ARTIFICIAL EVOLUTION OF EFFICIENT FLAPPING APPENDAGES BY USING A VORTEX FORMATION PARAMETER

MORTEZA GHARIB* AND MICHELE MILANO *

* GRADUATE AERONAUTICAL LABORATORIES
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA 91125, USA
MGHARIB@CALTECH.EDU

Flapping appendages can be considered as the final result of a complex evolutionary process, which produced a mechanism to swim and fly by unsteady vortex generation. In this study we introduce a parameter that allows to fully characterize this mechanism, predicting optimally efficient flapping trajectories and appendage shapes. It has been shown that propulsive efficiency of flapping foils is optimal when vortices of maximum circulation are shed in the wake [1-4]. From these studies it can be inferred that generation of vortices of maximal circulation is one of the primary goals of the natural evolutionary process that led many animals to develop flapping appendages to achieve optimally efficient propulsion. Many constraints, however, act in concert to limit the range of possible trajectories for flapping appendages. For example, mechanical joints and muscle strength directly limit the range of possible flapping kinematics, for a given body morphology. Yet, as noted before, evidence suggests that flapping appendages are moved so as to achieve the specific goal of optimally efficient propulsion by producing vortices of maximal circulation. The formation parameter is a time scale for vortex formation that correlates the kinematics, shape, and vorticity production of a flapping appendage in a detailed way. It can be used to characterize in detail the kinematics of an oscillating body. The universality of this parameter is demonstrated experimentally for several fundamental cases concerning pulsating jets, cylinders oscillating in a free stream, flapping wings and fins. We present detailed results for the design of optimally efficient flapping wings that generate maximum lift, showing that artificially evolved trajectories and wing shapes closely match those of Drosophila Melanogaster. The fin movement of an artificial fish is also optimized, and the formation parameter is used to explain the optimal swimming patterns observed.

References

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