AIRCRAFT STRUCTURAL DESIGN
SESA3026

2. Wing Structural Details
2.2 Composite Wings

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Course Content

- Chapter 1 Aircraft structural design
- Chapter 2 Wing structural details
  - Components
  - **Composite Wings**
- Chapter 3 Aircraft loads
- Chapter 4 Fatigue of aircraft structures
- Chapter 5 Effects of dynamic response
- Chapter 6 Static aeroelasticity
- Chapter 7 Dynamic aeroelasticity

- **SN**
- **ADR**

Learning Objectives

From the previous session, you know how to

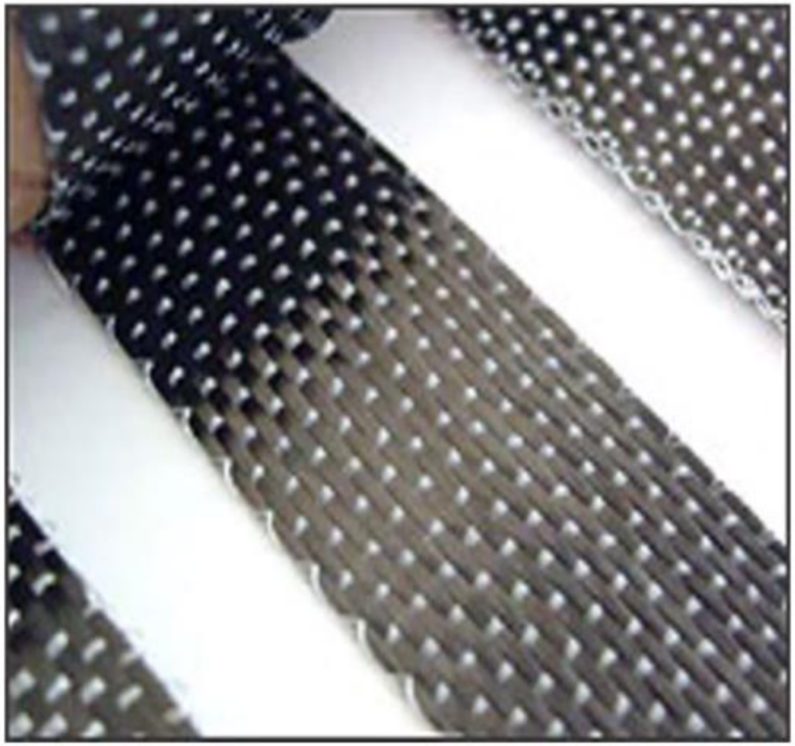
- Analyse a conventional wing design

By the end of this section, you will be able to:

- Discuss use of composite materials

Complement slides with Sections 3.3 to the end of Chapter 3 of the "Aircraft Structural Design" book

- Strong fibres and lightweight matrix and bonded together (plastic)
- Similar material structure in bones, wood , horns etc
- Allow the stiffness and strength of the material to change with the direction of loading



Unidirectional carbon fibre laminate

Composite Aircraft Structures

https://eandt.theiet.org/content/articles/2020/03/making-future-aircraft-wings-through-composites-manufacturing/

Composite materials are used more and more for primary structures in commercial, industrial, aerospace, marine, … structures

https://www.youtube.com/watch?v=M04V6qJfVHY&t=69s&ab_channel=TheNationalCompositesCentre

