Open water manoeuvring model tests at the Joniny Test Station, Ship Hydromechanics Division, CTO S.A.

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Abstract

Although the role of computational methods (CFD) in prediction of the hydromechanic qualities of ships grows rapidly, the role of the physical experiment is still very important (if not principal). Concerning the experimental investigations focused on manoeuvring abilities of ships, there are two main approaches to be applied: open water model tests and captive model tests (Planar Motion Mechanism). The paper contains some basic information concerning the first of mentioned methods including the evolution of the measuring techniques, applied equipment and methodology. These changes result not only from technological progress, but also reflect different expectations of our Clients. In the case of mentioned open water manoeuvring model test, its specific character determines a little bit different approach, which combines some strictly scientific objectives, i.e. prediction of the manoeuvring abilities, with commercially attractive and direct demonstration of the results. Thus, in parallel with description of the measuring systems used during the tests (starting from mechanical/optical torograph system to modern laser tachimeter system), evolution of the visualization systems is also presented. In addition, some future trends in the development of the open water tests station in Joniny has been described including experimental work as well as basic/auxiliary equipment.

Keywords: *free sailing model tests, manoeuvring abilities of the ship, manoeuvring tests, model tests*

Figure 1 *That is how it started – preparations for the free sailing model tests in the early seventies*

Foundation of the test station Joniny

The open water test station in Joniny was founded in the early seventies as a part of the Ship Model Basin, Ship Design and Research Centre (Centrum Techniki Okrętowej). In fact the origin of the facility should be dated a little bit earlier, in the sixties – then surroundings of the Wdzydze Lake located about 70-80 kilometres from Gdańsk (see Figure 3) had been chosen as the reserve localization of shipyards' design offices and in parallel first model tests at this localization were carried out (including some experiments with remotely controlled models). Finally, when both design offices (COKBPO and CBKO 2) had joined together into CTO, all experience and equipment was transferred to the newly born organization

Figure 2 *First model tests carried out with assisting auxiliary vessel*

Figure 3 *Localization of the joniny test station (for details of the localization - see www.Pilot.Pl)*

At the early beginnings mainly resistance and self propulsion tests were carried out on the lake – they were carried out by means of an auxiliary vessel (built as a catamaran) which followed the model; and the same idea was originally used for first manoeuvring tests, model was followed by the catamaran equipped with measuring apparatus. But the real impulse for serious manoeuvring investigations was given shortly after the commissioning of the m/s 'Profesor Siedlecki', research vessel built for Sea Fisheries Institute in Gdynia; due to her poor directional stability it was decided to start intense programme of manoeuvring investigations prepared on the basis of model tests, which were also validated on the real ship. Thus open water test station was activated in the actual form and methodology of model tests carried out by means of remotely controlled models was developed.

Free sailing model tests – advantages and disadvantages

In fact, at the early stage of design, ships are usually not designed and optimised from the point of view of manoeuvring abilities. These abilities are somehow inherited from (for example) resistance/self-propulsion optimisation - thus manoeuvring investigations are realized as the last stage of the programme and they might be considered rather as validation of ships' manoeuvring performance. There are some options for experimental investigations of manoeuvring abilities, e.g. captive model tests, carried out by means of rotating arm or PMM (Planar Motion Mechanism) – this methodology was developed especially for tests in model basins; optionally manoeuvring performance of a ship can be verified on the basis of free running model tests – carried out in special tanks or natural water areas. The last approach has been applied in CTO. What is the advantage of this solution? Unrestricted deep water area, which allows to use the hull models manufactured originally for the resistance/propulsion/sea-keeping tests; application of larger models (6-10m in length and 1.5-3 tons of displacement) reduces the scale effect and makes the model less sensitive to the weather conditions. On the other hand we still strongly depend on the weather conditions: global (we are not able to carry out our model tests during the winter and early spring) and local ones (when the model tests are stopped due to the heavy rains or winds). There is also another important profit coming from free sailing model tests – purely commercial one: the Client can observe the model directly during some typical manoeuvres (specified set of measurements contains usually tests defined in IMO Regulations); thus it gives the general impression about the ship's performance (not only manoeuvring abilities but also about the generated wave system, etc.).

