

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.

⇒ ***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
⇒ 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

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 \rightarrow 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?

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

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

⇒ loading for level flight = weight)

⇒ Design Limit = n_{limit} x weight

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

But, each wing carries 1/2 of this

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

⇒ Design ultimate load for one wing = 202,500 lbs.

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

202,500 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
-
-
-

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



Aircraft
Under
14,000 lbs.

Part 25



Aircraft
Above
14,000 lbs.

Part 27



Part 29



Helicopter

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