# Cetacean-Inspired Wind Technology

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Biomimicry is using nature as inspiration for human technological achievements. Nature essentially is being used as a template to further human technological advances (Fish, 2009). The goal is to make technologies that take the biological performances of organisms in instances when that organism's performance surpasses that of human-engineered technologies (Bar-Cohen, 2006). One such example of this biomimicry lies in the construction of cetacean inspired wind turbine blades. Marine scientists who have studied humpback whales know that they possess an innate ability to move in the water with efficiency and agility because of protuberances on the leading edge of their pectoral flippers. This science has been applied to technology, specifically wind technology, as a means to utilize the energy wind can provide in a more efficient way (Hamilton, 2008).

Humpback whales, *Megaptera noveaeangliae*, are among some of the most agile ceteaceans in the ocean. They are not particularly long cetaceans, compared to some of the other rorquals in the family Balaenopteridae (Fish et. al., 2011). They are most well known for their acrobatic performances on the surface of the water. Their maneuverability in the water is supreme and is extremely useful in terms of feeding behaviors (Fish et. al., 2011). These cetaceans utilize their flippers to act as biological hydroplanes to make sharp turns during feeding times. For example, these animals create bubble nets when feeding and it is essential that they can swim in tight circular patterns in order to trap their prey (Fish et. al., 2011). Their pectoral flippers are about one third their body size and possess rounded protuberances on the leading edge of these flippers (Fish et. al., 1995). These protuberances are called tubercles and are essential for the agile abilities these cetaceans possess as it promotes less energy to move for these animals (Carter, 2008).

These tubercles enable an increased lift and decreased drag which makes the cetacean's movement and agility in the water more efficient (Fish et. al., 2011). The tubercles are referred to as morphological complexities and they produce a variation in pressure that allows for this decreased drag and increased lift. These tubercles delay stall as well as increasing total lift which enables efficient movement (Fish et. al., 2011). When water flows over the cetacean's flippers, the water gets separated along the flipper via the tubercles. They cause small vortices along the flipper that allows for the flow of water to be passed down along the fin. This reduces flow disruption and means that the cetacean can move and change positions more efficiently in the water.

Troughs, or valley-like spaces are created between each tubercle and within each trough the flow of water accelerates. Flow acceleration decreases pressure which means the drag decreases (see Fig. 1). It also likely leads to regions of low pressure within the troughs themselves, at the leading edge. The flow from behind the tubercled-peak gets sucked towards this low pressure region and causes counter-rotating vortices behind each trough. This creates a more efficient exchange of momentum, more lanes of water and it also increases the velocity of flow in each trough thereby creating accelerated streams of flow between the bumps. Essentially they alter the flow of water along the flipper and make it much more efficient (Hansen, 2009). The main idea behind this tubercle biomechanicry is that there is a significant improvement in lift-to-drag ratio which decreases stall, increases lift and enables for more momentum to occur at a lower cost of energy. (Hansen, 2009).

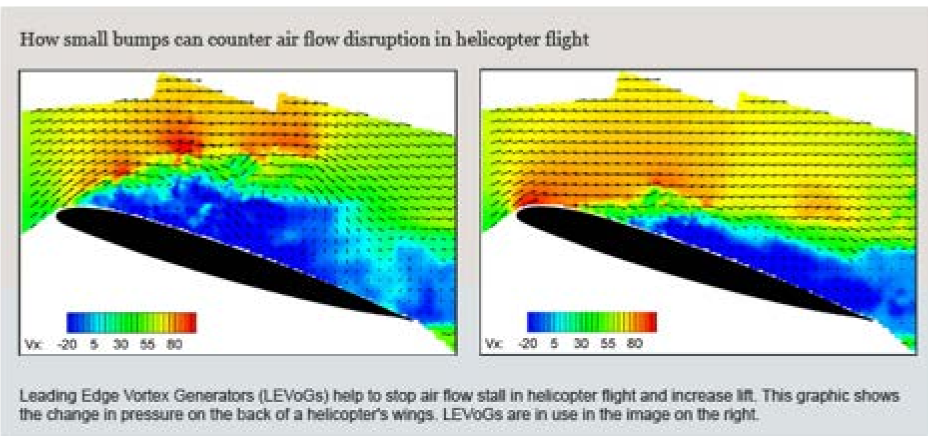


*Figure 1: (Taken from Schmidt, 2012) This image shows the differing pressures seen on a standard, non-tubercled blade and on a tubercled blade (LEVoGs as depicted in this figure) of a helicopter. The image on the left is a non-tubercled blade and it shows that airflow and pressure is not streamlined and this decreases lift and increases drag. A low velocity of air flow is represented by the dark blue and it is very prominent. However, the image on the right, the LEVoG or tubercled blade, shows that airflow and pressure is in fact streamlined. The velocity of air flow is much higher as represented by the yellow and orange coloration. This means that drag is decreased and lift is increased. The pressure is less and this will increase lift and make for more efficient movement of airflow.*

