Gyroscopic boat stabilizer

Based on a real system for teaching industrial engineering sciences

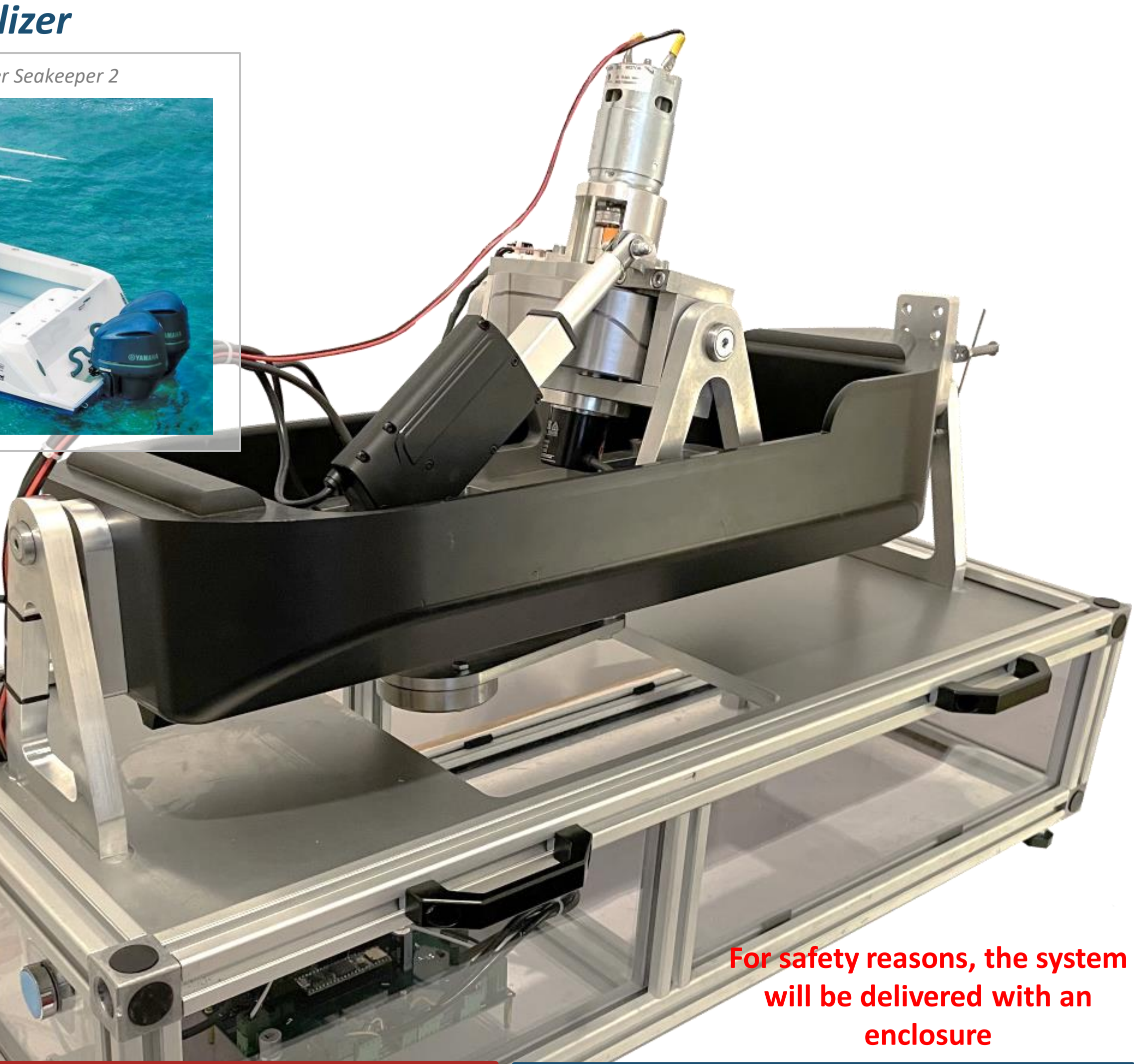
From a real system

Industrial gyroscopic boat stabilizer

Gyroscopic stabilizer Seakeeper 2

To a didactic system

Gyroscopic boat stabilizer



For safety reasons, the system will be delivered with an enclosure

The training bench includes:

- ✓ a **boat hull** (mass 9,9 kg)
- ✓ Two instrumented **electric cylinders** to control
  - the gyroscope (gyroscopic torque)
  - The overloading (to produce roll)
- ✓ a **flywheel** (up to 4000 rpm)
- ✓ an **inertial unit**
- ✓ an **angle encoder**
- ✓ a **Teensy card** (controle/command via USB)
- ✓ Over **forty usable signals**

