Seventh International Conference on Ship Hydrodynamics, 1954

Subjects 1 and 5 - Scale Effects on Propellers and on Self-Propulsion Factors

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1. Experiments with "Hakubasan Maru"

Since 1950, under the financial assistance of Ministry of Education, the Experiment Tank Committee of the Society of Naval Architects of Japan has carried out the expensive experiments with a single-screw cargo ship "Hakubasan Maru" and her models, to investigate the scale effects on the resistance and propulsion of ships. The first report, entitled "Trial Results of Hakubasan Maru" was published in 1951, and its abstract was given in "Abstract Notes and Data Concerning the Subjects at the Sixth International Conference of Ship Tank Superintendents, 1951", which was distributed at the Conference. A copy of the second report, entitled "Report of the Experiments on the Hakubasan-Maru Models", which the Experiment Tank Committee of Japan has prepared for the Seventh International Conference on Ship Hydrodynamics, 1954, is to be distributed to each delegate at the coming Conference. I believe that it will serve as a good reference to discuss the present subjects, and also subjects 2 and 4.

2. Experiments with "Yayoi Maru"

Under the financial assistance of Ministry of Transportation, the Shipbuilding Research Association of Japan has completed the full-scale experiments with a single-screw small training ship "Yayoi Maru" of the University of Mercantile Marine, and with her models, to investigate

(1) the scale effects on the resistance, wake, propeller performance, and other self-propulsion factors,

(2) the effect of bottom fouling on the resistance, wake, and propulsive performance of the ship,

(3) the effect of propeller fouling on the propulsive performance of the ship, and

(4) the combined effect of bottom and propeller foulings on the propulsive performance of the ship.

Her principal particulars are

Length B.P.	18.288m
Breadth including skin	4.284m
Depth	2.414m
Draught from bottom of keel	1.934m
Displacement	78.7t
Main engine ..... 200B.H.P. x 380R.P.M. diesel engine	
Propeller .... 3-bladed solid type	
Diameter	1.625m
Pitch(constant)	0.983m

"Yayoi Maru", which had been carefully repainted with commercial paint at the end of June of 1952, was moored in Orio Bay of Shimizu. About ten series of measurements having been made, the whole test scheme with the full-sized ship was accomplished at the beginning of June of 1954. The measurements consisted of

(1) the measurements of resistance and wake with "Yayoi Maru", towed by a single-screw tug, and

(2) the measurements of the thrust, torque and revolutions of a propeller of "Yayoi Maru", moored to the quay, as well as self-propelled under the conditions of running freely and towing sea-anchors.

The model tests, corresponding to these measurements, have been carried out at Experiment Tank and Wind Tunnel of Transportation Technical Research Institute in Tokyo.

The test results obtained with both "Yayoi Maru" and her models are now under analysation, and the final conclusions will be drawn by the end of 1954. I believe that they may throw light on the scale effects on propellers and self-propulsion factors, and also on the problems of skin friction.

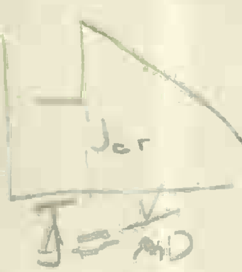
3. Scale effect on a propeller with air-drawing phenomenon

For a propeller which is deeply immersed, and free from cavitation or air-drawing phenomenon, the scale effect on its characteristics is mainly due to the viscosity of water, and is believed to disappear practically at Reynolds numbers higher than a certain critical value.

The characteristics of a propeller, which works near the surface of water and air is sucked down, are considered as a function of not only advance constant and Reynolds number, but Froude and Weber numbers. However, since Reynolds and Weber numbers have little effect on the characteristics of a propeller with air-drawing phenomenon, its characteristics may be represented by the expression

$$C_T,\ C_Q \text{ and } \eta_p = f\left(\frac{V}{nD},\ n\sqrt{\frac{D}{g}}\right).$$

According to Shiba's experimental results, the influence of Froude number $n\sqrt{D/g}$ disappears practically when its value reaches about 3, which means that air cavity takes an ultimate form at this value. With most full-sized marine propellers, their Froude numbers for ordinary working conditions are within 1.0 to 1.4, so at the open-water tests with model propellers after air is sucked down Froude number should be chosen the same as for the working conditions of their full-sized propellers.



The critical advance constant, J_{cr}, where a marked fall in characteristic curve takes place due to the occurrence of air-drawing phenomenon, are also considered as a function of the three numbers quoted above. But, as Reynolds and Froude numbers have little effect on the critical advance constant, it may be deal with as a function of Weber number only, namely,

$$J_{cr} = f\left(nD\sqrt{\frac{\rho}{S}D}\right),$$

where S is the surface tension of water. Shiba's experiments show that the critical value of Weber number at which its influence practically disappears is about 1.8×10^2. In general, Weber numbers for ordinary working conditions of most marine propellers are much higher than this critical value. Therefore, if we want to predict the accurate value of the critical advance constant of a full-sized propeller, it is absolutely necessary to choose Weber number higher than 1.8×10^2 at its model-propeller open-water test.