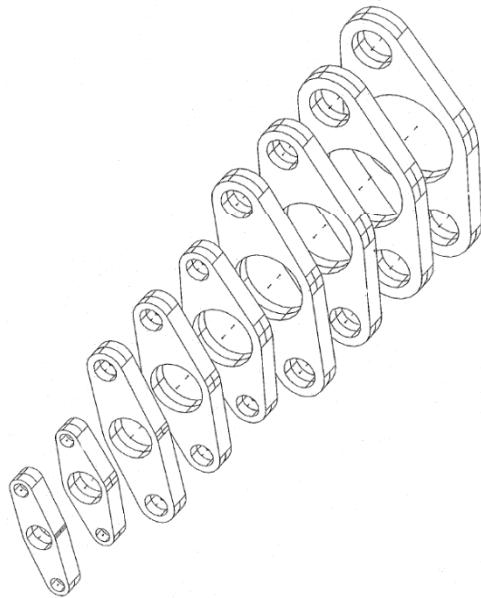


FEA Vibration Analysis

**Is based on the displacements of
parametric solid models**



Overview, 1

- **Every structure has the tendency to vibrate at certain frequencies, called a resonant or *natural frequency*. Spring-mass: $\omega^2 = k/m$**
- **Each natural frequency is associated with a certain shape, called *mode shape*, that the model tends to assume when vibrating at that frequency. (Also known as *simple harmonic motion*.)**

Overview, 2

- **When a structure is excited by a dynamic load with a frequency that coincides with one of its natural frequencies, the structure undergoes large displacements and stresses.**
- **This phenomenon is known as *resonance*.**

Overview, 3

- **For undamped systems, resonance theoretically causes infinite displacement and stresses.**
- **Damping, however, always puts a limit on the response of the structures due to resonant loads.**

Overview, 4

- **A real part has an infinite number of natural frequencies.**
- **A FE model has a finite number of natural frequencies, equal to the number of unknown displacements in the model.**
- **Only the first few modes (5-10) are usually needed for most purposes.**

Overview, 5

- **Frequency analysis (*FA*) requires the stiffness matrix, K , used in static models, plus the mass matrix, M , which measures the distribution of mass in space.**
- **It requires an matrix eigenvalue solution: $|K - \omega^2 M| = 0$ for *frequency* ω , and a corresponding displacement *mode shape*.**

Overview, 6

- **Frequency analysis includes the part's kinetic energy.**
- **For a particle, $KE = 0.5 \text{ mass} * \text{velocity}^2$**
- **If frequencies are important, make the mesh size small where you expect large velocities.**

FA Data Reliability, 1

- **Geometry:** generally most accurate, if not de-featured. A crude mesh creates a good mass matrix.
- **Material:** the mass density can be known to 4 or 5 significant figures.
- **Mesh:** use smaller elements where you expect large velocities.

FA Data Reliability, 2

- **Loads:** are not considered in a *FA*
- However, initial stresses can be, such as in a spinning part.
- **Restraints (prescribed displacements):** drastically effect frequency results; several reasonable restraint should be studied.

General Approach for *FA*, 1

- **Select verification tools to independently check the *FA* study**
 - **Use handbook, experimental, another *FA* method, etc.**
 - **Predict the mode shapes based on restraint points.**
 - **Compare plotted modes with your prediction**
 - **If significantly different, re-access the assumptions used for both solutions**
 - **Repeat the prediction and/or *FA* study**

General Approach for *FA*, 2

- **SW solver** → **Properties** → **Number of frequencies**, defaults to the 5 lowest values.
- Determine how many frequencies you need.
- Change the default to a higher number until the results for your frequencies do not change upon re-solving the system.

FA Result Reliability, 1

- **Eigen-problem Equation Solver:** Has a much higher operation count than a static solver.
- **Accuracy:** Each higher frequency value, ω , is less accurate than the previous one. The same is true for each corresponding mode shape.

FA Result Reliability, 2

- **Zero (or slightly negative) frequencies correspond to a rigid body motion (OK for airplanes and rockets).**
- **They usually denote a system that is not properly supported.**