Composite Aircraft Structures

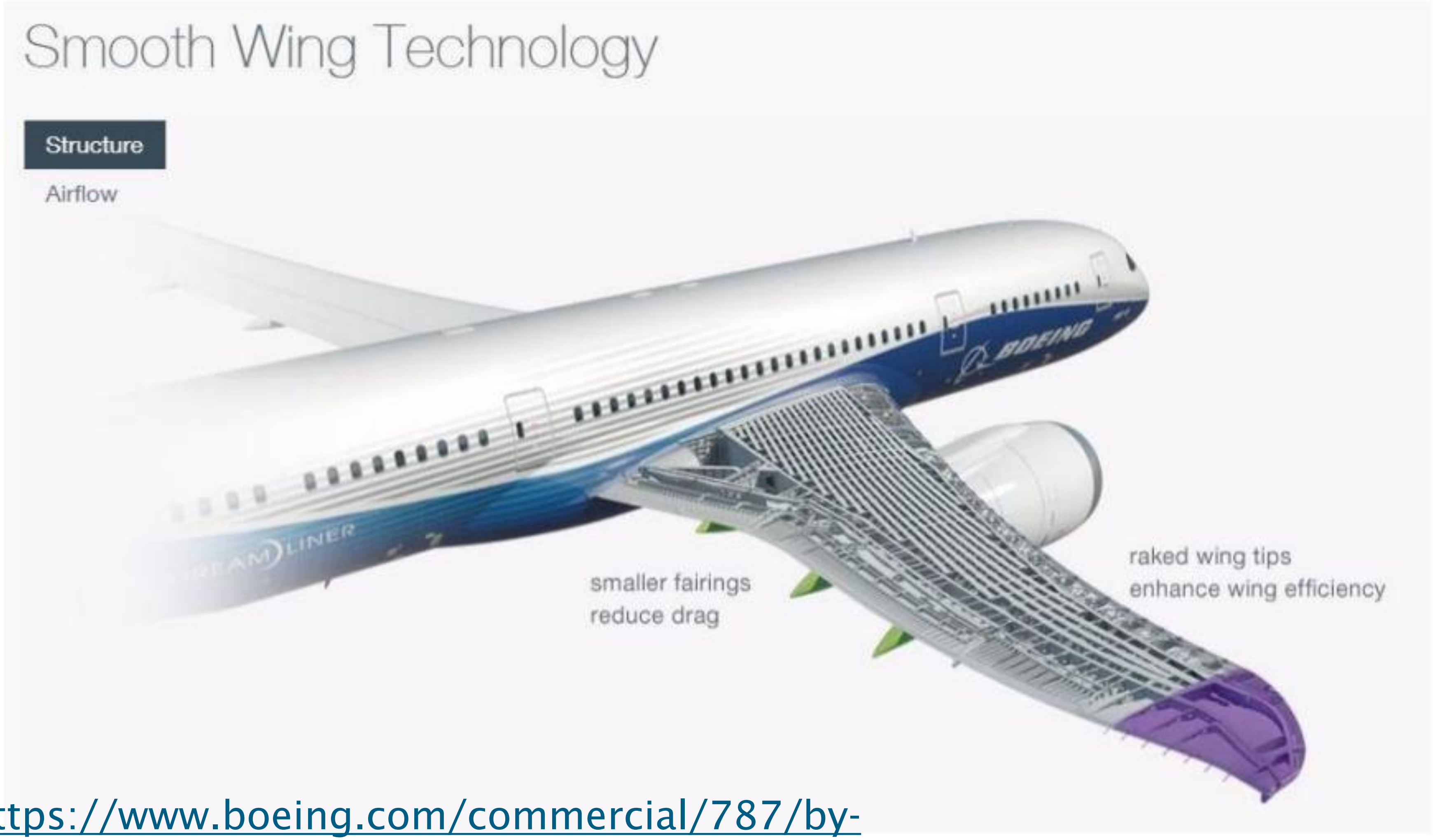
Airbus A350 XWB (1)

The A350 XWB has learned from nature to help ensure a healthy future for the planet, whether it's the revolutionary adaptive wing design – inspired by birds – which morphs while airborne to achieve maximum aerodynamic efficiency by optimising wing loading, reducing drag and lowering fuel burn; or the savings generated by innovative technological advances.

https://www.airbus.com/en/products-services/commercial-aircraft/passenger-aircraft/a350-family

Smooth Wing Technology

Boeing 787 (1)



https://www.boeing.com/commercial/787/by-design/#/smooth-wing-technology

Advanced Composites

Boeing 787 (2)

https://www.boeing.com/commercial/787/by-design/#/advanced-composite-use

Composite Aircraft Structures

Boeing 787 (3)

The materials selected for the 787 Dreamliner provide the lowest operating costs over the life of the airplane. Selecting optimum materials means analyzing every area of the airframe to determine the best solution based on the operating environment and loads experienced over the life of the airplane.

The chief breakthrough material technology on the 787 is the increased use of composites. The 787 is 50 percent composite by weight. A majority of the primary structure is made of composite materials, most notably the fuselage.

Composite materials have many advantages. They allow a lighter, simpler structure, which increases airplane efficiency, reduces fuel consumption and reduces weight-based maintenance and fees. They do not fatigue or corrode, which reduces scheduled maintenance and increases productive time. Composites resist impacts better and are designed for easy visual inspection. Minor damage can be repaired at the gate in less than an hour. Larger damaged sections can be repaired exactly like today's aircraft, through bolted repairs, or using a bonded repair.

https://www.boeing.com/commercial/787/by-design/#/advanced-composite-use

Composite Aircraft Structures

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Wing Flex

Boeing 787

Composite Aircraft Structures

Boeing layup and autoclaves

https://www.boeing.com/features/2016/05/777x-composite-wing-center-05-16.page

Composite Aircraft Structures

Airbus & Sustainability

Carbon fibre reinforced polymer

The two most commonly used types of CFRP are 'thermoset' and 'thermoplastic.' While thermoset CFRPs are currently more widespread in the aeronautics industry, thermoplastics are gaining popularity because of their recyclability – an important lifecycle consideration that has long been a factor against wider CFRP adoption.

