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Numerical analysis of effect of asymmetric stern of ship on its screw propeller efficiency

Tomasz Abramowski, Ph. D.
Katarzyna Żelazny, D.Sc., Eng.
Tadeusz Szelangiewicz, Prof.
West Pomeranian University of Technology, Szczecin

ABSTRACT

During designing the ship its designer tends to achieve as-high-as possible efficiency of ship's propulsion system. The greatest impact on the efficiency is introduced by ship's screw propeller whose efficiency depends not only on its geometry but also distribution of wake current velocity. To change wake current distribution and improve propeller efficiency an asymmetric form is usually applied to stern part of ship hull. This paper presents results of numerical analysis of wake current velocity distribution, performed by using a CFD method for a B 573 ship of symmetric stern and the same ship of an asymmetric stern. Next, the mean values of screw propeller efficiency in non-homogenous water velocity field were calculated for both the hull versions of B 573 ship.

Keywords: asymmetric ship's stern; computational fluid dynamics (CFD); screw propeller efficiency

INTRODUCTION

During designing the ship one of the most important tasks is to so design its propulsion system as to ensure reaching an assumed service speed at as-high-as-possible propulsion efficiency. Screw propeller constitutes the crucial element of the propulsion system, whose efficiency decides on the overall propulsive efficiency of the ship. Screw propeller efficiency depends mainly on its geometry and loading as well as water velocity distribution in wake current. To improve the wake velocity distribution various additional devices such as: nozzles, half-nozzles or suitably profiled fins attached to underwater part of ship's hull before screw propeller, are applied [13] (sometimes they are intended for the mitigating of hull plating vibration resulting from operation of screw propeller). Another solution intended for the changing of wake velocity distribution and improving of propeller efficiency is to apply an asymmetric form to ship's hull stern in its underwater part.

Since 1982 have appeared ships of an asymmetric stern, designed and built in accordance with the patents [8, 9, 10, 12]. Model tests and measurements performed on existing ships showed a decrease in propulsion power in the range from 5 to 10 % [4, 6, 7, 11]. Also, B 183 container carriers built by Szczecin Shipyard, were fitted with an asymmetric stern.

Within the frame of the R&D project [9] comparative wake current investigations for the B 573 ship of symmetric stern, whose model test results were available [5], and for the ship's hull of a modified form – introduction of an asymmetric stern, were made. The modification of underwater part of hull was introduced in a very limited range so as to keep the ship's main design parameters, unchanged. For both the obtained wake currents, the calculations of mean value of screw propeller efficiency in non-homogenous water velocity field, were performed.

NUMERICAL CALCULATIONS OF WAKE CURRENT

The numerical calculations of wake current for the B 573 ship's hull of modified stern part, were conducted with the use of Fluent system; the hull stern body lines are presented in Fig. 1.

In advance of the actual calculations a comparative test was performed for the symmetric version of the ship's hull (Fig. 1a), results of which compared with those of the model tests are presented in [2]. Next, wake current calculations for the asymmetric ship hull (Fig. 1b) were made (details concerning its computational model and numerical mesh are contained in [1]). Example axial velocity profiles and velocity vectors in propeller disc area are given in Fig. 2 and 3. Distribution of circumferential and axial velocity components for the asymmetric stern, is shown in Fig. 4. The effect of the asymmetric stern on wake fraction distribution as compared with that for the symmetric stern, is presented in Fig. 5.

