Assignment 3

TASK	OVERALL MODELLING AND SIMULATION ASSIGNMENT 3
Description	This assignment is to develop mathematical models (theoretical modelling) and simulation programs for marine systems using MATLAB and Simulink including GUI (graphical user interface) and/or App Designer programming. The main tasks are to: 1. Use the attached sheets for dynamic (marine) systems (*); 2. Make assumptions based on relevant theories related to the marine systems in order to derive equations governing the characteristics of the marine systems. 3. Represent the derived equations in appropriate form/s for programming; 4. Determine which numerical integration methods can be used in order to have acceptable accuracy; 5. Make simulation programs for the dynamic systems under various working/operational conditions using both MATLAB/GUI or App Designer (where applicable) and Simulink/GUI or AppDesigner (where applicable); 6. Use the simulation programs to learn the characteristics of the marine systems through various simulated scenarios, and compare the simulated results(**); and 7. Write an individual report and submit it and all simulation programs on the due date. (*) Those who have marine systems of interest which are equivalent to the assigned systems, please contact the lecturer to discuss and get approval. (**) Simulated results should be presented in a proper manner, neither snapshots of Scope (Simulink programs) nor snapshots of MATLAB programs are accepted.
Task Length	Limited length (excluding appendix) is a ***minimum of 6 to a maximum of 20 pages*** to describe the theory related to the marine systems, simulation method, simulation programs, presentation and analysis of computed results. The simulation programs should be including comments/annotations (and any instructions for user if needed) and must be attached with the assignment report and ready to run. Use the AMC/NCMEH assignment template and cover sheet at http://www.amc.edu.au/ncmeh-course-information/assignment-templates. However, your assignment report can be written in form of a conference or journal paper.
Due Date	**23:59 pm on Mon 11th November 2024**. Submit your assignment report with assignment cover and all program files (*which must be zipped/compressed*) via MyLO.
Assessment %	**50**% of the unit marks

ASSESSMENT OUTCOMES & CRITERIA

UNIT LEARNING OUTCOMES

1	Apply engineering principles in theoretical modelling of marine systems	√
2	Apply simulation techniques, including numerical methods and block diagrams, in development of computer simulation programs for marine systems	√
3	Develop MATLAB programming skills for simulation of marine systems	√
4	Develop Simulink programming skills for simulation of marine systems	√
5	Use computer simulation programs to learn behaviour and characteristics of the simulated marine systems under varying conditions	√

Assessment Criteria

(See the attached rubrics for details.)

Student name:				Student ID:	
JEE506 Modelling and Simulation of Marine Systems - Semester 2, 2024					
Overall Modelling and Simulation Assignment				Weight: 60%	
Criteria	**HD**	**DN**	**CR**	**PP**	**NN**
Demonstrate and apply theoretical and practical knowledge of related engineering principles to mathematical modelling of marine systems 30%	Demonstrate and apply *comprehensive* knowledge of engineering principles and related theory in mathematical modelling by - *thoroughly* describing the dynamic systems and make *reasonable and meaningful* assumptions; - *correctly* and *fully* deriving all of expected equations and models; and - c*orrectly* and *fully* representing the derived equations in appropriate forms with *relevant* and *full* initial conditions	Demonstrate and apply *broad* knowledge of engineering principles and related theory in mathematical modelling by - describing the dynamic systems and make *reasonable* assumptions - *correctly* deriving most of expected equations and models; and - *correctly* representing the derived equations in appropriate forms with *relevant* initial conditions	Demonstrate and apply knowledge of engineering principles and related theory in mathematical modelling by - describing the dynamic systems and make *assumptions*; - deriving most of expected equations and models; and - p*artially correctly* representing the derived equations in appropriate forms with initial conditions	Demonstrate and apply *basic* knowledge of engineering principles and related theory in mathematical modelling by - describing the dynamic systems and make *at least half the required* assumptions; - deriving some of expected equations and models; and - representing the derived equations in appropriate forms with *some* initial conditions	- *Insufficien*t demonstration and application of Engineering principles and mathematical modelling theory. - Description of the dynamic system and assumptions are *insufficient or incorrect*. - Equations, initial conditions and/or models are *erroneous*.
Demonstrate ability to solve engineering problems and apply knowledge and skills of numerical methods, MATLAB and Simulink in simulation and analysis of marine systems 30%	Demonstrate and apply *comprehensive* theoretical knowledge and skills of computer simulation with MATLAB and Simulink by - developing *well* out MATLAB and Simulink simulation program with *creative ideas* - *Successfully* using MATLAB and Simulink to simulate the marine systems in various working / operational conditions and represent simulated results *neatly* and *clearly*	Demonstrate and apply *broad* theoretical knowledge and skills of computer simulation with MATLAB and Simulink by - developing out MATLAB and Simulink simulation program with some *creative ideas* - using MATLAB and Simulink to simulate the marine systems in *various* working / operational conditions and represent simulated results *clearly*	Demonstrate and apply theoretical knowledge and skills of computer simulation with MATLAB and Simulink by - developing MATLAB and Simulink simulation program with *some ideas* - using MATLAB and Simulink to simulate the marine systems in *some* working / operational conditions and represent simulated results in some manner	Demonstrate and apply *basic* theoretical knowledge and skills of computer simulation with MATLAB and Simulink by - developing MATLAB and Simulink simulation program with *ideas* - using MATLAB and Simulink to simulate the marine systems in working / operational conditions and represent simulated results	- *Insufficien*t demonstration and application of computer simulation with MATLAB and Simulink - MATLAB and Simulink simulation programs are *incomplete or erroneous*; - Presentation of the results related to the simulated marine systems which are *incorrect or irrelevant*.
Evaluate the performance and behaviour of the simulated marine systems through simulation programs and their outcomes 20%	*Thoroughly and methodically* evaluate and analyse the marine systems and their components by: - *clearly* justifying your judgements and assumptions be referring to *relevant* and *curren*t literature, theory, calculation and simulated results - comparing and justifying *all* calculated and predicted performance and results against: • stipulated design	*Methodically* evaluate and analyse the marine systems and their components by: - justifying your judgements and assumptions be referring to *relevant* and *curren*t literature, theory, calculation and simulated results - comparing and justifying *most* calculated and predicted performance and results against: • stipulated design	Evaluate and analyse the marine systems and their components by: - justifying *most* of your judgements and assumptions be referring to *partly relevant* literature, theory, and calculations - comparing *most* calculated and predicted performance and results against: • *most* stipulated design specifications and operational conditions; and	Evaluate and analyse the marine systems and their components by: - justifying *at least half* of your judgements and assumptions be referring to *partly relevant* literature, theory, calculations and simulated results - comparing *at least half* of calculated and predicted performance and results against: • *some* stipulated design	*Insufficient* evaluation and analysis of the marine system and their components.