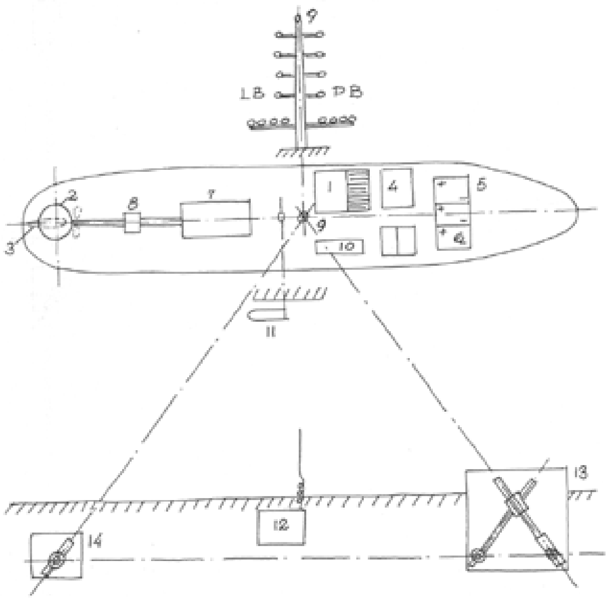

Figure 4 *Description of equipment used for manoeuvring model tests, in the second half of the seventies: radio set with transducers (1), steering engine with the indicator of the rudder position and dynamometer for measurement of the rudder stock moment (2), rudder (3), 5-channel recorder (4), battery of accumulators (5), battery amplifiers (6), driving motor with gear (7), propeller revolution counter (8), mast with signalling system (9), revolution controller (10), leeway (drift) angle indicator (11), 10-channel radio transmitter (12), trajectory recorder with recording desk (13), trajectory recorder with selsyn transmitter (14)*

Figure 5 *Equipment used during free sailing manoeuvring model tests at the present time*

Equipment used for the manoeuvring model tests and its evolution

Systems used during the tests can be divided into the following groups (see also Figures 4 and 5):

- propulsion system (including diesel generator, electric engine(s), shafts, transmission gears, etc. and appropriate stock model propeller(s));
- steering systems (including appropriate rudder(s), steering gear with integrated rudder angle meter);
- measuring systems (including controllers, course-gyroscope, rudder-meter and separate system for recording the trajectory of the model) with associated data collecting system;
- radio control unit with programmable manoeuver controller;
- auxiliary systems for transporting, storing and launching the model.

Although applied systems have been changed many times since the open water test station was founded, this general description is still valid – the configuration of the equipment used during the model tests in the second half of the seventies is presented in Figure 4, while the sketch of actual configuration is given in Figure 5. In the following subchapters some details concerning components of the mentioned subsystems will be shortly described (including its evolution).

Propulsion system

At the early beginnings the system was composed of an electric engine powered by diesel generator located at the auxiliary vessel; power was transferred via cables by means of the special extension arm (as shown in Figure 2). In fact, this solution (with auxiliary vessel following the model) was troublesome because of limitations caused by extension arm; it also required a synchronisation between operator of the auxiliary vessel and the operator of the extension arm.

Therefore, the mentioned system has been modified into the current version of fully independent free sailing model equipped

Figure 6 *Model during the manoeuvring tests, Joniny, in the second half of the seventies*

with the electric engine and power generator located on the model (initially, three batteries of accumulators were used instead of the power generator). Other components are the same as for the self-propulsion or sea-keeping tests – it means system of shaft(s) and propeller(s). The actual parameters of the electric engine are adjusted by means of additional controller; orders are given by the model operator from the radio-console.

