Very large wind turbine rotor blades require damage tolerance and damage monitoring

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Very large wind turbine rotor blades require damage tolerance and damage monitoring

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The most effective way of increasing the power produced per wind turbine is to increase the length of the rotor blades as the produced energy is proportional to the swept area. A major challenge is to design future very large rotor blades so that they can endure minimum 20 years of service in a harsh off-shore environment.

Rotor blades are made as very large parts using relative low-cost fibre composite materials and low-cost manufacturing methods. It is not possible to manufacture “perfect” blades. Setting high quality control (allowing only blades with small manufacturing defects) leads to a high rejection rate, which is not attractive since large blades are costly.

Since each blade will have different manufacturing defects and will be subjected to different loading histories, it will undergo its own unique damage evolution. Having no detailed information about the manufacturing defects and loading history of each blade, it is not possible to make accurate prediction of the lifetime of blades individually.

Regular manual inspection is neither an economical nor a technical efficient solution, since manual inspection of off-shore wind turbines is costly and difficult.

The new approach

We propose a novel approach that allows blades to contain defects and develop stable damage under operation [1]. The key idea is to use damage tolerant materials and design methods which ensure that defects do not develop into unstable damage leading to blade failure.

Increasing reliability by damage tolerance

A key issue is to create damage tolerance, meaning that damage from defects must always progress stably, i.e. slowly under increasing load, while at the same time be detectable by sensors. Damage tolerant design can be obtained by structural design optimization and by the use of damage tolerant materials, e.g. materials that possesses increasing fracture resistance with increasing crack extension.

Perspectives

This new approach enables the service life of each blade to be decided individually on the damage state of each blade. It then becomes possible to extend the lifetime of healthy blades beyond their originally planned service life. It is not critical to be able to calculate the loads for each wind turbine with high accuracy since the damage evolution can be assessed on the basis of sensor signals.

Conclusions

The development of more damage tolerant structures and materials together with damage monitoring can be the technological opportunity that enables the safe development of future very large wind turbine rotor blades approaching 100 meters in length.

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