	specifications, and operational conditions; and • initial assumptions, engineering theory, and relevant industry and engineering data	specifications, regulations and operational conditions; and • initial assumptions, engineering theory, and relevant industry and engineering data	• *most* initial assumptions, engineering theory, and relevant industry and engineering data	specifications, regulations and operational conditions; and • *some* initial assumptions, engineering theory, and relevant industry and engineering data	
Communicate in writing in the form of a technical report. 20%	Communicate *concisely* and *coherently* in a *structured* and *readable* report that adheres to the given *format* by - including *comprehensive*, *fully detailed and correct sketches* and *drawings* that make it easy to comprehend the design, layout, the relevant simulations and analysis. - presenting information in a format that is *easily interpreted* because it is *neat*, *clearly* and *accurately sorted* and *labelled; uses clear, concise and accurate legends* and *units;* and *correctly* states observations terminology	Communicate *concisely* and *coherently* in a *structured* and *readable* report that adheres to the *given format* by - including *detailed and correct sketches* and *drawings* that make it easy to comprehend the design, layout, the relevant simulations and analysis. - presenting information in a format that is *easily interpreted* because it is *neat*, *clearly* and *accurately sorted* and *labelled*; *uses clear, concise and accurate legends* and *units*; and states observations terminology	Communicate *coherently* in a *structured* and *readable* report that adheres to the *given format* by - including *correct sketches* and *drawings* that *assist* in comprehending the design, layout, the relevant calculations and analysis. - presenting information in a format that is *interpreted* because it is *neat* and *accurately sorted* and *labelled* and *uses clear and accurate legends* and *units*	Communicate in a *structured* and *readable* report that largely adheres to the *given format* by - including *sketches* and *drawings* that *assist* in comprehending *most* of the design, layout, the relevant calculations and analysis. - presenting information in a format that is *interpreted* because it is *sorted* and *labelled*; and *uses accurate legends* and *units*	Reports, sketches, drawings, presentation of figures and information *do not adhere to the given format*.
Comments			Grade:		

Dynamic Systems for Assignment 3

Problem 1 (Compulsory): Modelling and Simulation of a Container Vessel Model - Ship Manoeuvring System (MATLAB and GUI/AppDesigner) (Guidelines)

1.1 Modelling of Ship's Hull Manoeuvring Dynamics

The model scaled vessel named Hoorn is shown in **Fig. 1**. The vessel has twin propellers driven by two separate motors (36V), a rudder driven by a servo motor and two thrusters driven by dc motor (7.2V). The vessel turns in different ways: 1) by rudder only, 2) by twin propellers only, 3) by both rudder and twin propellers, 4) by thrusters, and 5) by combination either of thruster with rudder and/or twin propellers. More information on Hoorn is given in Appendix 1.

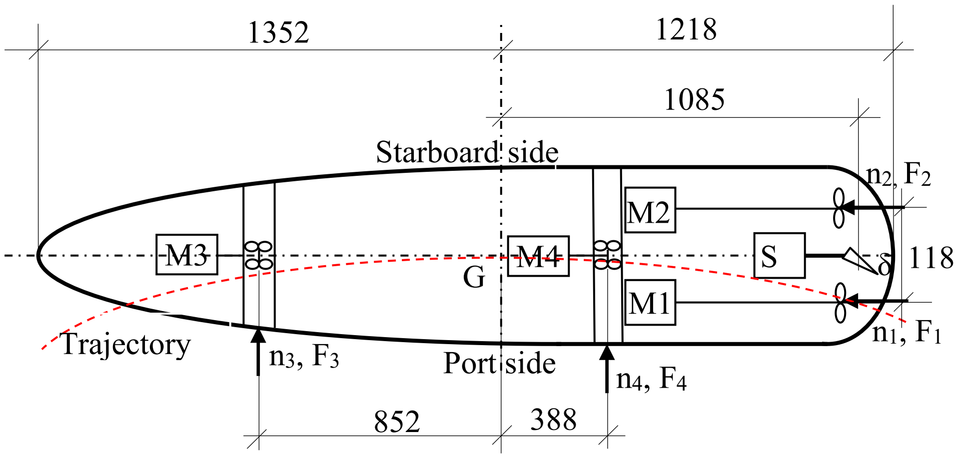


Fig. 1 Model scaled vessel, namely Hoorn, with twin propellers, rudder and two thrusters (SV = servo motor, M = motor)

