Model tests in open waters – a concept that did pay off

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Abstract

The paper presents the concept of performing model tests in open waters. This concept was realized in the Ilawa Experimental Station arranged on the shore of the Jeziorak Lake in 1956. Since then model tests of high-speed craft, manoeuvrability and propulsion characteristics of conventional seagoing ships and inland waterways push tugs-barges systems have been performed there. New concepts of how to perform the tests were developed. The advantages of performing model tests in open waters were stressed and future possible applications suggested. The activity of the experimental station that belonged to the Technical University of Gdańsk greatly contributed to.

Keywords: *high-speed craft, ship model tests, ship hydrodynamics, the development of ship hydrodynamics science in Poland*

INTRODUCTION

Model test are the most important tool in ship design. When William Froude in 1872 constructed the first towing tank for testing ship models, in order to predict resistance and propulsion characteristics of ships to be built, the model testing technique started to develop rapidly. In several countries interested in shipbuilding a number of towing tanks were constructed, and in the course of years, apart from testing ship resistance and propulsion characteristics of ships, other facilities were constructed for testing cavitation characteristics of ship propellers, seakeeping and manoeuvring characteristics of ships and for testing hydrodynamic characteristics specific to some types of ships. Large universal ship hydrodynamic laboratories came to life. The cost of building and operating such laboratories was, however, enormous.

In Poland, after the WW II shipbuilding industry started to develop rapidly and there was an

initiative to build a hydrodynamic laboratory. This, however, would require several years to achieve. There was a compelling need to arrange model tests as soon as possible in order to perform research programs, to train students and research workers for the future towing tank as well as to solve current problems of the industry that would require model testing.

In this situation in the year 1956 in the Chair of Naval Architecture, Technical University of Gdansk the concept was proposed to conduct model tests in open waters, such as lakes and large ponds. Suitable place was found in Ilawa and preliminary tests were performed there. The concept appeared to be very successful and in the following years many research projects were executed there as well as hundreds of ship models were tested for the shipbuilding industry.

Strictly speaking the concept of conducting model tests in open waters was not new. There were some historical references about model tests performed in open waters in 18th century, e.g. tests performed by D'Alembert in 1775. Later, construction of towing tanks caused that performing model tests in open waters was not expedient.

In the early 1930s the need emerged to predict manoeuvring characteristics of ships during the design stage and then free running self propelled models started to be used for this purpose. Such tests could not be performed in the conventional Froude-type towing tanks and this resulted in increased interest in performing model test in open waters. In the early 1970s some nine experimental stations were involved in this activity [4]. Ilawa experimental station was, however, unique because it was able to perform wide range of model tests, including resistance and propulsion, seakeeping and manoeuvring test, tests of high speed and non-conventional craft and many others. The ideas and facilities were developed over the years and the whole enterprise started in 1956 with tests of a hydrofoil craft manned model.

Construction of a hydrodynamic laboratory by the shipbuilding industry caused that some model tests were not performed in the Ilawa experimental station any more. There were attempts made in order to find suitable field of activity for the facility. One of the new fields was to use large manned model for training of ship masters and pilots in ship handling. This idea appeared to be very fruitful and in the late 1980's – early 1990's a separate ship handling research and training centre was organized on a nearby Silm lake. The old experimental station is still active used mainly for performing tests of high-speed craft and to perform some non-conventional tests impossible to execute in a towing tank.

The development of the Ilawa experimental station is illustrated by two sketches: Fig.1 showing the lay-out of the station in 1957 and Fig. 2 – in 1971. At present the plan of the station is almost the same.

