Sample Abstract

33rd Symposium on Naval Hydrodynamics
Osaka, Japan, 31 May - 5 June 2020

Experimental Study on Drag Reduction by Air Cavities on a Ship Model

Oleksandr Zverkhovskyi[1,*], T. van Terwisga[1,2], R. Delfos[1], J. Westerweel[1] and M. Gunsing[2]

[1]Delft University of Technology, the Netherlands
[2]MARIN, the Netherlands
*Corresponding author, E-mail: o.zverkhovskyi@gmail.com, Tel.: +31-620830303.

Topic Category: Cavitation and Multi-phase Flows

INTRODUCTION

For slow steaming ship such as tankers and inland ships, the frictional drag has the largest contribution to the total resistance. Therefore reducing the frictional drag can contribute significantly to reduction of energy consumption. In this paper the friction drag reduction (DR) by air lubrication is experimentally investigated, since it is potentially one of the most efficient techniques to reduce the power consumption of ships [1, 2, 3, 4, 5]. Air cavities are applied at the bottom of the ship model to reduce the amount of wetted surface. It is presumed that reduction of the drag exceeds the extra drag created due to the devices required to create the cavities.

The objectives of this study are to:

- investigate the geometrical parameters of the cavities on the bottom of the ship model at different velocities,
- estimate an efficiency of the drag reduction by air cavities on the ship model,
- study an influence of the ambient waves on the cavities and their drag reduction effect.

APPROACH

An 8 m scale model of the DAMEN River Liner is used for the model test, which is regarded as a representative model for an inland waterway ship. This ship model was equipped with an air cavities generating system that includes cavitators, skegs and air supply system. It was tested in the Sea-keeping and Maneuvering Basin (SMB) at MARIN.

The total drag force was measured to determine the efficiency of the air cavities. The total resistance of the self-propelled model was measured as the sum of the obtained values for the thrust on the two propellers and the towing force measured in the X-direction by a load cell (see Figure 1a). For each velocity a reference value was defined without any air injection followed by the measurement with air injection.

Two underwater cameras were used to visualize the cavities during the test. The video recordings give information on the contours and dynamics of the cavities in the bottom plane. The experimental program comprised tests of the system in both calm water and in waves. In calm water the measurements were done at a velocity range from 1.1 to 1.9 m/s (Fr=0.12-0.21) with a step of 0.1 m/s, both with and without air cavities. This velocity range represents typical working velocities of the vessel. For further exploration of the stability and dynamic characteristics of the air cavities system, the experiments were conducted in regular head waves which are only one of

the possible wave directions in reality. No beam waves could be tested because of the specifics of the measurement set-up that restrained the roll-motion of the model.

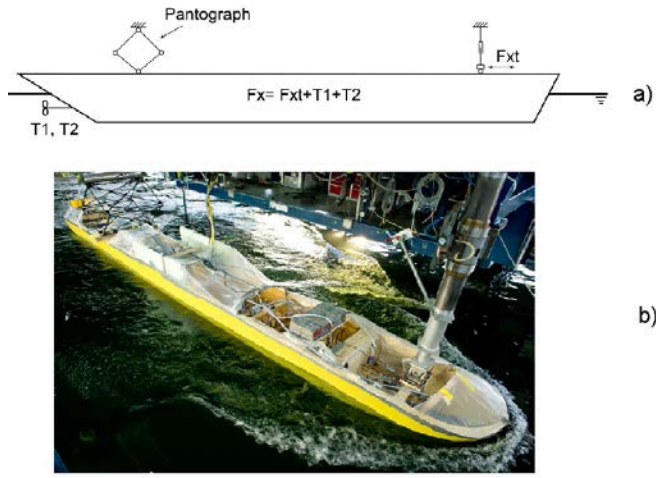

Figure 1. Experimental setup: (a) schematic (b) photo.

RESULTS

It was observed that the flow around the ship model affects the the cavities. More specifically, the cavities in the forward part of the bottom are affected, most likely, by the pressure and velocity non-uniformity generated by the bow. This effect was expressed in the extended cavity length and thickness. The local flow characteristics around the ship are expected to significantly influence the cavity parameters.