Develop a simplified 3DOF (degree of freedom) model to describe the motion of the container model, including surge velocity [m/s], sway velocity [m/s], yaw rate [rad/s] and yaw [rad or deg], and trajectory (ship's hull dynamics) as shown in **Fig. 2**. The variables used in the model are:

- δ = rudder angle [rad] (from -60 degrees to +60 degrees) (*Note that the rudder is driven by a servo motor, not a hydraulic steering machine*.)
- n_1 generates F_1 and n_2 generates F_2: n_1 and n_2 are speeds of propeller motors, and F_1 F_2: drag forces generated by twin propellers [N]. Please make assumption.
- n_3 generating F_3 and n_4 generating F_4 : n_3 and n_4 are speed of thruster motors, and F_3 & F_4:thrust forces generated by the thrusters [N]. Please make assumption.
- r yaw rate [rad/sec]
- ψ yaw angle [rad]

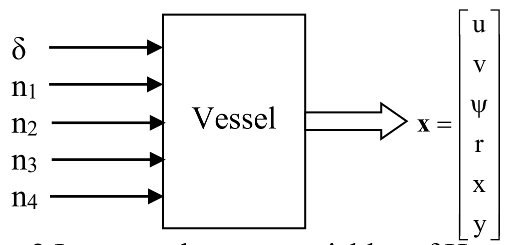


Fig. 2 Inputs and output variables of Hoorn

Use the following variables, numerical values and information:

- Moment of inertia about z-axis (J_{zz}): 22.5 [kgm^2];
- Distance from the rudder to G: 1085 [mm];
- Distance between twin propellers: 118 [mm];
- Distance from the bow thruster to G: 852 [mm];

- Distance from the stern thruster to G: 338 [mm];
- The overall length is: 2570 [mm]
- The mass of vessel: 65.0 [kg];
- The maximum speed of propeller: 1000 [RPM];
- The maximum drag force generated by each propeller is assumed to be 50 N;
- The water resistance torque coefficient between the hull and water is K_r = 6.725 Nm/rad/s;
- The rudder moment constant is K_δ = 2.5 Nm/rad (the rudder turning torque is assumed to be proportional to the rudder angle, i.e. $T_\delta = K_\delta \delta$ Nm);
- The maximum thrust force for each thruster is 25N;
- The equations for trajectory (assume a value of the ship speed) are
  $\dot{x} = u \sin\psi + v \cos\psi$
  $\dot{y} = u \cos\psi - v \sin\psi$ (where u is surge velocity [m/s], and v is sway velocity [m/s], x and y are positions in x-axis and y-axis, respectively).

2) Represent the derived equation/s in the appropriate forms (where applicable) for programming, for examples:

- Transfer function/s (if applicable);
- A state space model; and
- A block diagram model.

1.2 MATLAB Simulation Program/s

Based on the above developed equations/models, make programs to simulate the vessel system in various scenarios. It is recommended to make MATLAB programs to confirm the simulated results (solutions):

- MATLAB program/s
- Comparison of simulated results with known results (if any).

1.3 GUI/App Programs

Once the MATLAB program/s in 1.2 completed, design and make a GUI/App Designer Program with the following options:

- Selection of turning circle with propeller only
- Selection of turning circle with propeller and thrusters
- Selection of zigzag tests, etc.

<u>Hints</u>:

1. For each simulated scenario, you should describe the working conditions and parameters. The following scenarios may be considered for simulation:

- turning by rudder only,
- turning by propellers only,
- turning by rudder and propellers,
- turning by rudder, propellers, thruster/s,
- 20-20 zigzag test with rudder only;
- 20-20 zigzag test with propellers only;
- 20-20 zigzag test with rudder and propellers
- 20-20 zigzag test with rudder, propellers, and thruster/s.

2. You may need to assume the directions of turning motion cause by propellers and thrusters. For examples, the vessel goes forward when the port propeller runs counter-clockwise and the starboard propeller runs clockwise, and the vessel reverses when the port propeller runs clockwise and the starboard propeller runs counter-clockwise.

(continue next page for Problem 2)

Problem 2 (Compulsory): Modelling and Simulation of a Multi-variable Process System (Level and Temperature Process System) (Use the information as guidelines)

Fig.3 shows a schematic diagram of the Delorenzo multi-variable process system consisting of level and temperature processes.

