Universidad
Carlos III de Madrid
www.uc3m.es

Aerospace Structures

Chapter 1.
Structural description of the aircraft

Loads on structural components

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Index

CHAPTER 1. Structural description of the aircraft

Loads on structural components

Introduction

Structure definition

"The set of resistive elements capable of maintaining its forms and characteristics over time, under the action of external load“
(E. Torroja)

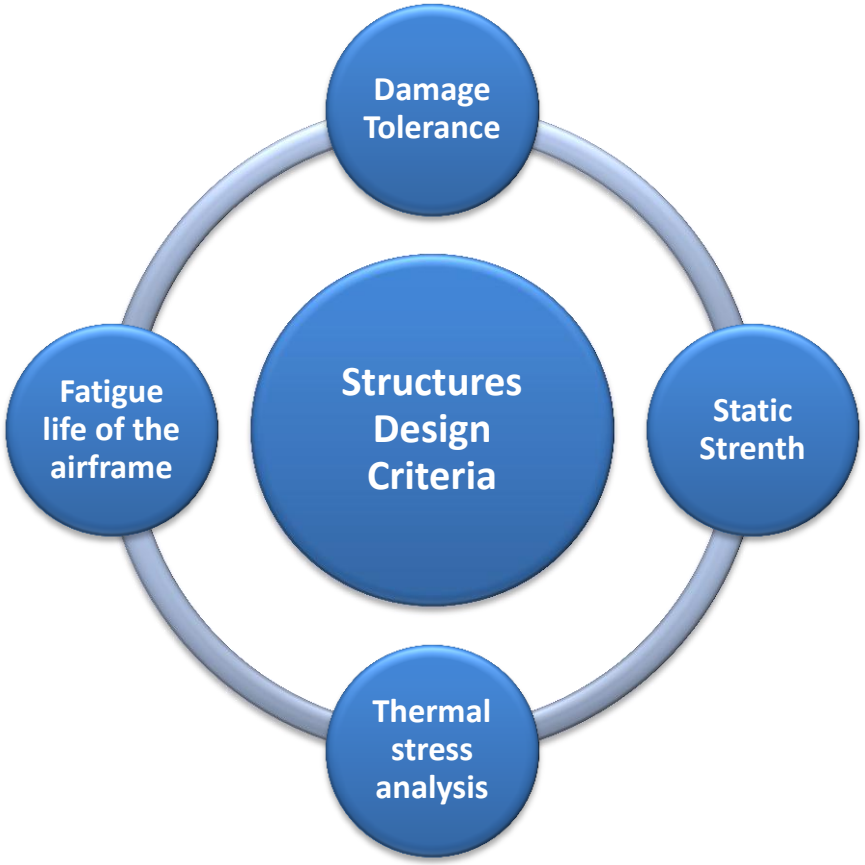
Structure function

- Transmit and resist the applied loads
- Provide an aerodynamic shape
- Protect passenger and payload
- Support of aircraft systems

