Space Structures

1 Structural Types and Loads

Space structures are present to support and protect the payload. First there is the **primary structure**, which is the backbone of the structure. There are also the **secondary structures**, supporting instruments and such. If the structure fails, than the mission fails, so structures need to be **reliable**. They should give **protection** against the harsh space environment. They should be **strong** enough to withstand the loads and **stiff** enough to prevent unwanted vibrations.

Now let's look at the loads. We can distinguish five groups.

- The **static loads**, which are more or less constant in time.
- The **low-frequency vibrations**. These are usually sinusoidal loads. Its frequency ranges from 5-100Hz.
- The **high-frequency vibrations**. These are random vibrations, with a frequency ranging from 20-1000Hz. Its power is proportional to a^2, where a is the acceleration of the spacecraft.
- The **acoustic loads** are induced by noise, usually coming from the engines. Its frequency ranges from 20-10000Hz. Especially secondary structures are sensitive to these loads.
- **Shock loads** are high loads only present for a very short time.

2 Stiffness and Frequencies

Every structure can vibrate at its own **eigenfrequency** (also called **natural frequency**). **Resonance** occurs when something else is also vibrating at this eigenfrequency. This is very dangerous and should be prevented.

To find the natural frequency, we first would like to know the stiffness k. This is defined as

$$k = \frac{P}{\delta}, \tag{2.1}$$

where P is an applied load and δ is the resulting displacement. So for a straight bar, the stiffness in axial and lateral directions are

$$k = \frac{EA}{L} \text{ axial}, \qquad k = \frac{3EI}{L^3} \text{ lateral}. \tag{2.2}$$

The natural frequency can now be found using

$$f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}, \tag{2.3}$$

where T is the **vibration period** and m is the mass of the object. So we find that

$$f = \frac{1}{2\pi}\sqrt{\frac{EA}{mL}} \text{ axial}, \qquad k = \frac{1}{2\pi}\sqrt{\frac{3EI}{mL^3}} \text{ lateral}. \tag{2.4}$$

Designers can use these equations. It's their task to make sure that the frequency f is bigger than the minimum frequency f_{min}.

3 Margin of Safety

To see how well a structure is designed, the **margin of safety** can be used. It is defined as

$$MS = \frac{\sigma_{allowable}}{j\,\sigma_{design}} - 1, \tag{3.1}$$

where j is the safety factor. If $MS < 0$, then failure will occur. If $MS > 1.5$, then the structure is inefficient. So the margin needs to be between these values.