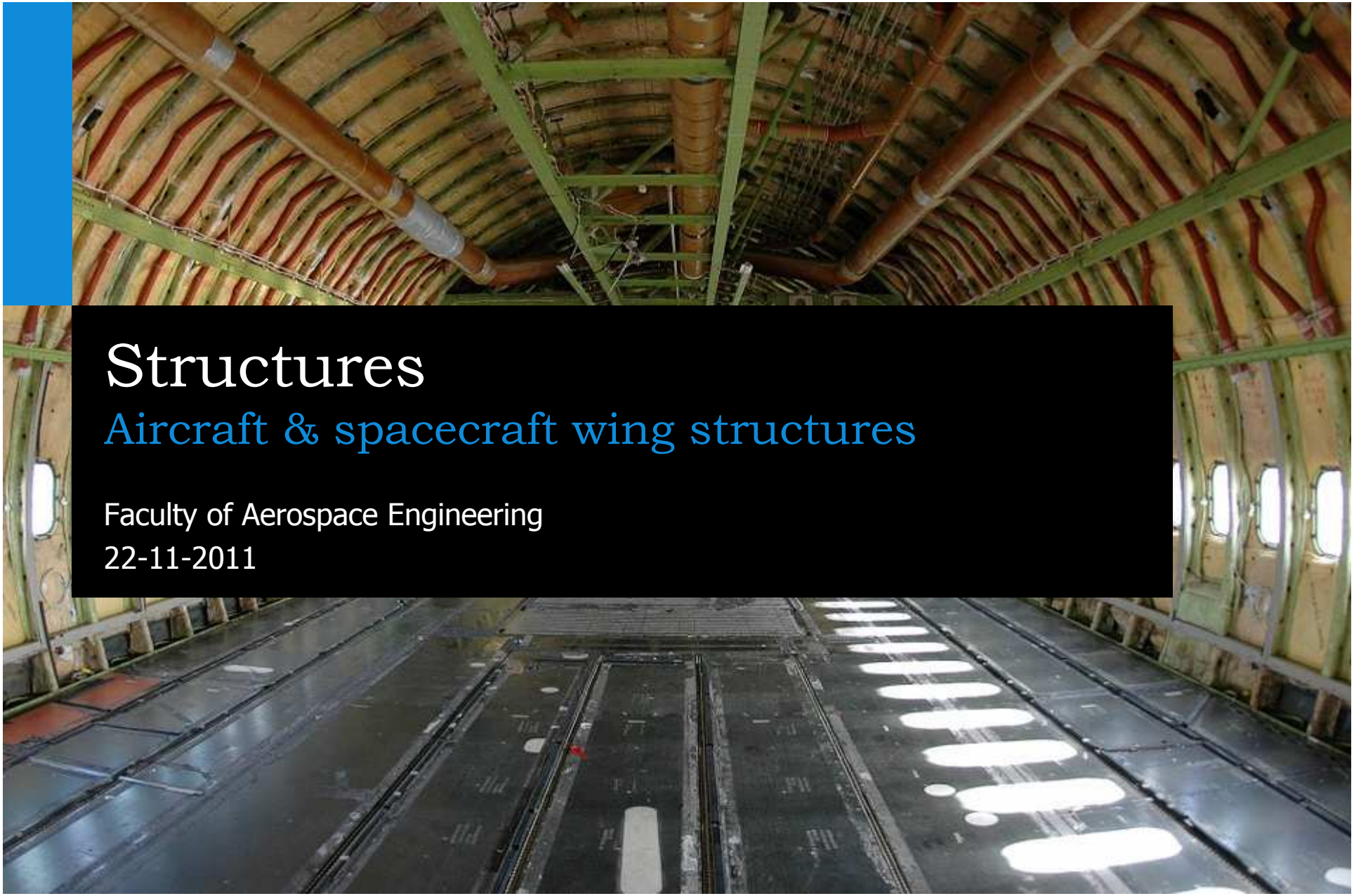
Introduction to Aerospace Engineering

Lecture slides



Structures

Aircraft & spacecraft wing structures

Faculty of Aerospace Engineering

22-11-2011

Learning objectives

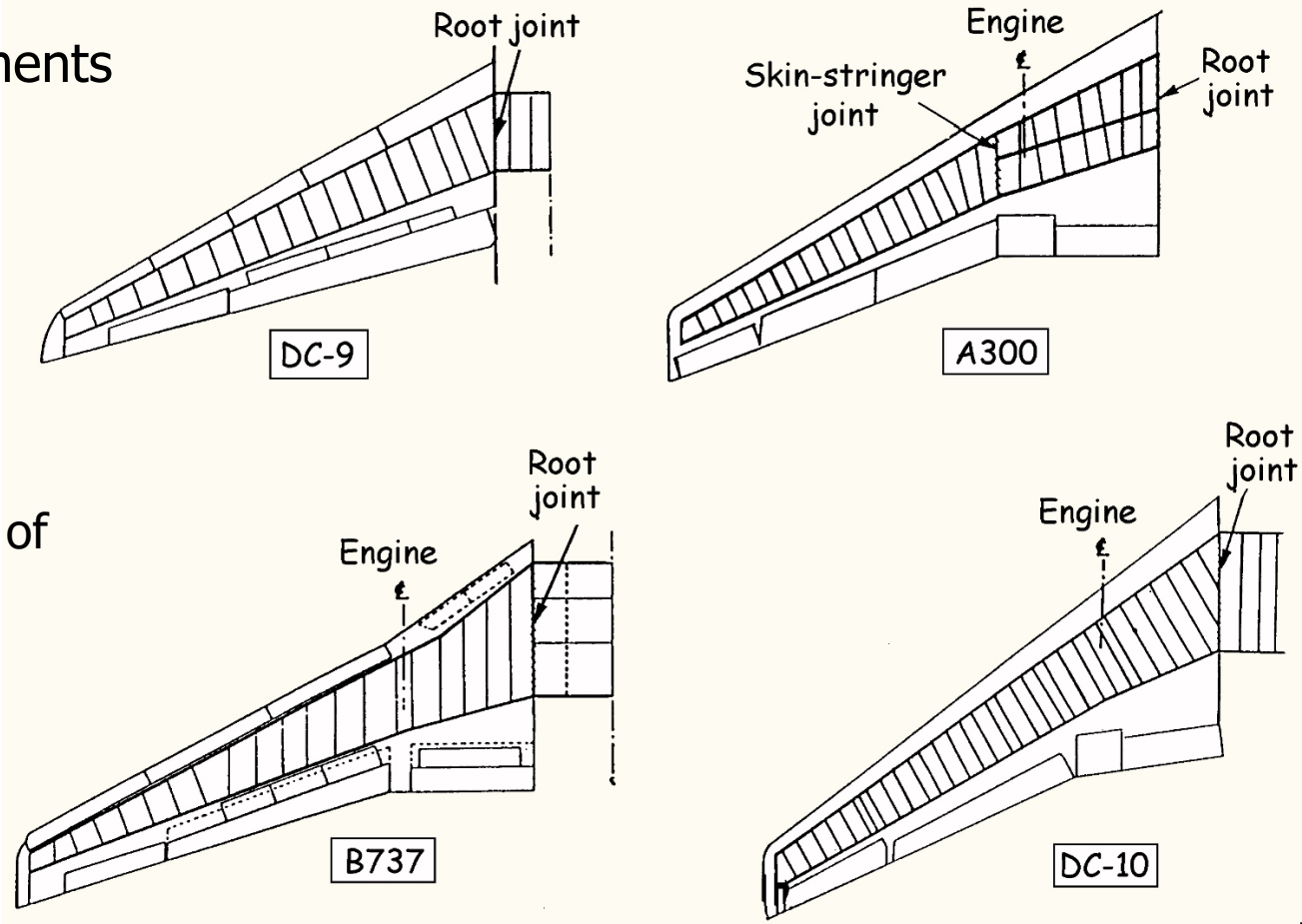
Student should be able to…

- List typical structural elements for wing structure
  - Skin
  - Stringers
  - Ribs
  - Spars
- Explain functions of
  - Ribs
  - Spars
  - Skin-spar assembly

Wing structures

Structural characteristics

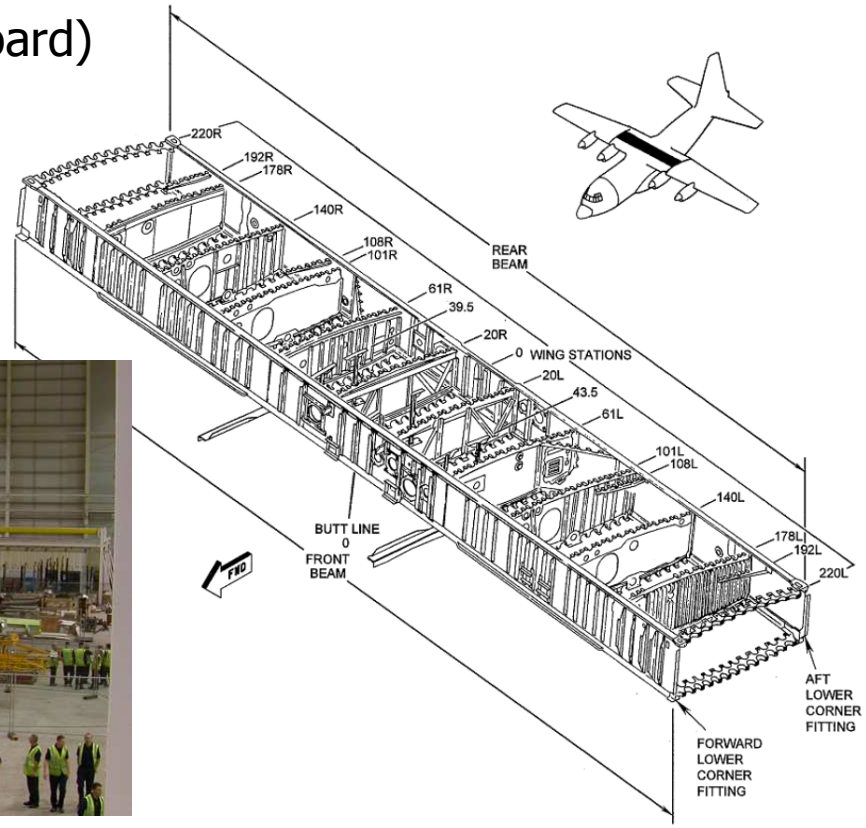
- Structural elements
  - Spars
  - Ribs
  - Skin
  - Stringers
- Note