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Introduction

❑ Structural requirements



- ✓ **Maintainability**
- ✓ **Productivity**
- ✓ **Crashworthiness**

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

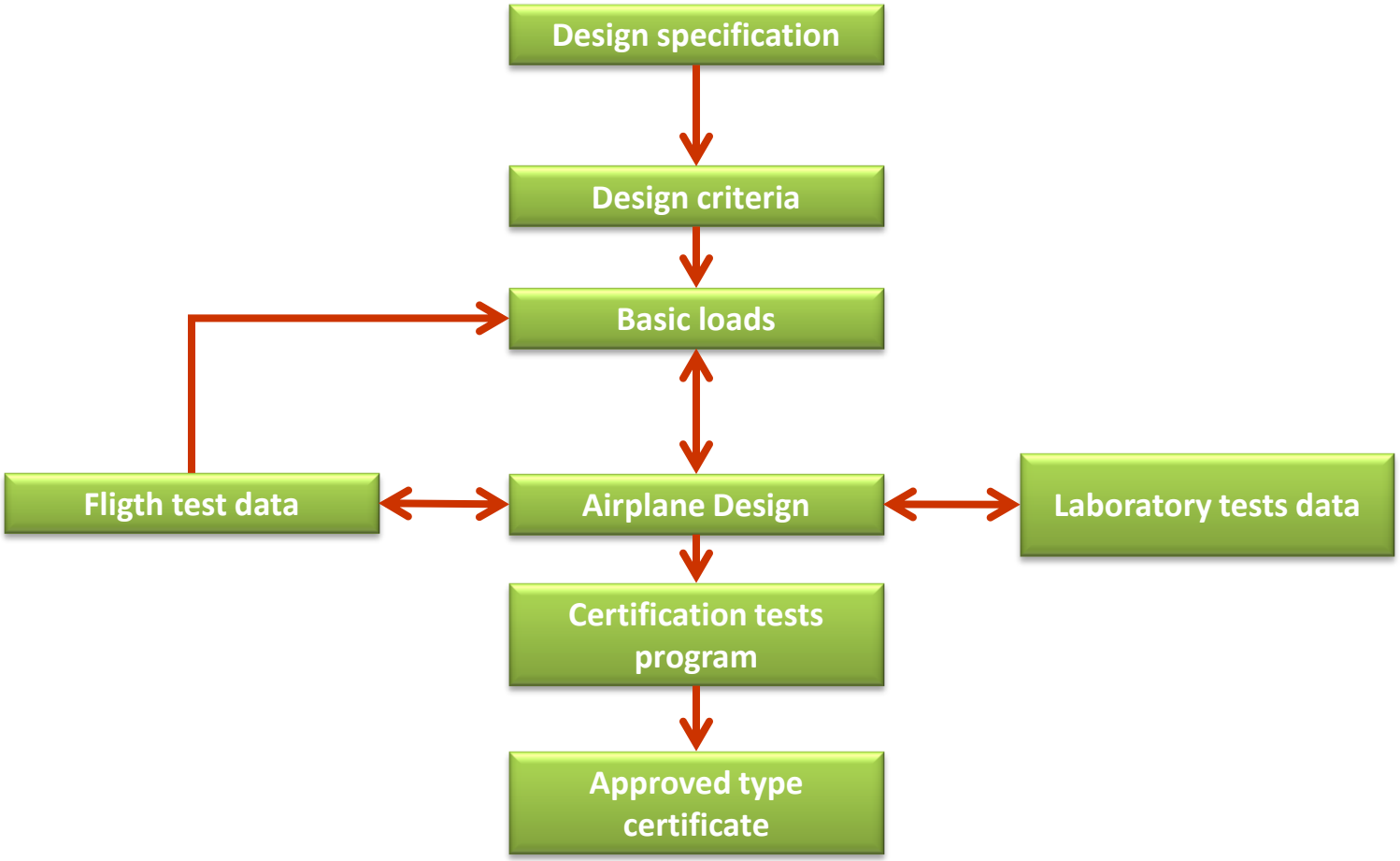
Introduction

❑ Phases of structural design

- Specification of function an design criteria
- Determination of applied load
- Calculation of internal element loads
- Determination of allowable element strength
- Experimental test

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

❑ Phases of structural design

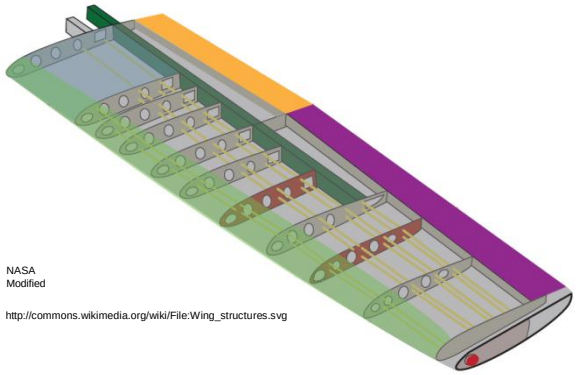


Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Introduction

❑ Types of structural analysis

Aircraft loads



NASA
Modified

http://commons.wikimedia.org/wiki/File:Wing_structures.svg

- Static analysis
- Damage tolerance
- Dynamics analysis/impact
- Aeroelastic analysis

Introduction

❑ Static structural analysis

Strength

- Static ultimate strength
- Deformation of undamaged structure

Failure analysis → **Buckling**

Damage tolerance

- Fatigue crack initiation
- Fatigue life of damaged structure
- Static residual strength of damaged structure

Introduction

❑ Static structural analysis

Mode of failure	Design criteria	Allowables data
static ultimate strength	Structure must support ultimate loads without failure for 3 seconds	Static properties
Deformation of undamaged structure	Deformation of the structure at limit loads may not interfere with safe operation of the element	Static properties and creep properties for elevated temperature conditions
Fatigue crack initiation of undamaged structures	-Fail-safe structure must meet customer service life requirements for operational loading conditions -Safe life components must remain crack free in service. Replacements times must be specified for limited life components	-Crack growth properties -Fracture toughness properties
Residual static strength of damaged structure	-Fail-safe structure must support 80-100% limit loads without catastrophic failure -A single member failed in redundant structure or partial failure in monolithic structure	-Static properties -Fracture toughness properties
Crack growth life of damaged structure	-For fail-safe structure inspection techniques and frequency must be specified to minimize risk of catastrophic failures -For safe-life structures must define inspection techniques and frequencies and, replacement times so that probability of failure due to fatigue cracking is extremely remote	-Crack growth properties -Fracture toughness properties