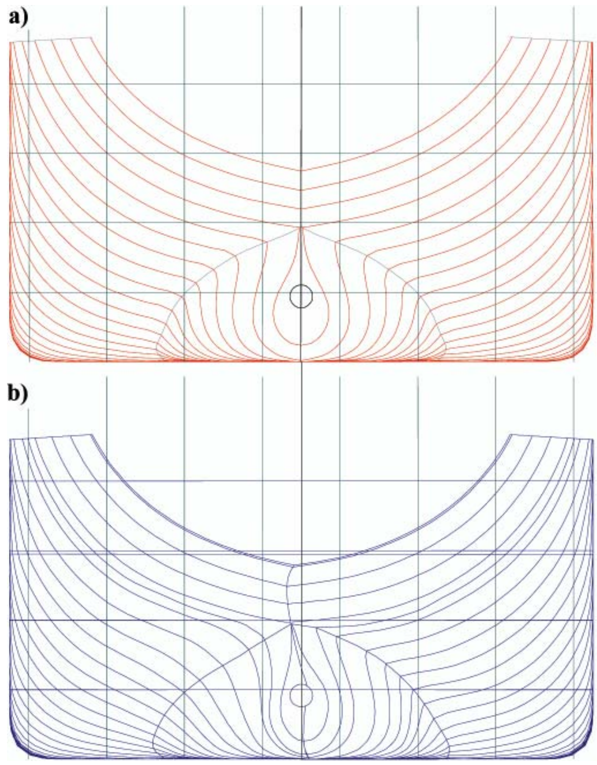

Fig. 1. *Body lines of stern part of B 573 ship hull:* ***a)*** *before modification (symmetric stern),* ***b)*** *after modification (asymmetric stern)*