The drag reduction was estimated from the difference between the drag measurements with and without air cavities. The results of the drag reduction as a function of the Froude number are shown in Figure 2. The gross drag reduction appears to vary between 12 and 17.5%. An approximation of the total wetted area reduction, assessed from the underwater visualization, is also shown in Figure 2. The drag reduction correlates well with the wetted area reduction. The highest drag reduction effect of 17.5% is observed at the highest wetted area reduction of 39%, whereas the bottom area where the cavities were formed is 45% of the total wetted area on the ship with the skegs. Thus, for the most efficient case, the cavities cover 85% of the possible area.

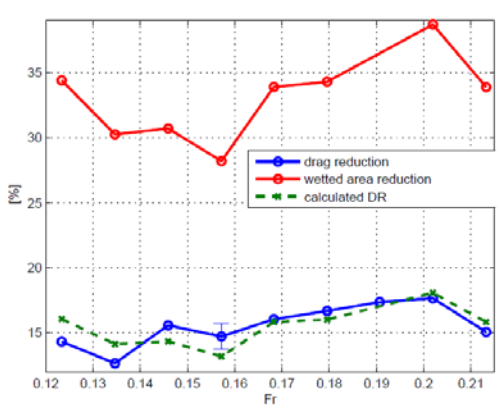

Figure 2. Drag reduction and wetted area reduction as a function of Froude number. Calculated DR is based on the measured wetted area reduction.

Sample Abstract

The total drag force measurement in waves normalized by the calm water force measurements are shown in Figure 3 as a function of the wave period for conditions with and without air. As can be seen from this figure, the maximum added resistance with no air is about 15% and 43% for a 0.5 m and 1 m wave height respectively.

The short period waves also have an influence on the cavities. The video observations showed that the cavity length fluctuated within ~10% during a wave passage, sometimes leading to an instability of the cavities. At the longest wave period there was no significant influence of the waves on the cavities any more. This reduction of the wave action effect can also be observed from the drag force measurement data with air in Figure 3. The efficiency of the drag reduction drops to 10-12% for the short period waves whereas for the long period waves it is the same as for calm water.

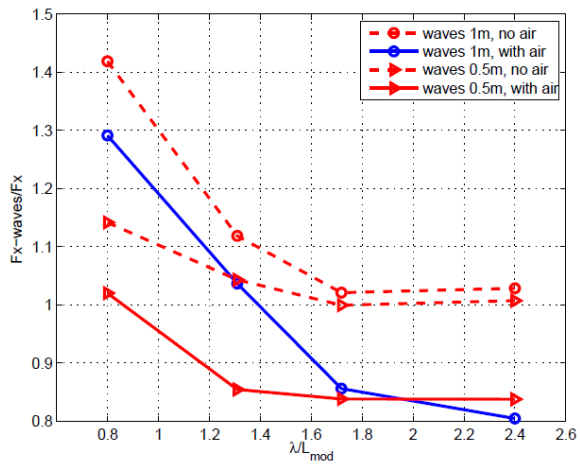

Figure 3. Added drag of the ship model in head waves, with and without air cavities.

REFERENCES

[1] Butuzov A.A., 1965, "Experimental investigation on artificial cavities created on a flat ship bottom," *Sudnostroenie*, 218, 100-112 (in Russian).

[2] Lay, K. R.Yakushiji, S. Makiharju, M. Perlin, and S.L. Ceccio, 2010, "Partial Cavity Drag Reduction at High Reynolds Numbers," *Journal of Ship Research*, Vol. 54, No. 2, pp 109-119.

[3] Matveev, K.I. 2003, "On limiting parameters of artificial cavitation," *Ocean Engineering*, 30, pp 1179-1190.

[4] Shiri, A., M. Leer-Andersen, R.E. Bensow and J. Norrby, "Hydrodynamics of a displacement air cavity ship," Proceedings of the *29th Symposium on Naval Hydrodynamics*, Gothenburg, Sweden, August 2012.

[5] Mkiharju, S.A., B.R. Elbing, A. Wiggins, D.R. Dowling, M. Perlin and S.L. Ceccio. "Perturbed partial cavity drag reduction at high Reynolds number," Proceedings of the *28th Symposium on Naval Hydrodynamics*, Pasadena, California, September 2010.