

The Ship Model Basin of Naples' University Federico II: Facilities, Experimental Tests, Measurement Systems

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Abstract – This work presents the main facilities of the Naples Towing Tank, LEIN: the instruments and the potential of the laboratory are presented, highlighting some strategies to resolve critical points typical of the towing tank tests. As example we point the attention on three aspects, typically critical: towing point of planing vessels, the accuracy of wave spectra generation and the settings of the radii of gyration for the seakeeping models.

axis normal to the walls of the tank at a deep of 1.5 m from the free surface of the water. The fiberglass paddles are 2.0 m high and 1,125 m wide; each has its flat side exposed (face) to flat water, the other (the back) is dry, suitably shaped for structural and kinematic needs.

Each paddle is moved by an electric servomotor through a rack-and-pinion mechanism. The hydrostatic pressure is compensated by gas springs placed on the back of the paddles.

FACILITIES

A. Towing Tank

Dipartimento di Ingegneria Industriale (DII) of Università degli Studi di Napoli Federico II has a towing tank of 137.2 m total length, width 9 m and depth of 4.2 m, equipped with towing carriage with maximum forward speed of 10 m/s to perform the model for power prediction, seakeeping and non-conventional hydrodynamics experiment. This dimension of towing tank and carriage maximum speed allow relatively hull models and very good tank-sea correlation

B. Towing Carriage

The carriage of 10t weight is moving by eight asynchronous motors of 18 kW power delivered by independents inverter system. Carriage movement is controlled by a SIEMENS PLC which guarantees velocity stability accuracy of 4mm/s and resolution of 1mm/s with maximum acceleration of 1m/s², and a resolution of position of 1mm and accuracy of absolute position of 4 mm.

The robust construction guarantees very good stability and avoid vibration propagation to the models under test.

C. Wave Maker

The towing tank is equipped with an Edimburgh Design wave maker. It is placed at the end of towing tank, composed of eight oscillating paddles, hinged on a single

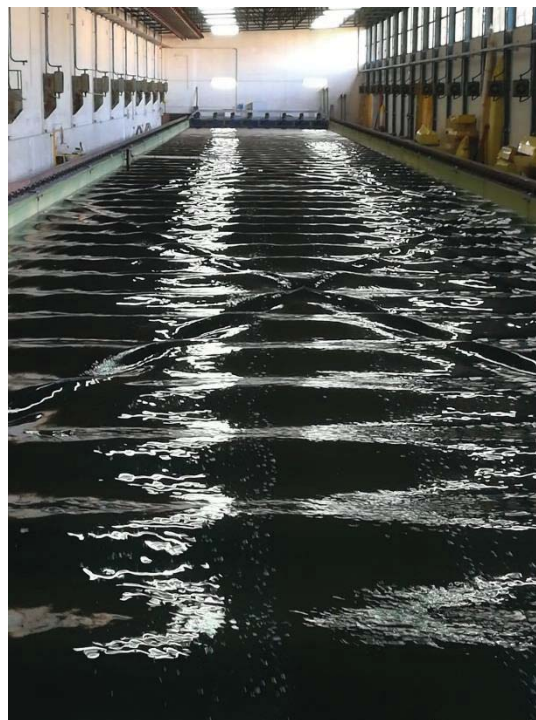


Fig. 1. Towing Tank of Naples University Federico II

The movements of the paddles are independent, so it is possible to generate composite spectra but also to change the direction of propagation of the waves by appropriately phase lag (snacking) the oscillation of the paddles.

dimensions.

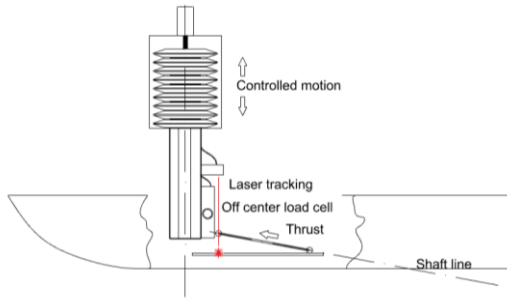


Fig. 3. Controlled towing system

The TC system allows taking in to account the vertical component of the thrust that could affect the dynamic of the model and the sailing trim, as shown in [2]. Therefore, bare hull tests, of high-speed craft, could be considered more plausible.