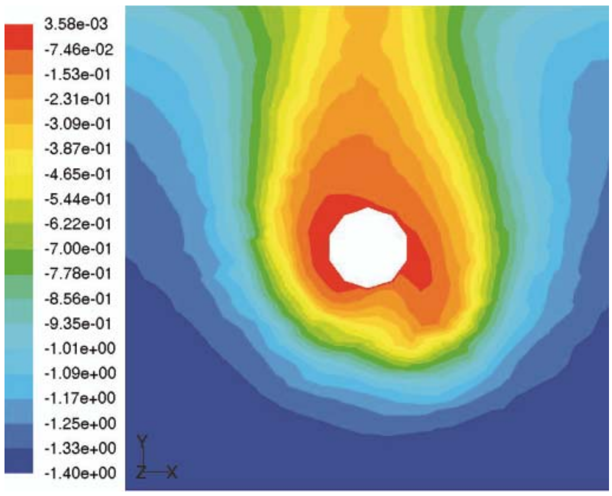

Fig. 2. *Axial velocity profiles – asymmetric stern*

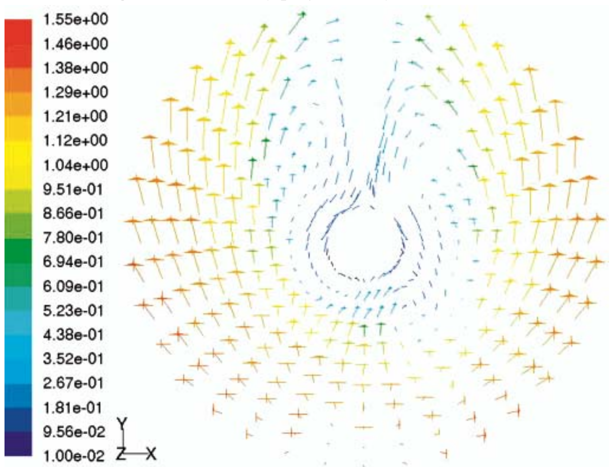

Fig. 3. *Velocity vectors – asymmetric stern*

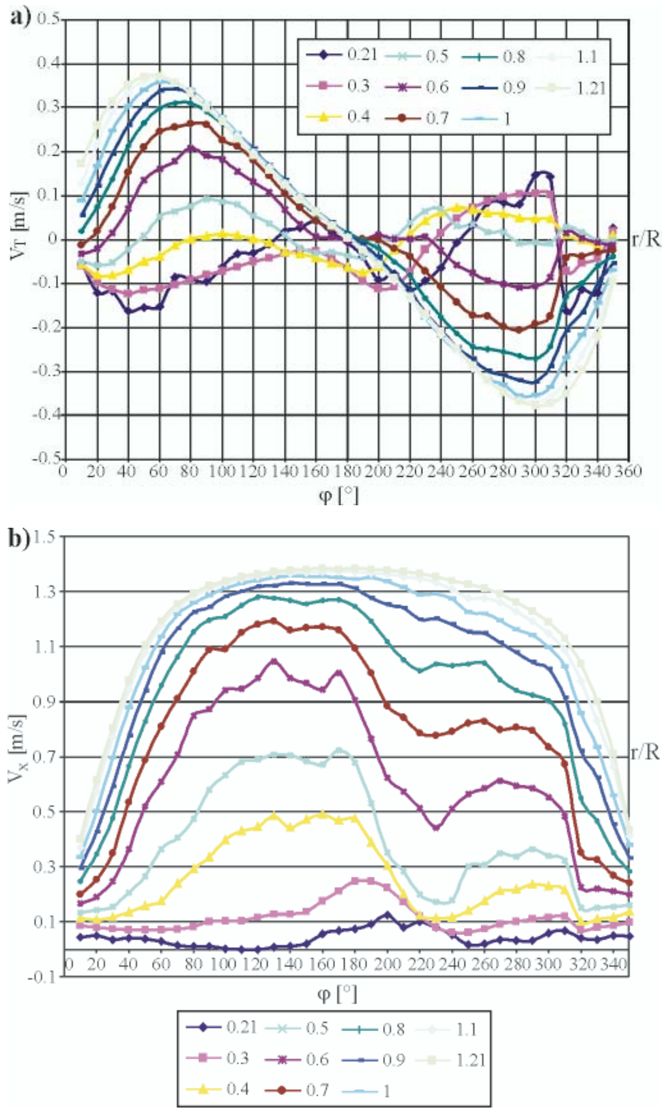

Fig. 4. *Distribution of velocity components:* ***a)*** *circumferential,* ***b)*** *axial – for the asymmetric stern, given at different values of the relative radius(r/R)*

MEAN EFFICIENCY OF SCREW PROPELLER IN NON-HOMOGENOUS WATER VELOCITY FIELD FOR ASYMMETRIC STERN FORM

The modification of stern part of B 573 ship hull (consisting in making stern form asymmetric) was aimed at checking which way the modification would affect the mean efficiency of screw propeller in non-homogenous water velocity field. The authors of the following publications or patents [4, 6, 7, 8, 9, 10, 11, 12] have argued that for an asymmetric stern to obtain a propulsion power decrease is possible at the same ship's speed relative to the ship fitted with symmetric stern. Calculations of the mean efficiency of the final screw propeller of B 573 ship, operating in non-homogenous water velocity field, were performed for both the ship's versions: with symmetric and asymmetric stern. The way of conducting the calculations and relevant tests are described in [3]. The results of numerical calculations of the mean efficiency of screw propeller are given in Fig. 6 where the results for all the remaining hull form modifications analyzed in [3], are also shown.

