International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 11 | Nov 2020 www.irjet.net p-ISSN: 2395-0072

Predicting the Effect of Different Parameter on Ship Resistance using CFD

Rohit Suryawanshi

Graduate Scholar, Dept. of Mechanical, Lokmanya Tilak College of Engineering, Maharashtra, India

---

Abstract - *Shipping is the most energy-efficient mode of transport and there are many opportunities for an improvement in energy efficiency and the associated emissions. Therefore, accurate prediction of the added resistance in waves is essential to evaluate the additional power, to assess the environmental impact, and to design ships with high fuel efficiency in actual operating conditions. Also, the Maneuverability and resistance prediction with suitable accuracy is essential for optimum ship design and propulsion power prediction. Reducing the frictional resistance of ships would dramatically reduce their fuel consumption, leading to reduced carbon emissions worldwide. In this paper, an attempt is made to present a comprehensive review of the literature in detail analysis of ship resistance at different conditions.*

Key Words: Ship Resistance, CFD, Hull optimization, RANS, Biofouling, Propeller, Wave-making resistance.

1. INTRODUCTION

Shipping has been, and still is, one of the most important methods of transport, with more reliance and importance now being placed on this mode of transport as a consequence of advances in shipping technology and the ability of ships to store and transport increasing capacities of goods. However, these improvements bring some problems to the industry due to an increase in fuel consumption, which is detrimental to the environment and which erodes company revenues.

Generally, it is not easy to obtain the resistance of a full-scale ship directly. Conducting ship model tests, therefore, acts as an important technique to predict the full-scale ship resistance. During the tests, the coefficient of wave-making resistance (Cw) is commonly assumed to be a function of Froude number (Fr) only (i.e., independent of viscosity). Thus, Cw remains identical for a ship and its scaled model (ITTC, 2017a). This assumption acts as the basis of resistance extrapolation from model scale to full scale after model tests. The added resistance in waves can be broken down into three components: the wave radiation originated by the ship motions, the phase shift between the wave excitation and the ship motions, and the diffraction of incident waves by the ship hull. Especially added resistance in short waves is one of the predominant factors for a large ship's performance because most of the time ships travel in relatively short wavelength conditions under low sea states hence the added resistance in short waves preserves its importance which means a reliable prediction of the added resistance in short waves is crucial for the accurate estimation of a ship's performance in waves. Computational Fluid Dynamics (CFD) has advanced rapidly in recent years and become one of the most important techniques in engineering fields. Especially the CFD technique plays an important role in shipbuilding industries by replacing experiments successfully at the early design stages.

The trimaran configuration may offer some advantages over conventional hull forms. It is widely accepted that both wave-making and form resistance decrease as a vessel becomes slenderer. Because of the stability gained from the side hulls, the trimaran can adopt a slenderer main hull that can greatly reduce residuary resistance. The trimaran may also have some advantages in waves. The distances between the side hulls and the main hull provide a relatively long arm of force for roll, which can reduce the roll motion of the ship. The Hull resistance is of paramount importance to ships since it directly affects their speed, power requirements, and fuel consumption. For this reason, reducing a ship's resistance is a fundamental requirement for naval architects, to benefit ship owners. Ship resistance can be classified into two types: frictional resistance and residuary resistance. Frictional resistance can account for up to 80–85% of a ship's total resistance, particularly for merchant ships sailing at low speeds. As 95% of the world's cargo is transported by sea, a means of reducing the frictional resistance of ships would dramatically reduce their fuel consumption, leading to reduced carbon emissions worldwide. The best method to reduce frictional resistance is to apply a treatment to a ship's hull, to minimize its physical and biological roughness.

2. LITERATURE REVIEW:

Qingsong Zeng [1] Investigate the scale effect of Cw on Wigley hull and kKCS hull at different Re. The conventional extrapolation of ship resistance from model tests to full scale presumes that the coefficient of wave-making resistance (Cw) depends on the Froude number only. This leads to the assumption that Cw of a ship is identical to Cw of its scaled model. However, this assumption is challenged in shallow water due to viscous effects, which are represented by the Reynolds number (Re). Generally, two types of resistance require to obtain Rw separately. The first one is the free surface and the second one is free surface suppressed (double body test). The coefficient of the total resistance (Ct) can be decomposed into three parts: coefficients of frictional resistance (Cf), viscous pressure resistance (Cvp), and wave-making resistance (Cw), which is shown in equation (1):

Ct =Cf + Cvp + Cw (1)

The form factor (k) remains the same for both cases with free surface and its corresponding double body test this assumption is considering for the rest of the study because All coefficients on the right side of equation (2) can be obtained through CFD computations, which makes it possible to determine Cw separately.