  - Orientations of spars & ribs



Wing structures

Structural characteristics

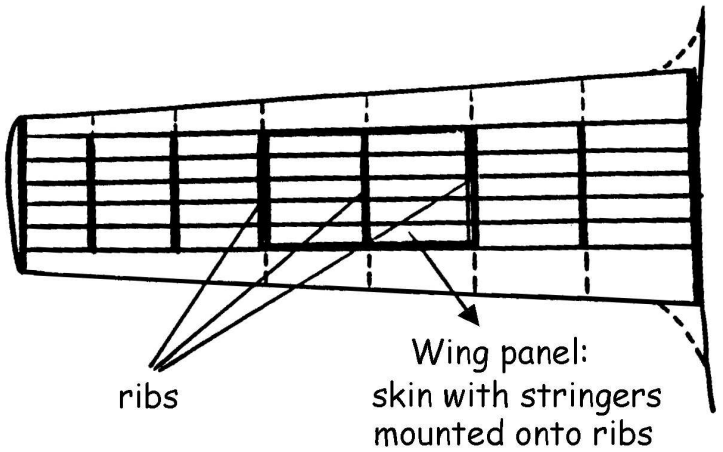
- Wing panels can be very long (difficult to manufacture)
  - Centre/outer wing (inboard/outboard)
  - Splices/joints/fitting



Wing structures

Function of ribs

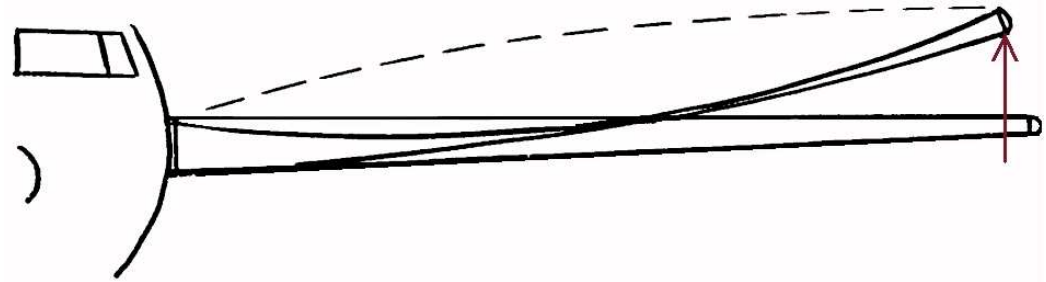
- Maintain aerodynamic profile of wing
- Transfer aerodynamic & fuel loads on skin to structure
- Provide stability against panel buckling
- Introduce local load into the structure
  - i.e. landing gear, engines, flaps, ailerons, etc
- Sealing the integral fuel tank
  - Fuel surge/splashing



