Composites in Aircraft

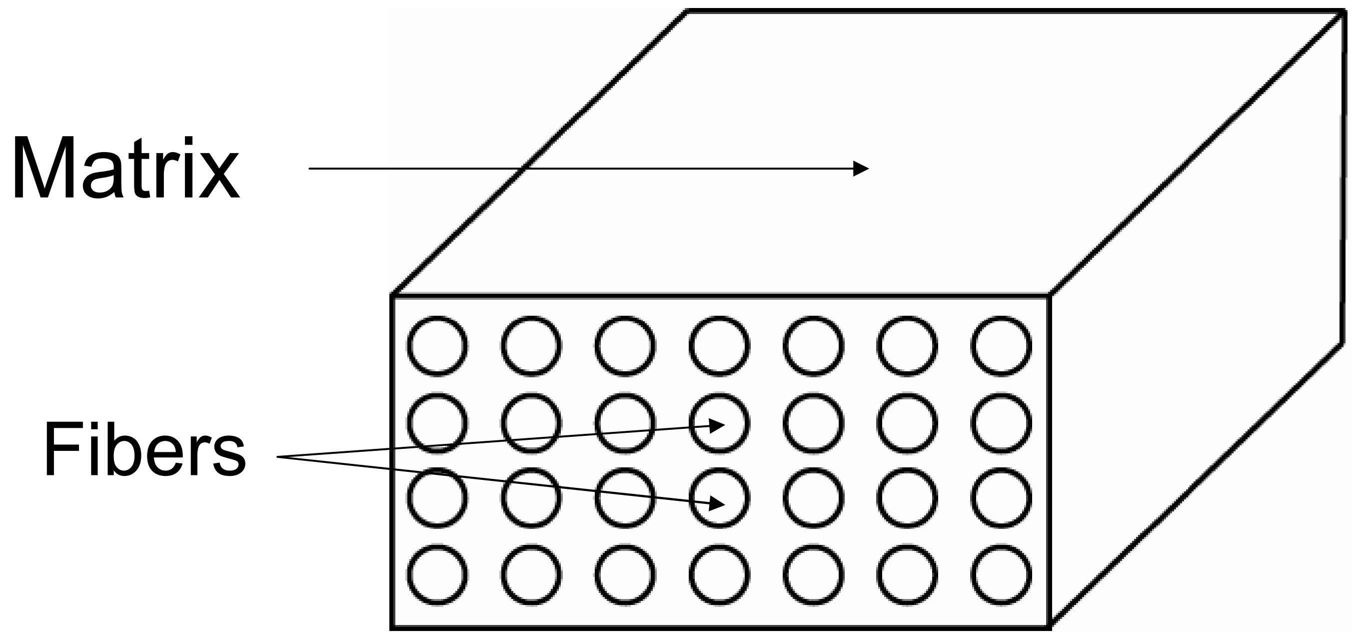
September, 19 2005

Overview

- What are composites?
- Boeing 7E7-787
- Drawbacks / Problems with Composites in Aircraft Structures
- Future of Composites / Nanocomposites

What are Composites?

- Composite materials are formed by combining two or more materials that have quite different properties.