This tubercle technology has been applied to human technology by means of wind turbine technology. In fact, it is the most appropriate biological system for the application to wings that are involved with aerodynamics as the flow and energy of water is similar to that of air. Specifically, WhalePower Corp. has taken advantage of this biological system and has applied it to technology to form a new hybrid technology on wind turbines (Fish et. al., 2011). This hybrid system was absolutely intentional because scientists such as Dr. Frank E. Fish, the founder of WhalePower Corp. took his knowledge of cetacean flipper biomechanics and applied it to this human technology. He realized that humpback whales displayed the most efficient manipulation of water flow and he applied that to wind turbine technology so our human needs could be fulfilled in a more efficient and sustainable manner. Just like the whale flippers, this tubercle technology, when applied to wind turbine blades, reduces drag and increases lift, thereby increasing the wind speed produced in less time (Howle, 2009).

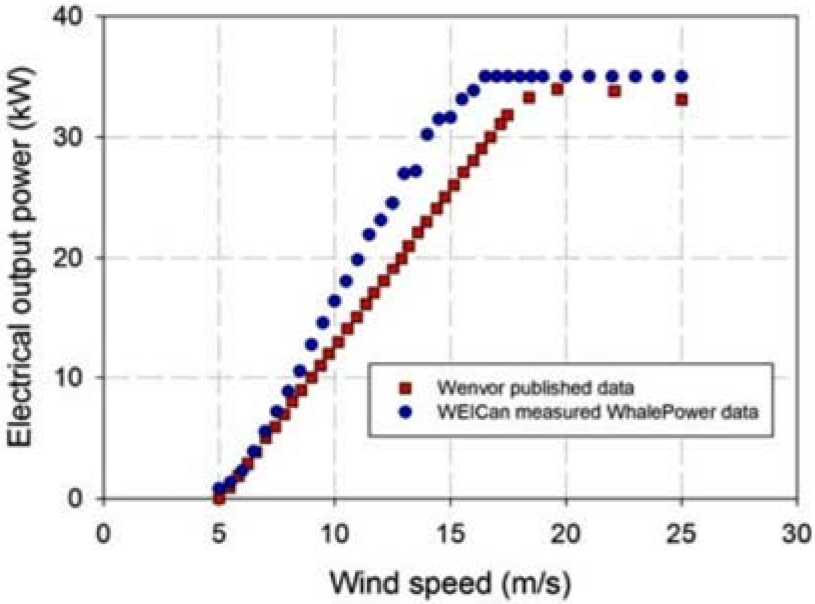


*Figure 2- (Taken from Howle, 2009). Electrical output power (kW) produced through wind speed was tested using both a WhalePower (tubercled) blade and a general (smooth) blade. The WhalePower blade shows to be more efficient than the Wenvor blade as it produces the same amount of electrical output power much faster than the Wenvor blade. It can also sustain this power output whereas the Wenvor blade drops in power output capabilities with an increase in wind speed.*

This tubercle technology produces a more efficient electrical power overall compared to a smooth surface blade. In Figure 2, it is seen that a WhalePower blade generates a high electrical output power much faster than a standard blade does. Here it can be seen that the WhalePower blade produces about 35kW at 16 m/s which is nearly 5 m/s faster than a general blade. The WhalePower blade reaches a maximum electrical output power at a more efficient time than a general blade does. Results from tests show that the WhalePower and Wenvor blades both have a start-up wind speed of 5 m/s. However, the WhalePower blade showed to have a greater power curve slope than that of the Wenvor blade. It also reached its maximum power output at 12.5 m/s whereas the Wenvor blade reached its maximum power output at 15 m/s. This shows the absolute efficiency of this applied technology (Howle, 2009). The only downside to this type of technology is that takes a lot more materials and production to make than a traditional, standard blade without tubercles. This means that the price will be high and it will be less available for the public to use. However, if this particular technology could be mass produced, more people would be available to invest in it thereby decreasing the cost.

With that said, this type of technology will be most useful not just for wind turbine technology but for any kind of aerodynamic technology. Essentially, this hybrid technology could be applied to personal fan blades as well as airplane blades. But we should not just stop at manipulating air flow energy. This type of technology could prove useful to any kind of blade that could be used in the water as well. After all, the tubercles on the cetaceans manipulate water flow so it could be very useful to further human technology that uses water flow energy (Fish et. al., 2011). This type of technology could really change the way we as humans use wind and water biological systems and to help give us new ideas as to how we can use them to produce more efficient and effective ways to utilize such technology.

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