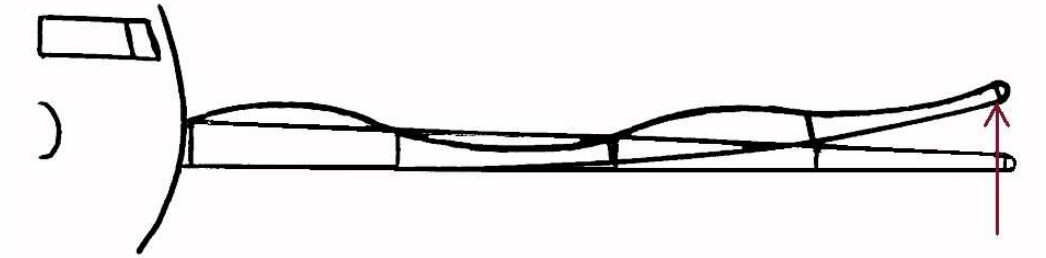
Wing structures

Function of ribs

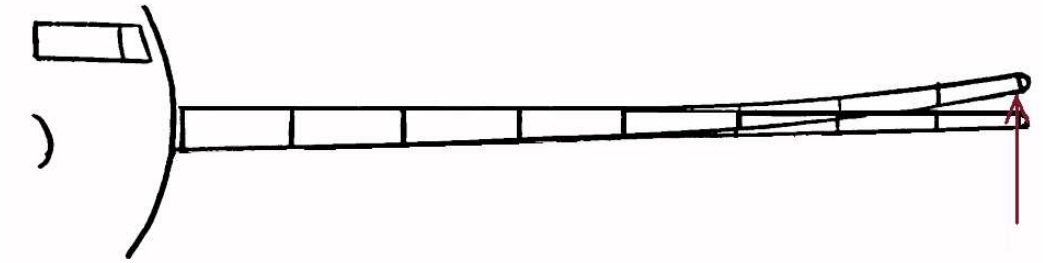
- No ribs
  - Crushing



- Not enough ribs
  - Buckling



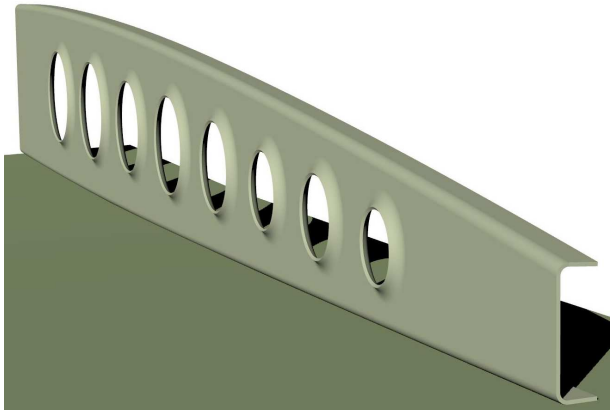
- Rib pitch
  - ~20 - 100 cm

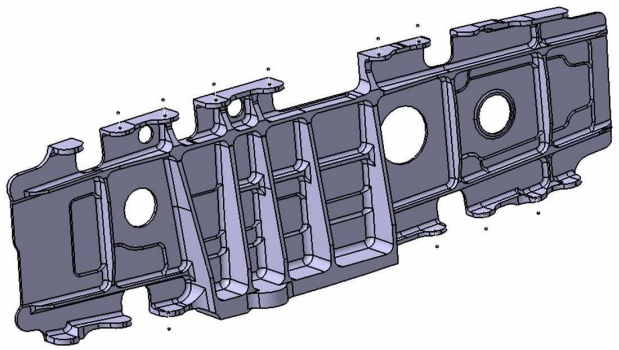


Wing structures

Types of ribs

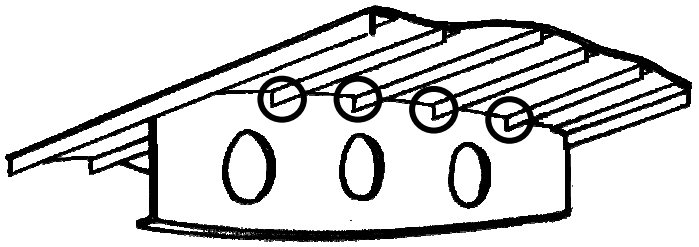
- Selection of rib type and manufacturing method depends on
  - Loads
  - Design philosophy
  - Available equipment and experience
  - Costs
- Form & plate ribs
  - Stiffening profile
  - Low loads
- Forged or machined ribs
  - Very high loads