The following figure shows the different results testing the C5 model of Naples Systematic Series [3] with horizontal tow, OT and the TC system, with a shaft line of eight degree; the tow point in OT was positioned as suggested by ITTC procedure [1]. The model has LWL = 2.4 and displacement of 37.4 Kg in model scale.

It is possible to observe that, the higher the speed, the higher the overestimation of the horizontal tow both in trim and resistance.

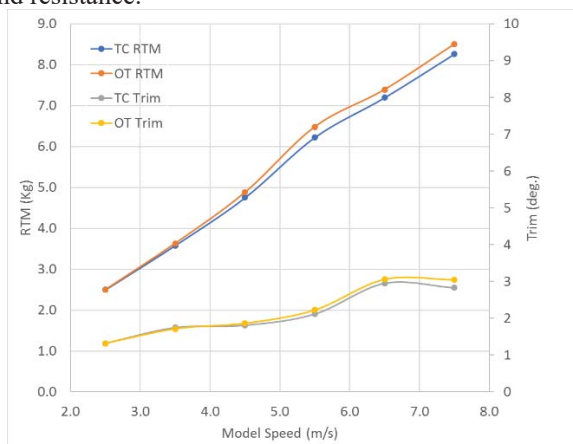


Fig. 4. Controlled towing system comparison.

D. Propeller Open Water Test

The H29 System of Kempf&Remmers is used. It is an arm equipped with an axial load cell for thrust measuring, two orthogonal cells for measuring transversal forces, a torque meter and an encoder for torque and the revolutions number measuring respectively. The under-test propeller is moved by a 5kW servomotor and a maximum speed up to 3000 RPM, with a scale range of 10 Nm for the propeller torque and 400 N Trust.

E. Self-Propulsion Test

The laboratory has a line of speed-controlled servomotors and integrated dynamometers that simultaneously measure torque and thrust on the axis line of the models under test.

OTHER SENSORS AND INSTRUMENTATION

Schaevitz inclinometers, referring to gravitational acceleration, are particularly suitable to measure the heel and trim of the model at rest, on contrary, they can't be used in tests with non-stationary dynamics. For dynamic pitch and roll measurement, are used laser distance meters and Qualisys Motion tracking System.

For statical elevation wave measurement, probes with a capacitive effect are used with accuracy of one mm, instead with the moving carriage where it is not possible to use the capacitive probes, narrow spot ultrasonic probes are used. These probes although they have an accuracy of 1 mm on the of the calm water level measurement, in the presence of waves the beam spot changes (less on the crest, greater in the trough) and this introduces a systematic error that can be considered negligible only if the wave length is much greater than the emitted spot.

The spot extension is also a function of probe height respect to the water level, so it must be positioned as close as possible to the surface of the water. Despite these defects, the ultrasound probe remains the only sensor capable of being used when the carriage is moving.

An Xsense inertial platform is also used to measure body motion, where the Qualisys system is not adoptable. The inertial platform is composed by a triaxial accelerometer and gyroscope, whose signals are combined through a fusion algorithm, adopting Kalman filters, to measure the 6 Dof of the body.

DATA ACQUISITION SYSTEM

The data acquisition system (DAQ) is developed internally and it is customizable to follow the needs of non standard tests. The DAQ use a National Instrument PXI rack, with SCXI conditioning modules.

