Numerical Friction Lines for CFD Based Form Factor Determination Method

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ABSTRACT

The friction line, i.e the dependency of flat plate frictional resistance coefficients on Reynolds number, is used in the 1978 ITTC method for scaling of ship resistance measured in a towing tank. The 1978 ITTC method includes the form factor concept as described by Hughes [1], where the viscous resistance is expressed in relation to the “ITTC 57 model-ship correlation line”. The form factor concept, as well as the determination method proposed by Prohaska [2] has been questioned and investigated for many decades. The scale effects on form factor has been well demonstrated in [3] , [4] and [5] using geosim test data analysis and in [6] using CFD. Considering the growing disposition to leave the Prohaska method of form factor determination and growing confidence in numerical resistance calculations, CFD might be able to provide a new method of form factor determination, which can increase the accuracy of full-scale resistance predictions.

In this study, frictional resistance coefficients of an infinitely thin 2D plate have been computed at 14 Reynolds numbers (between $log_{10}(Rn) = 6.25\ to\ 9.5$) in sets of five geometrically similar structured grids in order to perform reliable grid dependence studies as described in [7]. Additional grid dependency studies have been performed by using 5 sets of grids which have the same number of cells in all directions but varying first cell sizes normal to the flat plate at the Reynolds numbers $log_{10}(Rn) = 6.25$ and 3 sets of grids at $log_{10}(Rn) = 9.5$. Average y^+values for each grid set for the finest grid varies between approximately 0.0075 to 0.5 (from set 1 to 5 respectively) while none of the simulations exceeded y^+ average value of 1. Two turbulence models have been used for the investigations: $k - \omega$ SST and EASM. Simulations have been performed with two different CFD codes SHIPFLOW and FINEMARINE, using the same grids. Special attention was paid to the transition from laminar to turbulent flow at the lowest Reynolds number since laminar part can cover a significant part of the plate. At $log_{10}(Rn) = 6.25$ for both CFD codes, laminar flow and transition to turbulent flow was distinctive even though no transition models were applied. Significant dependency on y^+ has been observed with FINEMARINE for the transition location and Cf_x values in the turbulent region which seems to be the main cause of substantial numerical uncertainties (up to 8% for set 5) on friction resistance coefficient. On the other hand, SHIPFLOW exhibited significantly less sensitivity to y^+ variation, hence, yielding significantly smaller numerical uncertainties in general. In order to ensure a numerical uncertainty of frictional resistance component below 1%, $y^+ < 0.1$ have been used for generating the data points of friction line for each turbulence model. Data points of 14 Reynolds number have been transformed into numerical friction lines by applying curve fits. Obtained friction lines are compared with ITTC 57 line [8], Schoenherr, Katsui [9], Grigson [10] lines and two numerical friction lines [11] and [12].

REFERENCES

[1] G. Hughes, "Friction and Form Resistance in Turbulent Flow, and a Proposed Formulation for Use in Model and Ship Correlation". Trans. RINA, Vol. 96, p.314-376, (1954)

[2] C. W. Prohaska, "A Simple Method for the Evaluation of the Form Factor and Low Speed Wave Resistance" , Proceeding of 11th ITTC, (1966)

[3] A. García-Gómez, "On the Form Factor Scale Effect", Ocean Engineering, Vol 26, pp.97-109, (2000).

[4] N. Toki, "Investigation on Correlation Lines through the Analyses of Geosim Model Test Results", Journal of the Japan Society of Naval Architects and Ocean Engineers, Vol 8, pp. 71-79, (2008).

[5] S.-H.Van, H. Ahn, Y.-Y. Lee, C. Kim, Hwang, S. Hwang, J. Kim, K.-S. Kim, I.-R. Park, "Resistance Characteristics and Form Factor Evaluation for Geosim Models of KVLCC2 and KCS", Advanced Model Measurement Technology for EU Maritime Industry, pp.282-293, (2011).

[6] H. C. Raven, A. van der Ploeg, A.R. Starke, L. Eça, "Towards a CFD-based prediction of ship performance --- progress in predicting full-scale resistance and scale effects", International Journal of Maritime Engineering, Vol. 135, (2009)

[7] L. Eça and M. Hoekstra, "A Procedure for the Estimation of the Numerical Uncertainty of CFD Calculations Based on Grid Refinement Studies", Journal of Computational Physics, Vol 262, pp. 104-130, (2014).

[8] Proceedings of the 8th ITTC, Madrid, 1957

[9] T. Katsui, H. Asai, Y. Himeno, Y. Tahara, "The Proposal of a New Friction Line – Fifth Osaka Colloquium on Advanced CFD Applications to Ship Flow and Hull Form Design", Osaka, Japan, 2005.

[10] C.W.B. Grigson, "A planar algorithm and its use in analysing hull resistance". Trans. RINA, Vol 142, pp. 76-115. (1999).

[11] L. Eça and M. Hoekstra, "The numerical friction line", Journal of Marine Science and Technology, Vol 13, pp. 328-345, (2008).

[12] Z.-z. Wang, Y. Xiong, L.-p. Shi, Z,-h, Liu, "A Numerical Flat Plate Friction Line and Its Application", Journal of Hydrodynamics, Vol 23 (3), pp.383-393 (2015).