Model tests of the resistance, propulsion and manoeuvrability of ships in the Experimental Centre in Ilawa

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Abstract

Paper presents the development of resistance, propulsion and steering quality model tests carried out on lake. Such pioneering investigations began in 1956 and were gradually improved and extended. Original equipment and measurement methods were developed. The paper presents those research methods and techniques,and also accuracy of the results, in a historical perspective. Described are also several most important research programmes accomplished in the Centre.

Keywords: *resistance, propulsion, manoeuvrability, ships*

INTRODUCTION

Rapid development of shipbuilding in Poland in the 1950s caused as rapid increase of demand for model testing of hydrodynamic characteristics of the designed ships. The first model basin (30 m) was established in the Maritime Institute (1954) and not much later (1955) a similar basin at the Chair of the Theory of Ships, Faculty of Shipbuilding, Gdansk University of Technology. Small size of those basins allowed to test the resistance and later also propulsion qualities, but results were not accurate due to the scale of the models. Manoeuvrability could not be tested. Then, on the initiative of prof. Lech Kobylinski, a decision was taken to substitute open water for a large test tank and in 1956 organization and construction began of the Experimental Centre on Jeziorak Lake in Ilawa. Specific testing conditions on a lake required special, often original, measurement techniques and investigation methods to be developed. The work was started in 1956 and in 1959 first tests were carried out. In the following years, as experience was gained, the methodology was improved, measurement equipment diversified and the scope of investigations widened.

Method and technique of the resistance and propulsion tests

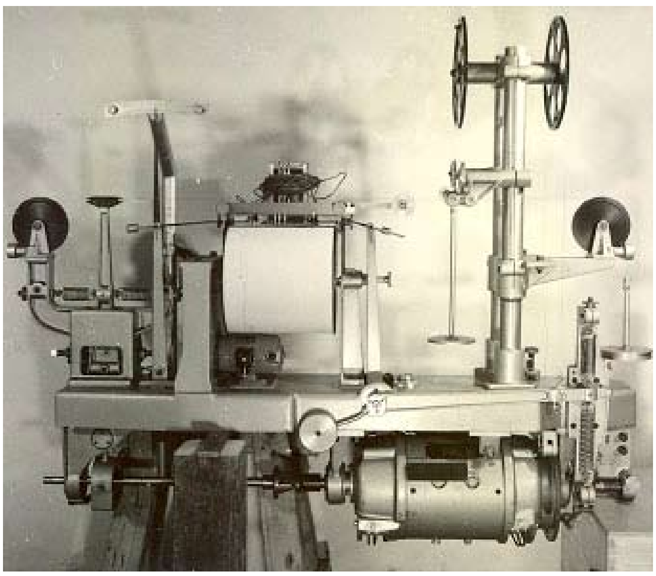

Figure 1. First propeller dynamometr used in Ilawa (K&R type A-II)

Preparations for such tests began in 1957. A screw dynamometer (large and heavy, combined with a DC electric motor), Ward-Leonard generating set, screw log for model speed measurements and hydrometric current meters for the wake speed measurements were bought in a well known Kempf & Remmers company. However, before that valuable apparatus was acquired, first resistance tests had been performed in Ilawa of two models of the L-250 and L-500 type ice-breakers for lower Vistula. The models were simply towed on a long line by a motor-boat and resistance was measured with an ordinary spring dynamometer. Bollard pull measurements were also carried out on the L-250 model. Both icebreakers were then built and, oddly enough, no reservations were ever made to their predicted characteristics!

More or less full propulsion tests, ordered by the inland navigation craft design office in Wroclaw, with the above mentioned measurement apparatus, were carried out in 1959 on a „Zubr" type push train model and in 1960 on a H-660 type tug model. The tests were performed on free models with helmsman, which means that the measurements were taken at the point of model own propulsion. The model speed was measured with a screw log fastened on a boom in front of the

Figure 2. Model of tug boat M-660 ready for tests

model bow, propeller revolutions, moment and thrust with the Remmers dynamometer. The wake coefficient was determined from the measurements of nominal wake with hydrometric current meters, corrected by empirical data, thrust deduction factor from the difference between thrust and resistance and the relative rotative efficiency was assumed equal to zero.