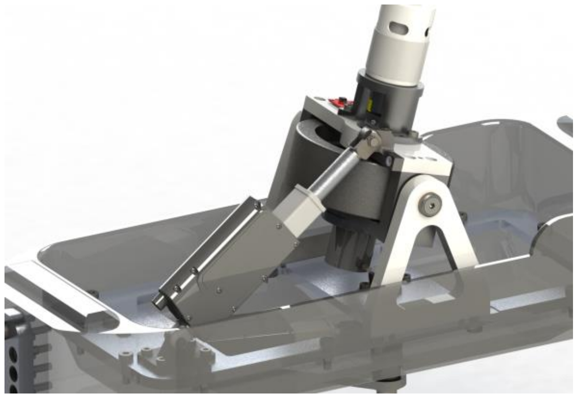
Supplied with:

- ✓ a **gyroscopic boat stabilizer** *(LxWxH = 82 x 38 x 50 cm)*
- ✓ a **control and acquisition software**
- ✓ a **digital twin** (virtual model)
- ✓ a **technical file**
- ✓ a **training file** with hands-on activities

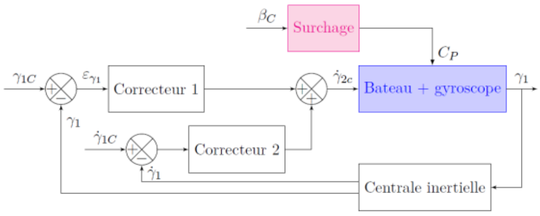
Reference : S2I//1400

The **Gyroscopic boat stabilizer**, inspired by an industrial boat stabilizer, features

- **1 inertial wheel**, speed-controlled (up to 4000 rpm)**;**
- **1 articulated gyroscope support frame**, driven by an electric cylinder, with speed control to enable a controlled gyroscopic torque;
- **1 articulated overload**, driven by an electric cylinder, to modify the boat's center of gravity and enable a rolling motion.



Flywheel mounted on its articulated frame



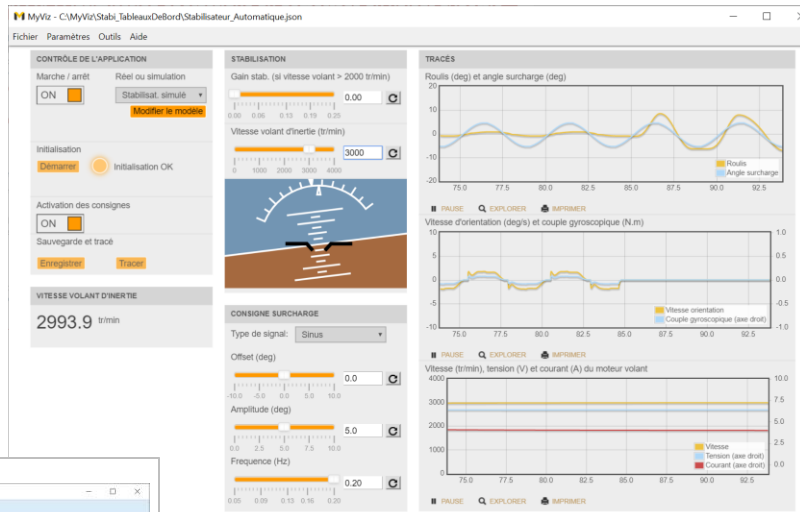
Block diagram of the boat's roll servo system

The **3 actuators** are equipped with an **encoder**, and an **inertial unit** is mounted on the **articulated frame**, all of which enable the following program configuration :

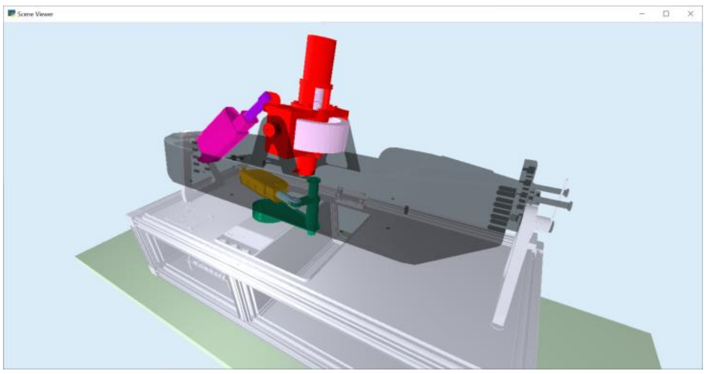
- **Control** (characterization, identification, modeling, correction)
- **Geometric/kinematic law**
- **Static**
- **Kinetics/Dynamics/Energetics/Power**
- **AI process**

The control software **MyViz** integrates

- **dashboards** adapted to each training activity, with only the control values associated with the activity visible ;
- an interface for analyzing **all measured and calculated signals** (over forty) with CSV export, cursors on curves, time curves, XY …



MyViz : Automatic mode dashboard



Real-time 3D model from the digital twin

- a **digital twin**, 3D model controlled in real time, reflecting the real dynamics of the system. **All students** can work simultaneously on different computers. This facilitates **group activities**.