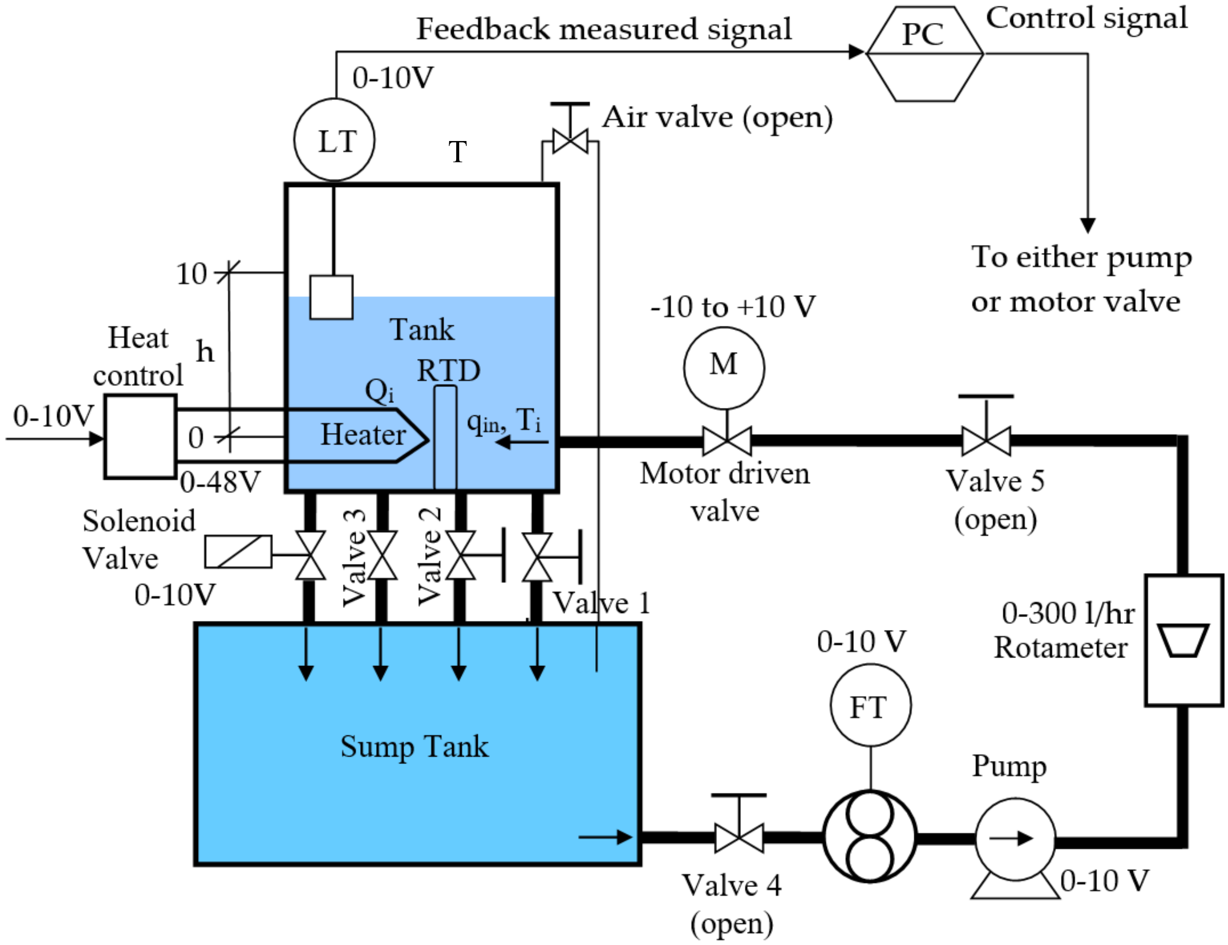


Fig. 3 Schematic diagram for the level and temperature control system

2.1. Modelling of level and temperature process system

2.1.1 Level control loop (also see Assignment 1)

As shown in **Fig. 3**, the level process control loop can use either the pump or motor driven valve as an actuator. The variables and their ranges are below:

- u_l is the input voltage of the pump (control signal), 0V to 10 V;
- h is the level of the liquid in the tank in the range of 0 to 10cm, i.e. the level can be controlled from 0cm to 10cm only, the range of the level to be controlled is 0cm (from 6cm reading of large scale) to 10cm (16cm reading of the large scale).
- H_{max} is the maximum height of the tank, H_{max} = 21cm (from the 0cm reading of large scale to the ceiling);
- q_{in} is the inlet flowrate, 0 litre/hour to 300 litre/hour; and
- q_{out} is the the outlet flowrate through the drain valve which has a valve constant, assumed to be $K_v = 0.00125\ m^2/s$ (which can be changed based on the position of the drain valve); it is assumed that $q_{out} = K_v h$ where h is the level [m].

Notes: The air valve is open. The minimum level is set at zero cm by aligning the zero level of small measure (scale) to 6cm of the large measure (scale).

Develop equations to relate the pump input voltage u_1 and the level h(t); and then the equation/s to relate the pressure and the pump input voltage u_1. Represent the equations in appropriate form/s for programming.

2.1.2 Temperature control loop

As shown in **Fig. 3**, the temperature process control loop uses the heat control and heater as an actuator. The variables and their ranges for the temperature control loop are below:

- u_2 is the input voltage of the heater control/heater (control signal), 0V to 10 V;
- T is the temperature of the liquid in the tank in the range of 0 to 100°C, the heater works only when the water submerges the heater at i.e. 6cm of the large scale, its range is 0°C to 100°C.
- T_i is the temperature of the inlet water; and Ts is the surround (air) temperature;
- RTD is the resistance temperature detector transmitter, its output range is 0V to 10V;
- Q_i is the heat flow generated by the heater, 0W to 200W;

See more information on the Delorenzo multi-variable process system in Appendix 3.