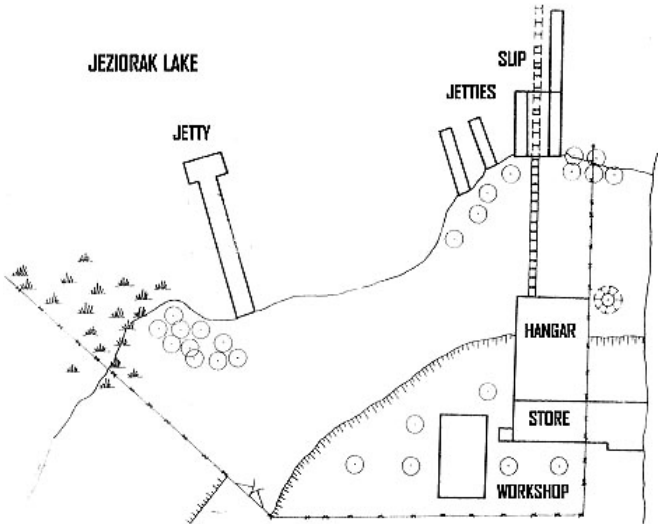
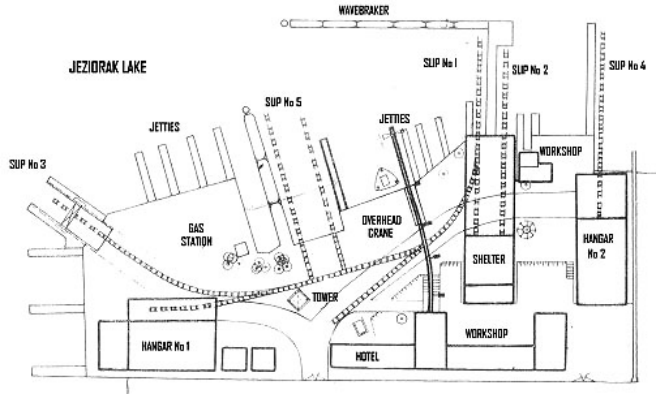


Fig.1. *Ilawa experimental station in 1957*
Fig.2. *Ilawa experimental station in 1971*



Tests of propulsive characteristics of ship models

From the point of view of ship design the most important issue is prediction of speed and power required. This is usually achieved on the basis of results of propulsive characteristics of ships.

From the early beginning of the activity of the Ilawa experimental station attempts were made to test propulsive characteristics of models as accurately as possible. The main difficulty consisted in measurements of resistance and propeller characteristics of models. In towing tanks there is a routine technique where model is towed by the towing carriage. In order to test propulsion characteristics the model is self-propelled , but in order to achieve self propulsion point of ship it is necessary to apply to it additional towing force to allow for the difference between frictional resistance of the model and full scale ship

During the first trials the models used were self propelled and manned, however it was impossible to measure model resistance without propulsion and also to apply additional towing force in the self-propulsion tests. Prediction of speed and power was therefore not accurate enough. But as the proverb says: "the need is mother of invention", so later a kind of towing carriage was built in the form of a catamaran (Fig.3) where model was towed (or rather pushed) enabling measurements of resistance without propeller and measurements of propulsion characteristics with additional towing force applied. Measuring team was located on the catamaran where also all measurements were taken. This method made open water tests very similar to measurements taken in a towing tank. The advantage of this method was that the measurement stretch was not limited and could be even a few kilometers, which was very useful for example, for taking measurements of pressure distribution in the propeller disc [2].

The above described method of performing propulsion tests was very successful, and in the industrial ship hydrodynamic centre similar catamaran had been built and used until the time

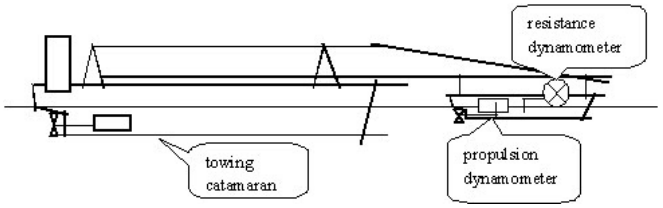


Fig.3. Scheme of the towing catamaran and model

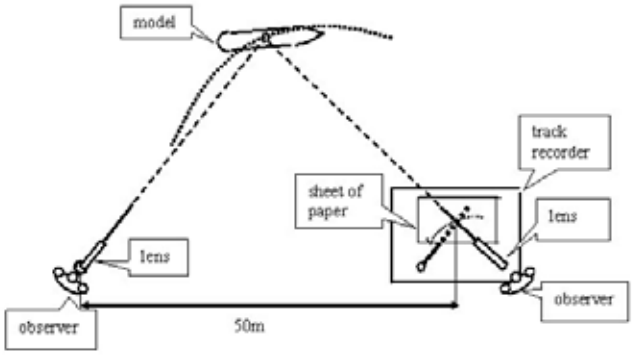
when the towing tank under construction was in operation. Some models were tested using this catamaran on Wdzydze Lake. Altogether in Ilawa in the years 1960-1975 almost 50 large self-propelled models were tested. Later, when the towing tank in Oliwa was put into operation the resistance and propulsion tests for shipyards were not performed any more, but still the catamaran was used for research purposes.

