HIGH-FIDELITY MODELING OF SWIMMING HYDRODYNAMICS USING CFD

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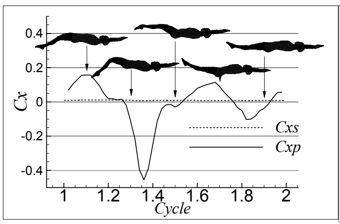
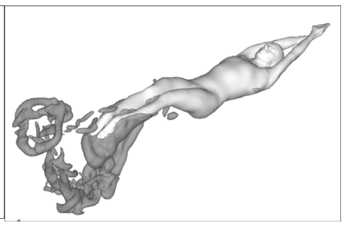
INTRODUCTION: Laser body scans, underwater video footage, animation software and computational fluid dynamics are used in combination to investigate the dolphin kick in competitive swimming. The "virtual swimmer" so created is immersed in a rectangular CFD domain of about 4.2 million mesh points in which the 3-D unsteady incompressible Navier-Stokes equations for viscous flow with constant properties are solved.

METHOD: The full-body geometry provided by laser scans is meshed in GAMBIT and animated in Autodesk MAYA in accordance with underwater video footage. The resulting full-body kinematics are immersed in a fixed non-uniform Cartesian mesh. Thus the flow simulations include a high-fidelity moving model of the swimmer without any steady or quasi-steady assumptions. There is no air-water interface. An immersed boundary method using a ghost cell formulation (Mittal et al. 2007) allows arbitrarily complex 2D and 3D immersed stationary and moving boundaries.

RESULTS AND DISCUSSION: Figure 1 shows instantaneous net streamwise force coefficients on the swimmer over the course of one cycle (kick). Negative values indicate thrust, positive values indicate drag. Forces due to shear are small and pressure forces dominate the flow. Two thrust peaks correspond to the start of the extensive kick and the end of the flexive kick. The extensive kick produces much more thrust than the flexive kick. The mean net force over the course of one cycle is near zero, indicating accuracy in the mean. The components of the net streamwise force, the active drag and thrust can be separated and analyzed. The mean and instantaneous forces on streamwise body segments are also under investigation. The contribution of individual segments to the overall thrust contribution are being examined. It is found that the feet are responsible for the majority of the thrust developed. Vorticity in the wake structure (Fig. 2) and surface pressure on the body are also being examined and these are allowing us to determine the thrust producing mechanisms for the dolphin kick. A variety of dolphin kick styles used by Olympic level swimmers are being analyzed to elucidate the hydrodynamic features of these styles.





Figures 1 & 2:Coefficient of net streamwise force and vorticity isosurfaces

CONCLUSION: Fluid dynamic simulations of the dolphin kick have been completed. Mean and instantaneous forces on the body and segments of the body have been calculated. The extensive kick produces much greater force than the flexive kick. Wake vortices and surface pressure is being examined to better understand the mechanisms for generation of thrust.

REFERENCE:

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