2.2 Simulink Programming

Open loop systems: Based on the above developed models, make a Simulink simulation program to simulate the multi-variable process system. Basic requirements for the Simulink simulation program are below:

- To allow user to enter the parameters;
- To visualise important variables; and
- To collect simulated data for reporting.

Closed loop system: The level and temperature are controlled by a proportional integral derivative (PID) controller with a transfer function of $U_c(s)/E(s) = K_P+K_I/s+K_Ds$ where K_P, K_I and K_D are the control gains of which initial values are assumed to be K_P, K_I and K_D, respectively, where K_P is your number in the attached list (see **Fig. 4**), and K_I and K_D are optional, selected by you. *Hints*: try to use a built-in PID controller block from Simulink Library Browser.

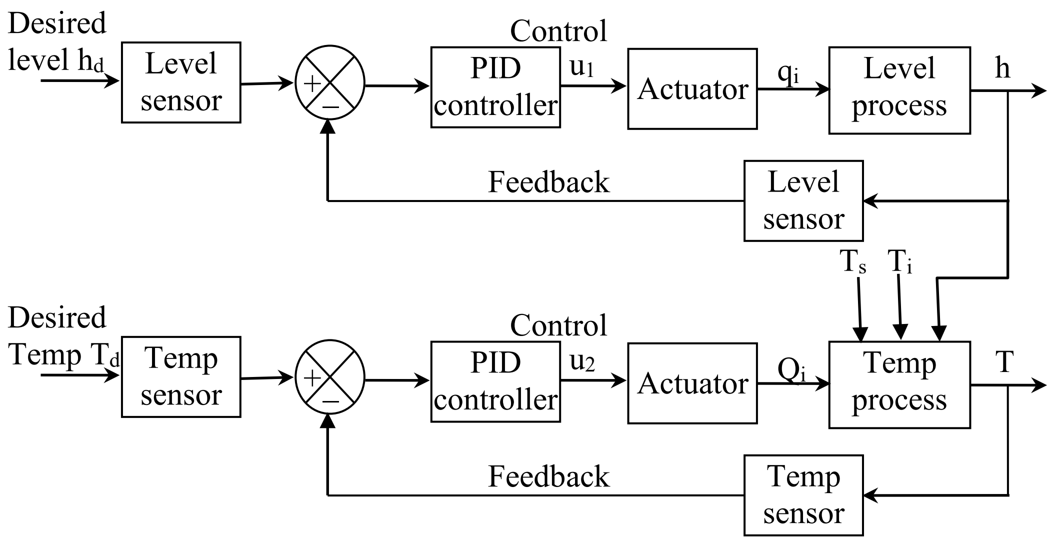


Fig. 4. Block diagram of a closed-loop multi-variable process system

Hints: Before simulating the entire propeller set, please simulate the motor without load to confirm physical properties of the motor are correct based on the datasheets.

2.3 GUI/AppDesigner Program with Simulink (Optional for Problem 2)

Design and make a GUI/App Design program/s with different simulation scenarios, for examples, entries of all important parameters for the multi-variable systems, open-loop scenario button, PID control.

Hints for GUI/AppDesigner programs:

- After you derive all equations, make Simulink programs and debug all Simulink to get correct solutions and graphs for reporting before you make GUI/AppDesigner program/s with good user interface.

(See Appendices for further information)

Appendix 1 – Model scaled container vessel Hoorn

FigureA1.1 Hoorn top view

Table 1 Vessel and Model Particulars

	Full Scale Vessel	Model (Scale 1:100)
LBP	247 m	2470 mm
B	32 m	320 mm
Draught	12 m	120 mm
Δ	64000 tonnes	62.4 kg
L/B	7.72	7.72
B/T	2.67	2.67
C_b	0.69	0.69
k_{yy}/L_{pp}	0.24	0.24
k_{xx}/B	0.328	0.328

The maximum speed is assumed to be 1.0 m/s corresponding to the motor speed at 1000RPM.