Tests of manoeuvring characteristics

Model tests are essential for the prediction of manoeuvring characteristics of ships during the design stage. When the Ilawa experimental station was organized, there already existed a few experimental stations in the world using free-running models tested in open waters. In Ilawa from the very beginning free-running self propelled and manned models were used for testing manoeuvring characteristics, and in particular turning tests, zig-zag tests, stopping tests and course-keeping tests were performed. The main problem to be solved was to arrange reliable monitoring system of the track of the model. The original method developed was "track recorder" based on the simple idea of observing model from two points located at certain distance. This idea is illustrated in Fig. 4.

Fig.4. *Scheme of the track recorder*

The instrument consisted of a table on which sheet of



paper was spread. There were two arms, one was attached to the lens and the other was under the sheet of paper and remotely controlled by another lens located at the point at a distance of 50 m. Two people observing the mast of manoeuvring model operated these two lenses. At every second, or half second, the spark was induced at the cross-section between two arms making small hole in the paper. The series of holes reproduced turning circle of the model in a reduced scale. The method was very accurate provided the two observers carefully followed motion of the model.

In the Ilawa experimental station also a different method of model tracking was used. In this method the camera located on a high tower on the shore of the lake recorded motions of the model on which there were two small lights blinking in one or half-second period. This method was used at night time only, and the main difficultly was to draw model track from the series of dots appearing on the plate.

In the 1960's and early 1970's there was little demand by shipyards for prediction of manoeuvring characteristics of conventional seagoing ships, therefore the majority of manoeuvring tests were performed with inland waterways vessels. In particular several pushing tug-barge systems designed for the Odra river were tested where different configurations of rudders were installed. Sometimes the models of pushing tug-barge systems tested were as long as 20m.

Tests of high-speed craft

The programme of development of high-speed craft was established in the Technical University of Gdansk quite early, in 1955. The main goal was to investigate possibilities of bui-

lding hydrofoil craft for military and commercial applications. In the 1970s also design studies of hovercraft were included. Also high-speed planning boats were investigated.

The important part of this programme consisted of model tests; all of them were performed in the Ilawa experimental station. Actually the development of the station started with test of hydrofoil craft, because the first experimental model craft must have been tested in large open water areas and the suitable place at that time was found in Ilawa.

From the very beginning of executing the research programme on the development of hydrofoil craft, the craft designed was tested in the model scale. The models were constructed in a large scale say 1:3, they were propelled either with an overboard motor or with the built-in motor as in the full scale craft and controlled by the crew. This method allowed testing not only propulsive characteristics of the model, but also manoeuvring and seakeeping characteristics and overall behaviour of the model in different operational situations – different loading, trim, effect of initial list etc. Completion of such tests provided very comprehensive view on the operational characteristics of the designed craft. Fig.5 shows photo of a model under tests [3].

Fig.5. *Hydrofoil model W-2 undergoing tests in Ilawa experimental station*

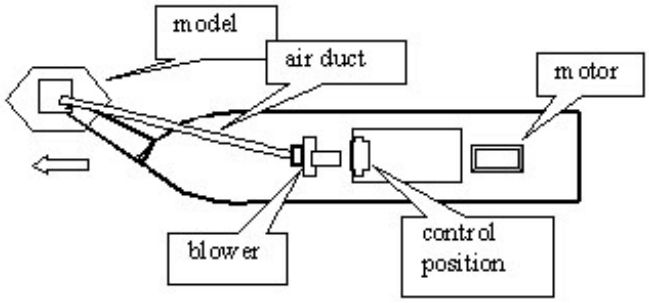
In order to obtain quantitative values of hydrodynamic

characteristics of the model ingenious measuring apparatus had to be designed and constructed, because at that time it was impossible to acquire suitable apparatus in the market. With the development of electronic computerised measuring devices the situation at present is completely different, but forty years ago there was nothing of that kind in the market.

