Hydrodynamic Analysis of Fish’s Traveling Wave Based on Grid Deformation Technique

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ABSTRACT
In this paper, hydrodynamic performance of a two-dimensional deformation plate is numerically simulated to mimic fish’s travelling wave by means of grid deformation technique. The influence of main parameters, such as wave length, linear wave amplitude and wave frequency, on the hydrodynamic performance is analyzed. The total length of the plate is selected to be 0.3m. The average thrust coefficients and propulsive efficiency as well as the pressure contours varying with different parameters are given to describe the results. The results show that, when the wave length is 1.6–1.8 times to the total length of multi-joints, thrust coefficient tends to the maximum. There are two main reasons for the change of the thrust performance. One is the pressure difference on both sides of the deformation plate. The other is the bending angle of the deformation plate which affects the horizontal and vertical components.

KEY WORDS: hydrodynamic performance; robotic fish; travelling wave; grid deformation technique; Star-CCM+;

1. INTRODUCTION
Due to its excellent maneuverability and low noise, robotic fish plays an important role in sea farming, marine biological research and marine ecological restoration. Different from the conventional propeller, the biomimetic propulsor provides a special propulsion mechanism for designing micro underwater vehicles or bionic fish. The recent application of biomimetic propulsor on underwater fish-like vehicles has made great progress. Romero (2014) developed a cost-effective fish-like Autonomous Underwater Vehicle (AUV) which can avoid obstacles in a swimming pool with a sophisticated intelligence. Wei and Yu (2012) proposed a new slider-crank centered flapping mechanism to mimic the oscillations of dolphin through the continuous rotation of the DC motor. Lau (2015) designed a new bio-inspired wire-driven robotic fish, the Robot Shark, which can sway its caudal fin to establish forward motion as well as ascending motion. More about the investigations can refer to the relative review papers (Raj and Thakur, 2016; Chu, 2012; Du, 2015). All of these investigations promote our understanding of the application of biomimetic propulsion and make the problem in biomimetic propulsion clarified.

In recent years, we have developed a robotic fish propelled by a three-joint propulsion system, the top view of which is shown in Fig.1. The motion of each joint is determined by fitting the travelling wave with three joints as shown in Fig.2.

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In recent studies, the mathematical model of traveling wave proposed by Lighthill (1960) is widely used to model the fish-like swimming motion of multi-joint robotic fish. The origin is said to occur at the joining point between fish body and tail.

\[ y_{\text{body}}(x,t) = (c_1x + c_2x^2) \sin(\frac{2\pi}{\lambda} x - 2\pi ft) \]  

Here, \( y_{\text{body}} \) is the lateral displacement of a tail unit from the center axis, \( x \) is the displacement along the tail, \( \lambda \) is the wave length, \( c_1 \) is the linear wave amplitude envelope, \( c_2 \) is the quadratic wave amplitude