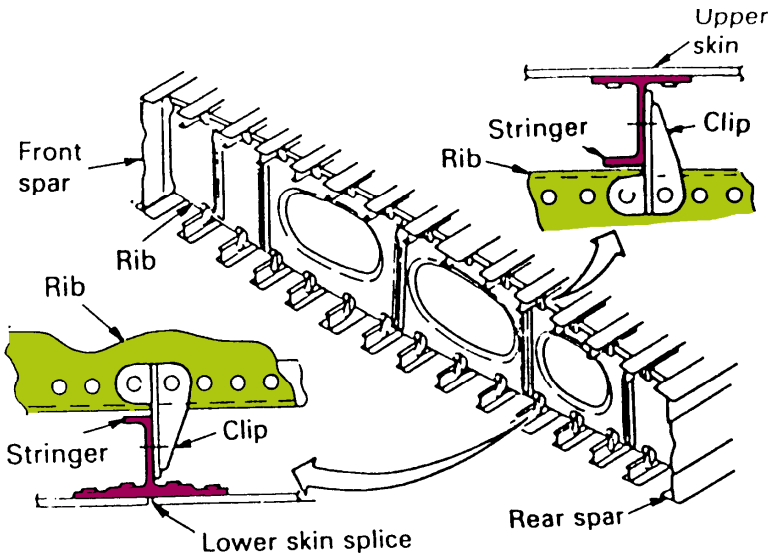


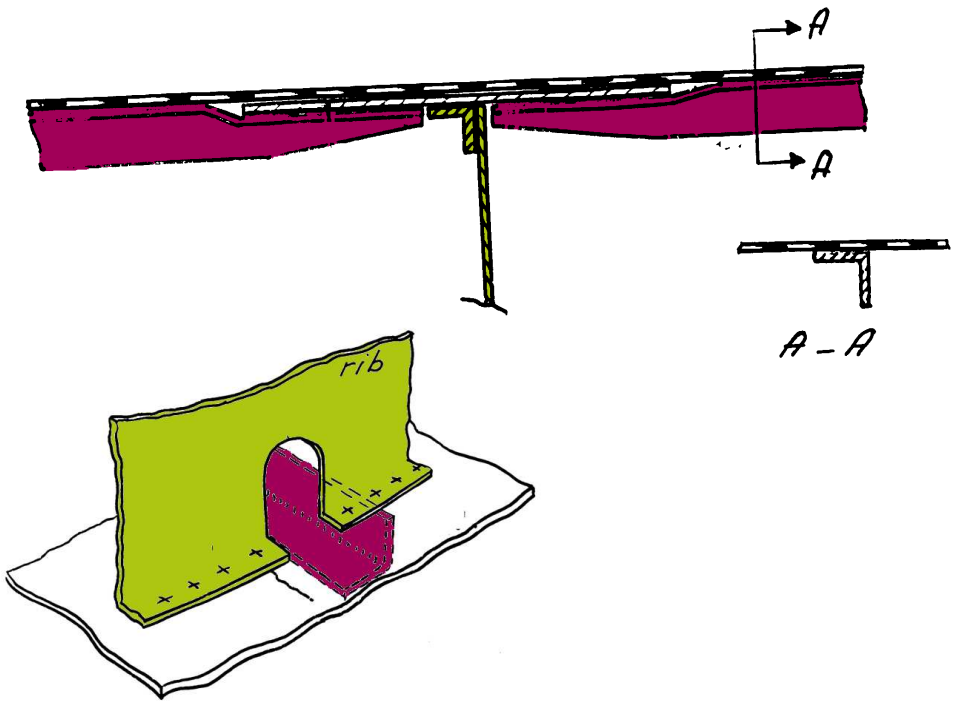
Wing structures

Rib – stringer intersections



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

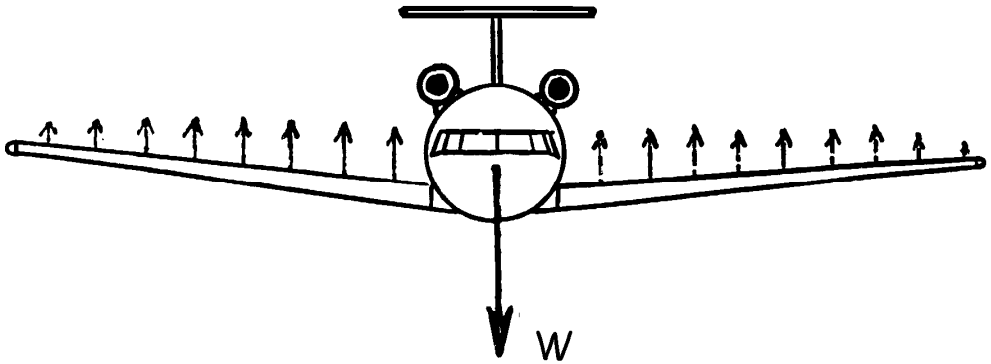


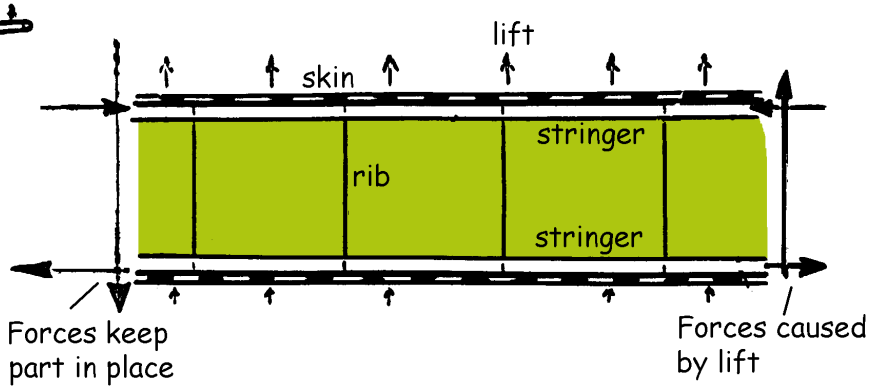


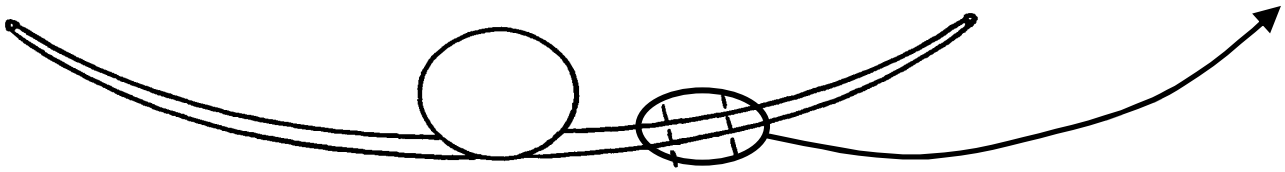
Wing structure

Function of spars

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



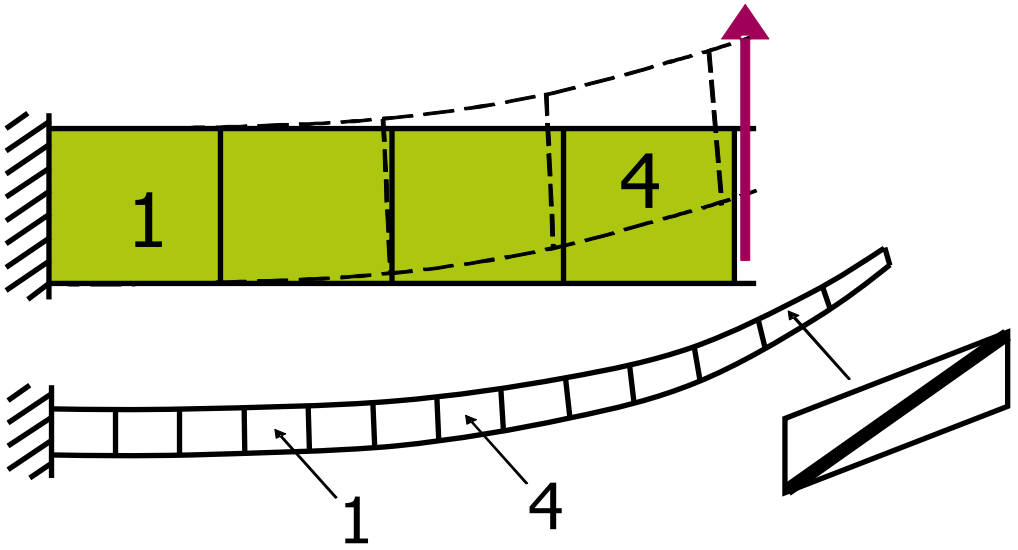




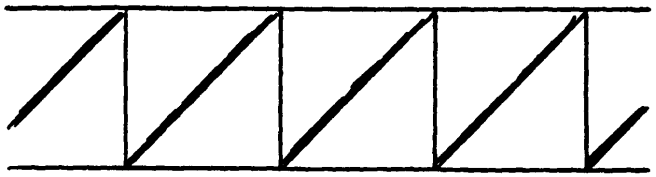
Wing structure

Bending deformation

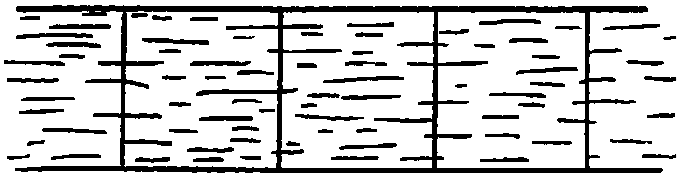
- Assume: wing clamped
  - 1 - little deformation
  - 4 - strong deformation
- Diagonal elements!



