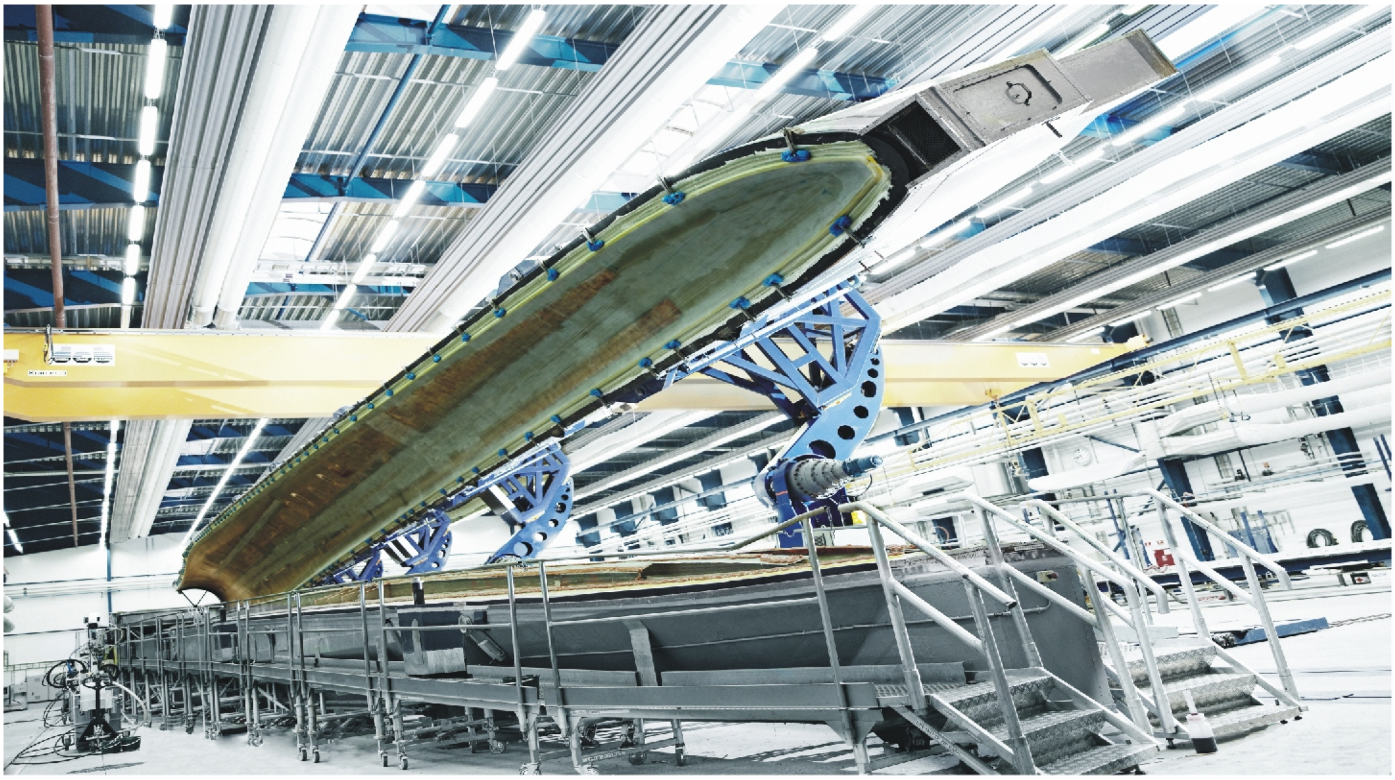
Carbon Fibers : This Decade's Reinforcement Of Choice For Wind Turbine Blades?

S Sundaram



Globalization has resulted in economic declines that have been remarkably synchronized the world over. Mercifully, new policy initiatives augmented by leading nations have resulted in the fiscal stimulus in industrialized countries amounting to a staggering 3.4% of GDP between 2009 and 2010.This has resulted in the global GDP forecast contracting by 1.3% in 2009 followed by a projected lukewarm 3.1% increase in 2010.

Glass fiber has been the traditional workhorse reinforcement of the polymeric composites industry. The industry is aware of several modified versions of traditional E glass in the past that have led to an increase in commercial applications for glass fiber composites. The performance envelope for glass fiber has been pushed quite far and a stage reached where further *significant enhancement* in the performance of glass fiber could hit a plateau. The industry has been looking at alternate reinforcements that are both commercially and technically viable for demanding applications when one uses the life-cycle cost benefit analysis approach. Carbon fiber has been emerging as a worthy option for several years in spite of a price disadvantage. Though it is more expensive than glass fiber, the industry at least now has the option of using carbon fiber for wind energy-*the tradeoff being performance relative to cost.*

The world's total installed capacity for wind energy reached 120GW in 2008 (official numbers for 2009 are awaited).The Global Wind Energy Council (GWEC) predicts, that in 2013, global wind energy capacity will be

332GW.The annual growth rate during the next four years will average around 22% in terms of total installed capacity.

