“Factor of Safety (FOS)” aka “Safety Factor”

What is/are FOS? FOS requires the part or system to have a greater structural capacity than the greatest anticipated load.

FOS = n = “designed ability” / “actual anticipated load.” Should be greater than 1. Why have a FOS? Because all engineers are ignorant! Good engineers are aware of their ignorance.

What are engineers ignorant about?

- Actual material properties of the part (yield strength is consistent and well controlled, but tensile strength of brittle materials is not.
- Effects of variation in manufacturing and assembly (may affect part/system performance)
- Long term degradation (such as corrosion or weathering)
- Applied loads!!!!! What is the greatest load the suspension on your car has ever experienced or will ever experience?

How does an engineering determine an appropriate FOS for his/her design?

- Codes and standards, governing organizations (such as FAA) o FAA requires FOS of 1.5 for static loads on wings to cause buckling
- Established by your company (many companies have lots of historical data to base recommendations upon).
- The greater the cost of failure, the greater the need for large FOS • The more ignorance, the greater the need for FOS
- The less likely a pre-failure will be detected, the greater the need for FOS. Example, corrosion can usually be detected, fatigue cracks can be detected by careful and costly inspection.

Typical: there is not typical, FOS may range from 1.5 to 10 or even higher.

NOTE: Different FOS may be applied to the same part based on different criteria. Example: static load on a wing is “easily” tested and has a FOS of 1.3 to 1.5. But a wing may never experience an overload. Most wings fail due to cyclic loads. So there will be a separate FOS regarding fatigue loading. The part must satisfy BOTH requirements.

Engineers must understand both sides to this equation: Material behavior (such as yielding) Applied loads (stress analysis) And they must be able to relate them!

For quasi-static overloads (aka “single cycle failure”):

FOS for plastic deformation (yielding) using the maximum shear stress failure theory (“Tresca”):

$FOS = S_{ys} / (\sigma_1 - \sigma_3)$ where σ_1 and σ_3 are principal stresses in the part

FOS for plastic deformation (yielding) using the distortion energy failure theory (“von Mises”):

$FOS = S_{ys} / \sigma_{effective}$ where $\sigma_{effective}$ is determined from the principal stresses in the part

Where $\sigma_{effective} = \{0.5*[(\sigma_1 - \sigma_2)^2 + (\sigma_1 - \sigma_3)^2 + (\sigma_2 - \sigma_3)^2]\}^{1/2}$

FOS for brittle fracture using the Maximum Normal Stress failure theory:

$FOS = S_{UT} / \sigma_1$ where σ_1 is a principal stresses in the part