- Add diagonal elements…



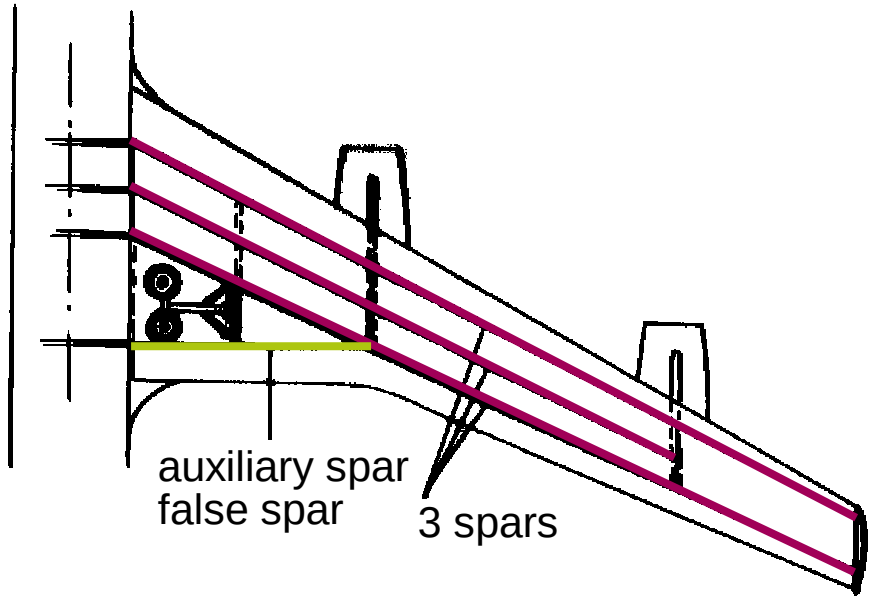
…or better: sheet

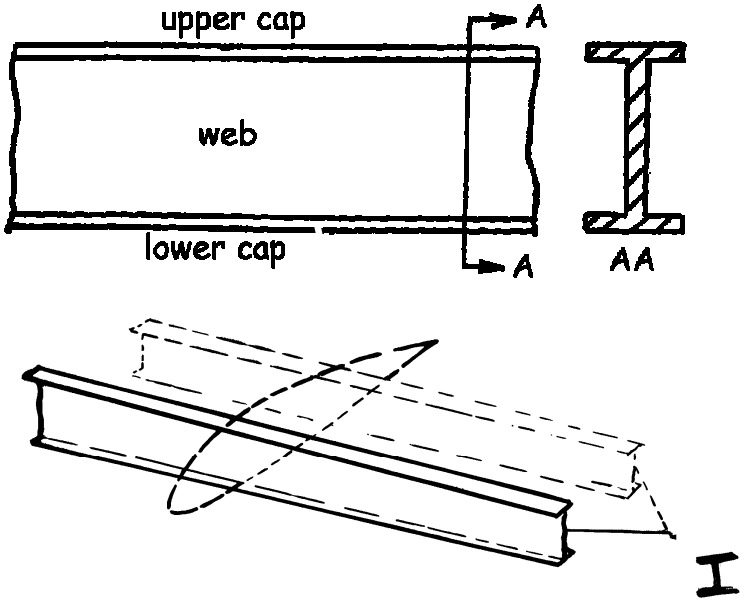


Wing structure

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

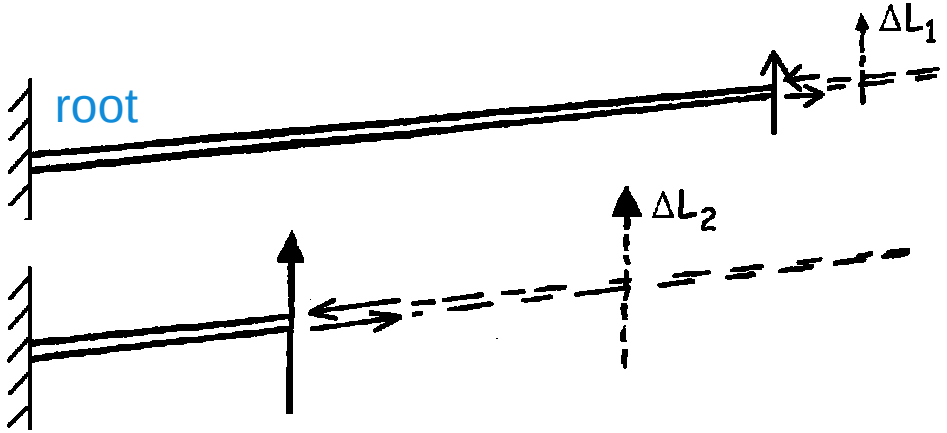




