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Dynamic modeling of a wave glider

Key words: Wave-propelled vehicle; Dynamic modeling; Sea surface vehicle; Wave glider

Corresponding author: Rong XIONG
E-mail: rxiong@zju.edu.cn

Motivation

- Current methods in motion control and path planning for mobile robots are all based on a known speed. However, this foundation does not exist for a wave glider. There is a need to predict the speed of the glider.
- A dynamic model of the glider is established, with which we can provide a method for incorporating environmental parameters into the model, and determine the forward speed of the glider consequently.

Main idea

- To predict the forward speed under different sea states and to optimize the mechanism parameters of the vehicle, a dynamic model related to sea state is established.
- The vehicle is regarded as a two-particle system working in sea environment. Kane's equations are utilized to establish the dynamic model.
- A testing prototype is developed and pool trials are conducted to verify the model.

Method

1. To simplify analysis, the heave motion of wave is assumed to be modeled as a sinusoidal. The surface part of the wave glider can be regarded as a particle moving with the wave.
2. Kane's method is adopted to build the dynamic model. Firstly, select generalized coordinates and speeds based on the degrees of freedom (DOFs) of the system; Secondly, generate the expressions for velocity, angular velocity, and acceleration of each body based on kinematic analysis; Thirdly, calculate the system's generalized inertial force and generalized active force contributed by each body; Finally, obtain the system dynamic model using Kane's equation.

Method (Cont'd)

3. A pool testing prototype is developed to simulate the motion of the vehicle motivated by ocean waves.

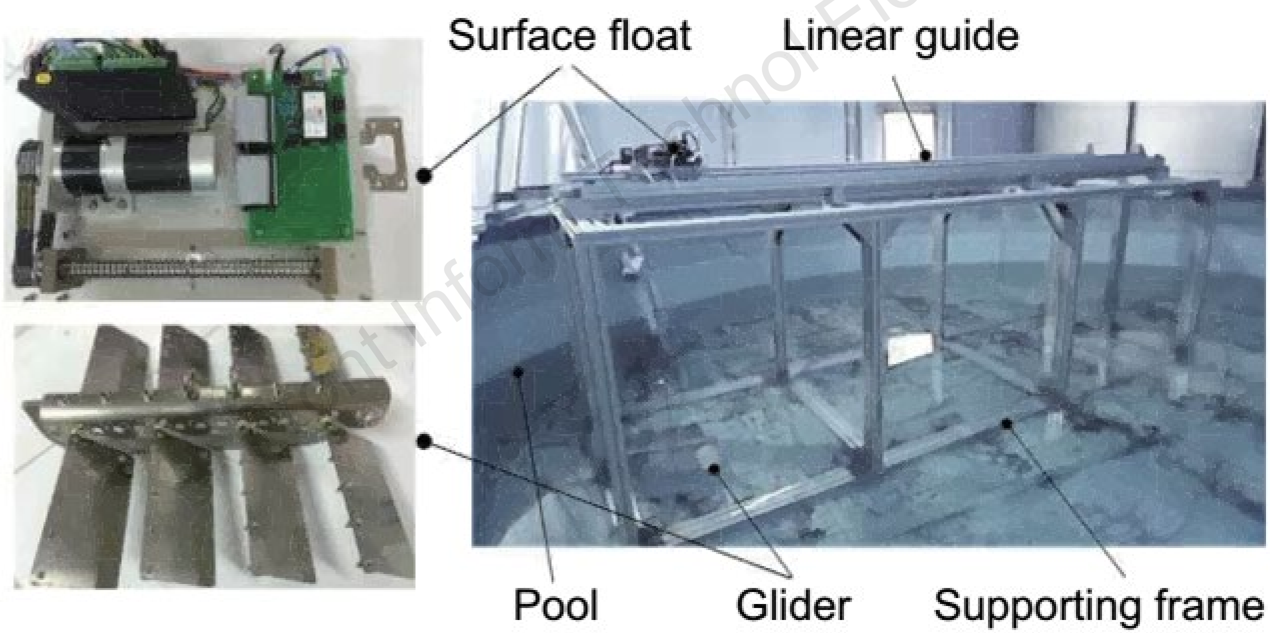

Fig. 9 Pool trial platform

Major results

- The motion principle of the dynamic model is consistent largely with that of the platform. The average speed computed from the dynamic model is very similar to that of the platform.