The results were converted to the natural scale in accordance with the Froude law with correction of thrust by a 0.9 multiplier to take the scale effect into account. When the units were built, the trial trip tests showed quite a decent agreement with the prediction - the discrepancies did not exceed 5% of the predicted values. Perhaps we were just lucky.

We were aware, however, that the investigation technique was inadequate and we invented a device that was meant to simulate a test tank towing carriage. It was a floating measurement platform in the form of a catamaran with widely spaced fine floats. The tested model was placed in the fore part in the area not disturbed by waves generated by the floats, under a jutting frame, and was connected with the catamaran through a resistance dynamometer. In the first version the catamaran was pushed and steered by a motor-boat, which soon appeared to be a poor solution as it was difficult to keep straight course and constant speed of such a set. A new measurement catamaran was quickly designed and built, where each float had its own car engine, propeller and rudder. The helmsman had respective indicators and was responsible for keeping the engine revolutions equal during the test. Keeping straight course was not difficult. The generating set and most of the measurement equipment, as well as the personnel stands, were installed on the catamaran.

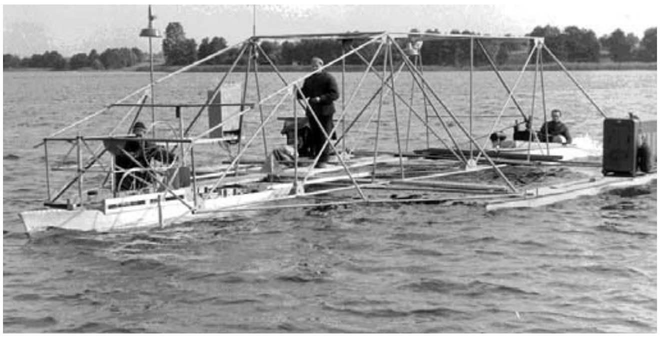

Figure 3. *First version of floating measurement platform*

Figure 4. *Modified floating measurement platform*

The resistance and propulsion tests could then be carried out in a full scope, by means of the same method as in a large towing tank. The floating measurement platform allowed to generate the pulling up force, i.e. transition to the point of model own propulsion. As changing and stabilizing the catamaran speed required long distances, a variable propeller load method, similar to the British method, was applied. Large lake stretches allowed to keep constant course in long runs. The great value of the ratio of catamaran mass to model mass practically eliminated the impact of model towing on the catamaran movement.

Hydrodynamic characteristics of an open-water propeller were determined experimentally in a similar way as in a test tank - special float was suspended under the measurement platform carrying a screw dynamometer and an electric motor moving the propeller mounted on a long shaft before the float.

In the following years, that floating „towing carriage" was systematically modernized - floats were replaced, equipment was improved (a modern screw dynamometer was purchased), the hydrometric current meters were replaced by a set of Prandtl tubes etc.. Basically the test method remained unchanged and it gave good results.

The main disadvantage of open water tests was dependence on the weather - sometimes one had to wait a week for a calm weather. Therefore the tests were often performed during the night or at daybreak (sunrise on the lake would many a time be beautiful). The tests could not, of course, be carried out during the winter.

The idea of using a floating towing carriage for open water model tests was then adopted for some time by the Gdansk Ship Design and Research Centre in their Experimental Station in Joniny, by the High Agricultural School in Szczecin (for the fishing net tests), and even in the Experimental Station of the University of California in San Francisco.

