Weekly Seminar: Spring 2010

Date: Friday February 26

Time: 11:00 AM

Location: Maryland Hall 110

Speaker: Frank Fish (West Chester University)

Title:"Hydrodynamic flow control by whales and dolphins for biomimetic applications"

Abstract

It has been a long-standing idea that new technologies can be developed from nature. Animals have served as the inspiration for various technological developments. Copying animals by the biomimetic approach attempts to seek common solutions from engineering and biology for increased efficiency and specialization. Because biological designs resulted from the evolutionary Darwinian process of "natural selection", it is considered that animals have already performed the “cost-benefit-analysis”, optimizing particular designs for specific functions. As engineers move from the world of large, stiff, right-angled pieces of metal to one of small, compliant, curved-surface pieces of heterogeneous parts, nature will become a more influential teacher. The immense diversity of animals with their particular morphological features presents a rich resource of novel designs that may be incorporated into advanced technologies and effectively reduce the time of development of innovative technological solutions. The biomimetic approach seeks to incorporate designs based on biological organisms into engineered technologies. Biomimetics can be used to engineer machines that emulate the performance of organisms, particularly in instances where the organism’s performance exceeds current mechanical technology or provides new directions to solve existing problems. For biologists, an adaptationist program has allowed for the identification of novel features of organisms based on engineering principles; whereas for engineers, identification of such novel features is necessary to exploit them for biomimetic development.

Optimization of energy by whales and dolphins requires adaptations that control hydrodynamic flow over the body to reduce drag, and improve thrust production and efficiency. Streamlining of the body and appendages minimizes drag. These highly derived aquatic mammals have body shapes close to the optimal hydrodynamic design for drag reduction. Oscillations of the flukes, which are caudal hydrofoils, generate thrust throughout the stroke cycle and maintain a propulsive efficiency over 80%. This high efficiency is dependent on the passive, self-adjusting spanwise and chordwise bending of the flukes and on the control of vorticity. Control of vorticity to enhance locomotor performance is demonstrated in the humpback whale (*Megaptera novaeangliae*). This whale is exceptional among the baleen whales in its ability to undertake acrobatic underwater maneuvers to catch prey. In order to execute these maneuvers, such as banking and turning, humpback whales utilize extremely mobile, wing-like flippers. The humpback whale flipper is unique because of the presence of large tubercles along the leading edge, which gives this surface a scalloped appearance. The position, size and number of tubercles suggest analogues with specialized leading edge control devices associated with

improvements in hydrodynamic performance on lifting surfaces. Examinations using various computational fluid dynamic models and wind tunnel testing have demonstrated that the tubercles modify the flow pattern around the flipper and postpone stall with increasing angles of attack. The tubercles function to produce vortical flows over the surface of the flipper and control lift characteristics at high angles of attack, where stall would occur.

The potential benefits from biological innovations applied to engineered systems operating in fluids are high speeds, vorticity control, reduced detection, energy economy, and enhanced maneuverability. Adaptations (leading edge tubercles to passively modify flow and high efficiency oscillatory propulsive systems) from marine animals demonstrate potential utility in the development of biomimetic products.