In early 1970's research programme concerning design aspects of hovercraft was established and a series of tests of different configurations of skirts were performed. The skirts must be tested in a rather large scale and for this purpose a special towing platform was constructed. It consisted of one of the large boats available in the station. The motor driven blower was installed on the boat and the hovercraft model was attached to the outrigger and connected by the air duct with the blower. Many different skirts were tested using this facility (see fig 6) [5].

For testing resistance characteristics of hydrofoil models and other high-speed craft the high-speed towing platform was constructed. The principle was similar to that of the towing platform for testing conventional vessels, in the form of a catamaran where the model was located in front of the platform, but the speed of the catamaran was considerably higher, up to 7 m/s allowing to test high speed models. This catamaran exists up to present days and is still used.

Fig.6. *Sketch of the arrangement for testing hovercraft skirts*

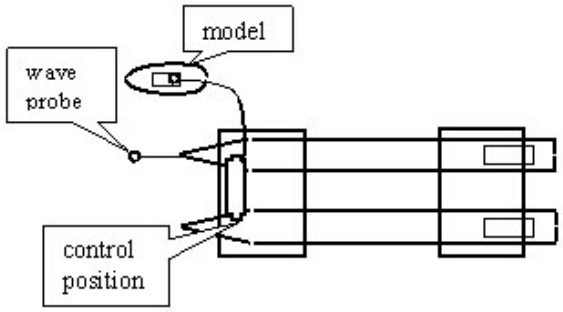


Seakeeping and stability tests

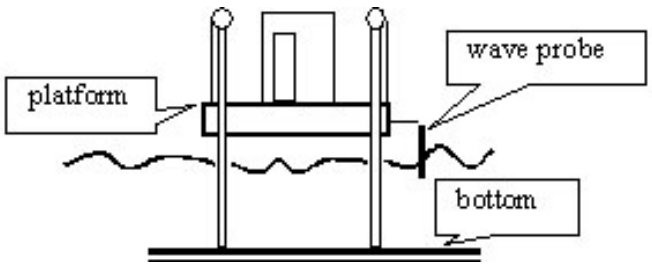
In the late 1960's – early 1970's research programme on stability criteria was established and as a part of this programme tests of behaviour of models in natural seaway leading to capsizing were planned. The University of Hamburg team previously performed capsizing experiments where remotely controlled models were tested on Ploener Lake.

In Ilawa different technique of performing these tests was used. Special floating platform in the form of a catamaran was constructed. The model was self-propelled running in proximity of the platform and connected with the platform with flexible cables. This solved the problem of power supply to the model and transmission of data, which were recorded on the platform. This allowed also to locate the research team close to the model, making photographs and visual observations that were very important. The sketch of the arrangement is shown in Fig.7 [1].

Fig. 7. *Sketch of the arrangement for capsizing tests*
Fig.8. *Sketch of the platform for wave measurements.*



Waves were measured in front of the catamaran using wave



probe. Other measurements of waves were taken in the area of experiments. For this purpose a movable platform on three legs resting on the bottom of the lake was constructed (Fig.8).

The arrangement used in Ilawa was a model for a similar arrangement used later by the University of Berkeley in San Francisco Bay.

Non- conventional tests

Apart from the above mentioned tests quite often Ilawa experimental station was used for non-conventional tests. In each such case original testing technique and measuring system must have been invented taking into account financial and technical limitations. Such non-conventional model tests comprised *inter allia*:

- tests of the tractor tug with various types of cycloidal propellers
- tests of model with jet-gas propulsion
- tests of side launching
- tests of side-wall air cushion craft
- test of fishing nets
- tests of sporting canoes
- tests of segmented barge
- tests of large SWATH model

and some others.

Training of ship masters and pilots

In the mid-1970's it was proposed to use the Ilawa experimental station for training ship masters and pilots in ship handling using large manned models. This method had been already used for some time in Port Revel in France and a few Polish masters were sent there for training, but as the cost of the training was very high the possibility was investigated to use Ilawa for this purpose.

There was already accumulated experience in Ilawa with building and operating large manned models, also some experiments intended to test port arrangement from the point of view of a possibility of easy handling of ships were already performed. In these tests the mock-up of Northern Port in Gdansk (under construction) was installed in the scale 1:25 in the northern part of the lake in shallow water and large tanker model was handled there using four model tugs. Students who pulled thin wires representing towropes in appropriate scale handled tugs. The experience gathered made it possible to prepare the experimental station for training purposes.