Use of Composites in Aircraft

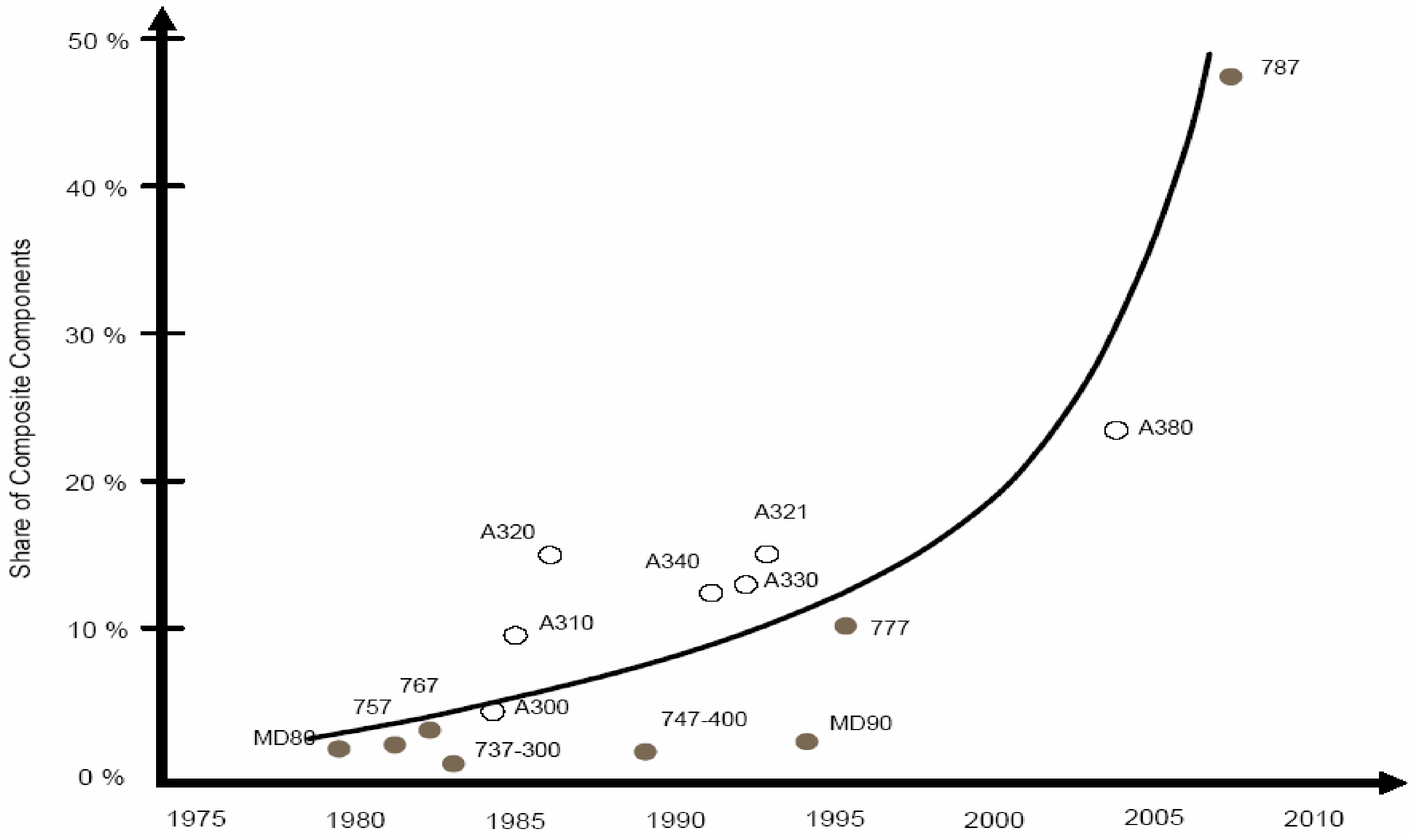


FIGURE 1-2 Percentage of composite components in commercial aircraft. SOURCE: *The Research Requirements of the Transport Sectors to Facilitate an Increased Usage of Composite Materials. Part I: The Composite Material Research Requirements of the Aerospace Industry.* Report prepared by EADS Deutschland GmbH, Corporate Research Centre, June 2004.

