Unit 2 Loads and Design Considerations

Readings:Rivello(Ch. 1)Cutler book(at leisure)G7.1

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Sources of Stresses and Strains

Depends on type of structure

<u>Aircraft</u>

Launch Vehicles

Space Structures



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.

<u>Ultimate</u> 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)

<u>Operationally</u>, 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.) = Ultimate Load

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

Limit MOS = Tested Limit X - Limit X Limit X

Ultimate MOS = Tested Ultimate X - Ultimate X Ultimate X

An MOS is an experimental reality.

Try to minimize M.O.S.

- Too conservative \Rightarrow too heavy
- Not conservative enough ⇒ 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?

Definition of M.O.S. = Tested Ultimate - Ultimate 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 $= 9 \times 30,000 \text{ lbs.} = 270,000 \text{ lbs.}$ <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, M.O.S. = 243,000 lbs. - 202,500 lbs. 202,500 lbs. = 40,500 lbs. = 0.2 = M.O.S 202,500 lbs. + 20% margin

What is "failure"?

It depends on use....

....may be deflection based (CTE example)may be fracturemay be buckling

Overall, you must consider:

Static Stresses

- Fracture
- Yielding
- Buckling

Deflections

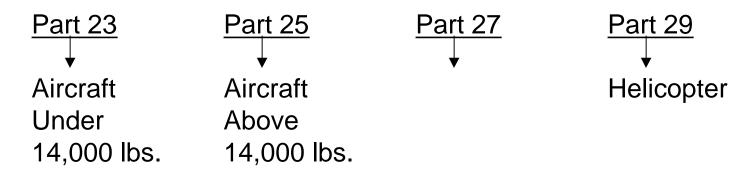
- Clearances
- Flutter
- Vibration
- Tolerances (e.g., C. T. E.)

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Life

- Damage accumulation
- "Fatigue"

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



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