Cw = (Ct_fre – Ct_dou) – (1 + Kdou) (Cf_fre - Cf_dou) (2)

To study scale effects on wave-making resistance, different scale factors that lead to a length of ship models within 1.5 m–15 m are selected, which covers the typical range of the model length used by most towing tanks in the world. All CFD computations are run on a commercial solver ANSYS Fluent. The turbulence is resolved approximately by solving the Reynolds-averaged Navier–Stokes (RANS) equations with the application of the SST k-ω model. The steady pressure-based solver is used. The discretization method is second-order upwind for momentum, turbulent kinetic energy, and specific dissipation rate. The domain size and boundary conditions are shown in fig 1.

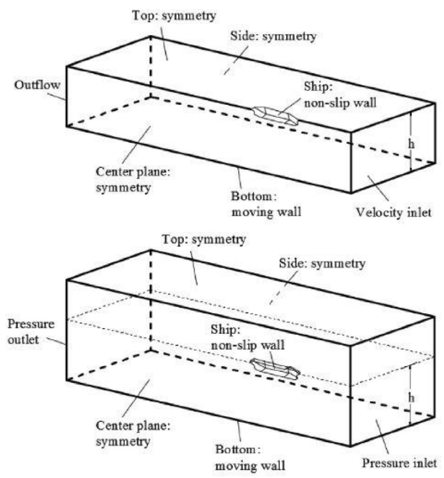

Fig – 1: Computation domain and boundary conditions for cases without free surface (top) and with free surface (bottom).

Linear wave theory is applied to predict the number of wavelengths along with the ship hull. Based on this theory, the number of ship-generated waves within a ship length distance (n) is a function of Froude number (Fr):

N= 1 / 2πFr2 (3)

After calculating Cw with different values of y+, the effect of water depth on Cw is shown to be one order higher than the effect of y+. A strong relationship is found for the changes in the coefficient of frictional resistance (Cf) and the changes in Cw between model scale and full scale. The Contours of the velocity of KCS shown in fig 2. In general, scale effects on Cw decrease with an increasing Reynolds number. If the bank and blockage effects are at an acceptably low level, the ship model should be as large as possible to reduce scale effects on wave-making resistance.

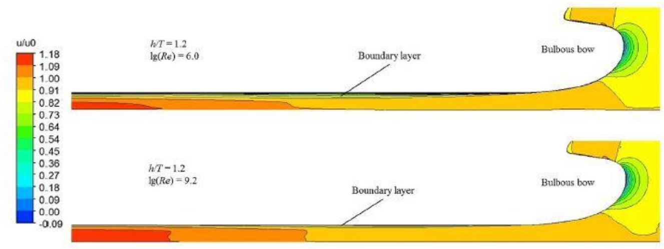

Fig – 2: Contours of velocity at y=0

Hafizul Islama [2], providing some of the resistance and maneuverability characteristics of a container ship model, MOERI KCS in calm water using a computational fluid dynamics solver named Ship Motion. They compare the numerical results of the calm water test for the KCS model with available experimental results. The calm water test results include the total drag coefficient, average sinkage, and trim data. Total six cases were simulated for different Froude and Reynolds numbers and for validation; results were compared with the experimental data presented in the Tokyo 2015 workshop. It can be seen from fig.3 that the prediction of total drag is in good agreement with experimental data. The deviation margin decreases with an increase in Froude number, Fn. However, at design speed, the deviation becomes negative. Generally, at design speed, ships perform optimally and the flow pattern around hull form changes slightly.