A key difference between thermoset and thermoplastic materials is what happens during the curing process. When cured in the autoclave, thermoset material undergoes a chemical reaction that permanently changes its makeup. A thermoplastic part, though, can be re-melted and still maintain its composition.

That difference makes thermoplastics attractive since Airbus and its suppliers produce hundreds of tonnes of scrap composites each year. While scrap thermoset resin cannot be reused, thermoplastic scrap can be used in a variety of ways and in a number of sectors beyond aeronautics.

https://www.airbus.com/en/newsroom/news/2017-08-composites-airbus-continues-to-shape-the-future

Composite Manufacture

Airbus - High tech looms

An aircraft component is fed through a high tech loom where strands of carbon fibre are braided together. From the cornerstone A310's vertical stabiliser to today's A350 XWB, Airbus has pioneered the use of such composite materials in its commercial jetliners.

Composite Aircraft Structures

Summary of advantages

So, combined with the intrinsic properties of composites, the lighter, simpler material

Higher stiffness to weight ratio

- Increases efficiency
- Reduces fuel consumption

- Reduces scheduled maintenance and increases productive time
- Reduces weight-based maintenance and fees
- Makes visual inspection easier

- Resists impacts better
- *Resists crack propagation*
- Makes minor damage repair possible at the gate

- Does not corrode or fatigue

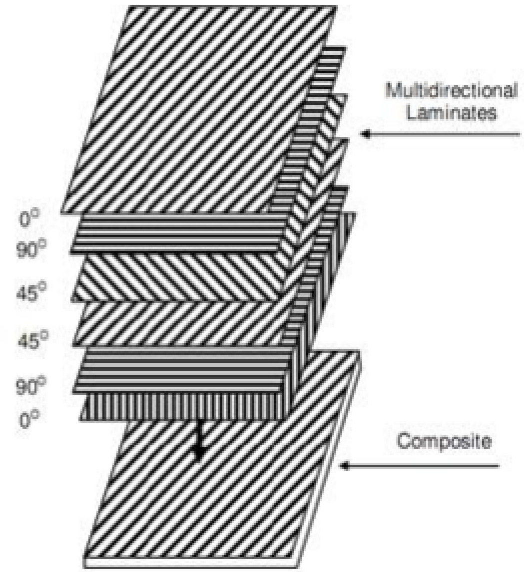
https://www.boeing.com/commercial/787/by-design/#/advanced-composite-use

Composite Aircraft Structures

Further advantages

- Crack propagation hindered by fibres enables
  - Higher pressure in the cabin and
  - Passengers' comfort increases

- No susceptibility to corrosion enables
  - Higher humidity in the cabin

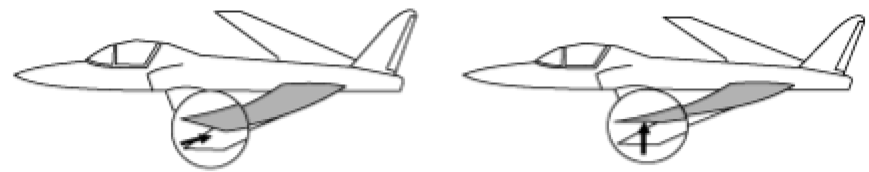


Concept behind aeroelastic tailoring

- The mechanical properties can be tailored for improved aeroelasticity using unidirectional laminates in different orientations

Composite Aircraft Structures

Aeroelastic tailoring

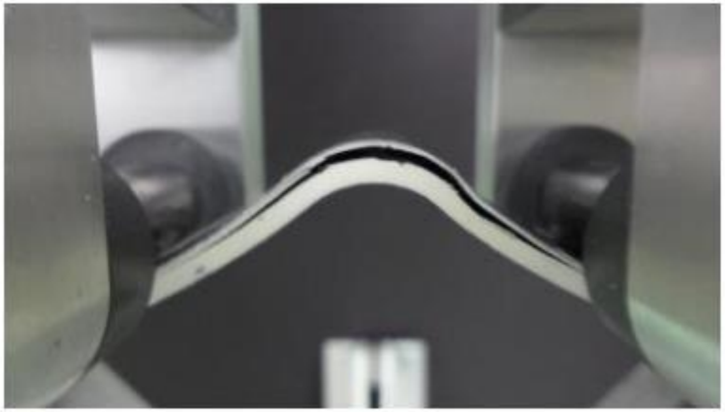


Conventional metal wing twists under load

Composite wing: structure bends but does not twist

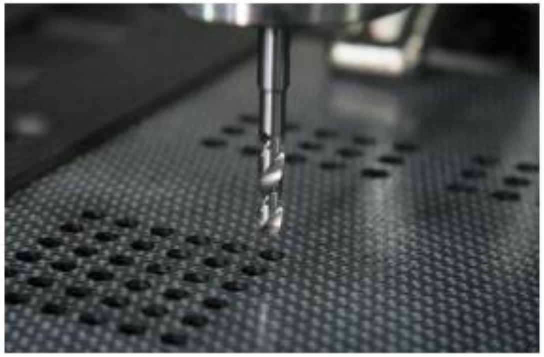
Variable camber on leading and trailing edges of a wing changes in camber may be effected mechanically or automatically

