Turbine Manufacturing

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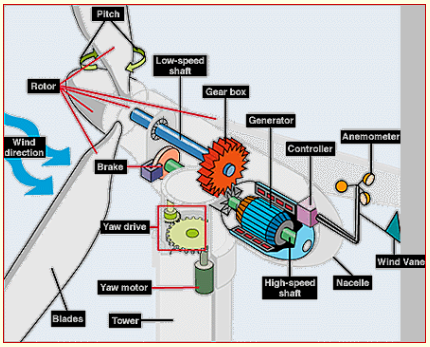
Major Turbine Components

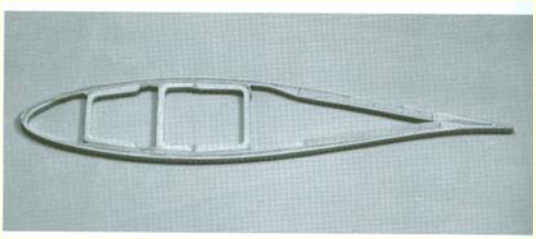


Rotor Blade Materials

- ✓ Rotor blades are usually made using a matrix of fiber glass that is impregnated with a material such as polyester (GFRP = Glass fiber reinforced polyester)
- ✓ The polyester is hardened after it has impregnated the fiber glass
- ✓ Epoxy may be used instead of polyester
- ✓ Likewise the basic matrix may be made entirely or partially from carbon fiber, which is lighter, but more expensive material
- ✓ Wood-epoxy laminates were also used for some rotor blades

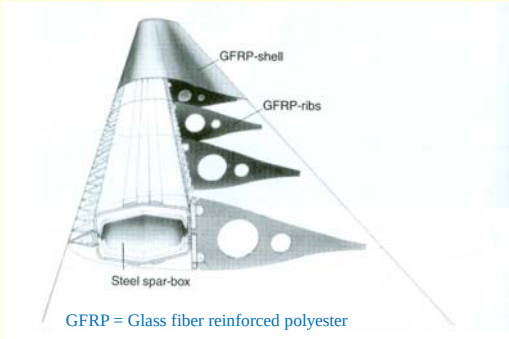
http://web.mit.edu/windenergy/windweek/Presentations/Nolet_Blades.pdf

Modern Blade Design



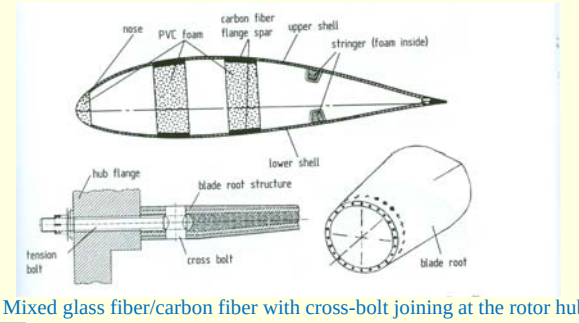
Laminated shell design with spar box and spar webs

