Freedom and Constraint Topology: Design Chart

Legend:

Translation

Rotation

Screw

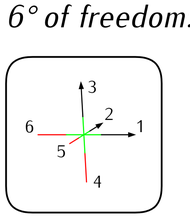
Constraint line

Flexure elastic deformation limit (approx):

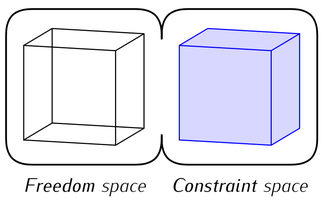
Input values are thickness of the flexure wire/blade and flexure height. Angular deformation was optimized for X blade flexure and parallel for ½ height travel.

$$\frac{\text{elongation at yield}}{\text{safety factor}} = \begin{cases} \frac{\text{thickness}}{\text{height}}\left(0.5\frac{\text{arc travel}}{\text{height}} + 0.025\,\frac{\text{arc travel}}{\text{height}}^{3}\right), & \text{if angular} \\ \frac{\text{thickness}}{\text{height}}\left(2.76\frac{\text{travel}}{\text{height}} + 0.2\frac{\text{travel}}{\text{height}}^{2} + 2.3\frac{\text{travel}}{\text{height}}^{4}\right), & \text{if parallel} \\ 0.5\,\frac{\text{thickness}}{\text{minimal deformation radius}}, & \text{if other} \end{cases}$$

6° of freedom:

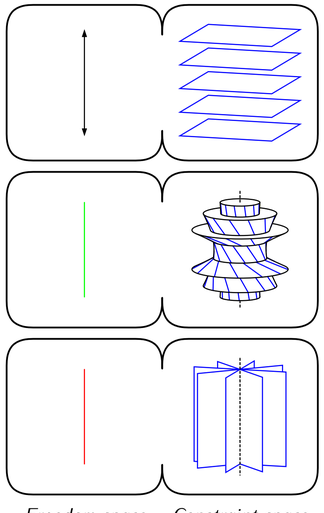


0° of freedom:



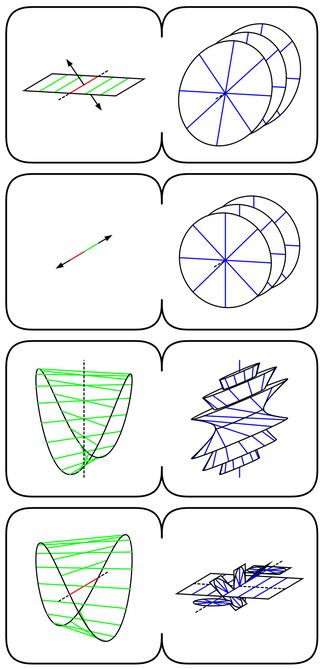
Freedom space *Constraint space*

1° of freedom:



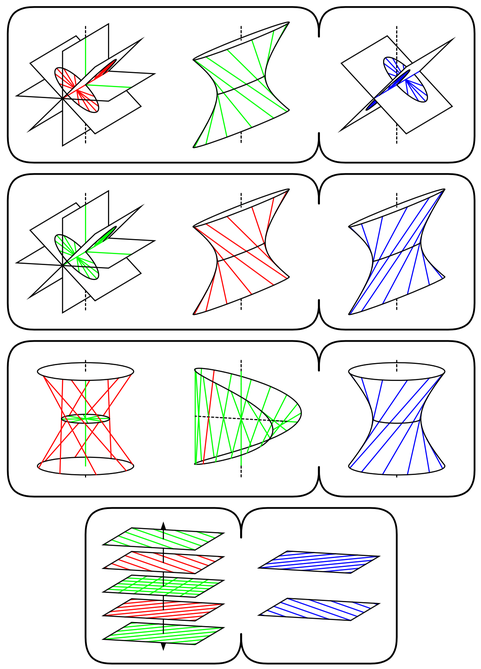
Freedom space *Constraint space*

2° of freedom:



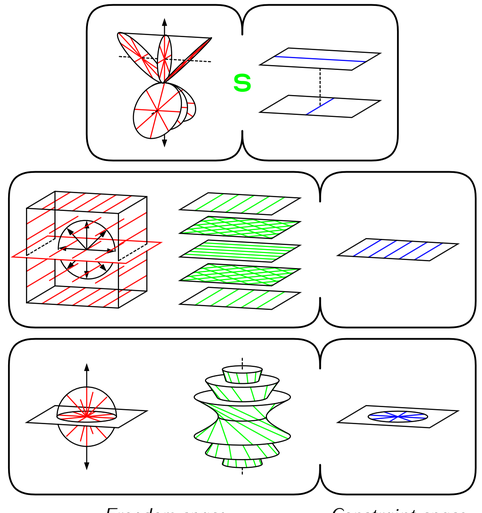
Freedom space *Constraint space*

3° of freedom:



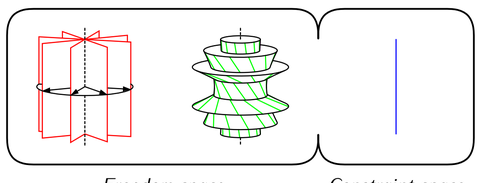
Freedom space *Constraint space*

4° of freedom:



Freedom space *Constraint space*

5° of freedom:



Freedom space *Constraint space*

Degrees of freedom:

One wire constrains one degree of freedom in an exactly constrained flexure. Redundant wires result in an over-constrained flexure. Only serial flexures are under-constrained.

Screws:

For a screw motion, pitch is defined as a ratio of translation over rotation.

$$\text{pitch} = \frac{\text{travel}}{\tan(\text{angle at wires})}$$

Serial / Parallel:

For a serial flexure, the final freedom space is the sum of intermediate freedom spaces.

For a parallel flexure, intersection defines the new freedom space.