Current Aircraft Structures

Candidate Application	Current Material	Critical Conditions	Current Limitations	Motivation for Change	Challenges/Barriers to Move to New Materials
Aircraft					
Aeroshell	Al, Ti, or superalloy	350 to >700°F	Fatigue, weight, loads, thermal efficiency	Increase functionality, weight, reduced part count via unitized structure	Material and fabrication costs, temperature capability, strength and reliability, repairability
Conformal fuel tank	Titanium	−350 to −70°F	Cyclic stress, cracking, permeability	Reduced size and lighter than welded metallic system	Thermal stress, microcracking, delamination, fabrication costs, fatigue life, repairability
Engine duct	Titanium or superalloy	400 to 800°F	Fatigue, erosion, thermal stress	Cost, weight, stability	Liner integration, special performance, stability
Control surfaces, leading edges	Titanium, superalloy, or ceramic matrix composites (CMCs)	350 to 1200°F	Erosion and thermal stress. Failure due to impact.	Lower weight, unitized structures, reduced erosion, improved impact resistance	Fitting integration, thermal capability, erosion resistance, impact resistance, repairability
Nacelles (inner wall)	Aluminum	450 to 800°F	Fatigue, maintenance damage, corrosion	Weight, unitized structure, and corrosion resistance. Reduced maintenance costs.	Thermal resistance, fatigue strength, compatibility with hydraulic fluids, and cost to manufacture and repair

Uses of Composites in Aircraft

- Physical Strength
- Specific Toughness
- Light Weight
- Low CTE
- Resistance to Corrosion

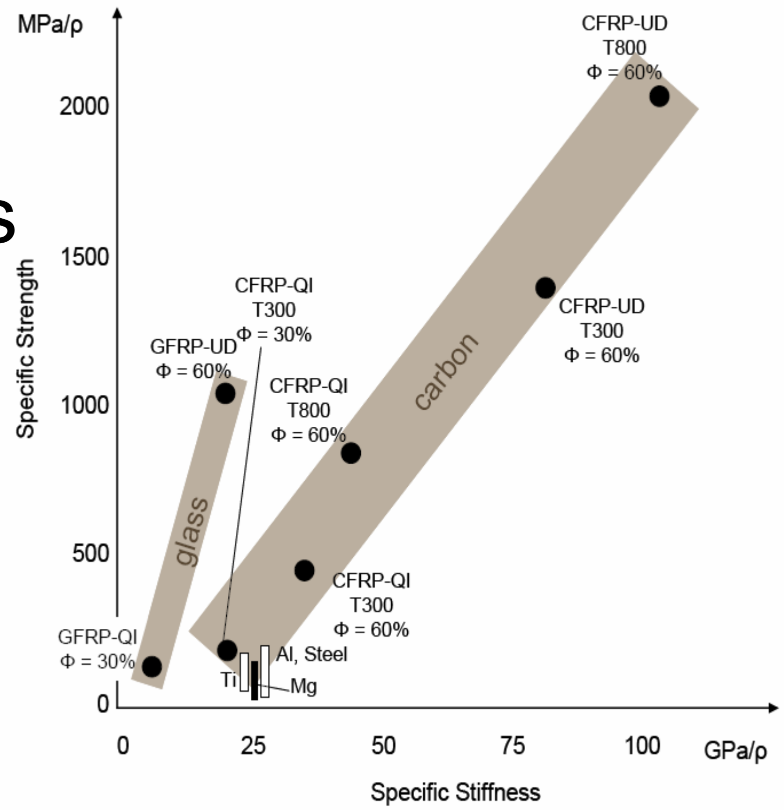


FIGURE 1-1 Specific stiffness and strength of a variety of PMCs in comparison to some metallic materials: Φ is the fiber volume fraction, ρ is density, CFRP is carbon-fiber-reinforced polymer, GFRP is glass-fiber-reinforced polymer, UD is unidirectional, and QI denotes quasi-isotropic. SOURCE: *The Research Requirements of the Transport Sectors to Facilitate an Increased Usage of Composite Materials. Part I: The Composite Material Research Requirements of the Aerospace Industry*. Report prepared by EADS Deutschland GmbH, Corporate Research Centre, June 2004.