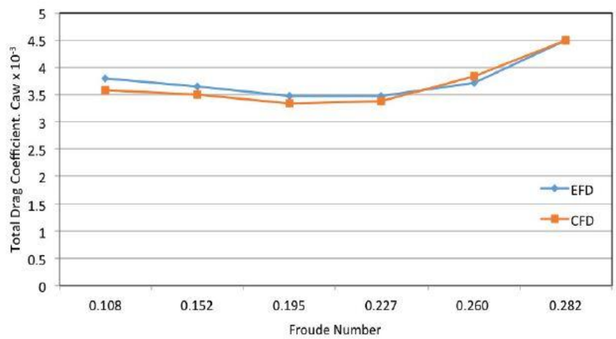

Fig - 3: Total drag co-efficient for KCS model at various Froude no., Fn

The average deviation in the case of resistance prediction is found to be around 2%, which is very reasonable considering the used mesh resolution of around 1 million. The sinkage result shows a significant percentage of deviation, however, in actuality, the deviation value is on a centimeter scale. In motion prediction, deviation with experimental data increases with an increase in Froude number. This is mainly because of the increase in turbulence with increasing

Reynolds and Froude numbers. Overall, it may be concluded that the solver SHIP Motion is efficient and economical in predicting ship resistance and maneuverability characteristics.

Some research work on CFD computation of ship motions and added resistance in waves for a high-speed trimaran is carried out by Cheng-sheng Wu [3] by solving RANSE (Reynolds Averaged Navier-Stokes Equations). The governing equations are discretized by the finite volume method. The volume of fluid method is adopted to deal with the nonlinear free surface. The ship motion is analyzed in the global coordinate system. The governing equations of the six degrees of freedom (6 DOF) of a rigid body motion. A trimaran model advancing in regular head waves of amplitude (A) about 0.03m and the wavelength (λ) varies from 0.5L to 3.0L with different speeds corresponding to Froude number (Fr) 0.52 and 0.70 respectively, are simulated in this paper. The configuration of the trimaran is shown in Fig. 4.

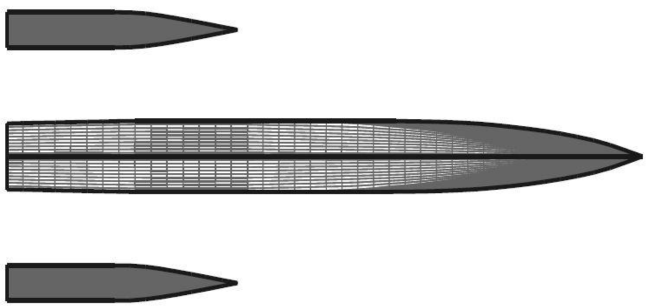

Fig – 4: Configuration of the Trimaran

In general, wave-induced motions and added resistance for trimaran advancing in regular head waves can be predicted quite well by using the numerical method.

Geon-Hong Kim [4] focused on how to enhance the robustness and efficiency of the OpenFOAM® solver, especially HiFoam, to make it comparable to commercial codes without losing accuracy. The governing equations described in the preceding section are discretized utilizing the finite volume method on an unstructured grid. The Local Time Stepping (LTS) scheme was selected for temporal discretization for an efficient quasi-steady simulation. The gradients of flow properties can be estimated by using either linear interpolation or the least square method. However, the author did not modify the velocity-pressure coupling algorithm in the present work because a quasi-steady solution is of interest. It is worthwhile to note that Fig. 5 represents the PISO algorithm that is used in solvers of OpenFOAM®-2.1.x where the step for updating phase fraction is included in the outer corrector loop in the later versions.

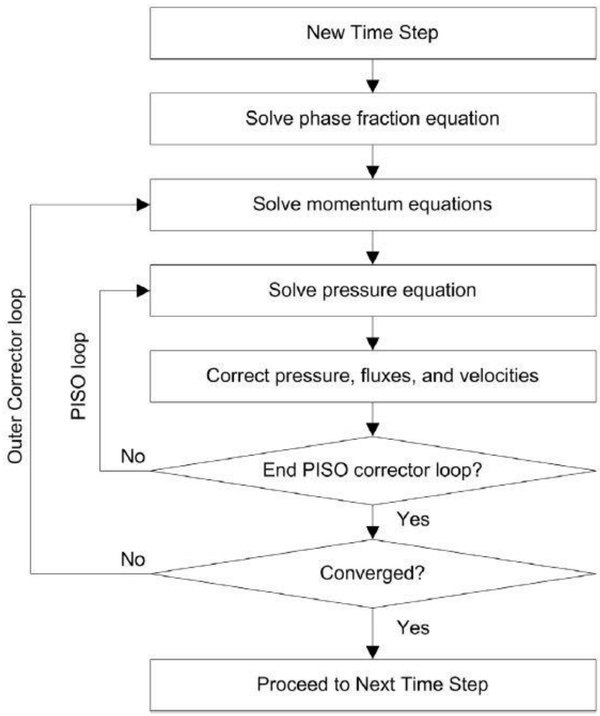

Fig – 5: Flow chart of the pressureevelocity coupling procedure of solver interFoam

