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MSc Maritime Engineering Science: Yacht and High-Performance Craft

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Developing an International Moth testing platform in a DVPP-driven real-time simulator

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More info, sim videos, etc.

Motivation

Testing and developing new components for foiling and high-performance boats is both risky and costly. The ever-changing wind and wave conditions make it very challenging to compare sailing performance in a consistent way.

There is a clear need for a new testing method that accounts for dynamic effects and environmental factors.

What if we could apply the state-of-the-art simulators used in the America's Cup to the world's fastest and most advanced dinghy: the International Moth?

Conclusions

- **C1.** The simulator is a **useful platform** for testing dynamics and control.
- **C2. Simulator outputs match VPP data**, giving confidence in the model.
- **C3. Wand gearing and angle define z-stability**; PID more customizable.

1. Background

- The implementation of new hydro-foiling technology in sailing yachts over recent years has brought new challenges. Traditional Velocity Prediction Programs (VPP) no longer accurately describe the dynamic nature of foiling. It has been necessary to develop a time-domain Dynamic-VPP [1].
- In the 37th America's Cup, the use of sailing simulators that seamlessly integrated design development, mechatronics testing, crew training, and virtual racing, built inside Simulator in Motion, established simulation not as an option, but as a mandatory path to engineering excellence [2].

2. Objectives

- **O1.** Build a testing platform inside the SiM that works seamlessly and is able to obtain similar performance metrics as the D3VPP, with the help of three PID's (heel, TWA, heave).
- **O2.** Modelling the mechanical wand flight control system inside the simulator to be able to test how different variables like the gearing or the wand length affect the flying behaviour.
- **O3.** Compare the behaviour of the PID-controlled and the wand-controlled flight and conclude about the benefits and drawbacks of each system.

3. Methodology

Stage 1. Developing the specific physics models (foil, hull, mass, rudder, sail and windage) for the forces acting on the Moth (Fig. 1). Existing models previously developed by D3, such as the Hydro Lifting Line - FSI model for the underwater lifting surfaces, were used as the main foundations.

Stage 2. Assembling the Exploder Moth D3 v2 (2025) geometry and foils, together with the above-mentioned models into the SIM environment.

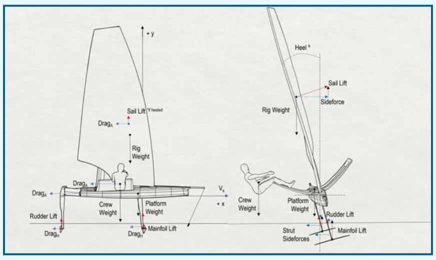
Stage 3. Developing 3 Proportional–Integral–Derivative (PID) controllers for heel, heave, and TWA to obtain a dynamically stable testing platform.

Stage 4. Verifying that the forces and performance indicators of the SIM model were close to the D3VPP targets in different conditions and performing the data analysis. The confidence in the reliability of the simulator results comes from the extensive testing with real boat data made by D3 made in their D3VPP.

Stage 5. Developing a flight control system. The first flight control system developed was a PID controlling the main foil flap angle as a function of the moth's ride height.

Fig. 2. International Moth running inside the SiM Interface

Fig. 1. Forces existing in the International Moth [3]



The second flight control system focuses on the mechanical parts, and replicates the boat's actual wand + pushrod connection, using the wand angle between the bowsprit and the free surface to output a flap angle, modified with a gearing mechanism. A set of analyses were conducted to assess the sensitivity of the two flight control systems in flat seas and excited by a regular wave of H = 0.1 m, in upwind and downwind conditions. The influences of the 6 gearings and the wand length of the wand system, and the Kp, Ki and Kd of the PID, are among the variables studied. In the results section only the most representative are shown.

4. Results

Results 1. Effect of different gearings in the moth's heave response in waves.

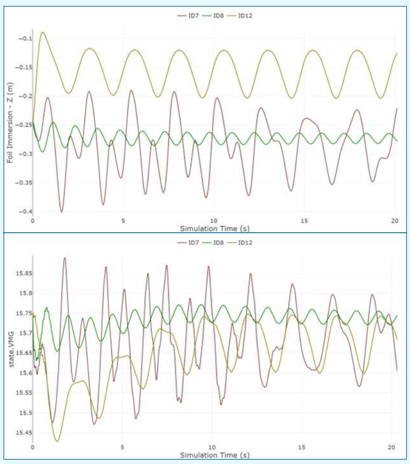


Fig. 3.a. Three heave responses as a function of the gearing.

The gearing 2 (ID-8, green) clearly showed the best response to waves with a more stable foil immersion than the other two (Fig 3. a), and accordingly, provided the best boat performance in terms of upwind VMG (Fig 3. b)

Fig. 3.b. Responses measured in terms of boat upwind performance (VMG) for the same conditions as in Fig. 3.

Results 2. Differences between wand-controlled and PID-controlled flight.

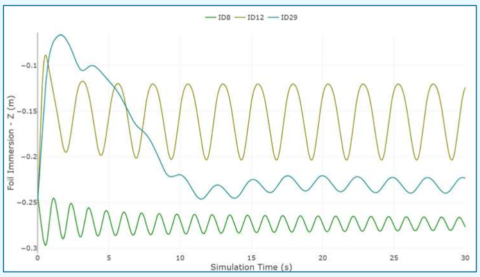


Fig. 4. Comparison of foil immersion between two wand-controlled systems (gearing ID-8 and ID-12 from Fig. 3) and one PID-controlled system (ID-29).

The PID works properly, however, a well-adjusted gearing shows better results

- **Limitations:** simplified physics in aero, simplified wave trains, no crew dynamics, no tacking or gybing yet.
- **Future work:** varying sea states, refine wand model and PID, refine aero sail model, study other attitudes and heel.

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Fundación Barrié

References: (1) Castañeda Sabadell, I. 2018. Design of a physical and interactive real-time simulator based on a dynamic VPP as a support tool for sailing yacht design and operation. Ph.D. dissertation, ETSI Navales, UPM, Madrid. (2) Ozanne, J. 2025. Simulator in Motion. Simulator and A.I. Team Lead at Alinghi Red Bull Racing. www.linkedin.com/in/josephozanne (3) International Moth Class Association Rules, Dec. 2024. World Sailing. https://www.sailing.org/classes/moth/#Documents