Introduction to Aerospace Engineering

Lecture slides
Structures
Aircraft & spacecraft shell structures

Faculty of Aerospace Engineering
22-11-2011
Introduction

Outline of lectures/lecturer

- 15/11 Material physics & properties / environment
- 22/11 Structures
- 29/11 Loads
- 6/12 Materials & manufacturing
- 13/12 Selection of materials & structures / space
- 20/12 Design & certification / fatigue & durability
- 6/1 Manufacturing & joining

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Learning objectives

Student should be able to…

• Give definition of
  • Airframe
  • Principal structural elements
  • Secondary structural elements

• List typical structural elements for aircraft and spacecraft

• Explain the function of sheets
• Explain the difference between material stiffness and structural (geometrical) stiffness
Aircraft & spacecraft structures

Definition of airframe

• Aircraft/spacecraft without installed equipment and furnishing

• Consists of load bearing parts: parts that take up forces during
  • normal flight
  • maneuvers
  • take-off
  • Landing, etc.

• Consists of skin and framework (skeleton) that provide aerodynamic shape

• Protects contents from environment
Aircraft structures

Examples

• Skin and framework
Spacecraft structures

Examples

- Skin and framework
Aircraft & spacecraft structures

Definition of primary/secondary structure

- Primary structure
  - Critical load bearing structure of an aircraft/spacecraft that in case of severe damage will fail the entire aircraft/spacecraft

- Secondary structure
  - Structural elements of an aircraft/spacecraft that carry only air and inertial loads generated on or in the secondary structure
Aircraft & spacecraft structures

Typical elements

- Fuselage shells
  - Skin
  - Frames
  - Stringers
  - Bulkheads
  - Splices

- Wing structure
  - Wing skin panels
  - Ribs
  - Spars
  - Assembly of spars & skin
Shell structures

Recall: from truss to shell structures

- Function of diagonal elements (tension & compression)
- Replacement by sheet (compression causes buckling)
Shell structures

Examples of buckling

- Buckling of sheet
Shell structures

Sheet material

• A sheet has more capabilities than reinforcing a structure!

  • Tension

  • Compression

  • Diagonal function: shear

  • Sealing function (air tight, fuel tight)
Shell structures

Stiffness of sheet material

- A sheet in compression bends out
  - Sheet in tension is not a problem
Shell structures

Example of folding/corrugating sheet

- Junker 52 - 1932
Shell structures

Selection of stiffening configuration

- Comparison of stiffener geometry
- Stiffening spacing
Shell structures

Stiffener geometry

- Preferred shape depends on type of load
Shell structures

Stiffener geometry

- **Z-stringer**
- **J-stringer**
- **Y-stringer**
- **I-stringer**

- **Hat-stringer** (Lower wing)
- **Z-stringer**
- **Hat-stringer** (Upper wing)
- **Hat-stringer**
Shell structures

Stiffener geometry

- Sheet geometrically reinforced by stiffeners

- Example stiffeners
  - Stringers
  - Longerons
  - Frames
Shell structures

**Stiffener intersections**

- Stringers in combination with thickness steps (jogging)
  - Butt-joints
  - Doublers
- Intersection of stiffening elements
Shell structures

Other stiffening concepts

- Integral structure by machining
  - Extra material milled away

- Sandwich structure
  - Skin
    - face sheet
    - core
    - face sheet
Shell structures

Other stiffening concepts

- Integral structure by machining
  - low cost
  - low part count
  - simple blade stiffening
  - thickness continuously adaptable

- lot of scrap (90%)
- rapid crack growth
- thick skin $\Rightarrow$ large aircraft
Monocoque structures

Stiffening concept

- Sandwich structure
  - No stringers needed
  - Smooth structure

- Difficult to repair
- Difficult to join
Monocoque structures

Stiffening concept

- Sandwich structure
  - No stringers needed
  - Smooth structure
- Difficult to repair
- Difficult to join

- Excellent structural concept, however..
  - complex and expensive details
  - corrosion (metal) and delamination (composites) problems
Monocoque structures

Stiffening concept

- Sandwich: Excellent structural concept, however..
  - Corrosion (metal) and delamination (composites) problems

- 1970s: Bréguet Atlantic
- Problem: Moisture ingress in honeycomb $\rightarrow$ corrosion
Monocoque structures

Stiffening concept

- **Sandwich**: Excellent structural concept, however...
  - Corrosion (metal) and delamination (composites) problems

- March 6, 2005: Airbus A310-308 - Air Transat Flight 961
  - Problem: In-flight separation of composite rudder
Summary

Aircraft & spacecraft structures

• Shell structures
  • provide function as diagonal element
  • Can be geometrically stiffened

• Stiffeners
  • Have different shapes depending on load and manufacturing
  • Can be attached to skin sheet or milled from thick plate

• Sandwich panels
  • Face sheets carry tension/compression loads
  • Core carries the shear load