Modeling a canoe paddle stroke using a body force method

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Propulsion, Body-force, Paddle.

Understanding the influence a propulsion system has on the resistance of a ship has always been a key part of hull design and optimization in the Naval Architecture industry. Increasingly CFD simulations are used to investigate propeller hull interactions, however the computational cost accurately resolving the time varying flow around a propeller can be debilitating. By using a body force model, which accurately induces the accelerations produced by a propeller into the fluid [1], the global effect of the propeller on resistance can be assessed at a relatively low computational cost.

As the world of elite sport becomes increasingly technical and scientific it is envisaged that CFD could be used to study the interaction of the propulsion systems and hulls found in competitive water sports, such as canoeing and rowing. Due to the computational costs involved in modelling complex moving geometries a similar body force methodology is developed and presented, with the aim of optimising hull forms or stroke technique to increase performance.

In this Study a time averaged body force model of a canoe paddle stroke is first developed and implemented based on previous self-propelled ship simulations, conducted by the University of Southampton using OpenFOAM [2]. The body force model is applied over a half cylindrical region within the fluid domain which is split into a number of sub-domains based on angle and radial position, see figure 1. The momentum source vector for each sub-domain is calculated using quasi steady lift and drag coefficients for a paddle blade and the local velocity vector at the sub-domain centre, based on a constant free stream velocity and a constant angular velocity of the paddle. The momentum source is then time averaged over a full stroke cycle and applied to all the cells that lie within a given sub-domain.

Using this simplified model the average thrust produced by the paddle throughout a stroke can be simulated. However due to the periodic nature of the propulsive force generated by a paddle a time accurate model is required to study the time varying resistance on a canoe. Therefore the body force model is refined to apply the momentum source term over a time dependant sector of the paddle stroke domain within the fluid. This allows the passage of the paddle through the domain to be simulated, inducing the large local velocities produced by a real paddle.

This time accurate body force model of a paddle stroke is validated against unsteady experimental force data obtained from a mechanical paddle stroke, of constant torque, being

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applied whilst moving down a towing tank [3]. The experimental tow rig used can be seen in figure 2 and an example force trace with zero forward speed can be seen in figure 3.

It is believed that the presented methodology will provide a computationally inexpensive method for assessing the self propelled resistance of hull forms in elite water sports.

Figure 1 - Paddle domain

Figure 2 – Paddle stroke tow rig

Figure 3 – Resistance and side force data for constant torque paddle stroke.

REFERENCES

