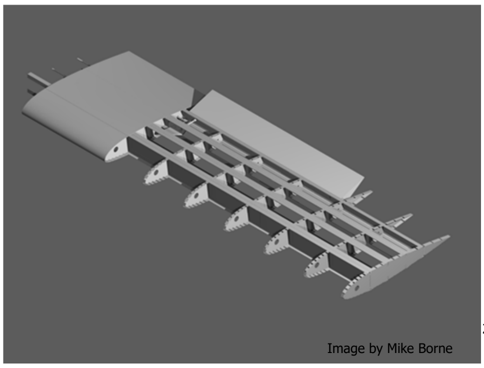
Aerospace Structural Design

General introduction to structural design



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Content

- These notes provide some general background to structural design, including procedure, structural hierarchy, loading, definitions and useful references.
  - You will have seen some of the content of this introduction previously in StM1 but it is repeated here as a recap.

Procedure

Stages of structural design

- **Define** the structural problem in terms of geometric envelope, function, loading, environment, longevity …
- **Scheme** a qualitative trial scheme wrt: structure, materials & manufacture following guidelines, previous experience and engineering judgement.
- **Check** the trial scheme by modelling the structure quantitatively - the simpler the better to start off. Check stiffness, strength and stability. Iterate + refine model.
- **Trade-off** checked trial schemes against fitness for purpose and select final scheme

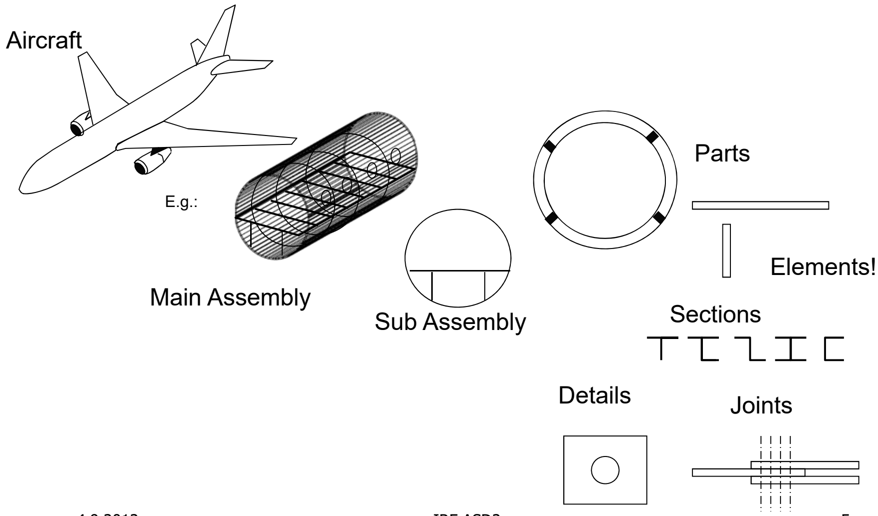
Compromise!

Procedure

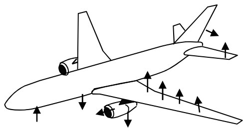
Typical Design Procedure

- Determine the greatest loads and allowable deflections
- Sketch out to scale, a rough design, e.g. using squared paper for preliminary sketches.
- Apply appropriate formulae to check deflections, stresses and and stability. I,e. "**stiffness, strength & stability**"
- Modify the sketch
- Repeat until satisfactory
- Prepare "proper" engineering drawings for manufacture: CAD!
- Worry! Confidence results in unexpected failures, worry prevents them. So go over your sums many times!
- Groups should independently check the design. "Check-stress"

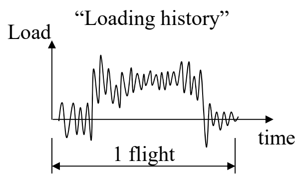
Structural Hierarchy



Load Cases



Load cases represent particular loading conditions according to the flight phase and aircraft configuration.



Ground:
- Taxi, Take-off, Landing

Flight:
- Manoeuvre, Gust
- Fuselage pressure
- Bird strike
- Fuel pressure, Crash
- ...

+ Configurations:
  - Flaps
  - Fuel distribution
  - Combinations

Hundreds of loading cases are defined for design consideration

Load limits and factors

- **Ultimate design load** = limit load x ultimate safety factor
  – the maximum load that the component must withstand without failure – typical Ultimate Safety factor = 1.5 for aerospace.

- **Proof load** = limit load x proof factor
  - A test load producing an acceptable limited permanent plastic deformation after which the component can still be used in service.
  - Typical Proof factors = 1.0 for civil, 1.125 for military

- **Factor of safety** (safety factor) = a factor to establish a safe design load allowing for uncertainties in design, e.g. proof factor and ultimate safety factor.