Direct Comparison on C-17

- Redesign of C-17 Horizontal Stabilizer
  - Historically constructed of Aluminum
  - Redesigned using PMCs resulted in:
    - 20% Reduction in weight
    - 69% Reduction in tooling
    - 81% Reduction in fasteners
    - 48% Net cost reduction
  - Reduction in fasteners reduces sources of corrosion

Current use of Composites

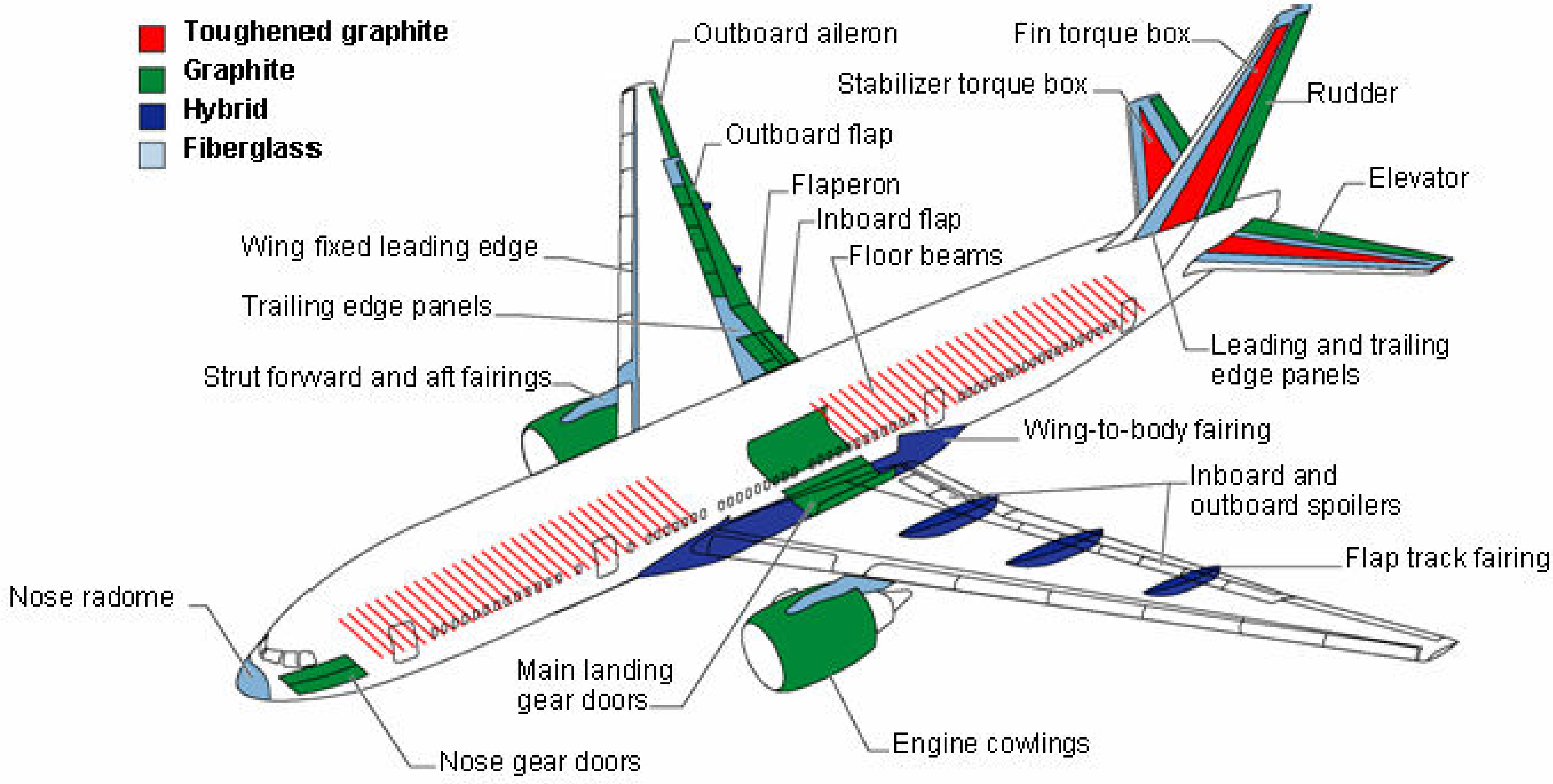
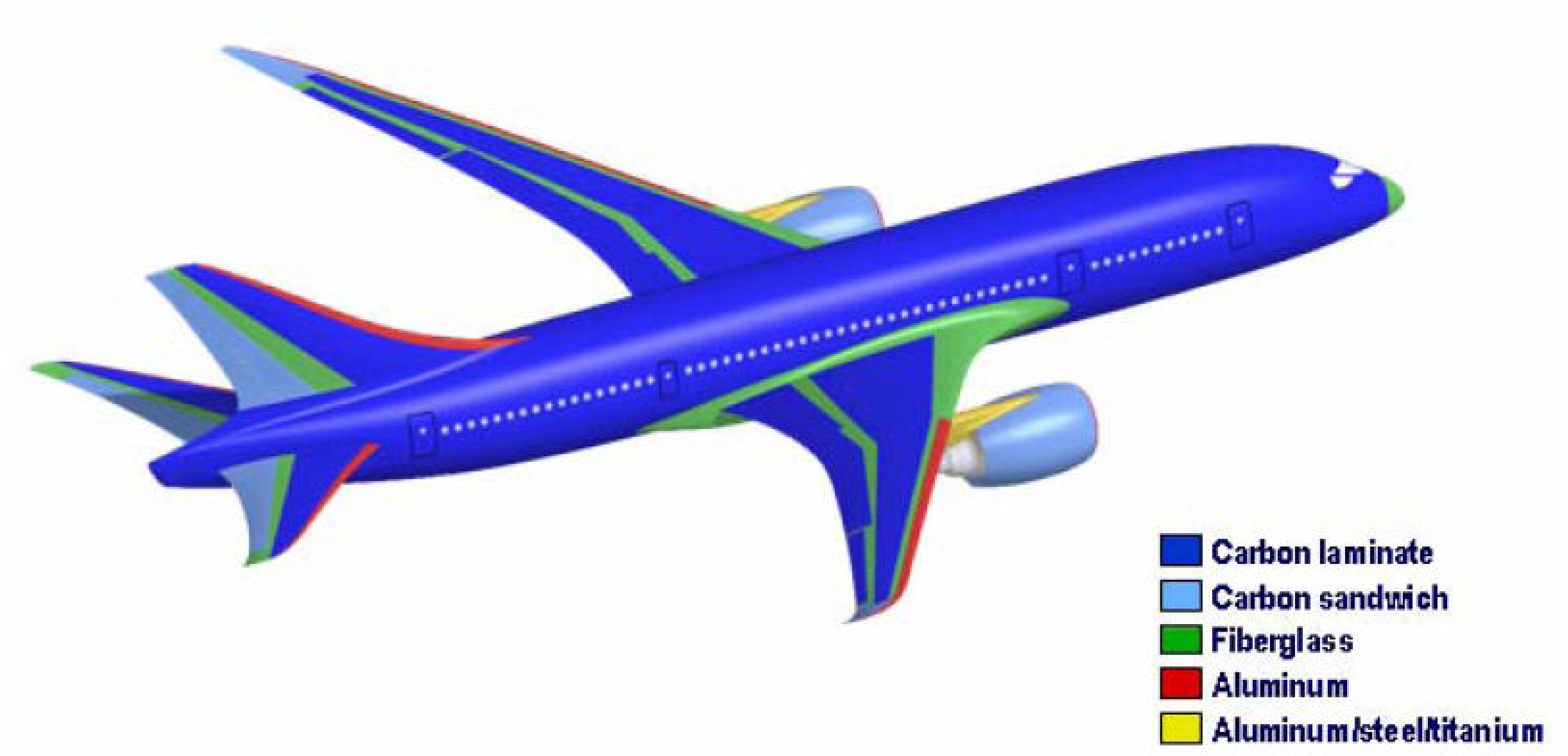