it has been applied to various types and speeds of ships including container carriers, VLCC's, LNG/LPGC's, and PCTC's. We see that the HiFoam is highly efficient and robust with good accuracy in predicting resistance of ships, which is competitive with other commercial CFD codes and fully capable to replace them.

Demirel [5] model enables the prediction of the effect of antifouling coatings on frictional resistance with the help of the CFD model. The details of CFD simulations of resistance tests on coated plates in a towing tank. Firstly, they evaluated roughness functions and roughness Reynolds numbers for several antifouling coatings using an indirect method. A flat plate of length 170 m was chosen to represent a handymax tanker. Different types of antifouling coatings were considered at an operational ship speed of 13 knots. The plate was fully submerged since the surface roughness does not affect the wave-making resistance. Frictional resistance coefficients of the plate were evaluated for each case. The selection of the roughness height is critical to define a roughness function model, though the selected roughness height does not affect the roughness function value – it only affects the abscissa of the profile of roughness functions against roughness Reynolds numbers. For this reason, the roughness height can be selected such that the roughness function values fall on a predefined roughness function model, provided that the observed behaviors are still deemed appropriate relative to each other.

The results of the validation study were in fairly good agreement with the experimental data, with the differences between CFD and the experiment ranging from 0.14 % to 2.54% for CF and from 0.3 % to 2.5 % for k+ as sown in Table 1. It has been shown that surface roughness can be modeled by employing modified wall laws within the wall functions. It may be concluded that the proposed approach is capable of predicting the roughness effects of antifouling coatings on frictional resistance. Hence, the increases in the CF values of a ship due to different types of antifouling coatings were predicted using the proposed CFD model.

Surface	C_f (CFD)	Increase in C_f (%)
Smooth	0.001494	-
Silicone 1	0.001550	3.77
Silicone 2	0.001558	4.32
Ablative Copper	0.001554	4.05
SPC Copper	0.001562	4.59
SPC TBT	0.001585	6.10

Table 1: The comparison of CF values at full scale at 13 knots.

The fuel consumption of a ship is strongly influenced by her frictional resistance. This would be causing higher fuel consumption and CO2 emissions. It would therefore be very beneficial to be able to accurately predict the effects of roughness on resistance. Demirel [6] also predicts the effect of marine coatings and biofouling on ship resistance with the help of CFD and for that full-scale 3D, KRISO Container Ship (KCS) hull was used for the study. The SST (Shear Stress Transport) k-ω turbulence model was used to complete the RANS equations. the Courant-Frederich-Lewis (CFL) number was always held at values less than unity to ensure numerical stability. It is of note that the ITTC recommends the use of t = 0.005 ~ 0.01 L/V, where L is ship length and V is ship speed, for the selection of the time step. The boundary conditions of the simulations were chosen to represent the full-scale KCS model being towed in a deep water condition. The inlet is placed at ~1.5LBP lengths upstream and the outlet boundary is placed at ~2.5LBP lengths downstream, to ensure boundary independent solutions are produced. Similarly, the top is located at ~1.5LBP and the bottom and the side are positioned at ~2.5LBP away from the KCS hull.

The resulting CF values obtained using flat plate CFD simulations and using 3D full-scale CFD simulations were compared with each other. The increase in the effective power of the full-scale KCS hull were predicted to be 7.1% at a ship speed of 24 knots and 5.9% at a ship speed of 19 knots for a typical as applied antifouling (AF) coating, 18.1% at 24 knots and 21.2% at 19 knots for a deteriorated coating or light slime condition and 30.8% at 24 knots and 37% at 19 knots for a heavy slime condition. An important finding of the study is that the wave resistance and wave systems are significantly affected by the hull roughness and hence viscous effects, which is contrary to the major assumption which proposes that the wave resistance is not markedly affected by surface roughness and viscosity as shown in fig 6. The reduction in the wave resistance of the KCS hull in heavy calcareous fouling condition was found to be 55.8% at 24 knots and 72.3% at 19 knots