The **trainer** will be delivered with:

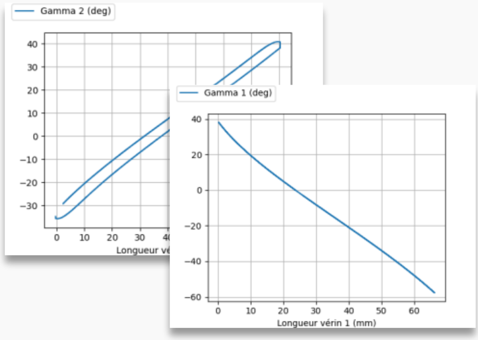
- a **technical file** with detailed geometric, kinematic and dynamic modeling calculations
- a training file with **hands-on activities**
- a **Solidworks volume model** that can be used directly for **simulations in Meca3D**
- **Parameterizd kinematic diagrams** for easy use/adaptation of training activities

Solidworks model

S2iDidac
5 Allée de Faucillon
71700 TOURNUS

ERM Automatismes – Didactique | Robotique | Fab&Test | Energies
561, Allée Bellecour – 84200 CARPENTRAS – France
Tél. : + 33 (0)4 90 60 05 68
www.erm-automatismes.com - contact@erm-automatismes.com

Training activities

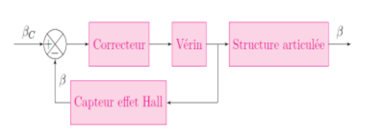


Activity 1 : System overview

- Analyze the influence of overload position on boat behavior.
- Analyze the influence of gyroscope orientation and speed on boat behavior.
- Identify the 3 functional chains (boat inclination, flywheel inclination and gyro rotation).

Activity 2 : Geometric analysis

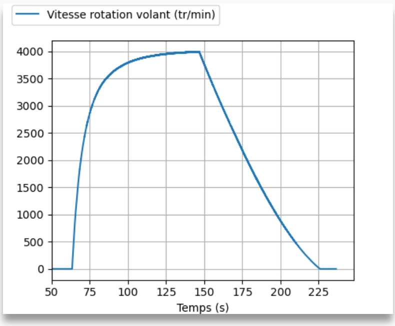
- Identify the structural chain used to position the overload in order to determine the geometric I/O law (overload position as a function of actuator length).
- Identify the structural chain used to position the gyroscope frame in order to determine the geometric I/O law (frame orientation as a function of actuator length).



Block diagram of the overload position servo system used to impose roll on the boat

Activity 3 : CILS performance and modeling

- Propose a behavior model for the various components of the position servo-control chain and characterize the performance of this servo-control.
- Propose a behavior model for the various components of the flywheel orientation speed servo system, and characterize the performance of this servo system.

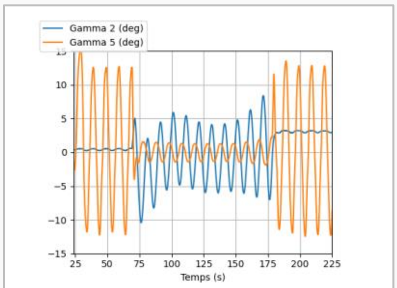


Activity 4 : Corrector

- Select a corrector based on the open-loop behavior of the gyroscope orientation.

Activity 5 : Modeling mechanical actions

- Determine the heel of the boat as a function of the position of the overload in order to deduce the equilibrium orientation of the assembly.



Temporal evolution of the boat's forced heel (blue) and gyro frame inclination (red)

Activity 6 : Kinetics

- Determine the equivalent inertia of the power train associated with the flywheel speed.

Activity 7 : Energetics

- Describe the flywheel start-up process to minimize energy consumption (limited on a boat).

Activity 8 : Dynamics, gyroscopic torque

- Study the gyroscopic effect: determine the relationship between the rotation speed of the flywheel frame and the dynamic behavior of the boat.

Dashboard: Neural network

Activity 9 : AI - Energy optimization of flywheel start-up

- To address the problem of the availability of electrical energy on board a boat: implement an artificial intelligence numerical solution to determine the most energy-efficient flywheel start-up procedure.