# Unit 2
# Loads and Design Considerations

Readings:

| | |
|---|---|
| Rivello | (Ch. 1) |
| Cutler book | (at leisure) |
| G | 7.1 |

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# Sources of Stresses and Strains

Depends on type of structure

Aircraft

Launch Vehicles

Space Structures

General

Other Considerations

Can generally divide these into:

- Normal operational effects (regular use)
- Environmental effects (internal stresses, material property degradation)
- Isolated effects (lightning, impact)

In a (large company)

- “Design” group does general management
- “Loads” group determines operating conditions
- This is passed on to “stress” group that analyzes stresses and deformations
- “Materials” group provides material ultimates, etc.

$\Rightarrow$ ***Need to understand each part***

NOTE:

New approach in companies: IPT (Integrated Product Teams)

DBT (Design Build Teams) - people from each branch including manufacturing and marketing
$\Rightarrow$ even more important to understand various factors

# Factors, Margins, etc.

Two important definitions for static considerations

**Limit** Load/Stress/Condition: Maximum load/stress/condition where structure shows no permanent deformation.

**Ultimate** Load/Stress/Condition: Maximum load/stress/condition where structure does not "fail."

Definition is key; often defined as "break" (i.e., carry no more load)

Operationally, the limit load is the maximum load the structure is expected to see

The ultimate load provides a "factor of safety" for unknowns

$$\text{Ultimate Factor of Safety (U.F.S.)} = \frac{\text{Ultimate Load}}{\text{Limit Load}}$$

This is a design value

F.O.S. is also a "Factor of Ignorance"

This accounts for

→ probability & statistics
(also in material allowances)

U.F.S. = 1.5 for Aircraft
1.25 for Spacecraft (unmanned)

Design is usually conservative and an additional "Margin of Safety" (M.O.S.) is used/results

$$\text{Limit MOS} = \frac{\text{Tested Limit X} - \text{Limit X}}{\text{Limit X}}$$

$$\text{Ultimate MOS} = \frac{\text{Tested Ultimate X} - \text{Ultimate X}}{\text{Ultimate X}}$$

**An MOS is an experimental reality.**

Try to minimize M.O.S.

- Too conservative $\Rightarrow$ too heavy
- Not conservative enough $\Rightarrow$ plane falls out of sky (things have flown with negative M.O.S.)

So, begin with "operational envelope", the way the structure will be used

- Aircraft --> v-n diagram
- Spacecraft, etc.

Then add special conditions (gusts, etc.)

Also need to account for

- Environmental effects
  - change in material properties
  - causes stresses and strains
- Special conditions
  - Lightning
  - Impact
  - etc.

- Fatigue (cyclic loading)
  - Effect on material properties
  - Damage growth

## Example

A fighter aircraft has a gross take-off weight of 30,000 lbs. In a test of one wing, the wing fails at a total loading of 243,000 lbs. What is the margin of safety?

$$\text{Definition of M.O.S.} = \frac{\text{Tested Ultimate - Ultimate}}{\text{Ultimate}}$$

We know: Tested Ultimate = 243,000 lbs.
(for one wing)

How do we get the Design Ultimate?

Design Ultimate = Design Limit x Factor of Safety

For aircraft, F.O.S. = 1.5

How do we get the Design Limit?

Use the v-n diagram

From U.E., max n for fighter = 9 = limit n

(Note: n for level flight = 1

$\Rightarrow$ loading for level flight = weight)

$\Rightarrow$ Design Limit = $n_{limit}$ x weight

= 9 x 30,000 lbs. = 270,000 lbs.

*<u>But</u>*, each wing carries 1/2 of this

Design limit load for one wing = 135,000 lbs.

$\Rightarrow$ Design ultimate load for one wing = 202,500 lbs.

Finally, $\text{M.O.S.} = \dfrac{243{,}000 \text{ lbs.} - 202{,}500 \text{ lbs.}}{202{,}500 \text{ lbs.}}$

$$= \frac{40{,}500 \text{ lbs.}}{202{,}500 \text{ lbs.}} = \boxed{0.2 = \text{M.O.S}}$$

**+ 20% margin**

# What is “failure”?

It depends on use….

….may be deflection based (CTE example)
….may be fracture
….may be buckling

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Overall, you must consider:

Static Stresses
- Fracture
- Yielding
- Buckling

Deflections
- Clearances
- Flutter
- Vibration
- Tolerances (e.g., C. T. E.)

Life

- Damage accumulation
- “Fatigue”

For aircraft, design guidelines provided by FAA F.A.R.’s (Federal Aviation Regulations)

| Part 23 | Part 25 | Part 27 | Part 29 |
|---|---|---|---|
| Aircraft<br>Under<br>14,000 lbs. | Aircraft<br>Above<br>14,000 lbs. | | Helicopter |

USAF guidelines (e.g., Damage Tolerance Regulations)