Carbon fiber has been making its presence felt in wind energy. Carbon fiber is much lighter with a specific gravity of 1.8 compared to 2.56 for glass. Fatigue and stiffness properties are superior to glass fiber, which make it an attractive proposition for wind turbines with bigger blades.

In recent years, wind turbine manufacturers and carbon fiber suppliers have been collaborating closely in achieving synergistic technology breakthroughs. Wind turbine manufacturers have been systematically progressing towards larger rotor blade diameters. This is logical, as the *power derived (from wind) is directly proportional to the rotor area and depends on the square of the rotor blade diameter. Traditional metrics point to the volume and mass being scaled to the third power of rotor diameter.* While wind power increases cubically with wind velocity, the power capture capability decreases beyond a critical wind velocity-with a view to avoid mechanical damage due to material constraints. Historically, blade length has increased 10% annually and doubled approximately every seven years. In the mid 90s, the largest turbine had an output of 800KW. Today, a turbine of average size is rated between 1.5MW to 2.0MW and at least three of the top ten blade manufacturers have successfully tested and commercialized 2.5MW and 3.5MW turbines using carbon fiber. The fact that efforts in this direction have paid dividends is evident in generating capacities increasing from just 3KW in the 1980s to almost 2.5MW in the 1990s.Increase in specific strength and stiffness is vital in wind turbines-hence the distinct advantage in using carbon fiber (specific strength of 2.0GPa) over glass fiber (1.3-1.5GPa). The lighter weight (through use of carbon fiber) and advanced aerodynamic profile helps to minimize the load on the nacelle and tower. *Reduced weight translates to reduced loads and improved efficiency.* Turbine blade sizes have witnessed a quantum jump with passage of time--up from 7.5 meters in the 1980s to 50+meters in 2004 and 60+meters in 2008. *Increased blade size results in greater rotor-swept area.* For blade sizes greater than 45 - 50 meters, weight is a criterion and hence the advantage of using carbon fiber. *Fatigue loading is critical in blade design* and, more so, with increase in blade size-here again carbon fiber displays inherently superior fatigue properties compared to glass fiber. Manufacturers are slowly, but surely, moving to 2.5MW and higher capacities. In the next five years, more than 20% of all new turbine installations will have capacity of 3.5MW per turbine. In 2009, 25% of all new turbine installations were rated at greater than 2.5MW. Vestas, Gamesa and Dewind have reportedly tested carbon fiber blades and also reportedly signed up with carbon fiber producers. It is understood that approximately 800-1200kgs of carbon fiber is required per MW and this can change depending on blade design and construction. In 2006,2950Tons of carbon fiber was used in this sector equivalent to 6% of global demand (including glass fiber) and this was a 50% increase over 2005.This is forecast to reach 8% by 2010 and 10-11% by 2012.The wind energy sector has been growing at 25-30 % annually over the past 5 years. At current growth rates, carbon fiber consumption in the wind energy sector is expected to reach around 7,500Tons by 2012 and 14,500 Tons by 2014.

For carbon fiber usage in this sector, the tip of the iceberg is apparently offshore wind farms. While the smallest installed units are in the 2MW category, those under construction are

S Sundaram

gigantic ones in the 5.0 to 6.1 MW category (and going up to 8.0MW or higher!) with rotor diameters in the 126 meter category. The largest blade to date measures 61.5 meters with a rotor diameter of 126meters.With longer blades, gravity loads increase and have a greater effect than wind loads -- the blades must have sufficiently high stiffness and strength in both static and fatigue.8-10MW turbines are expected to be in demand by 2015/2020 and carbon fiber appears to be the best bet at this point of time unless the composites industry comes up with a material with superior stiffness and strength and/ or innovative blade design and fabrication.

With more than 40 offshore sites likely to become operational by 2015 accounting for around 12,000MW and most of these turbines being in the 5.0MWplus range; carbon fiber producers have their task cut out in meeting the demand (for both onshore and offshore wind farms), while blade manufacturers and designers challenge themselves and keep plugging at innovative ways of fabrication and weight reduction.

Will carbon fiber be the reinforcement of choice for wind energy this decade? *The winds of change apparently seem to be blowing in that direction!*

S SUNDARAM
E mail : ssundaram50@yahoo.com