

Abstract

The tail (caudal fin) is one of the most prominent characteristics of fishes, and the analysis of the flow pattern it creates is fundamental to understanding how its motion generates locomotor forces. A mechanism that is known to greatly enhance locomotor forces in insect and bird flight is the leading edge vortex (LEV) reattachment, i.e. a vortex (separation bubble) that stays attached at the leading edge of a wing. However, this mechanism has not been reported in fish-like swimming probably owing to the overemphasis on the trailing wake, and the fact that the flow does not separate along the body of undulating swimmers. We provide, to our knowledge, the first evidence of the vortex reattachment at the leading edge of the fish tail using three-dimensional high-resolution numerical simulations of self-propelled virtual swimmers with different tail shapes. We show that at Strouhal numbers (a measure of lateral velocity to the axial velocity) at which most fish swim in nature (approx. 0.25) an attached LEV is formed, whereas at a higher Strouhal number of approximately 0.6 the LEV does not reattach. We show that the evolution of the LEV drastically alters the pressure distribution on the tail and the force it generates. We also show that the tail's delta shape is not necessary for the LEV reattachment and fish-like kinematics is capable of stabilising the LEV. Our results suggest the need for a paradigm shift in fish-like swimming research to turn the focus from the trailing edge to the leading edge of the tail.