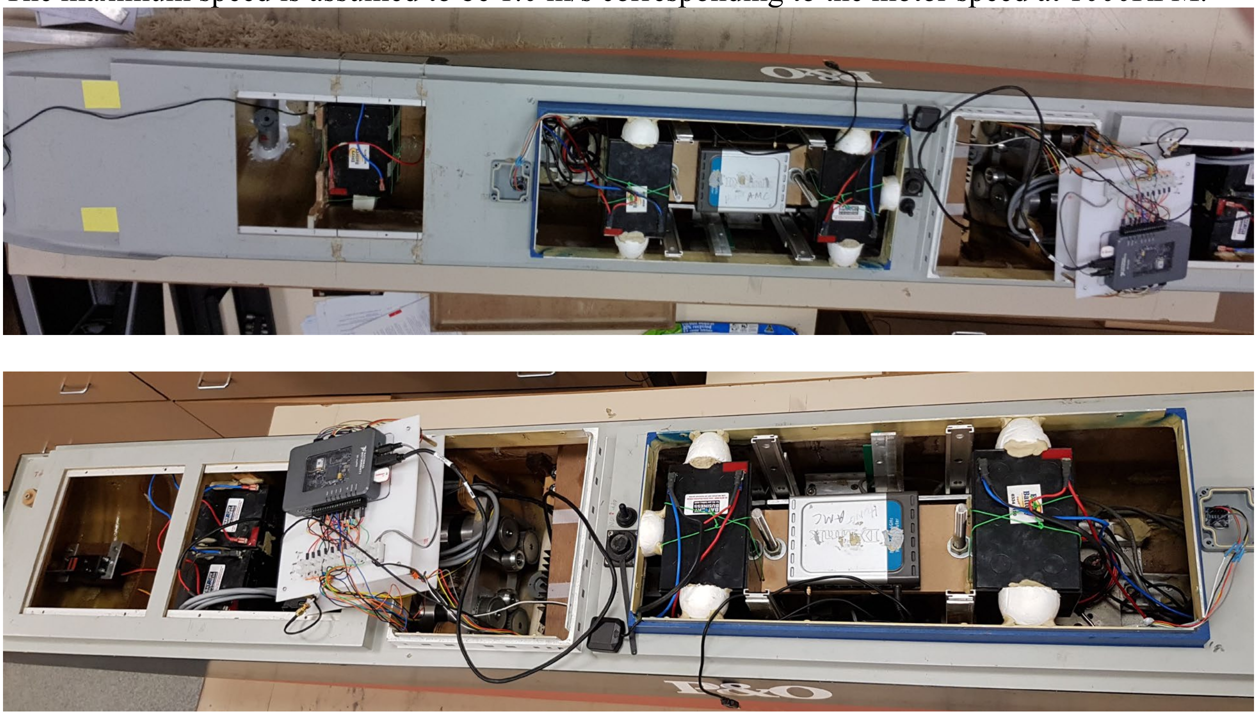


Figure A1.2 Electronics components of the motor sets

Figure A1.3 Twin propellers (port: left-hand, starboard: right-hand) and rudder

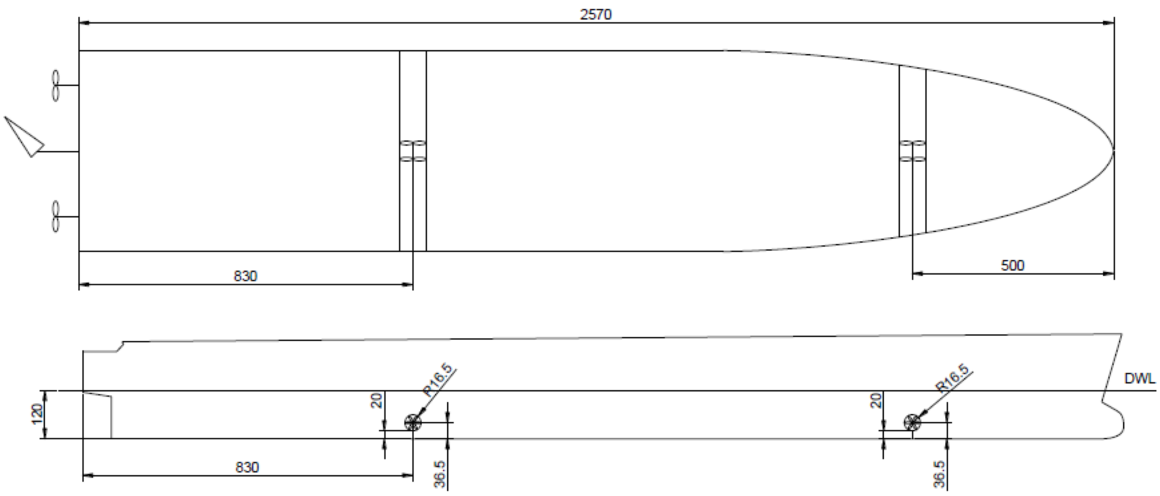
Figure A1.4 Hoorn in the AMC Model Test Basin

Further reading:
Thomas, G., Duffy, J., Lilienthal, T., and Watts, R. (2008). Parametric rolling in head seas – an Australian perspective. *Ausdtralian Maritime Safety*, 312-317.

Appendix 2: Thruster motor and Positions of Thrusters

Raboesh 7.2 V dc motor

Link https://www.componentshop.co.uk/bow-thruster-108-30-30-33-x-148mm.html



Positions of two thrusters

Appendix 3 Description of the Delorenzo Process Control Trainer

The following figure shows the Delorenzo process control system trainer for the air pressure control system. Dimensions of the system are as follows:

Diameter of the tank: 180 mm

The total height: 210 mm (from the bottom to the ceiling)

The range of level, h, to be controlled and measured by an LVDT level transmitter: 0 mm (0cm) to 100 mm (10cm)

The outer diameter of the pipe: 12 mm; the inner diameter is 10 mm

The flowrate range (as designed): 0 l/hr to 300 l/hr (the flow can be circulated by the pump, and adjusted by either pump or motor driven valve), the feedback flowrate range is 0V to 10 V.

Valve 3 is an automatic release valve: The pressure range is 0 bar to 2.5 bar, when the pressure is equal to or larger than 2.5 bar, the Valve 3 is open automatically

The operation of the pressure process system is below:

Set 0-cm reading of the small scale (0-10cm) at the 6-cm reading of large scale (0-21cm), then closed the air-valve, the corresponding pressure is 0 bar. When the level reaches 10cm on the large scale, the pressure is assumed to be 2.0 bar. The level can be adjusted by either motor driven valve while the pump is to circulate water, or by the pump while the Valve 4, Valve 5 and motor driven valve are fully open.

