Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 54(11) (2023) 497-500
DOI: 10.22060/mej.2022.20972.7351

Numerical Analysis of Pre-Swirl Stators for Ship Propeller

A. Nadery, H. Ghassemi*, H. Bahrami

Department of Maritime Engineering, Amirkabir University of Technology, Tehran, Iran.

ABSTRACT: In this paper, the pre-swirl stator for the propeller of a container ship is numerically simulated and analyzed. The parameters of the pre-swirl stator are stated, and the two most important parameters, namely the number of stators and the angle of attack are considered and analyzed. The stators are chosen in three blades (four, six, and eight blades) and at five angles of attack (10, 11.25, 12.5, 13.75, and 15 degrees). In addition, the position of the stators is important, which is determined according to the flow direction in the ship's stern. After analyzing the stator simulation results, the three stators, which have favorable performance in terms of efficiency, were selected as reference stators. Then, the thrust and torque coefficients for all blades and one blade of the propeller, and pressure at one point on the propeller blade are examined. The results indicated that the stator with eight blades and at an angle of attack of 10 degrees has a better performance in terms of changing the direction of propeller inflow and producing thrust and torque. Therefore, it is improved that the efficiency and delivered power by 3.46% and 4.05%, respectively. Moreover, the four blades stator with an attack angle of 10 degrees has improved the pressure fluctuations by 8.45% compared to the non-stator condition.

Review History:

Received: Jan. 11, 2022
Revised: Nov. 01, 2022
Accepted: Nov. 11, 2022
Available Online: Oct. 26, 2022

Keywords:

Pre-swirl stator
Propeller efficiency
Improvement of ship propulsion system
Energy saving devices

1- Introduction

One of the important issues in the field of environment is the increase in the temperature of the earth due to the increase of greenhouse gases in the atmosphere. There are many ways to reduce the fuel consumption of vessels. One of these methods is to improve the performance of the floating propeller. The propeller performance can be improved by different methods, which were categorized and presented by Naderi and Ghassemi [1] in 2018. But in this article, the Pre-Swirl Stator (PSS) has been analyzed and investigated as one of the ways to improve the performance of the propeller. These stators are placed in front (upstream) of the propeller and by applying a rotating current against the rotation of the propeller, they reduce the rotational loss of the propeller and thus improve their hydrodynamic performance.

In the design of the propeller PSS, various parameters can be effective, if they are incorrectly determined, not only the stator does not improve the efficiency of the propulsion system, but it can also reduce it. Therefore, determining the size of these parameters is very important. Also, determining the size of these parameters is different according to the operational conditions of the propeller and stator for each vessel. Among these parameters, we can mention the length of the chord of the stator, the span (radius) of the stator, the distance between the stator and the propeller, the angle of attack of the stator, the type of stator section and the number of stators. In this article, two important parameters of the stator design, i.e. the angle of attack of the stator and the number of stators with the type of arrangement of the stators, which have a significant impact on the design results, are discussed and investigated.

2- Methodology

Navier-Stokes and continuum equations are used to simulate the flow. The simulation is in three dimensions and assumes incompressibility of the fluid. The simulation results are presented in the form of propeller thrust coefficient (K_T), propeller torque coefficient (K_Q), propeller efficiency (η), advance coefficient (J), and delivered power (P_d).

In this study, the flow around a container vessel named Korea Research Institute of Ships and Ocean engineering (KRISO) is simulated. This vessel was tested at the National Marine Research Institute of Japan, and the results of the stern wake and its resistance data are presented in Ref. [2]. Also, in this article, a five-blade propeller named KP505 is used for simulation. The test results of this propeller are also presented by Fujisawa et al. [3] in Japan. In order to check the quality of the mesh generation of simulations, the grid convergence index method proposed by Click et al. [4] is used for the thrust coefficient, torque coefficient and propeller efficiency and total resistance of the ship.

*Corresponding author's email: gasemi@aut.ac.ir

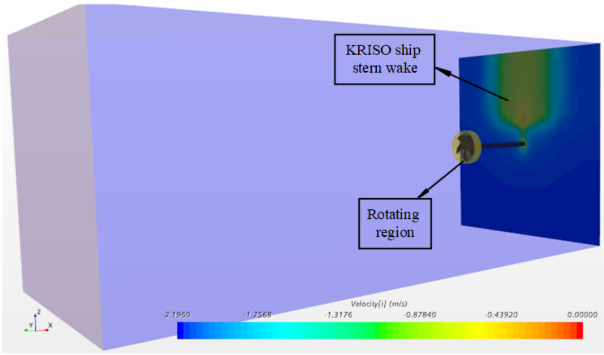

Fig. 1. Simulation of the propeller in the KRISO ship stern wake

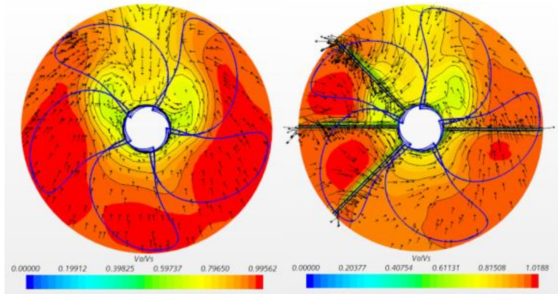

Fig. 3. Axial velocity (contour) and transverse velocity (vectors) in a section at a distance of 0.2D upstream of the propeller: (a) Without stator, (b) Four stators

