Mechanics of Underwater Marine Vehicles

Syllabus

Spring 2022

Course description: Unmanned underwater vehicles take a major part in the study of the deep sea. In the course we will review the kinematics, dynamics, the hydrodynamic forces and moments acting on marine vehicles and we shall develop the capability to model underwater marine vehicles. We shall solve the 6DoF equations for an Autonomous Underwater Vehicle (AUV) in the undisturbed underwater medium. We shall also study the environmental disturbance imposed by sea waves and currents. Stability and Control of Underwater Vehicles will be also treated. Part of the course will take place in a lab for familiarization with underwater vehicles

Number of credits: 3

Prerequisites by topic:

1. Fundamentals in Underwater Engineering 4001
2. Mechanics, Statics & Dynamics (academic course in Physics or equal)
3. Differential and integral calculus
4. Knowledge with programming in MATLAB

Course objectives: The student will:

1. Develop the kinematics and dynamic for the motion of marine vehicles in 6 degrees of freedom.
2. Estimate the hydrodynamic forces and moments acting on underwater marine vehicles.
3. Model an underwater marine vehicle in 6DoF and solve the equations of motion.
4. Review the concepts of disturbances in the marine environment: waves and currents
5. Develop basic knowledge in stability and control of underwater vehicles: Optimal distribution of Propulsion and Control Forces, open-loop stability, conventional autopilot design, decoupled control design concept
6. Familiarize with underwater vehicles; ROV and AUV

Course schedule: Wednesday, 12:00– 14:00, 13 weeks

Class: IOLR, Class room

Grading: Final assignment.

Detailed Content: (may be modified during the semester)

Topic 1	Kinematics: coordinate frames, linear velocity transformation, angular velocity transformation, expression of the kinematic equations in vector form
Topic 2	Rigid-Body Dynamics: Newton-Euler formulation, translation motion, rotational motion, Inertia tensor, 6DoF rigid-body non-linear equations of motion.
Topic 3	External forces and moments: hydrostatic and hydrodynamic damping forces, Kirchoff's relations, added mass forces, Munk moment, strip theory and computation of added mass coefficients.
Topic 4	External forces and moments: Body lift & moment, Fins lift (angle of attack contribution, angle of side slip contribution, angle of control contribution, combination of forces)
Topic 5	Propulsion – thrusters, propeller, duct and motor models.
Topic 6	Solution of the equations of motion in Simulink Environment. Calibration and Validation of the model, Hybrid Simulation.
Topic 7	Environmental disturbances: Linear wave theory, wave spectrum, sea currents.
Topic 8	Stability of underwater vehicles: linearization of the equation of motion, open loop stability
Topic 9	Stability theory: Lyapunov stability theory
Topic 10	Decoupled control design: forward speed control, steering, depth and pitch control.
Topic 11	Familiarization with underwater vehicles: Autonomous Underwater Vehicle (AUV) - Hydrodynamic Vehicle Structure vs. Hovering Vehicle, Stability, Propulsion and Energy Balance, Structure and General Arrangement. Remotely Operated Vehicle (ROV) - Structure, capabilities, buoyancy and stability, propulsion, operation and risks, maintenance principles