Method and technique of the manoeuvrability tests

Already in the 1930s attention was drawn to the ship manoeuvrability and the experience of the second world war stressed the importance of good steering qualities for the ship safety. Therefore, from the moment the idea of a lake experimental centre was formed, we were convinced of the need of testing the manoeuvrability qualities of newly designed ships and that open water testing facilities were particularly suitable for the purpose. There were no ready examples of such solutions

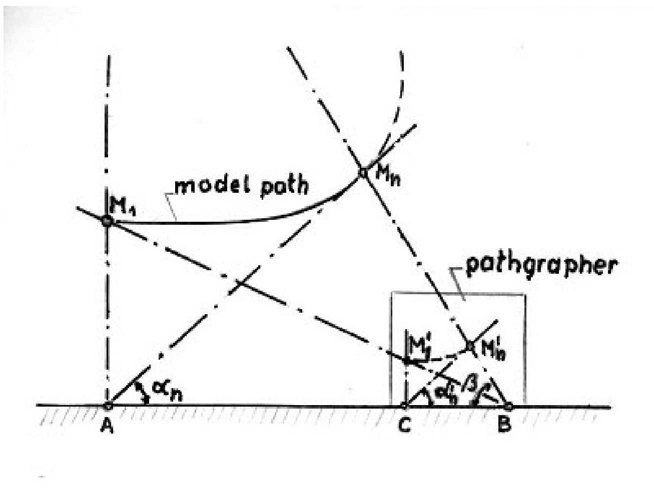

Figure 5. *Scheme of pathgrapher operation*

and the specialist apparatus was practically also not available, so we had to develop our own test methods and techniques.

The first steering tests were carried out on the above mentioned ice-breaker models in 1958, with a very limited scope due to lack of any measurement equipment. The models were self-propelled and were steered manually by helmsman. Tests were reduced to performing a series of circulation manoeuvres and various turns, with rough estimates of their effects.

A problem for those ships was steerability in the astern motion, which was easy to estimate visually and which we managed to improve considerably after those tests by introducing test-verified design changes.

In the period up to 1960 a test method was developed and a set of original measurement devices for model manoeuvrability tests in open waters were designed and built. The basic device was the so called path recorder - a device for the model path tracking and recording.

The path recorder consisted of two direction-finders A and B on the shore. The direction-finders were operated by observers who tracked the mast of the model manoeuvring in the water area before the AB base line. Movement of the direction-finder A, was transmitted by a selsyn to repeater C on the table where direction-finder B was installed. On the axes of repeater C and direction-finder B running arms were mounted moving horizontally over the table. Crossing point of the running arms marked the momentary model position. Between the running arms, at the crossing point, a timing clock generated in constant time intervals a spark piercing the sheet of paper stretched horizontally between the arms.

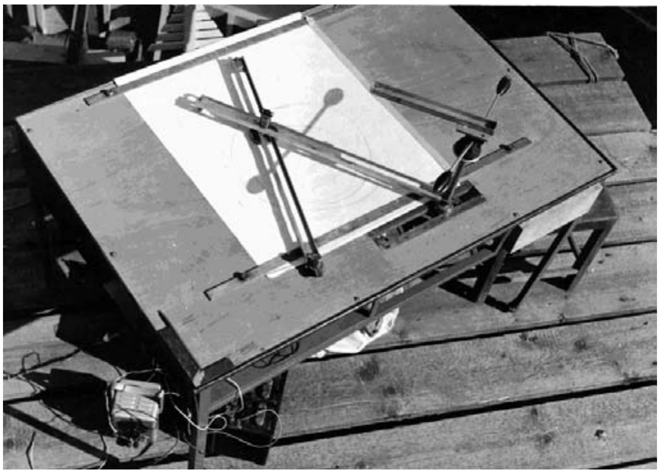

Figure 6. Operation table of pathgrapher – first version

In this way a current model path diagram was obtained in the scale determined by the AB/BC ratio. From distances of the points marked on the track in known time intervals the model speed during turn manoeuvre could be determined. In this way not only the turn manoeuvre elements but also other steerability characteristics, e.g. the stopping distance, were found. Accuracy of the diagram depended on the efficiency of the direction-finder operators (observers) and it was not as good as that of the present day automatic tracking devices, but then it was sufficient for practical purposes (the path recorder was developed by W.Welnicki and E.Adelman and patented under the patent number 55320).