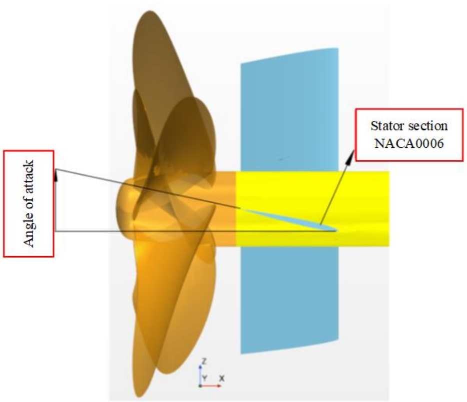

Fig. 2. Stator cross-section schematic and its angle of attack

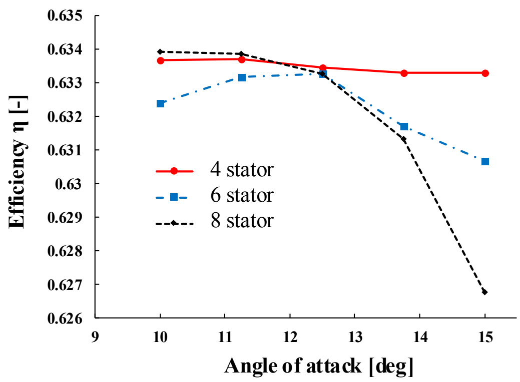

Fig. 4. Comparison of the effect of stators on the efficiency of the propeller

In order to reduce the computational cost, first the KRISO container ship was simulated at a speed of 2.196 m/s, and then its stern wake was taken and given as an input wake to the propeller simulation. Fig. 1 shows the propeller simulation in the stern wake flow of the KRISO ship. Here, the simulation is calculated without a free surface, without floating motion, and only with the rotation of the propeller, and these assumptions greatly help in reducing the computational cost.

Three different stator positioning modes with the number of 4, 6, and 8 stators at attack angles of 10, 11/25, 12/5, 13/75, and 15 degrees are investigated and analyzed. Fig. 2 shows the schematic of the stator cross-section and its angle of attack.

3- Results and Discussion

The position of the stators is chosen according to the flow field in the ship's stern. In Fig. 3, the flow in 0.2D upstream of the propeller is presented for the state without a stator and with four stators. As can be seen from the section of the propeller, the stators have been able to create the direction of flow opposite to the direction of rotation of the propeller.

In Fig. 4, the efficiency of these 15 types of stators is compared with each other. It can be seen here that the 8-stator mode has been able to improve the maximum efficiency at the angle of attack of 10 degrees, which has improved by 3.46% compared to the no-stator mode. But the interesting thing in these graphs is their rate of change in the angle of attack, which has decreased efficiency with the increase of the angle of attack. In the case of 6 stators, it can be seen that by reducing two stators, a higher angle of attack can be used to improve the input flow to the propeller. Now, by comparing the 4-stator mode with the 6-stator mode, we can see that by improving the positioning of the stators and removing the less effective stators, higher efficiency can be achieved. Therefore, by comparing these graphs, it can conclude that the angle of attack parameter and the number of stators are highly dependent on each other and it is not possible to use a specific angle of attack for any number of stators in front of the propeller.

4- Conclusions

In this article, the pre-swirl stators of the propeller of a container ship were investigated in 15 different states. The stators were investigated in 3 states of four, six, and eight in five attack angles of 10, 11.25, 12.5, 13.75, and 15 degrees. The position of the stators is of particular importance, and it was determined according to the flow field in the ship stern. After checking the simulation results of the stators, three stators that had the best effect from the point of view of increasing the efficiency were selected as reference stators, and the propulsion coefficient, torque coefficient, and pressure at one point on the propeller blade were checked for them. From the calculations, the following results are obtained.

The mode of eight stators with 10 degree angle of attack has had a better effect from the point of view of changing the direction of the speed flow and improving the efficiency and delivered power. This mode has improved the efficiency and delivered power by 3.46% and 4.05% respectively.

The 6-stator mode with 12.5 degrees attack angle produced more average propulsive power than the 8-stator mode with a 10-degree attack angle.

Although stators have increased the average propulsion and torque coefficients, on the other hand, they have also increased the fluctuations of these two coefficients.

In the pressure investigation, the eight-stator mode has a weaker effect than the four-stator mode. As a result, eight stators can be used in cases where the cavitation phenomenon is not important, and four stators can be used in cases where this phenomenon is important.

The use of four stators has reduced the pressure fluctuations by 8.45% compared to the state without stators.

References

[1] A. Nadery, H. Ghassemi, An overview of plans to increase efficiency and improve propeller performance and reduce ship fuel consumption, 20th Marine Industries Conference, Tehran, Iran, 2018, (in Persian).

[2] N.M.R. Institute, https://www.t2015.nmri.go.jp, downloaded 2020.

[3] J. Fujisawa, Y. Ukokn, K. Kume, H. Takeshi, Local Velocity Field Measurements around the KCS Model ((SRI M.S. No. 631) in the SRI 400m Towing Tank. Report of Ship Performance Division. SPD Report No. 00-003-2, Ship Performance Division. Ship Research Institute. Ministry of Transport, Shinkawa, 2000.

[4] I.B. Celik, U. Ghia, P.J. Roache, C.J. Freitas, H. Coleman, P.E. Raad, Procedure for Estimation and Reporting of Uncertainty Due to Discretization in CFD Applications, Journal of Fluids Engineering, 130(7) (2008) 078001-078004.

HOW TO CITE THIS ARTICLE

A. Nadery, H. Ghassemi, H. Bahrami, Numerical Analysis of Pre-Swirl Stators for Ship Propeller, Amirkabir J. Mech Eng., 54(11) (2023) 497-500.

DOI: 10.22060/mej.2019.15465.6128