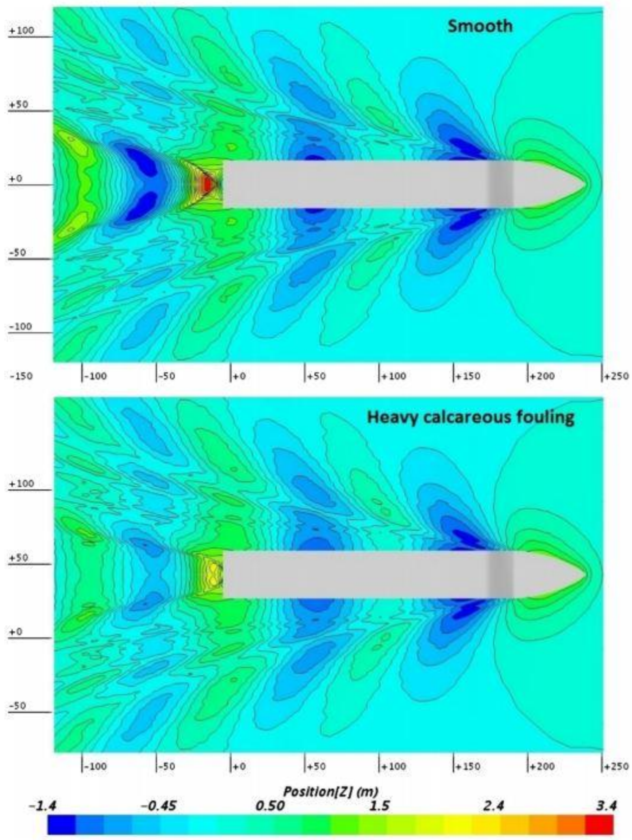

Fig. 6. Wave pattern around the KCS for smooth and heavy calcareous fouling conditions (V= 24 knots).

3. CONCLUSIONS

From the literature review, it is observed that ship resistance plays an important role not only help to reduce carbon emissions worldwide but also significantly improve overall ship performance. Some of the investigators, reconsider the conventional extrapolation to check wave-making resistance of ships sailing in shallow water with the help of CFD results and validate the numerical value with the experimental one. Whereas some investigator predicts the container ship performance in clam water using Reynolds averaged Navier-Stokes based Solver. Instead of conducting several physical experiments, any researcher used CFD software like ANSYS, Star CCM +, etc. to reduce computational time, some also used scaling model or flat plate with antifouling coatings to conduct frictional resistance test. Thus, optimization in the design of the ship, predicting the different types of ship resistance has been widely employed.

REFERENCES

1) Q. Zeng, R. Hekkenberg, C. Thill, H. Hopman, Scale effects on the wave-making resistance of ships sailing in shallow water, Ocean Eng. (2020). doi:10.1016/j.oceaneng.2020.107654.

2) H. Islam, M.M. Rahaman, H. Akimoto, M.R. Islam, Calm water resistance prediction of a container ship using reynolds averaged navier-stokes based solver, in: Procedia Eng., 2017. doi:10.1016/j.proeng.2017.08.112

3) C.S. Wu, D.C. Zhou, L. Gao, Q.M. Miao, CFD computation of ship motions and added resistance for a high speed trimaran in regular head waves, Int. J. Nav. Archit. Ocean Eng. (2011). doi:10.3744/JNAOE.2011.3.1.105

4) G.H. Kim, S. Park, Development of a numerical simulation tool for efficient and robust prediction of ship resistance, Int. J. Nav. Archit. Ocean Eng. (2017). doi:10.1016/j.ijnaoe.2017.01.003

5) Y.K. Demirel, M. Khorasanchi, O. Turan, A. Incecik, M.P. Schultz, A CFD model for the frictional resistance prediction of antifouling coatings, Ocean Eng. (2014). doi:10.1016/j.oceaneng.2014.07.017

6) Y.K. Demirel, O. Turan, A. Incecik, Predicting the effect of biofouling on ship resistance using CFD, Appl. Ocean Res. (2017). doi:10.1016/j.apor.2016.12.003