The acquisition is made by an analogue channels cards 16-bit precision, time-counting cards for encoders, and digital I/O modules. The DAQ currently has:

- 16 channels for load cells and potentiometers with anti-aliasing filters (16bit-200kS/s)
- 8 channels analog isolators with anti-aliasing filters for inclinometers and other instruments (16bit-300kS /s)
- 10 channels counter-timer for encoders and frequency modulated signals with anti-bouncing filters (32bit - 80MHz clk)
- 32 opto-isolated digital inputs for absolute encoders
- 96 digital I/O lines

- 6 analog outputs for instrument control

The SW is written in NI LabVIEW and allows the complete management of the various types of tests, from channel selection to data post processing and their storage in EXCEL/txt format. Furthermore, the SW can read the information coming from the SIEMENS PLC such as speed and position of the carriage in order to correctly manage automatically the acquisition subordinating it to acceleration. It is also able to send commands to the PLC, such as for example propeller Start-Stop and rpm settings of the H29 engine and other commands useful for automating tests.

: "STILLWATER" SYSTEM FOR MONITORING THE STATE OF CALM WATER.

Good practice is for standard towing measurements to be carried out in "calm water".

Even use of wave dampers, to make sure that the tank is still, waiting can be incompatible with experimental needs. This state of perturbation can be established by the operator who can observe the motion of the free surface and then decides that the test can begin, but in this way the estimation of the level of "perturbation" is strongly dependent on sensitivity and operator experience.

There is therefore a need to objectively establish a threshold level of residual perturbation below which the water is to be considered calm.

The problem was solved by use of an ultrasonic level sensor (located on the axis of the tank at the beginning of the absorber beach) which continuously monitors the change in the level of the free surface. A dedicated SW, whose front panel is shown in fig 1, calculates the standard deviation of the level referring to a time mayor than the fundamental period of the basin. Assuming the depth of the basin is less than its length we can use the approximate formula that binds the wave propagation velocity to the depth of the tank.

$$v_p = 3.1\sqrt{D} \quad \text{where}$$

v_p : propagation speed m/s

D : depth of the tank in meters (in our case D is 4.20 m) and then v_p it's 6.35 m/s from which we can derive the propagation time of a wave front

$$t_p = 2L/v_p \approx 50 \text{ s}$$

It integrates on a much longer time (120 s) and when the standard deviation of the level of the last 90 seconds is less than 1 mm, the SW warns that the water is to be considered calm and therefore it is possible to make a new test. Of course, parameters such as the integration time and level threshold can be set by the operator.

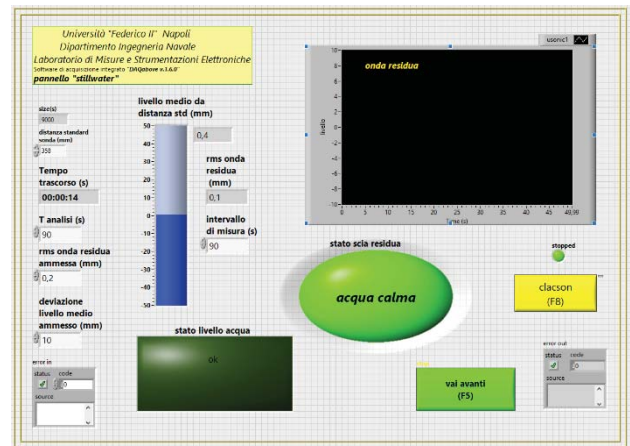


Fig. 5. Front Panel SW Calm water (acqua calma)

INERTIAL BALANCE

In seakeeping tests, centre of gravity and the radii of gyration of a model have to be set as shown in [4] and [5]. For this purpose, an inertial balance that works on the principle of the physical pendulum has been designed and built. The instrument has a range of 200kg and can mount models up to a width of 80cm.