Steering system

The model is equipped with a rudder unit (steering engine with dynamometer allowing optional measurements of the rudder stock moment); all steering engines were designed and manufactured in the Ship Hydromechanics Division – starting from the first of the electric-mechanical type up to the last generation built on the basis of servo-mechanism system. In the seventies the model was also equipped with the special rudder position indicator for optical signalisation of the actual rudder and heading angle – it consisted of a set of lamps located on the mast (mounted on the model as shown in Figures 4 and 6). Application of the new programmable Graupner controller has made this system redundant.

Radio control unit with programmable manoeuver controller

Originally, a 10-channel analogue radio-controller (Graupner) for remote control of models (and their systems) was used; later it has been replaced by a new programmable 24-channel controller of the same producer.

Measuring systems

The following values are measured during the tests:

· rudder angle;
· heading angle, turning rate, heel angle;
· position of the model (trajectory);
· rudder stock moment (optionally).

Other values (as speed, drift angles, etc.) are calculated, on the basis of the registered values, directly during the tests. The number of propeller revolutions is derived from the number of impulses from a signal generator installed on the propeller shaft and it is calibrated during the 'measured mile'; rudder angular velocity is set before the tests by means of controller. In fact registration of the measured signals is divided into two independent groups; trajectory of the model is registered independently of the rest and then synchronized. The general schema of the measuring system is given in Figure 7.

At the beginning the rudder angle was measured using two potentiometers mounted on the steering engine, which were connected with a 2-channel amplifier and pen-plotter; similar data acquisition systems were used for registration of the heading angle, while signal was transferred from the air gyro-compass. Both of them were supported (visualized) by mentioned indicator for optical signalisation of the rudder/heading angle. This system was upgraded in parallel with the rudder unit; then first PC computers were applied for registration of the signal (via AD converter cards) - in the nineties rudder and heading angle were recorded on a PC installed on the model. Finally the systems of wireless modems have been applied; thus all data are stored on the same computer and it is possible to observe and assess the registered signal directly during the run.

The trajectory of the model was registered by means of special model trajectory recorder designed and manufactured in CTO, which consisted of two optical viewfinders coupled together with two plotting arms (one mechanically and another one by means of selsyn arrangement, which made the arm follow the finder – see also Figures 4 and 8). During the tests, operators of the viewfinders were constantly following the model's mast; the model's path was visualized by means of a pen-plotter. This system was quite effective, but large group of people were necessary for its functioning; thus it has been

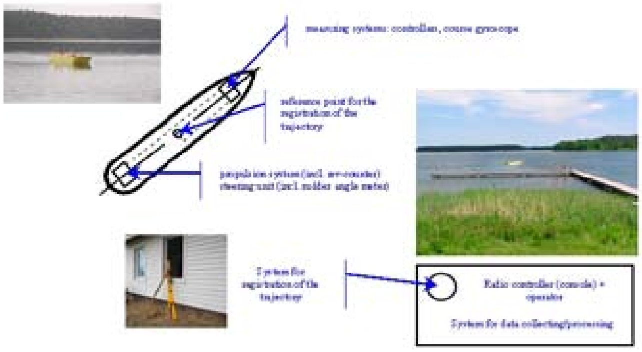

Figure 7 *General diagram of measuring equipment used for free sailing manoeuvring model tests*

improved in the second half of the eighties with additional potentiometers (instead of previous visualization tool) coupled via AD converter to a PC equipped with dedicated home made software. Finally, this system had been phased out a few years ago, when the new GPS system was started. Initially, the model was equipped with additional PC for independent registration of the trajectory signal from GPS; results from both on-board computers were transferred after the test to the data processing computer for synchronization and further analyses. Finally, two years ago a new system built on the basis of optical-laser tachimeter system was started and this solution is used at the present time. Remotely operated tachimeter device follows the

Figure 8 *Model during the turning test, joniny station, in the second half of the seventies*

position of the tachimeter's prism body located on the model (position of the centre of gravity); data are transferred directly to the data collecting/processing computer at the coastal station, for synchronization and further analyses, by means of wireless modems. This system allows the assessment of the correctness of model tests at the early stage, for example during the approach to the zig-zag tests; thus it can be stopped and repeated immediately, if necessary.