For the zig-zag test an aeroplane gyroscope (a Mig plane „artificial horizon"), whose indications, photographed together with a stop-watch by means of a camera with automatic shutter spring drive, allowed to draw a diagram of heading angle as a function of time. The helmsman, observing the gyro-compass indications, laid the rudder at proper moments. Later an electric steering gear coupled with the gyro-compass was constructed and also an angular velocity measurement system. The drift angle was measured continuosly by means of a driftmeter. The driftmeter consisted of an unbalanced fin rotating freely around the vertical axis, moved out under the model bottom outside the boundary layer. The fin positioned itself always in parallel to the direction of speed and a potentiometer on its axis measured the angle between the model axis of symmetry and the direction of speed.

Figure 7. Model of fast general cargo vessel ready for tests

Also designed and constructed was a rudder stock moment measurement dynamometer, but the device was of little use due to little experience at that time with tensometric systems. Photographic technique was also used for the model tracking. From the top of a 36-meter tower positioned on the shore a stationary camera photographed, in fixed time intervals, light installed on the model, thus obtaining the model path diagram. That technique might be used only by night. Anyhow, the night tests were quite frequent as during the night it was easier to chance upon calm weather.

Tests were performed on free self-propelled models steered by man. The steering-control system allowed to use twin-screw propulsion with a possibility of independent manoeuvring of each propeller. It was planned to introduce radio-controlled models, but eventually it was not accomplished.

Beginning from 1961, the manoeuvring tests were performed in full scope, as it is today required by the IMO resolution.

Accuracy of tests

Special correlation investigations were carried out of the suitability of test methods and techniques used in the Ilawa Experimental Centre.

For the resistance and propulsion characteristics a model of the „Victory" type ship was used, for which comparative data were available from the ITTC tests carried out in Wageningen. The resistance and propulsion tests on the lake in Ilawa (1964) with the use of the measurement platform were performed on a 1:23 (5.89 m) model. The model tested in Wageningen was the same. The methodology was as described above, but the wake coefficient was determined by two methods: the effective wake coefficient - from comparison of the open water propeller and behind-hull propeller characteristics, the nominal wake coefficient was measured with the hydrometric current meters.

Comparison of the results was satisfactory:

- resistance differences for small speeds reached 7%, for greater speeds were negligible,
- the open water propeller characteristics were practically identical, as were the moment and thrust measured behind the hull,
- the w(ef) and t coefficients oscillated around the same values with a maximum deviation of ± 4%,
- the differences in propulsion efficiency did not exceed 3%.

In the tests of manoeuvring characteristics the comparative data were used from the ITTC programme of model tests performed in several test tanks and tests on real ships for the „Mariner" type ship (L=165 m). Tests in Ilawa were performed in 1965 on a 1:25 model with the above presented technique.

Comparison of the test results with the real ship characteristics was the following:

- circulation diameter: deviations from +4.5 to +8% (in Lyngby 4.7 to 9%, PMM tests),
- speed drops in circulation: mean value +3%,

- drift angle: approx. -5%,
- dimensionless yawing period from the zig-zag test: -0.5 to -8.2%,
- departure angle: -13 to -19%.

The relatively large departure angle error may be justified by model manual steering during the test, which probably caused delays in rudder laying in relation to the gyro-compass indications. The results were evaluated as good, comparable with those of well known model basins. It may be worth adding that discrepancy in the real ship circulation measurements performed by two different methods reached 6% on average.

Interesting research projects carried out in the Centre

In the years 1959–1980 some 40 models were tested in the lake centre for their resistance-propulsion and manoeuvrability properties, to the order of the shipbuilding industry, inland navigation, the navy and the engineering force design offices as well as in the government-financed research and development programmes. Many of them were tested in a few versions. At the end of 1970s the number of orders began to decrease rapidly due to opening of the large Ship Design and Research Centre (CTO) model basin in Oliwa.

The most interesting of those tasks are described here below.

One of the first and largest research programmes was the programme of propulsion and manoeuvrability tests of push trains ordered by the inland navigation craft design office in Wroclaw. The tests aimed not only at prediction of the hydrodynamic characteristics of the designed units but first of all at optimization of such elements as the shape of propeller tunnels, simplified propeller sleeve, multi-rudder systems, the impact of shallow water on the propulsion and manoeuvrability properties etc..

