Polymer Composites as Construction Materials

Application Summary Sheet 27

Title: Wind Turbines

Target Audience: Design Engineers, Power Engineers, Energy Companies, Component Manufacturers

Keywords: Power generation, Wind energy, Renewable energy, Composite structures, Fatigue resistance, Durability,

Overview of application / summary:

The revival of wind power began in the 1980's in America, Germany and Denmark, countries that depended mainly on fossil fuels but wished to lower production related pollution. Wind energy exploits local and inexhaustible resources without emitting greenhouse gases. It also has a limited and controllable impact on the environment. In less than 15 years, wind turbines have evolved form small, simple machines into a technology that can compete with established power generation sources such as coal, nuclear, gas and oil. Since 1995, world wind-generating capacity has increased by nearly 500% and the use of coal, the principal alternative, has declined by 9%. Europe now forms the fastest growing market for this type of energy.

The use of FRP composite materials in the turbines is an important technical element. Components must exhibit excellent fatigue strength, resist random loading and corrosion, require minimal maintenance and serve for 30+ years. Uncertainties over the performance of initial experiments with steel and aluminium have been overcome with the use of composite members, on which production is now almost entirely based. The blades are the main components, and the performance of the turbine is ultimately dictated by their efficiency. The use of lighter weight FRP materials means that the turbines can produce more power per unit volume, minimising impact on the landscape.

There is mixed public opinion over the introduction of large wind 'farms', the main concerns being over visual intrusion. However, it is envisaged that the potential economic savings, along with substantial environmental benefits will dispel these concerns. There are numerous examples of wind farms world-wide that are now in public favour.

Offshore wind farms are a recent, high impact development. FRP composite materials will be instrumental in the success of offshore programmes due to their proven performance in corrosive and hostile environments, which will maintain efficiency of the structures under increased locational costs.

As composite materials and manufacturing processes develop rapidly, making turbines cheaper and more efficient, the cost of electricity they produce will be continually reduced.

Impact of application

Engineering:

- Composite materials allow the reduction of loads through less conservative designs. The flexibility of components such as blades and hubs leads to lower weights and overall machine costs.
- The use of light weight, high strength composites in the main structural components is now allowing larger turbines to be developed. In 1995 600kW turbines were the benchmark, in 1999 it was 2MW and in the near future 3-5MW machines will be seen.
- As the global wind energy market expands, higher quality composite materials, manufacturing techniques and machinery that are more efficient and cost effective will be developed.
- Production processes will move towards automated systems and away from labour intensive, hand lay-up techniques.
- Design of turbine components, especially the blades, is complex and involves numerous factors not encountered by many composite manufacturers. Therefore an education and training policy is required to ensure that high quality and performance components can be sustained with the development of the market.
- Composite turbine blades have successfully accomplished a 50% energy output upgrade over former segmented extruded aluminium blades.
- Survival wind speed has been increased to 130mph with composite blades.

Financial:

- The extensive use of composite materials in turbine structures minimises their weight, reducing transportation and site installation costs.
- The inherent corrosion resistance of composites significantly reduces maintenance costs.
- Pre-commissioning removes the need for on site assembly and eases maintenance.
- Energy production prices are continually falling due to the increasing efficiency of the turbines. At the present rate, wind energy production will soon be more economically viable than all other energy sources.
- Implications of the Kyoto protocol have lead to heavy government subsidy into the R & D of wind energy production for environmental reasons.

Environmental:

- By far the largest environmental impact is the elimination of carbon the dioxide emission synonymous with fossil fuels and other types of power generation. This in turn reduces contribution to the greenhouse effect. Electricity production from the present installed wind capacity in Europe will prevent the emission of 24 million tonnes of CO2 annually, which would be emitted from the burning of 16 million tonnes of coal.
- Wind energy farms significantly reduce 'upstream' impacts of mining, drilling, pipelines, oil spills, transportation of fuels and even wars.
- RTM/Resin infusion techniques have now widely replaced hand lay-up for blade manufacturing, eradicating emissions from the production process to the environment.
- Noise pollution is still a drawback. Two types of noise are generated by a wind turbine: aerodynamic (from the blades) and mechanical (from rotating machinery). The development of integral mechanical systems has seen the mechanical element diminish. At high wind speeds the ambient noise level from trees and buildings may increase sufficiently to mask the aerodynamic noise.
- The preference for larger wind farms for economic reasons implies that large areas of land are taken up by the turbines.

Social

- Visual intrusion remains a major concern for residents in the locality, however this is offset by the financial and environmental benefits they may directly receive.
- At present wind energy is still more expensive to produce than fossil fuel energy. However, studies have shown that people are prepared to pay more for environmentally friendly energy.
- The public are often directly involved at the early stages of a wind farm plan, so they have a chance to influence the project and be aware of the benefits. Motivation to accept change is increased in doing this.
- Social acceptance tends to increase after installation when it is realised there is little or no disturbance generated.
- Wind farms can be developed sequentially, making adjustment easier.
- Wind power developments are flexible and reversible.

Robustness of research

There is an abundance of research into the operation (eg. under fatigue) of composite turbine blades and components. The performance of these components is critical to obtain longevity of the machine.

The potential of offshore wind farms is reinforced by the proven performance of composite structures in highly corrosive and hostile marine environments.

Due to the rapid growth of the market, and turbine structures with it, manufacturers were challenged by the increasing expertise required to design competent structures. As a result, collaboration with the aeronautical industry has lead to the transferral of knowledge to the manufacturers in the form of tooling design, predictive modelling and production techniques.

Future developments

Market figures show the current wind energy growth rate is set to continue for the foreseeable future. Enforcement of the Kyoto protocol ensures that renewable, sustainable energy sources are a priority for national governments. Development of materials, manufacturing processes and designs will continue to cater for the demand for larger, better performing turbines.

Offshore wind farms are a recent proposal in which massive potential is seen. Stronger, more consistent wind loads are obtained and offshore fields would remove the noise and visual pollution associated with inland farms. Turbine materials will need to exhibit excellent fatigue and corrosion resistance properties to ensure the durability and hence cost effectiveness of the projects. However, the success of these developments is subject to environmental and social appraisal that is currently taking place.

Where to get further information

Companies

Peterson Products (California): www.petersonproducts.com
Aeropac (Netherlands)
LM Glassfiber (Denmark)
Aeroconstruct (Denmark)
Vestas (Denmark)
Zond (USA)

Research Organisations

Renewable Energy World Online: www.jxj.com/magsandj/rew
Offshore Wind Energy in Europe: www.offshorewindenergy.org
The British Wind Energy Association (BWEA): www.britishwindenergy.co.uk
Institute for Wind Technology, University of Delft:
www.windenergy.citg.tudelft.nl