FIGURE 1-3 Production primary and secondary structure for the Boeing 777, an example of 1990s commercial application of composites.

Boeing 7E7 - 787



Boeing 787

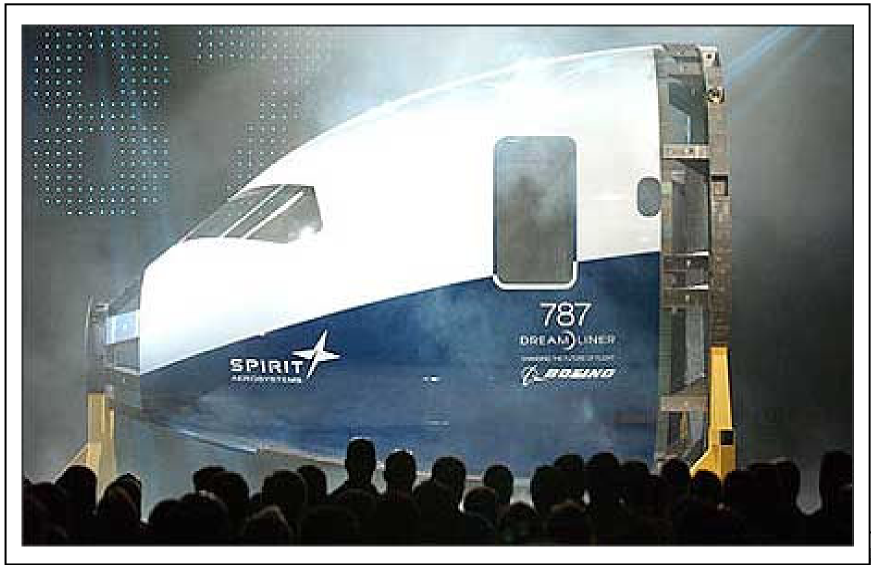
- First of its kind to use composite structures for wings, fuselage, and nose cone
  - Increased resistance to hoop stress in the fuselage allowing the cabin pressure increases
    - Previous aircraft - 9000 ft pressure rating
    - Boeing 787 - 6000 ft pressure rating
- Lower altitude pressure = Increased comfort for passengers.

Boeing 787 - Fuselage

Boeing 787

- Increased fuselage strength allows for the largest windows available on a commercial aircraft, which benefits passenger's experience.

Boeing 787 – Nose\Cockpit



Things to Consider

"With all these great benefits why are aircraft manufactures not using composites more?"

Things to Consider

- "If it's not broke, don't fix it"
  - Metals (especially Aluminum) have been tested extensively and have detailed models for their behavior.
- Airlines financial problems reduce the amount of money available for R&D

Things to Consider

- In environmental conditions differing greatly from the ambient the inherently complex material response of PMCs over time and the resulting evolution of their structural and functional properties have limited their effectiveness.
- Challenges exist in modeling the complexities of PMCs and testing and quality assurance costs can limit the benefit of using a composite

Environmental Factors

- Lightning Strikes
- Ice on Wings
  - Water penetration
  - Microcracking
- Extreme temperatures

Modeling of Composites

- Modeling of PMCs requires extensive knowledge of:
  - Matrix Polymer
  - Fiber inclusions
  - Fiber Lay-up
- In some cases PMCs are not used because the over designed part does not result in any design advantage

Future of Composites in Aircraft

- Nanocomposites
  - Carbon Nanotubes
    - Benefits:
      - High Yield Strength / Elastic Modulus
      - High Electrical Conductivity
      - Low Coef. Thermal Expansion
  - Polymer CNT composites can have the potential to vastly increases in mechanical properties at very low weight percentages.

Future of Composites in Aircraft

- Due to the small size of CNTs, (~1nm in diameter)
  - High surface area of interaction between CNT and polymer creates strong bonds between inclusion and polymer
  - Inclusion at small weight percentages gives no change in opacity.
    - Allows for clear sections of the fuselage, without having to cut sections for windows, eliminating an area of the aircraft with high stress concentrations

Composites in Aircraft

Thank you for your attention