The first model for training purposes was put into operation in 1980 and in the following years two other models were included into the fleet of models used for training. It appeared, however, that Jeziorak lake, on the shore of which the Ilawa experimental station is located, was not particularly suitable for training purposes. There was too much traffic of sailing yachts and other craft. The shores are not sheltered enough from prevailing winds and there was very limited possibility to install mock-ups of different ports and other facilities required for training. Therefore plans for a separate training centre located on lake SILM nearby were drawn and were presented to the Secretary General of IMO, Mr. H.Srivastava during his visit to Poland (see Fig.9) receiving his full support. Ultimately in 1990 new training centre was put into operation and the Foundation for Safety of Navigation and Environment Protection was created as a joint enterprise of the Technical University of Gdańsk, Marine Academy of Gdynia and the City of Ilawa. Now the Foundation is running the training centre [6]. In the years 1980-1990 almost 500 Polish ship masters and pilots were trained in Ilawa experimental station in week-long courses.

Contribution of the Ilawa experimental station to the development of ship research.

Organization of Ilawa experimental station and opening of the possibilities to perform model tests contributed greatly to the progress of knowledge in ship hydrodynamics in Poland. A number of research workers and students from the university, but also from other institutions, who performed model tests in Ilawa in open waters studied hydrodynamic phenomena connected with ship motions, many of them based their doctor thesis on experiments realized there. Many research programmes were accomplished, if only to mention *inter allia* the following:

- Investigation of basic hydrodynamic and design problems of hydrofoils and other high-speed craft
- Investigation of stability and capsizing phenomena in waves
- Optimisation of hull form of cargo vessels from the point of view of resistance and propulsion
- Optimisation of nozzle-propellers
- Investigation of scale effect in propulsion model tests
- Optimisation of rudder arrangement and manoeuvring characteristics of push-barge systems

Fig. 9. *Visit of the Secretary General of IMO, Mr. Srivastava in Ilawa experimental station (1975)*

The results of the research programmes and model tests in Ilawa were described in numerous articles in scientific magazines, papers presented at the conferences and in internal reports. In the list prepared in 1974 there were 240 items mentioned.

In 1971 the Symposium on Model Tests in Open Waters was organized in Ilawa. This was the first conference in Poland on ship hydrodynamics. It was followed in 1973 by the first HYDRONAV conference held also in Ilawa, which was the first in the series of conferences on ship hydrodynamics organized every second year by different interested institutions (the last one was 16th in the series, held in Ostroda). Since 1995 these conferences have had international character with papers presented in English. They create important forum for presenting results of research programmes and exchanging experience and views in the field of ship hydrodynamics.

General view on perspectives and possibilities of open water model tests

From the perspective of 50 years of existence of the Ilawa experimental station it may be stated that open waters, like lakes or large ponds, form an excellent area for performing model tests of various kind. They do not supersede towing tanks – routine model tests of propulsion, seakeeping tests, some manoeuvring test certainly could be better executed there. However, having suitable open water area considerably extends research capability.

First of all experience gathered in Ilawa shows that designing high-speed craft, in particular hydrofoils, hovercraft or wing-in-ground craft requires building large manned models forming intermediate stage between small model tested in a towing tank and full-scale craft. Only such large model al-

lows to investigate all motion characteristics of the craft and the effect of handling it.

Another field, where large models in open water are of use, is manoeuvrability. All manoeuvring characteristics including turning tests, stopping tests, spiral tests etc. could be performed only in open waters. Manoeuvring tanks are as a rule too small. Small models used there are burdened by considerable scale effect. Training in ship handling using large manned models requires also large open water area.

Open water areas are also very useful to perform non-conventional model tests. This was obvious from the experience gained in Ilawa. Finally, testing models by the towing catamaran over a very long distance reaching sometimes a few kilometres is very instructive allowing to make observations and measurements that could hardly be made on the short measuring section of a towing tank.

Open water model tests have also many disadvantages, first of all dependence on the weather conditions. From this point of view routine model tests with strict schedule and fixed deadline for providing results are difficult to perform. Model tests performed by universities within the scope of research programmes, student model experiments etc. are typical jobs of open water experimental stations. The advantage of such stations is rather low investment cost

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