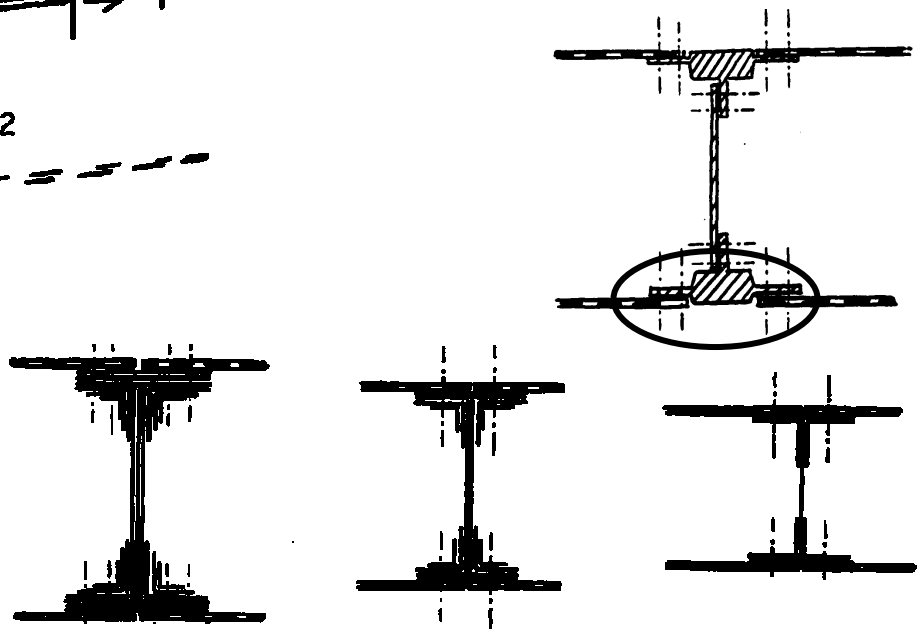
Wing structure

Spars

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



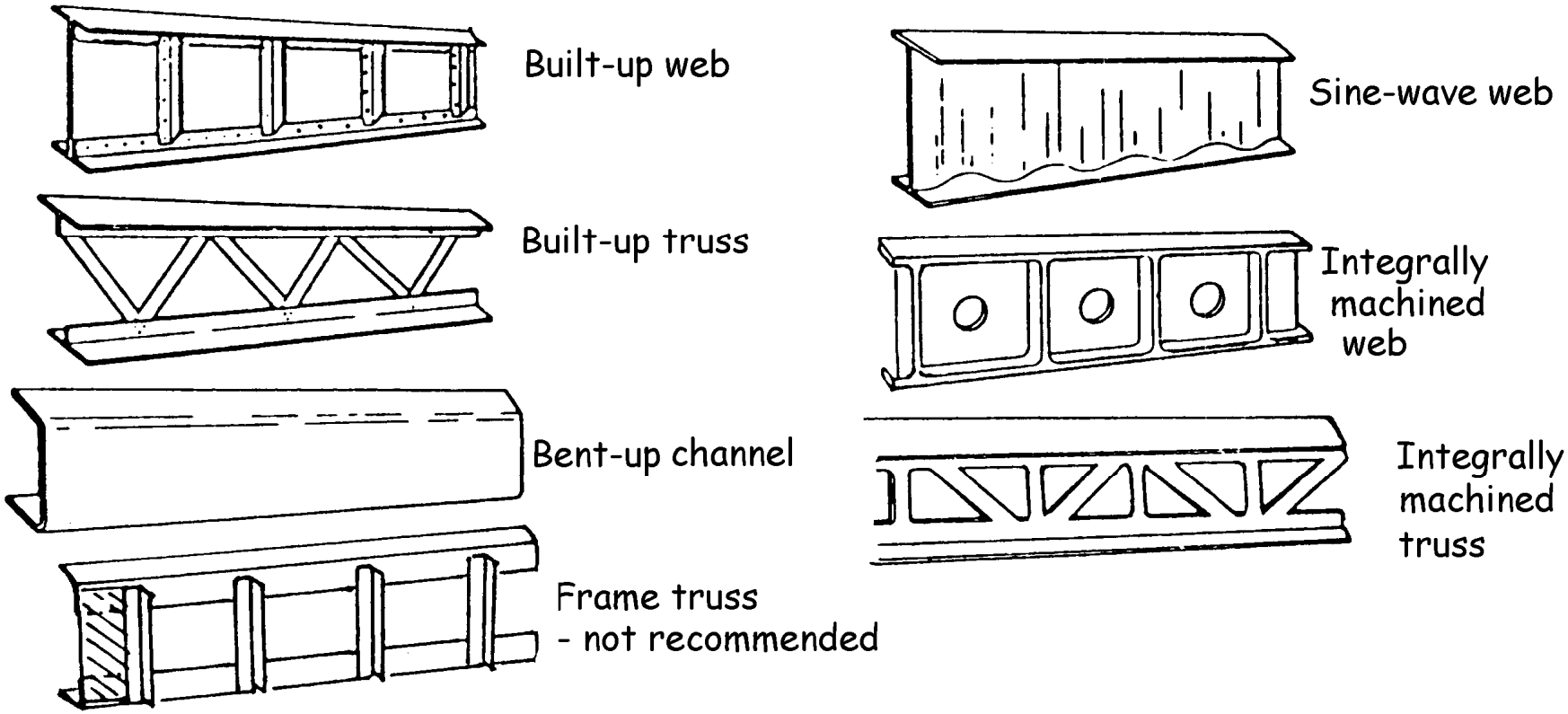
- Built up adhesive bonded sheet metal



Wing structure

Spars types

- Similar to ribs..