- **Limit load** = maximum anticipated load in operation.

Reserve factor and margin of safety

- **Reserve factor**, RF $= \dfrac{\text{allowable stress}}{\text{applied stress}}$
  (used in UK and Europe)

  RF = ###

  Box RF and write on RHS of page!

  – Defined at proof or ultimate*
  – Allowable stress represents the maximum that the material can be assumed to carry before failure, allowing for variability + environment.
  – Applied stress is the stress induced in the component at proof or ultimate load, usually defined at ultimate for aerospace*.
  – E.g. at ultimate:
    allowable stress = ultimate strength, applied stress = stress at ultimate load
  – RF < 1 implies failure, RF > 1 implies reserve of strength

- **Margin of Safety**, MoS $= \dfrac{\text{allowable stress} - \text{applied stress}}{\text{applied stress}}$
  (used in USA)

  – again, usually defined at ultimate
  – MoS ≡ RF-1
  – MoS < 0 implies failure, MoS > 0 implies margin of safety

Checks at proof and ultimate

- For aircraft structural design we normally design and check ultimate strength at ultimate loading to obtain an ultimate RF.
- We also need to retrospectively check proof strength at proof loading to get a proof RF.

NOTE:
- if the ratio of ultimate factor to proof factor exceeds the ratio of ultimate strength to proof or yield strength then the check at proof can be assumed to be covered by the check at ultimate.

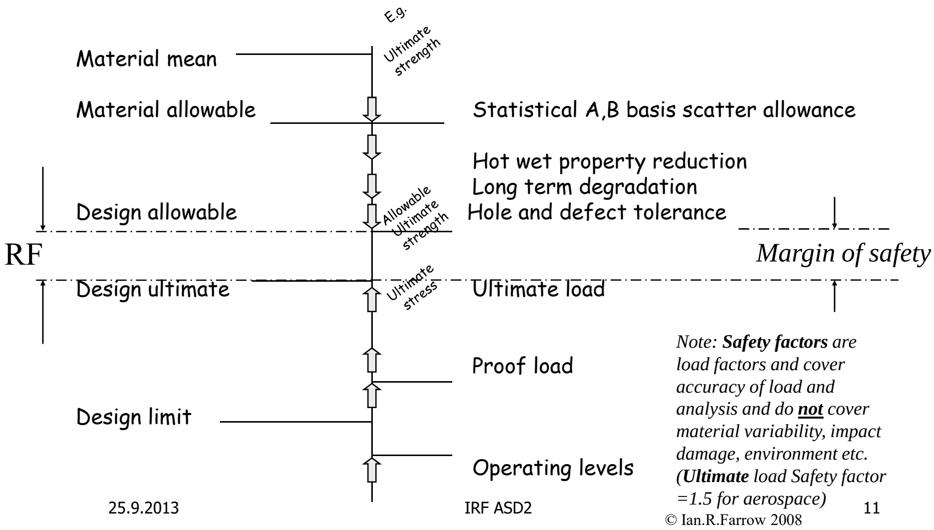
Allowables

- Stiffness: Deflection
  - Deflection limits
  - Dynamic response / flutter
- Strength: Material
  - Tension, Compression, Shear
  - Toughness: fracture
  - Longevity: fatigue
- Stability: Buckling
  - Global: Euler, lateral, torsional
  - Local: panel buckling, section crippling

Must account
For variation
and confidence

Definitions

Design Allowables & limits



Calculations

Design Calculation records

- <u>Log Book</u> - Professional engineers should <u>always</u> keep a logbook*. **All** ideas, sketches, rough calcs etc. should be written in the logbook and each day should be dated and initialled. Eventually you should collect and compile a series of logbooks as a chronological record.
- <u>Stress Report</u> – formal reports clearly laid out to illustrate the most refined check of the final design (<u>Not</u> an historic account – this is the job of the logbook).
- <u>Design Drawings</u> – General Arrangement "GA" and parts drawings defining geometry, details and assembly.
- <u>Mass Report</u> – listing the estimated mass of each part of the assembly.

Design Calculations

- Stress Check – a check of the proposed design by an independent group using independent methods.
- Design Methods & Data – In an engineering company a formal design must be verified by specific methods according to the company design manual and sanctioned verified data.
- Feasibility Studies & Preliminary Design – here methods can be less constrained with fewer limitations on data to promote efficiency and creativity. However, beyond the preliminary feasibility stage the methods and data used must be fully verified and accountable.

"Back of the envelope"

- This course relates to the Preliminary design level and you are encouraged to compile lists of formulae, standard structural configuration solutions, references and basic data, e.g. typical material properties etc.. I.e. your engineering "back of the envelope" key formulae and data.

References

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