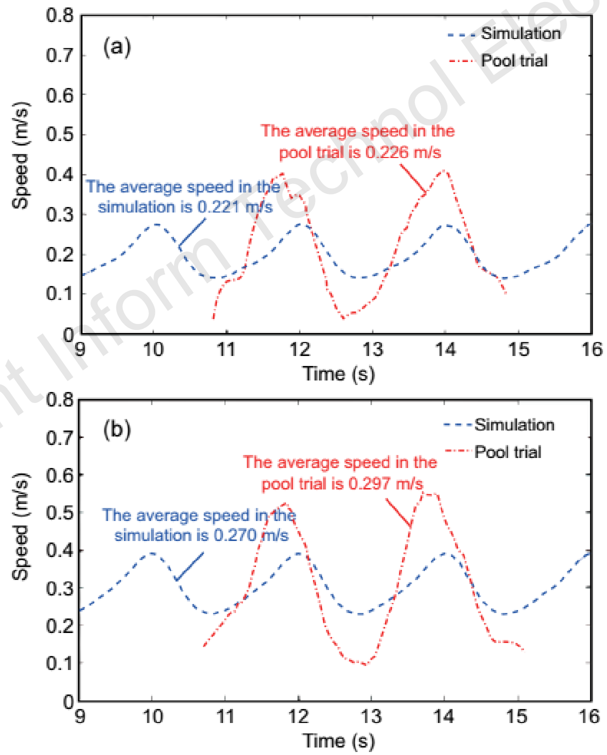

Fig. 10 Forward speeds in the simulation and pool trial under wave height 0.21 m (a) and 0.24 m (b)

Major results (Cont'd)

- The forward speed is also influenced by the angle of attack of the glider wings. There is an optimal angle of attack yielding the largest forward propulsion force, as predicted by the dynamic model. Experiments show that angles of attack between 20°–30° are preferred.

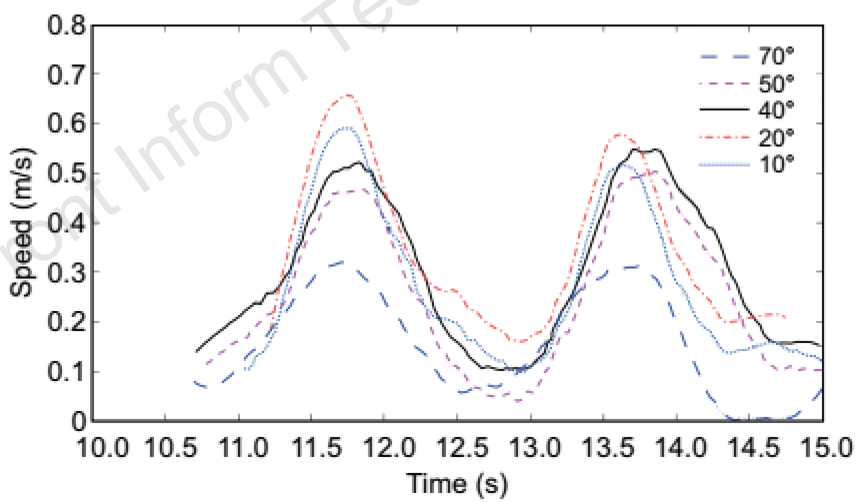

Fig. 11 Forward speeds under different angles of attack

Conclusions

- A dynamic model for the wave propelled ASV, which can be incorporated with sea states to predict the forward speed of the wave propelled vehicle, was established based on Kane's method. The validity of the model was demonstrated by simulation and pool trial to some extent.
- The model gives us a tool for improving the mechanical design of the vehicle to enhance its performance. Another obvious benefit is that it provides us with a prior knowledge of the vehicle speed under different sea states.