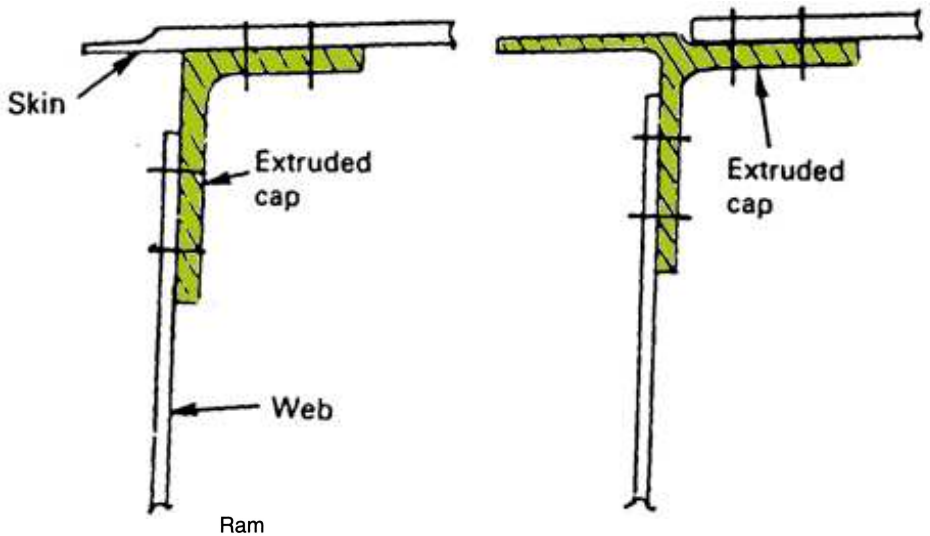


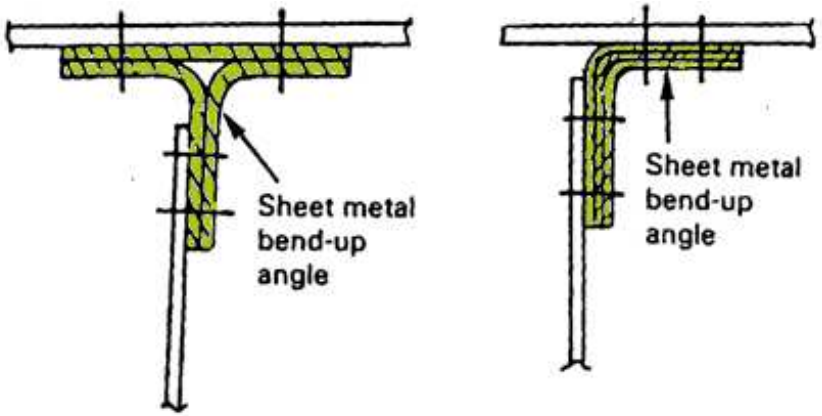
Wing structure

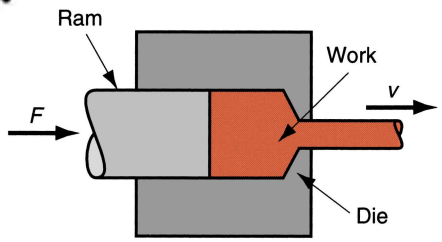
Built-up spars

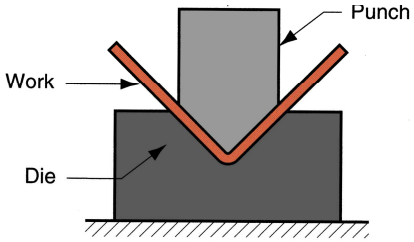
- Extruded spar cap

Sheet metal cap





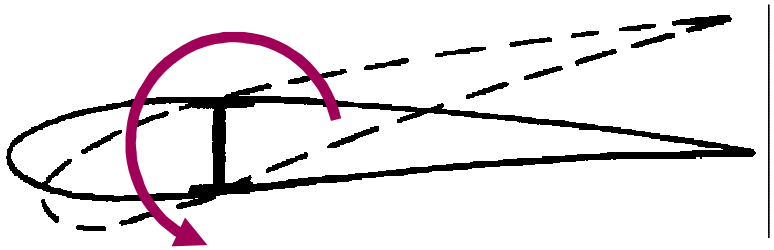


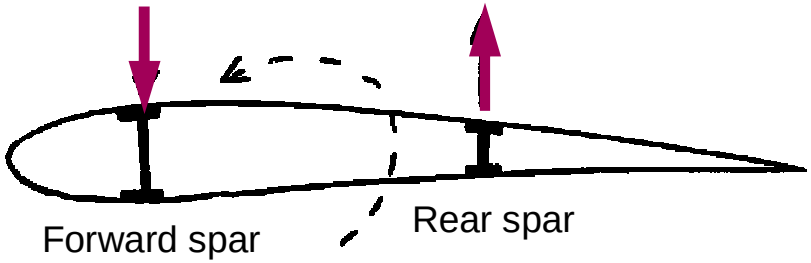


Torsion box

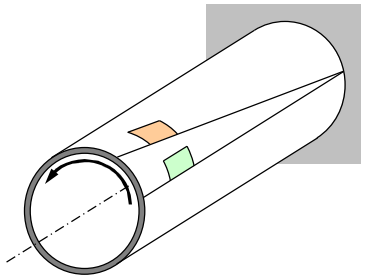
Single spar

- Single spar: low resistance against torsion
- Two spars: Differential Bending





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

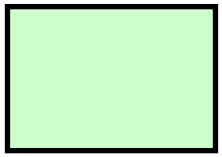


- Closed cylinder: Best against torsion !

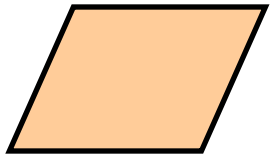
Torsion box

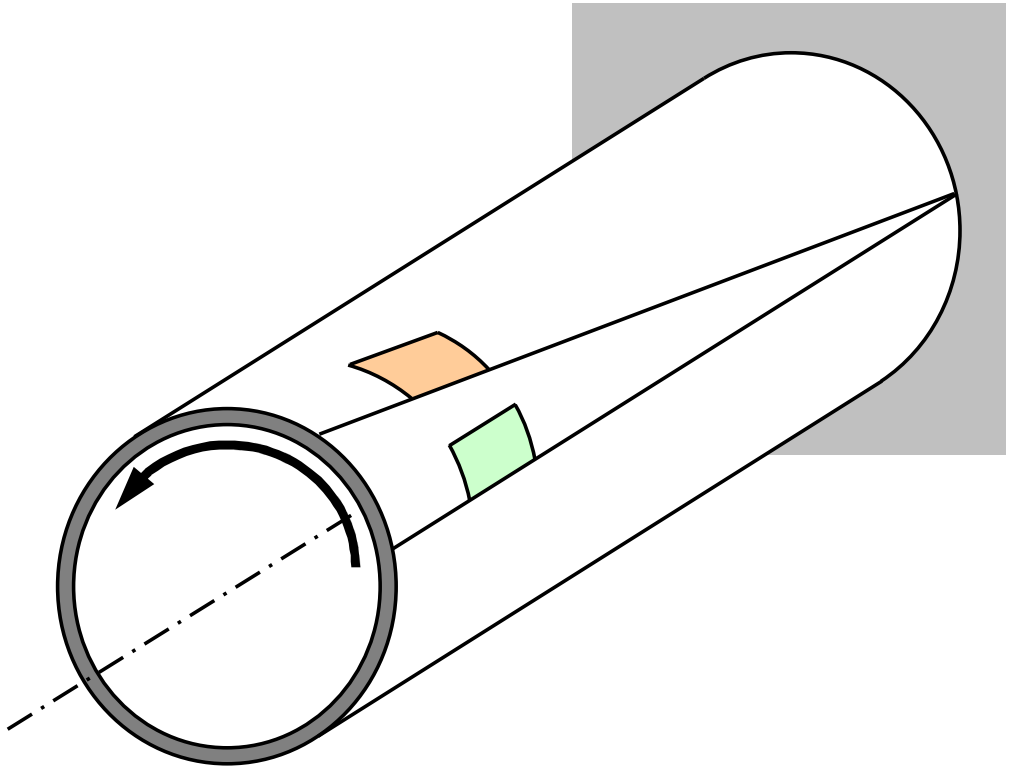
Torsion box

- Closed section has high resistance to torsion (not necessarily circular!)
  - Rectangular shape