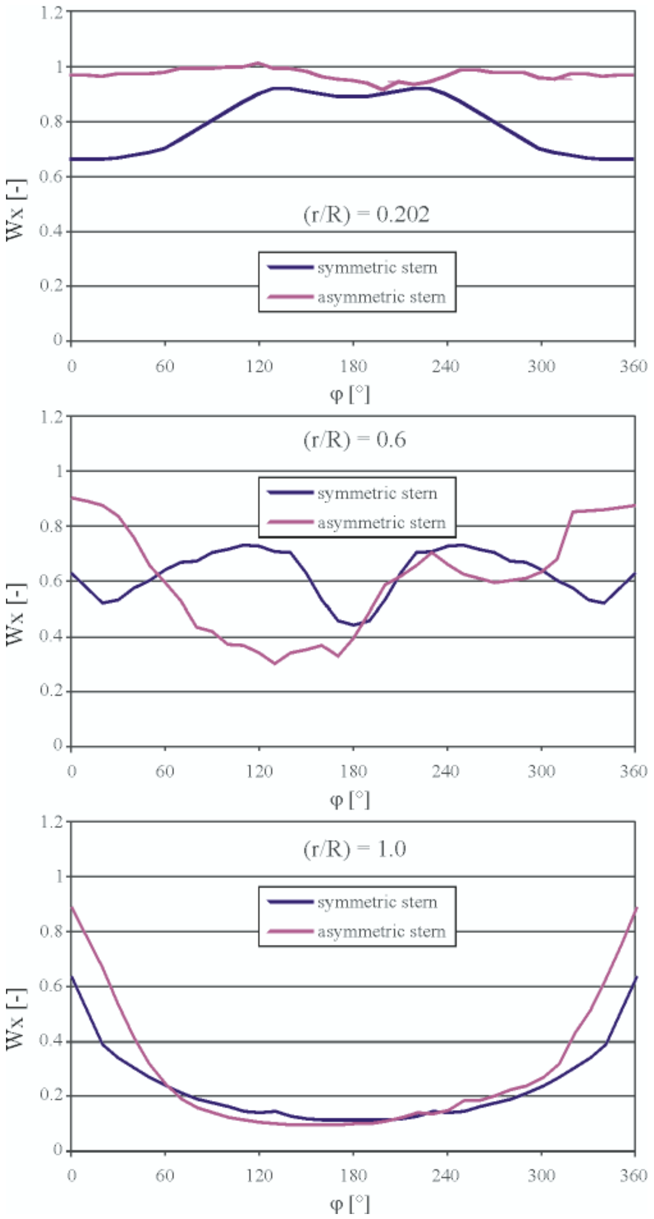

Fig. 5. Distribution of the axial wake fraction W_x for both the symmetric and asymmetric stern, given at the values of the relative radius (r/R) = 0.202; 0.6; 1.0

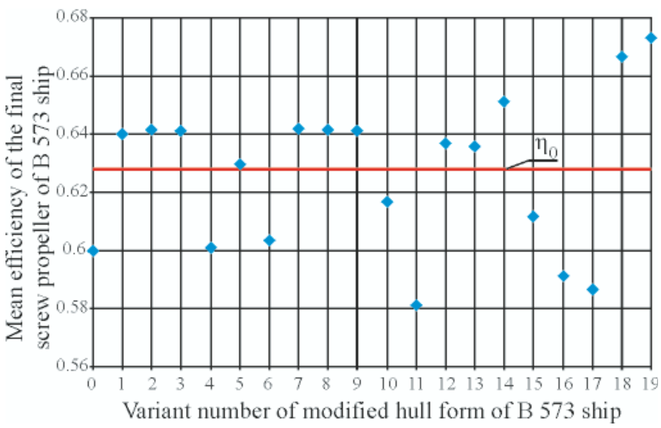

Fig. 6. Mean efficiency of the final screw propeller of B 573 ship, operating in non-homogenous wake current field. ***Notation:*** η_0 *– maximum efficiency of the final screw propeller in homogenous water velocity field (free propeller);* ***Variant No.0*** *– the initial hull form of B 573 ship (without modification), wake current field - as measured during model tests;* ***Variant No.18*** *– the manually modified stern part of ship's hull – symmetric hull form;* ***Variant No.19*** *– the manually modified stern part of ship's hull – asymmetric hull form*

CONCLUSIONS

1. The results obtained from the numerical analyses in question indicate that an asymmetric stern of underwater part of ship's hull introduces a very favourable effect to the mean efficiency of screw propeller operating in non-homogenous water velocity field. The results should be deemed preliminary but quantitive for both the variants of ship's hull stern, i.e. symmetric and asymmetric; in both the cases the same investigation method was used and the results were achieved with the same accuracy.

2. To be able to state how much screw propeller efficiency for the ship of asymmetric stern can be really increased, numerical investigations should be performed for a ship of known complete hull geometry and available results of model tests or full-scale measurements.

3. Authors of the patents concerning asymmetric ship stern (at least 4 patents are valid: 2 German and 2 Polish) defined a given form of stern part of ship's hull in relevant patent specifications. In each of them is defined a strictly determined form being simultaneously different from those given in the remaining patents. Every author states that his hull form is the best regarding increased propeller efficiency and lowered power demand for ship propulsion. The obtained results of numerical analyses confirm that fact, but during the performed investigations it was found out that the assumed form of underwater part of ship's hull stern is not at all one of the forms defined in the patent specifications in question. It was preliminarily concluded that an optimum form of stern part of ship's hull may also depend on many geometrical parameters of the entire hull as well as on ship's operational parameters, e.g. ship's speed or its screw propeller geometry and loading.

4. The preliminary results of the performed numerical analyses are deemed very encouraging therefore research work aimed at the determining of relations between geometrical quantities characterizing asymmetric stern form and screw propeller efficiency, will be continued.

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CONTACT WITH THE AUTHORS
Tomasz Abramowski, Ph. D.
Katarzyna Żelazny, D.Sc., Eng.
Tadeusz Szelangiewicz, Prof.
West Pomeranian University of Technology, Szczecin
Faculty of Marine Technology
Al. Piastów 41
71-065 Szczecin, POLAND
e-mail: tadeusz.szelangiewicz@ps.pl