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Load types

❑ Aircraft loads

The aircraft loads are those forces applied to the aircraft structural elements to establish the strength level of the airplane

- Flight loads
- Ground handling loads

The structural design is dependent on load therefore the loads must be determined early in the design

- Static loads
- Dynamics loads

- External loads
- Internal loads

Load types

❑ Loads classification

Flight Loads:

- Symmetric maneuvers
- Asymmetric maneuvers
- Control deflection
- Gust loads

Ground Handling:

- Take off
- Landing
- Taxiing (asymmetric braking, turning etc.)
- Towing, Pivoting etc.
- Catapulted take-off
- Arrested landing
- Landing in water

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Load types

❑ Loads classification

Surface loads

- Aerodynamic loads
- Hydrostatic pressure

Body forces

- Weight
- Inertial loads

One-point loads

Load types

❑ Loads classification

External Loads

•Aerodynamic loads
•Take off/Landing loads
•Impact loads

Local and Internal Loads

• Max./min. aerodynamic pressures (outer surfaces)
• Local accelerations
• System pressures
• Bay pressures (pressurised areas)
• Hydrostatic pressures (fuel tanks)
• Intake duct pressures
• Engine thrust
• Component interaction

Load types

❑ Loads classification

Static loads

Dynamic Loads:

- Buffet (Outer wing, vertical fin buffet etc.)
- Dynamic Gust
- Vibrations
- Acoustic Noise
- Limit cycle oscillation
- Shimmy (Undercarriage)
- Engine hammershock conditions (Duct)

Fatigue loads

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Load models

First of all the STRUCTURAL DESIGN CRITERIA (SDC) are prepared as a basic for design, and then a LOADS MODEL (LM) is built. The LM is based on:

- SDC (Standards)
- Aerodynamic data (wind tunnel or flight tests)
- Flight mechanic data (FEMs)
- Weight data (Structural, systems and role equipment masses and mass distributions)
- Balance data

The load are analysed for all manoeuvres. From the load time history the external load distribution for any component (bending moment, torque, shear forces, etc) are determined for each component (fuselage, wing, etc).

Load models

❑ Model types

Aerodynamic Panel model is considered just a geometric interface and can be used to deal with data of different nature:

- Theoretical coming from simplified potential flow tools.
- Theoretical, based upon more sophisticated CFD tools (Euler and/or Navier-Stokes codes)
- Experimental based upon W/T pressure plotting.
- Mix of previous, with an experimental basis supplemented with theoretical analyses for the areas non covered by tests.

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Load models

❑ Limit and ultimate loads

FAR Part 25. Sec. 25.301
Strength requirements are specified in terms of limit loads and ultimate loads

Unless otherwise provided, prescribed loads are limit loads.

Limit Loads are the maximum loads which the aircraft may encounter at any time during its lifetime. FAR Part 25 (and most other regulations) specifies that there be no permanent deformation of the structure at limit load.

Limit load cases are relevant for fatigue design requirements

Ultimate loads are load which may occur once in the lifetime of an aircraft. They are defined as the limit loads times a safety factor. The structure must be able to withstand the ultimate load for at least 3 seconds without failure. Permanent deformation may occur though.

Ultimate load cases are relevant for static strength requirements

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

Load models

❑ Limit and ultimate loads

Safety factor

- Limitations of calculus model
- Variation in physical properties of materials
- Variation in fabrication standard
- Emergency conditions
- Variation of loads (gust random

FAR Part 25 Section 25.303:	1.50
Research aircrafts:	1.20
Composite sailplanes:	1.75

Authors: Enrique Barbero Pozuelo, José Fernández Sáez, Carlos Santiuste Romero

References

- **Aircraft Structures for engineering students**
  H.G. Megson
  Elsevier
  Section B1 Principles of stressed skin constuction
    Chapter 12 Structural components of aircraft
  Section 12 B2 Airworthisess and airframe loads
    Chapter 13 Airworthiness
    Chapter 14 Airframe loads

- **Airframe Structural Design**
  M.C.Y. Niu
  Hong Kong Conmilit Press LTD
  Section 3. Aircraft loads
    Chapter 8 Wing Box Structure
    Chapter 11Fuselage