Dynamics and Control of Supercavitating Bodies

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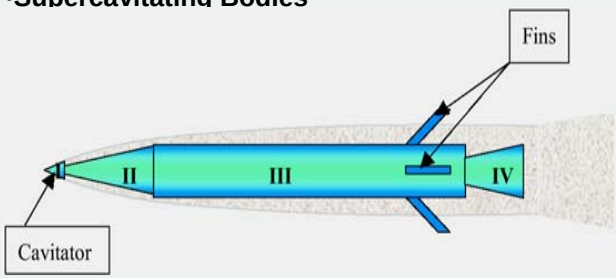
SYSTEMS OF INTEREST

•Supercavitating Bodies



•Supercavitation: Body enveloped in a gas bubble -- helps reduce hull skin-friction drag and increase speed dramatically

•Strong nonlinearities involved and hard to stabilize and control a supercavitating body

OBJECTIVES

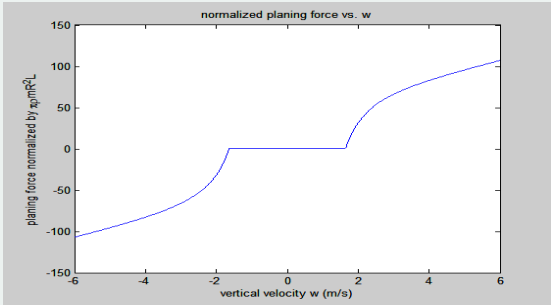
•Vehicle control and maneuvering

•Develop a fundamental understanding of system dynamics in terms of equilibrium and other solutions

•Construct control schemes to realize stable inner loop system dynamics

APPROACH

•Consider nonlinearities such as those due to kinematics and planing forces and focus on dominant nonlinearities

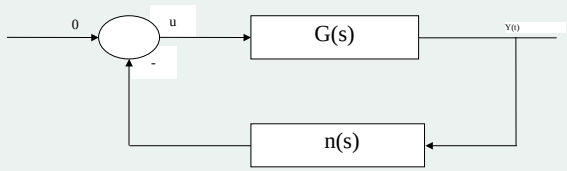


$$F_{planing} = -V^2\left(1-\left(\frac{R'}{h'+R'}\right)^2\right)\frac{1+h'}{1+2h'}a \quad \text{where}$$

$$h' = \begin{cases} 0 & \frac{L}{R}\left|\frac{w}{V}\right| < R' \\ \frac{L}{R}\left|\frac{w}{V}\right| - R' & \text{otherwise} \end{cases} \quad \text{and} \quad a = \begin{cases} \frac{w}{V} - \frac{\dot{R}_c}{V} & \frac{w}{V} > 0 \\ \frac{w}{V} + \frac{\dot{R}_c}{V} & \text{otherwise} \end{cases}$$

•Study dive-plane model and investigate equilibrium and limit cycle solutions – determine solution structure

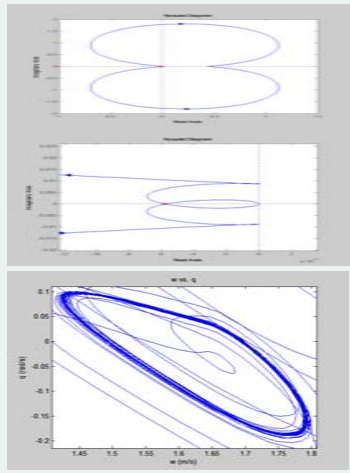
•Apply relevant analytical tools - such as the describing function method (DFM)



•Treat dive-plane model as a switched nonlinear system (SNLS) and approximate it as a switched linear system (SLS).

REPRESENTATIVE RESULTS

• Stable limit cycles predicted by DFM, in agreement with time-domain simulation results



•Switched feedback control scheme designed to stabilize the SLS (robust to perturbations) and the SNLS (for small initial perturbations).