  - Deforms like

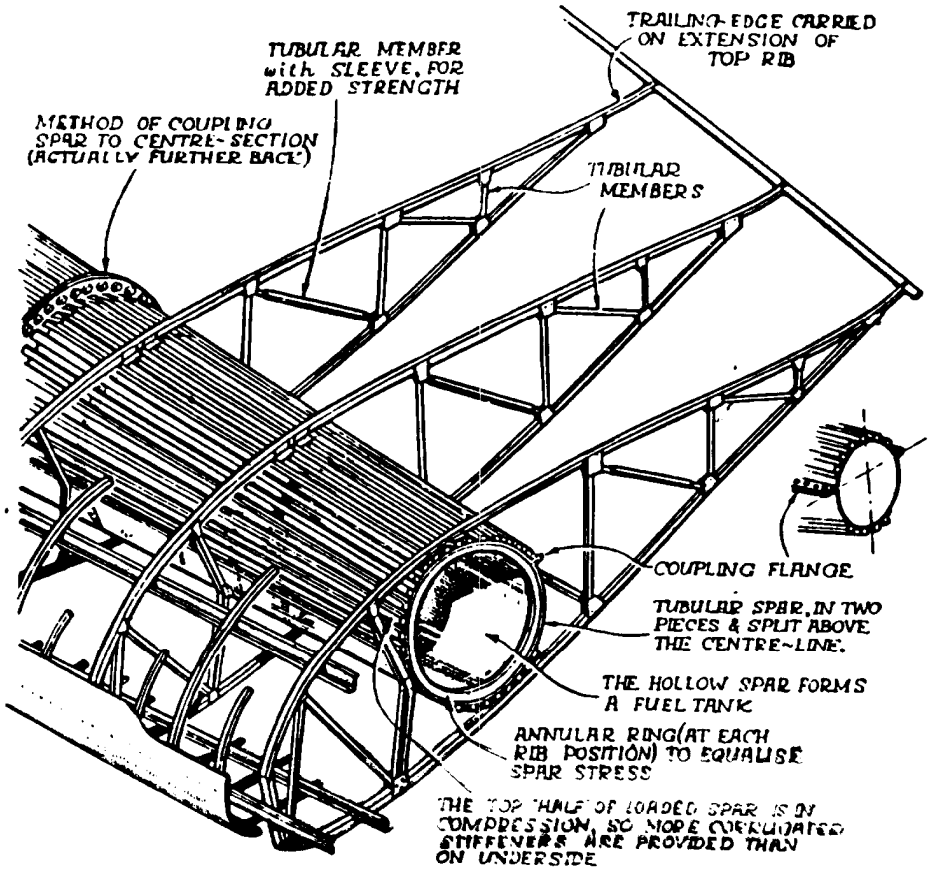




Torsion box

Blackburn Duncanson

- Single spar, torsion box and fuel tank in one



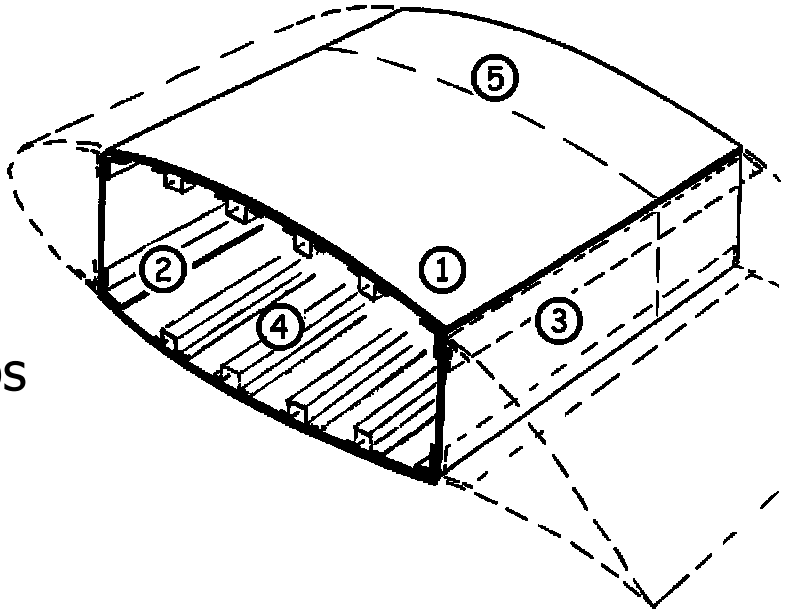
BLACKBURN-DUNCANSON WING CONSTRUCTION

(By courtesy of "Aeroplane")

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



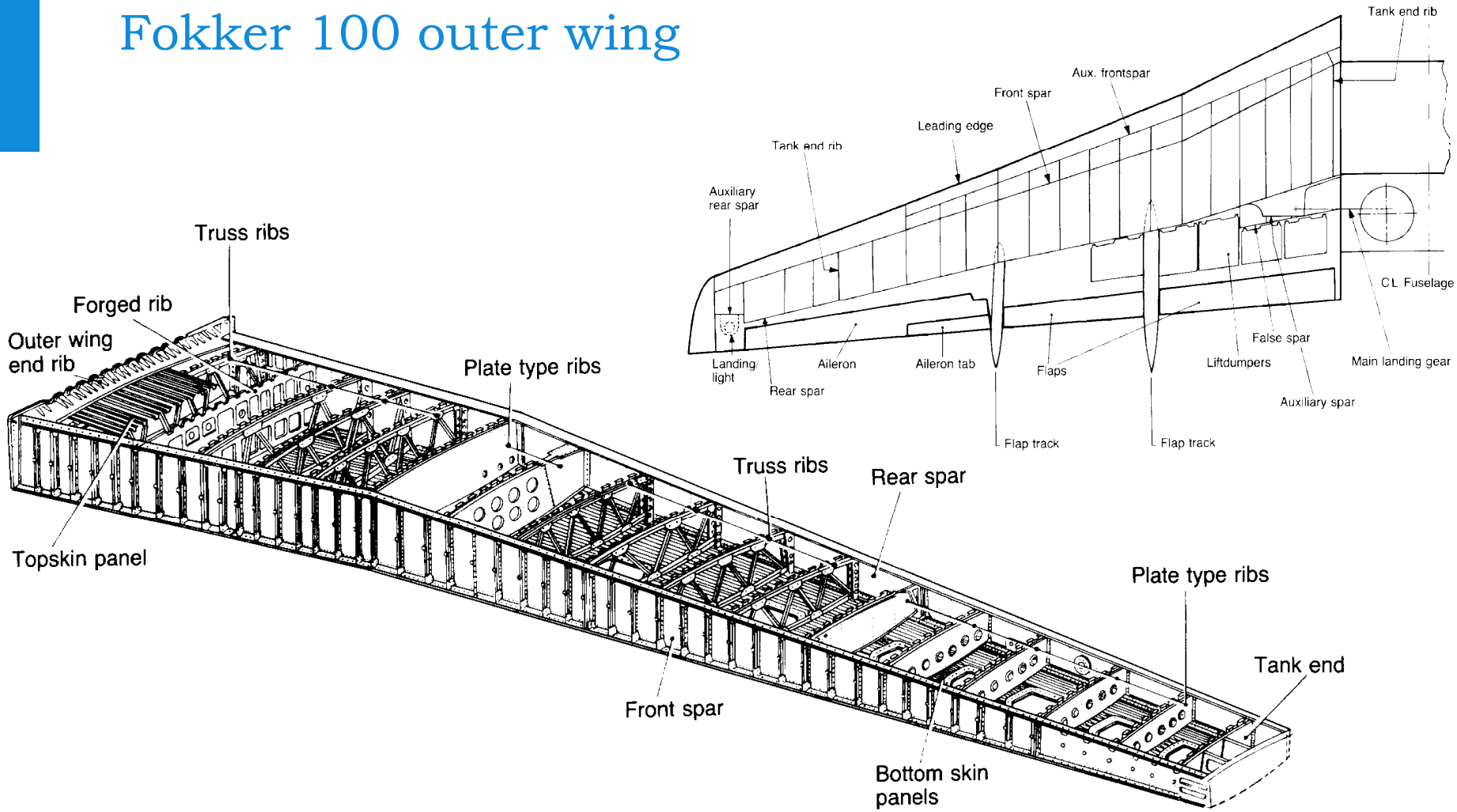
Torsion box

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