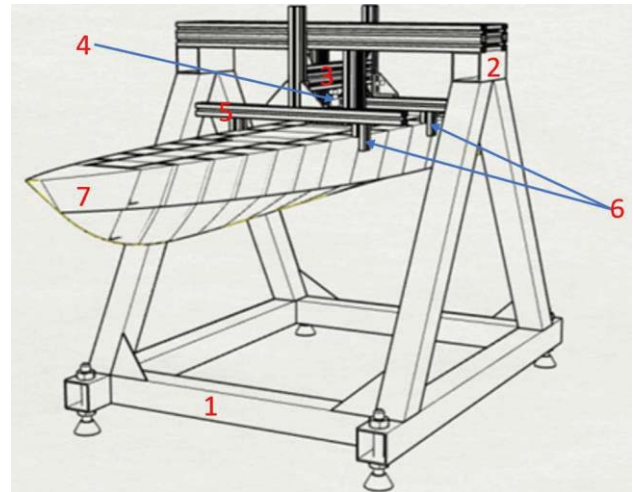


Fig. 6. Inertial Balance

Refers to figure 1, the inertial balance is composed of the levelled base (1), on which the beam frame stands firmly (2), in the centre of it on the plinth (3) rests the low-friction cardanic joint with vertical axis (4) that acts as a pivot, M. The components 1-4 are the fixed equipage.

On the top of the joint rests firmly the cradle (5) that ends with the shaped feet (6) adjustable in width to centre the model (7). The centre of gravity, CG, of the cradle coincides with the fulcrum and it is free to pitch and roll.

The moments of inertia of the cradle are known and

considered in the determination of the model characteristics. The model is fixed under the cradle and tightened by the bands (8). The position and orientation of the model relative to the fulcrum are known with accuracy of less than 1 mm and 0.1 deg.

POSITION DETERMINATION OF THE CENTER OF GRAVITY OF THE MODEL

The model is positioned to have the pivot M on the vertical position of the desired CG, so zero trim condition ensures the longitudinal CG assessment. Then a procedure similar to the inclining test were made to calculate vertical position of CG. Differently to the standard inclining test the model is constrained to rotate around the point M so large angles are allowed, overcoming the limit of the metacentric method and the uncertainty due to the calculation of the metacentre position. Therefore, the formula below represents the vertical distance from CG to the pivot M, similarly to the metacentre procedure. The constrained pivot M allows to incline the model in longitudinal direction.

$$GM = \frac{w \cdot d}{\Delta \tan \theta}$$

Where GM is the distance of G respect to M, w is the weight of the mass moved to incline the model, d the displacement of the mas w and θ the longitudinal inclination of the model

Moving it to known longitudinal positions and measuring the corresponding inclinations, known the weight of the model, with the best fit one goes back to the height of the centre of gravity with respect to the suspension point with inf accuracy to mm.

MOMENTS OF INERTIA DETERMINATION

The measurement is obtained by oscillating the mobile equipment and using the accelerometer to measure the periods of pitch and roll oscillation.

Once the moments of the mobile crew have been measured with respect to the fulcrum, the inertia of the cradle is deducted, the net moments are transported to the center of gravity of the model, and the measurement is completed. To achieve an adequate level of accuracy in the

estimation of radii of gyration, it is necessary to obtain the oscillating period with accuracy of two millisecond. The necessary precision is obtained by integrating the measurement on a hundred of free oscillations, adopting a peak detector algorithm, with a sample rate of 10 KS/s.

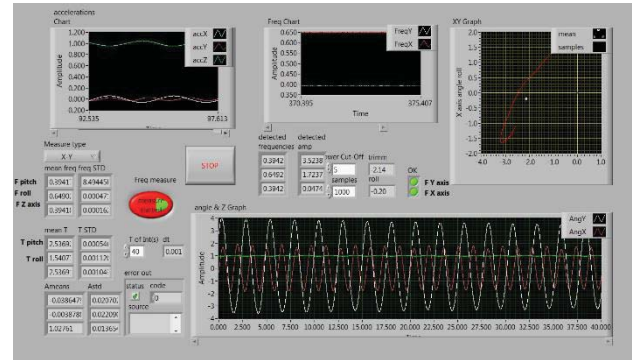


Fig. 6. Inertial balance SW front panel

The figure shows the front panel of the SW developed to estimate angles and oscillation period. The procedure adopted suggest repeating the measurement at least three times. Applying the approximate inverse formula for physic pendulum we obtain the radii of gyration whit a precision approximately of 0.001 m.

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