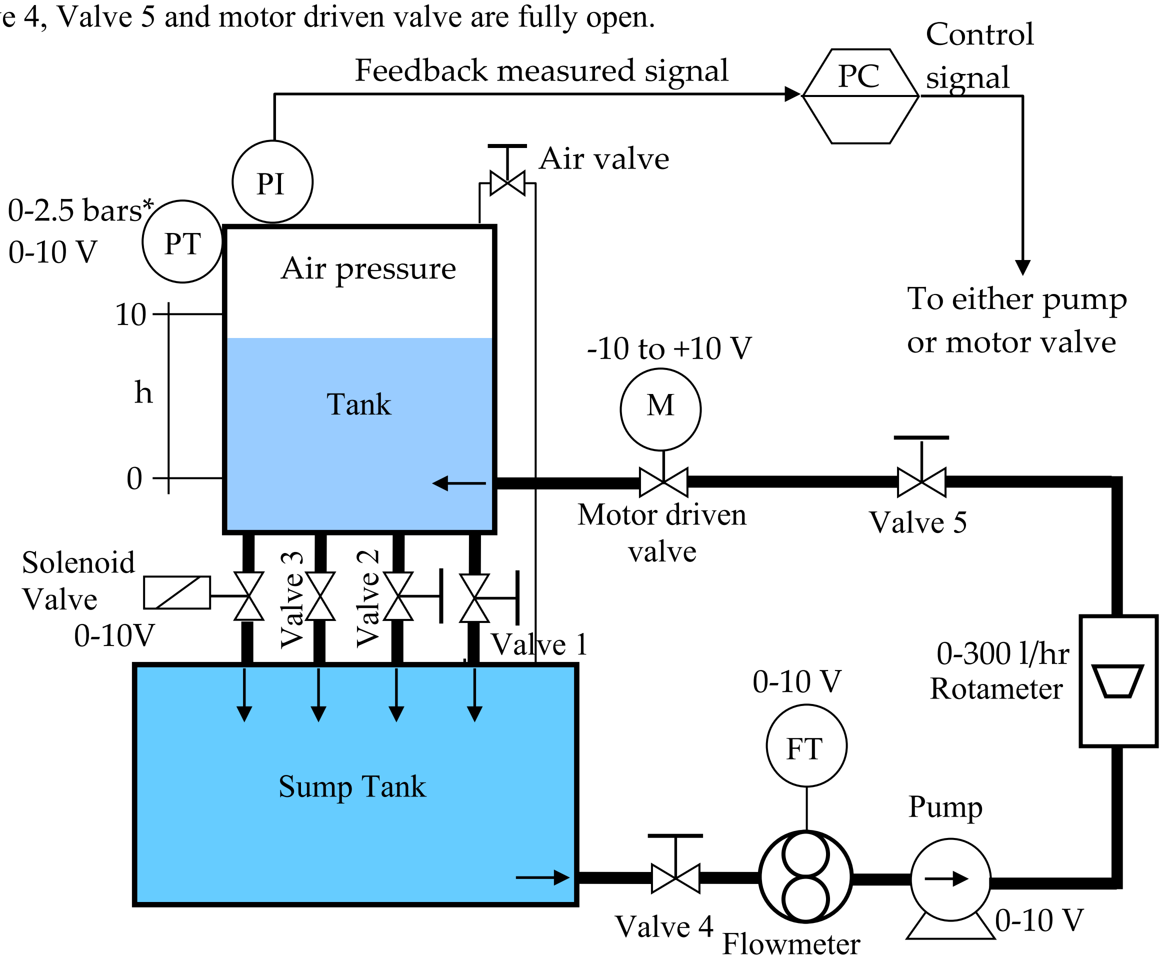
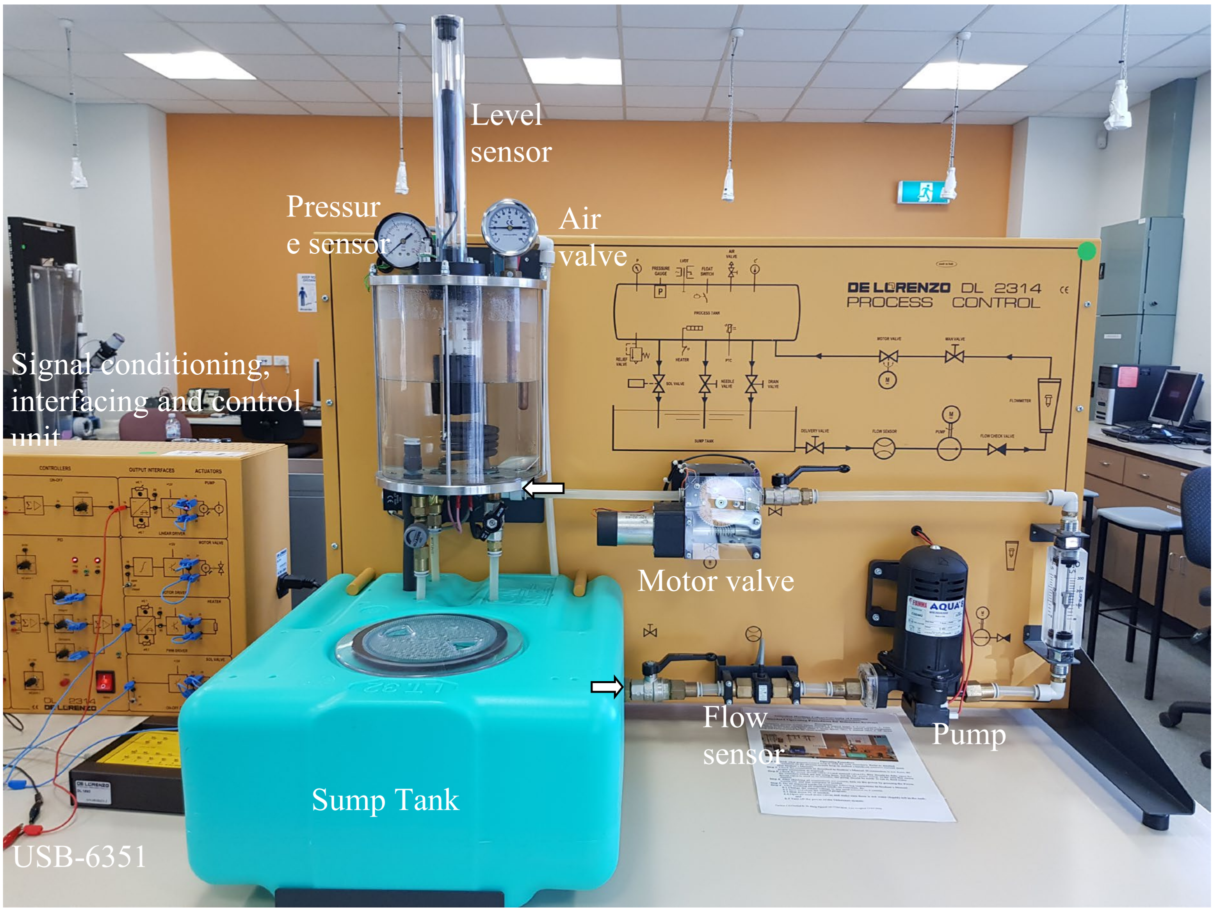
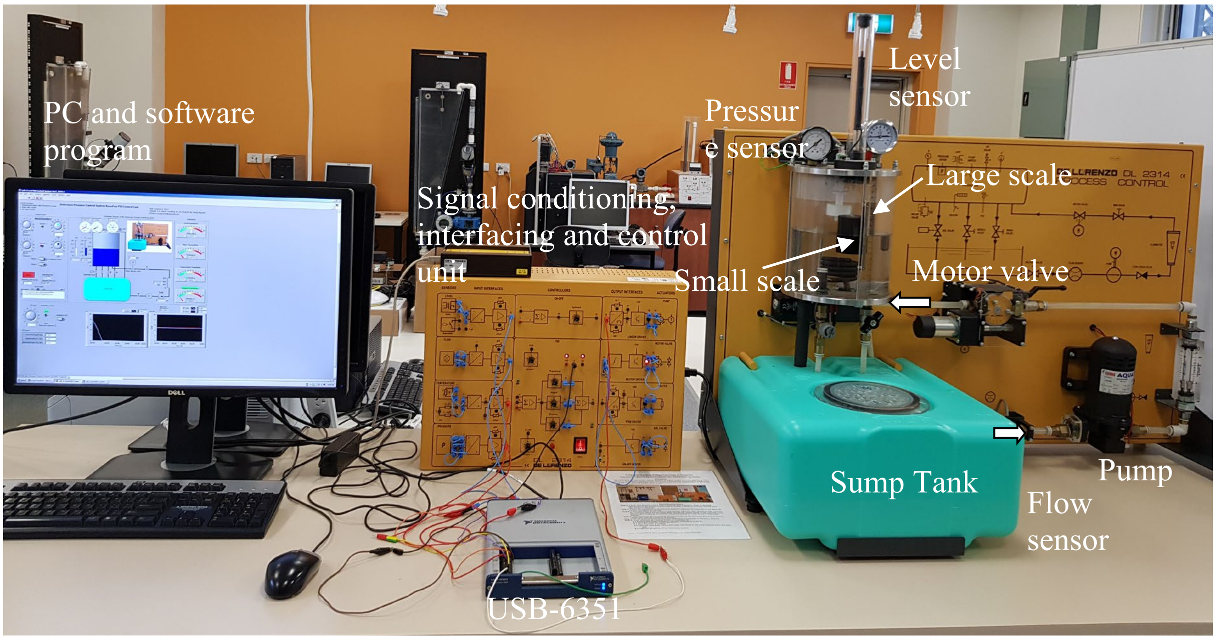


Fig. A3.1 Schematic diagram of Delorenzo pressure process system, the pressure can be adjusted by either motor driven valve (while the pump is running to feed water), or by the pump (while the motor driven valve is fully open).



(a) Delorenzo process trainer with processes only



(b) Delorenzo process cotnrol trainer with all components

Fig. A3.2 Two photos of Delorenzo process system (trainer)

List for your K_P gain in Assignment 3 2024

No	Surname	Other Name
1	**Chukwu**	Brian
2	**Dixon**	Michael
3	**Ekanayake**	Chandima
4	**Eri Devanathan Raghuram**	Pranavram
5	**Hogan**	Joel
6	**Huang**	Tiantong
7	**Lamnek**	Eugene
8	**Le Lacheur**	Nicholas
9	**Loth**	Benjamin
10	**Pikor**	Glen
11	**Pitkin**	Benjamin
12	**Rathod**	Dhananjay Vikramsinh
13	**Sasanala**	Phani
14	**Surakanti**	Uday Reddy
15	**Tran**	Nam
16	**Zhao**	Zhengyang