Rotor Blade Cross-section



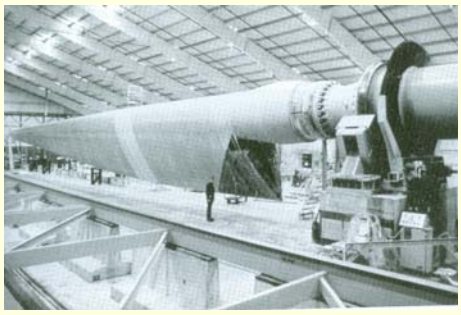
GFRP = Glass fiber reinforced polyester

New Blade Design

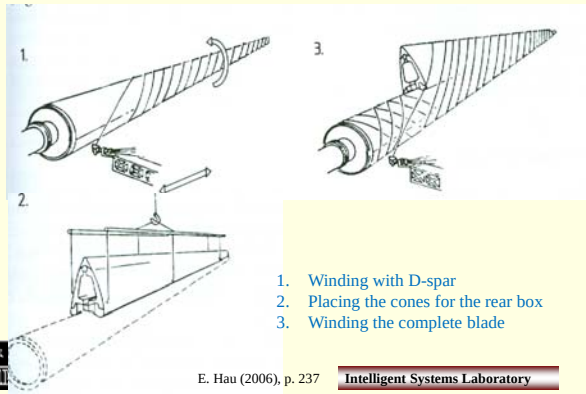


Mixed glass fiber/carbon fiber with cross-bolt joining at the rotor hub

Winding Machine

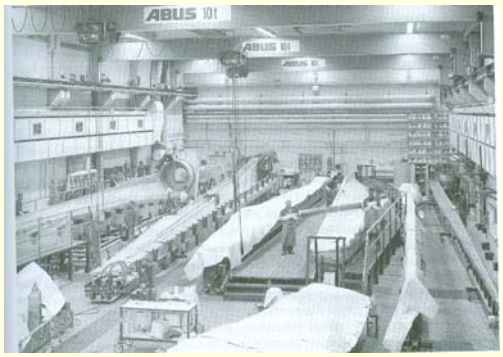


Automated Manufacturing



1. Winding with D-spar
2. Placing the cones for the rear box
3. Winding the complete blade

Blade Manufacturing Facility



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Tower Section

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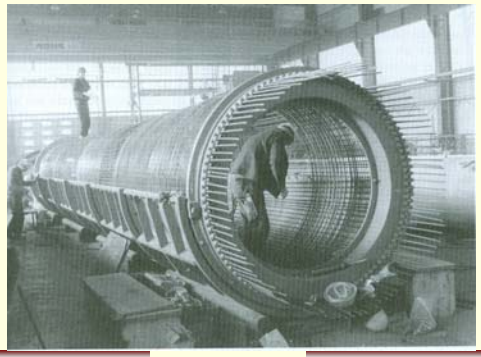
Concrete Tower Manufacturing



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Blade Testing

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The Purpose of Testing Rotor Blades

- ✓ The purpose of rotor blade testing is to verify that the blade are safe, i.e., that the layers of the rotor blade do not separate (delamination)
- ✓ Also, the test verifies that the fibers do not break under repeated stress

Nacelle on the Road

Tower Transportation

Tower Transportation

Tower Base

Foundation for a Tabular Tower

Assembly of Three Tower Sections

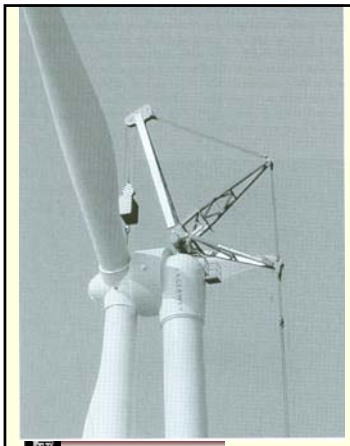
Puling up a Nacelle

Mounting the Complete Rotor

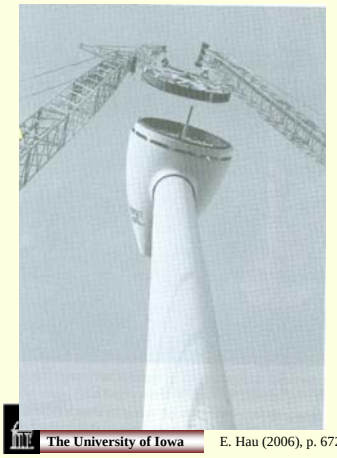
Helicopter Use

Portal Crane

Swinging Crane



Top Crane



Two Cranes Mounting a Generator

Concrete Tower Construction

Turbine Supply Chain

- ✓ Supply chain of importance due to global production of turbine components
- ✓ Product (wind turbine) assembled in the field
  - Mix of mechanical, electrical, and civil engineering activities
  - Different assembly equipment (e.g., cranes) and different assemblies (e.g., high power electricity, mechanical assembly)
  - Energy cost to manufacture and transport components and assemblies is an issue

Turbine Supply Chain

Characteristics

- ✓ Overlapping supply chain with the number of sinks equal to the number of wind turbines at a park
- ✓ Transportation distance (time) a significant component of the network
- ✓ Modeling such a network is challenging due to new network architecture (intertwined networks)

Turbine Supply Chain

Examples of supply chain modeling methodologies

- ✓ Network flow models
- ✓ Petri nets
- ✓ Neural networks
- ✓ Data-driven models (data mining)

Important to consider in modeling supply chains:

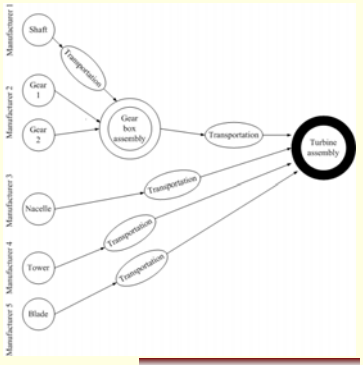
- ✓ Evolving network architecture
- ✓ Risks
- ✓ Costs

Turbine Supply Chain

Supplier options

- ✓ Single supply source
  - Ease of quality control
  - High risk of delivery disruption
  - Low control relative to the cost of components, and assemblies
- ✓ Multiple supply sources
  - More involved quality control
  - Lower risk of delivery disruption
  - Management of cost and quality is needed

Turbine Supply Chain



Turbine Supply Chain

- ✓ Many to many relationships prevail
- ✓ A supplier may work with many primes, and a prime may be supplied with components, assemblies, and services offered by many suppliers

Reference

http://books.google.com/books?id=Z4bhObd65IAC&printsec=frontcover&dq#PPP1,M1