TECH BEAT

Dr. Neil Canter / Contributing Editor

Humpback whales inspire new wind turbine technology

The unique design of their flippers enable a steeper operating angle of the blade—and a 40% performance increase.

KEY CONCEPTS:

- **Interest in using wind turbines is growing, but technical improvements to the operating angle of the blade are needed to boost performance.**
- **Scientists were inspired by a unique series of bumps called tubercles on the fins of humpback whales that enable the 45-foot animal to better maneuver when capturing food.**
- **Tubercles affect the flow of air over the blade generating a vortex on each side of a specific tubercle that prevents air flow from separating and stalling.**

The significant rise in the cost of petroleum oil has increased the search for viable alternative technologies. One option under consideration is wind power. A wind turbine operates by using the wind's energy to spin a shaft that drives an electricity-producing generator.

Lubrication is a key element in the operation of a wind turbine. One of the key applications is the bearings contained within the wind turbine gearbox. These bearings can be subjected to extremely high torques. At STLE's 2008 Annual Meeting & Exhibition in Cleveland, Dr. Larry Viterna of NASA Glenn Research Center indicated that as wind turbines increase in size and gain more power, the level of torque increases. He indicated that the gearbox remains the No. 1 challenge in the wind turbine industry.

Bearing manufacturers have developed specifications for the gear oils used.[1] Included is the need for the gear oil to operate up to five years under extreme conditions such as those encountered in saltwater.

One critical aspect of the wind turbine that has not been evaluated until recently is the blade itself. The operation of wind turbines at low wind speeds must be upgraded. These speeds are more prevalent under most operating conditions than high wind speeds.

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Stronger generators and blades can be employed at high wind speeds but are ineffective at low wind speeds. The main approach to improving the performance of the blade at low wind speeds is to increase its angle of attack (the angle that the blade makes into the incident wind). A recurring problem is that increasing the angle eventually forces the blade to stall.

Stalling, which is determined by wind speed and direction, is difficult to predict. This results in manufacturers developing blades with limited operating angles to ensure that stalling is minimized. Unfortunately, this leads to inferior performance.

Tubercles increase the operating angle from 11 degrees to 17 degrees, prior to stalling, a performance improvement of nearly 40%.

Figure 1

Improved wind turbine performance can be achieved by installing tubercles or bumps on the blades. This technology was inspired by the design of the humpback whale flipper. (Courtesy of West Chester University of Pennsylvania)

If a technology could be developed to boost the operating angle of the blade, the prospect exists for improved wind turbine performance and potentially less stress on the oils needed to lubricate bearings in the gearbox. Such a technology has not been proposed until now.

TUBERCLES

The answer for improving performance of the blades may lie with the flippers of humpback whales. Dr. Frank Fish, professor of biology at West Chester University of Pennsylvania, says, "Humpback whales have a unique series of bumps called tubercles on their flippers. These tubercles enable these huge whales to make very tight turns in maneuvering to secure their food."

Tubercles permit the humpback whales to move underneath their prey and release a ring of bubbles. These bubbles form a cage that facilitates the capture of food. In contrast, other baleen whales such as the blue and fin whales have smooth flippers and swim straight ahead to obtain their food.

Humpback whales were found to use their flippers at higher operating angles before stall would occur. The cross section of the flipper looks similar to that of an aircraft wing. This comparison led Fish to evaluate the potential for analysis of the tubercles in air as opposed to water.

Evaluation of the effectiveness of tubercles was literally conducted by construction of a model humpback whale flipper. Fish says, "We obtained an actual flipper from a humpback whale and then constructed one flipper with tubercles and a second flipper without tubercles. Both flippers were about two-feet tall and were evaluated in a wind tunnel."

The work in the wind tunnel showed that the flipper with tubercles exhibited a higher operating angle, prior to stall. Fish adds, "We found that the tubercles allow the operating angle to increase from 11 degrees to 17 degrees, prior to stalling." This represents a performance improvement of nearly 40%.

The reason for the effectiveness of tubercles has to do with how they affect the flow of air over the flipper from a three-dimensional viewpoint. Fish says, "As the air flows in the valleys between tubercles, a vortex is generated on each side of a specific tubercle. This vortex prevents the air flow from separating and stalling."

Fish believes that tubercles enable the flipper to exhibit not just enhanced lift but decreased drag. This factor allows the humpback whale to use less energy to turn.

He also points out that air flow is modified more in the direction of the flipper than perpendicular to the flipper. The technology for using tubercles in air flow applications has been licensed to WhalePower Corp., which is evaluating its effectiveness in wind turbines.

WhalePower Corp. has evaluated tubercle blades, as shown in Figure 1, on wind turbines. The result is that tubercles containing wind turbines operate more effectively at moderate wind speeds with no performance difficulties. Stalling at the tip is virtually eliminated, and the wind turbines are better able to handle higher wind speeds.

Testing has been underway for one year at the Wind Energy Institute on Canada's Prince Edward Island. Fish says, "This evaluation has shown that tubercle-based blades are a viable technology for generating power under low wind flow conditions."

Future work will involve testing tubercle-based blades in fixed pitch tests in a wind tunnel under low-speed conditions. Fish says, "We need to determine the best geometric placement of tubercles that will provide optimal power generation."

Fish is uncertain about the impact of tubercles on the stress applied to gearbox lubricants. But it appears that tubercles will enable more efficient use of the wind turbine, which should lead to less torque, longer operating life and fewer lubricant problems.

Additional information on the use of tubercles in wind turbines can be found at WhalePower Corp.'s Web site: **www.whalepower.com**.

REFERENCE

1. Afton Chemical Team (2005), "Raising the Bar for Wind Turbine Lubrication," TLT, **61** (10), pp. 24–28.