Composite Aircraft Structures



Disadvantages:

- Delamination
  - Out of plane loads
  - Compression loads
  - Delamination is generally internal and not visible
  - Different methodologies of inspection
- Need detailed insight on load path
  - Not needed in metals
- At joints
  - Imbalance of deformation with metals → joint failure
- Drilling holes breaks the fibres

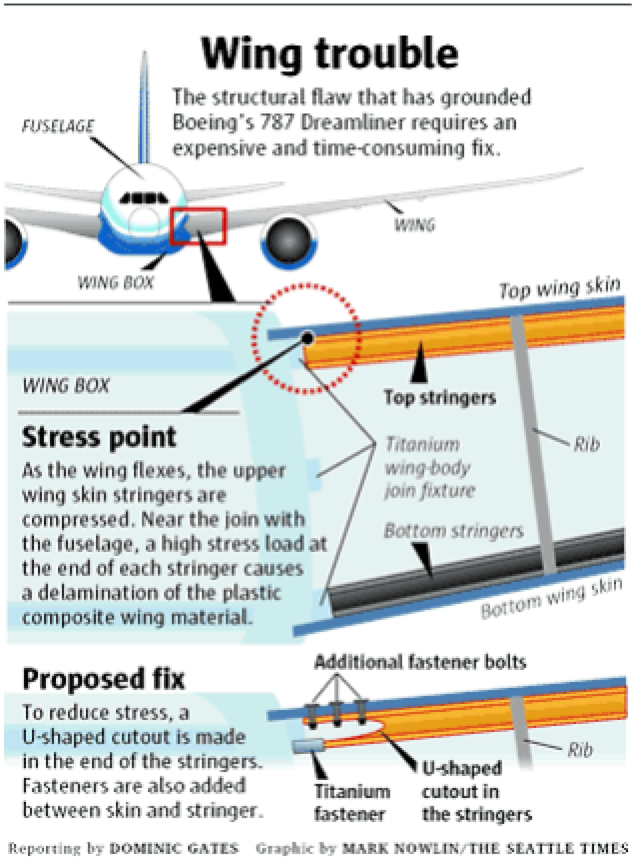


Boeing 787 Wing Trouble

The second engineer said the problem is caused by high loads at the ends of the stringers on the upper wing skins. Stringers are the long composite rods, shaped like I-beams, that stiffen the inside of the wing skin.

There are 17 stringers on each upper wing, all of them subject to compression forces when the wings flex upward in flight. At the point where each stringer ends, close to where the wing and body of the plane are joined, those forces pull the stringer away from the skin.

During a wing-bending test in May on the ground-test airplane inside the Everett factory, the fibrous layers of the composite plastic material delaminated at these stress points.



Boeing Patent

(19) **United States**
(12) **Patent Application Publication**
Balabanov et al.

(10) **Pub. No.: US 2016/0193806 A1**
(43) **Pub. Date: Jul. 7, 2016**

(54) **SKIN-STRINGER DESIGN FOR COMPOSITE WINGS**

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(21) Appl. No.: **14/588,536**

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B32B 5/02	(2006.01)

(52) **U.S. Cl.**
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(57) **ABSTRACT**

Composite skin-stringer structures which reduce or eliminate the risk of delamination at the skin-stringer interface. This can be accomplished by arranging ply directions (i.e., the angles of the fiber paths of the ply) in a layup in a way such that for the dominant loading, the skin and stringer will each deform in a way that reduces relative opening (fracture Mode I) and/or sliding (fracture Mode II) and/or scissoring (fracture Mode III) at the skin-stringer interface. This is possible when coupling between specific deformations modes is purposefully activated instead of being suppressed. The ply directions in the stringer are adjusted so that the stringer deforms in a controlled fashion to suppress or "close" cracks that are about to form—before the undesirable modes of failure form—as load is applied.

https://patents.google.com/patent/US20160193806

Learning Outcomes

A basic understanding of composites and how aerospace components are

manufactured from them

• Know how composites are used in modern aircraft

• Knowledge of the advantages (slides 18 and 19) and disadvantages (slide 21)of composites

Complement slides with Sections 3.3 to the end of Chapter 3 of the "Aircraft Structural Design" book