Application of the optical trajectory recorders restricted possible test area to the close neighbourhood of the viewfinder stations; moreover obtained results depended strongly on skills of the viewfinders' operators. GPS system was much more precise, while the test area was limited to the range of the differentional station (approx. 300 meters). Actual tachimeter system is limited only by the visibility of the tachimeter device and the tachimeter's prism body located on the model.

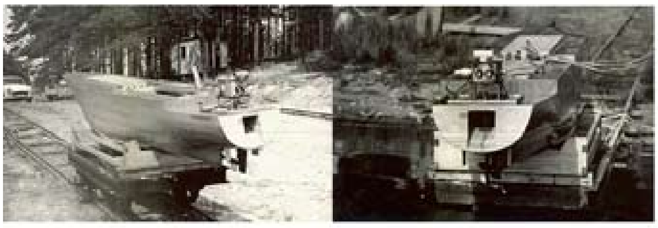

***Figure 9** Model of the ship (m/s "Profesor Siedlecki") positioned on the launching carriage*

If necessary, additional signals (up to 16 values) can be registered - for example, forces generated on the propulsors (for podded vessels), then the model is equipped with sets of extensometer blocks.

Auxiliary systems for transporting, storing and launching the model

In general the similar system containing the hangar, small crane with associated carriage and railways is used since the early 1970s for storing, transporting and launching the model; meantime its components have been modernised.

Preparation for the tests, scope of the tests

Model preparation for manoeuvrability model tests covers the following points (activities):

· equipment of the model;
· weighing and dynamic balancing of the model before the tests;
· preparation of the test station;
· transportation of the model to/from the Joniny Test Station.

Before the tests, model is equipped with all systems described in the previous chapters, then it is balanced both – statically and dynamically for proper location of the centre of gravity and appropriate moment of inertia.

During the tests, model is equipped with all appendages including the bilge keels. If the designed propeller is not applied (due to high risk of damaging the propeller during the tests), a stock propeller is selected; in fact set of stock propellers designed especially for manoeuvring model tests have been manufactured at workshops of the Ship Hydromechanics Division.

The manoeuvring model tests are carried out in deep, unrestricted water and at calm weather conditions with the range of parameters (load conditions, approach speed, etc.) specified in accordance with the Customer's request. Appropriate set of tests is preceded by the set of runs on 'measured mile' to calibrate the speed and adjust settings of the main engine controller. The model tests are carried out by means of automatic pilot devices. All signals are registered and synchronized directly during the tests; thus operator of the data acquisition system is able to assess the correctness of the test at its early stage.

In order to verify the manoeuvring properties of the vessel, a typical set of model tests according to the IMO Standards is usually proposed – it consists of:

· turning tests;
· zig-zag tests (20º/20º and 10º/10º);
· direct spiral test;
· stopping tests (inertial, crash-stop).

If requested, some additional manoeuvring model tests can be carried out as:

· modified zig-zag tests;
· reverse spiral test;
· pull-out test;
· special tests (other specified manoeuvres, measurements of additional quantities).

As it was mentioned, first manoeuvring model tests were carried out using additional auxiliary vessel; first 'real' free sailing model tests were controlled manually on the basis of indication given by a system of lights mounted on the mast. Newer generation of equipment enabled to automate the measurements – starting from the course recorder coupled together with the automatic rudder change arrangement; this way zig-zag and spiral tests were carried out, but turning tests and stopping tests were still realized manually. Application of the GPS system and registration of the results on two independent PC units enabled full automation of the tests including further synchronisation of data; then application of the new tachimeter system with system of wireless modems and dedicated home made software has made possible constant observation of the model during the tests.

Although construction of the special manoeuvring tank was planned in the late seventies, successful implementation of the described methodology suspended that tendency; at the present times model tests carried out at the Joniny Test Station seem to be an effective tool for fast and commercially attractive assessments of ship's manoeuvring abilities. In the near future further development of the auxiliary tools is considered including improvement of the dedicated software (allowing to correct the obtained results for actual weather conditions).

***Figure 10** Model during the manoeuvring tests at the present times*