Structures

Aircraft & spacecraft wing structures

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Learning objectives

Student should be able to...

• List typical structural elements for wing structure
  • Skin
  • Stringers
  • Ribs
  • Spars

• Explain functions of
  • Ribs
  • Spars
  • Skin-spar assembly
Wing structures

Structural characteristics

- Structural elements
  - Spars
  - Ribs
  - Skin
  - Stringers

- Note
  - Orientations of spars & ribs
Wing structures

Structural characteristics

- Wing panels can be very long (difficult to manufacture)
  - Centre/outer wing (inboard/outboard)
  - Splices/joints/fitting
Wing structures

Function of ribs

- Maintain aerodynamic profile of wing
- Transfer aerodynamic & fuel loads on skin to structure
- Provide stability against panel buckling
- Introduce local load into the structure
  - i.e. landing gear, engines, flaps, ailerons, etc
- Sealing the integral fuel tank
  - Fuel surge/splashing
Wing structures

Function of ribs

- No ribs
  - Crushing

- Not enough ribs
  - Buckling

- Rib pitch
  - ~20 - 100 cm
Wing structures

Types of ribs

- Selection of rib type and manufacturing method depends on
  - Loads
  - Design philosophy
  - Available equipment and experience
  - Costs

- Form & plate ribs
  - Stiffening profile
  - Low loads
- Forged or machined ribs
  - Very high loads
Wing structures

Rib – stringer intersections

- Three general solutions
  - Both rib and stringer not interrupted
  - Stringer interrupted
  - Rib interrupted
Wing structure

Function of spars

- Carry wing bending loads
  - Aerodynamic forces (Lift) create bending
Wing structure

Bending deformation

- Assume: wing clamped
  - 1 - little deformation
  - 4 - strong deformation
- Diagonal elements!

- Add diagonal elements...
- ...or better: sheet
Wing structure

Spars

- The basic form of the spar is the I-beam. The spar consists of
  - Spar caps/girders (flanges)
  - Web (plate)
- The web performs the diagonal function
Wing structure

Spars

• The forces are greater at the root ⇒ the spar must be thicker (difficult with extruded spar caps)

• Built up adhesive bonded sheet metal
Wing structure

Spars types

- Similar to ribs..

- Built-up web
- Built-up truss
- Bent-up channel
- Frame truss - not recommended

- Sine-wave web
- Integrally machined web
- Integrally machined truss
Wing structure

Built-up spars

- Extruded spar cap

Sheet metal cap

Extruded cap

Sheet metal bend-up angle

Ram

Work

Die

V

F

Munch

Work

Die
Torsion box

Single spar

• Single spar: low resistance against torsion

• Two spars: **Differential Bending**

  ![Diagram of Forward spar and Rear spar](image)

  - Torsion is transferred in bending R.S. upwards and F.S. downward
  - Spars give good resistance

• Closed cylinder: Best against torsion!
Torsion box

- Closed section has high resistance to torsion (not necessarily circular!)
  - Rectangular shape
  - Deforms like
Torsion box
Blackburn Duncanson

- Single spar, torsion box and fuel tank in one
Torsion box

Wing structure as closed box

1. Thicker skin
   - take up aerodynamic forces
   - part of the torsion box
   - partially takes over role of spar caps (bending function)

2. Degenerated spar caps

3. Thicker web - bending function and part of the torsion box

4. Stringers - support the skin and partially take over role of spar caps

5. Rib
Torsion box

Advantages

- Completely free load bearing structure, no support or strut
- Thinner wings (at given span) or longer wings (at given thickness)
- Torsion stiffness and bending stiffness can be engineered separately
- Lower weight
Wing structure - example
Fokker 100 outer wing
Summary

Aircraft & spacecraft structures

- Wing structural elements
  - Spar, rib, skin, stringers

- Function of rib
  - Primarily maintaining wing shape and avoiding buckling of skin

- Function of spar
  - Primarily resisting bending