The tests lasted from 1959 to 1968 and covered 6 basic types of push trains, with the horsepower from 180 to 600 KM (4 twin-screw and 2 single screw units, including one with the pump-jet propulsion). The models were made in a small scale, 1:5 - 1:10, due to limited draught (small propeller diameter). One of the push trains was tested in shallow water (h/T=2.8; 4.0; 8.) to check the impact of water depth both on the propulsion and manoeuvrability characteristics. As it was impossible to find a water stretch in the lake with flat bottom and the required depth, a fish pond with adjustable water depth was rented near Ilawa, the pond bottom was levelled

Figure 8. *Train of pushed barges at tests*

and the tests were performed there. The tests resulted in many significant changes introduced to the original designs. Four types of those push trains went to series production and they have been sailing on the Odra river until now, held in good repute by the owners.

Interesting and fruitful resistance-propulsion and manoeuvrability tests were performed at the beginning of 1960s on a series of models of the landing assault ships designed by the Ship Design Office No.2. The main purpose of the tests was optimization of the stern shape and choice of propellers and an important requirement was achieving a maximum pull in the astern motion.

Another interesting task was the programme of systematic tests of fast single- and twin-propeller general cargo vessels, carried out in the years 1969-1975 within the 08.12 research programme in cooperation with the Ship Design Office No.1. Preliminary resistance tests were performed on 11 small models in the GUT Department of Ship Hydromechanics test tank and the resistance-propulsion and manoeuvrability tests were carried out in Ilawa on 8, large 6-meter models. The programme included also measurements and analysis of the velocity distribution in the propeller disk for the stern shape optimization from the propeller design point of view.

In the 1984/85 winter interesting tests were performed of an ice-breaker in natural ice. For that purpose the non-freezing mouth of the river Ilawka to the lake was used - the model could gather momentum in the ice-free water and then enter the ice field with impetus. The problem to be solved there was the scale effect in the ice thickness and strength calculations.

In the years 1986-1991, within the 9.5 research programme, the task no. 9: „Hydrodynamic design of an energy-saving medium-size bulk carrier" was carried out. The project was performed in cooperation with the Polish Steamship Company in Szczecin. Part of the large model tests were performed in the CTO towing tank and part in Ilawa. The aim of the research work was optimization of the hull shape with particular attention given to the stern shape in order to increase the propulsive efficiency. Within that programme a patented design of fore-propeller nozzle was developed, which gave almost 5% improvement of the propulsive efficiency. It was then confirmed by measurements taken in a trip of the real ship.

An interesting task was testing of the resistance-propulsion and manoeuvring properties of a fast (40 knots) „wave-piercing" passenger catamaran, carried out in 1994. It was financed by a Scientific Research Committee grant „Twin-hull ships - an energy-saving type of ship for the near future". The model was 8 m long, speed was 9 m/s and it was driven by two outboard motors. Because of the great speed, the resistance and propulsion tests were carried out with the fast measurement platform normally used for the hovercraft and hydrofoil tests; the manoeuvrability tests were performed on the same free manned model.

Figure 9. *Fast catamaran model at turning test*

Other non-standard investigations included testing the thrusters for the 773 and 775 navy units (1969-1970), bulk-carrier optimization tests (1984-1986), investigations of the scale effect in the propulsion characteristics performed on the „Zawrat" type large tanker model (1981-1982).

Typical tests performed only with the aim of obtaining predictions for newly designed ships of various types are not a subject of this paper. More than 20 models were tested for that purpose in Ilawa.

Other interesting non-typical tasks are discussed in this Symposium by other authors.

Conclusion

Results of many above mentioned investigations were published in the technical journals and in many conferences in Poland and abroad. It may now be estimated that the GUT Experimental Centre in Ilawa has played an important role in the development of the Polish shipbuilding industry, being used as a substitute for the then non-existent large towing tank and contributing in its way to the progress in ship hydromechanics. This is to the credit of the great energy and initiative of professor Lech Kobylinski as well as of the intense work, creative ideas and involvement of all the workers of the GUT Chair of the Theory of Ships and later the Department of Hydromechanics, who simply cannot be all mentioned here by name.