MPI-Parallelized RANS simulation of turbulent free surface flow around a practical ship

Kwang-Soo Kim*, Jin Kim, IL-Ryong Park, Gun-Do Kim, Suwhan Kim and Suak-Ho Van

Maritime & Ocean Engineering Research Institute (MOERI)/KORDI,
171 Jang-Dong, Yuseong-gu, Daejeon, 305-343 Republic of Korea
E-mail: ksookim@moeri.re.kr

Key Words: PC clustering machine, WAVIS, self-propulsion, level-set method, lifting surface method, propeller force

ABSTRACT

The finite volume based multi-block RANS code, WAVIS[1-2] developed at MOERI is converted into MPI-parallelized code with a linux PC-clusterimg machine. The linux PC-clustering machine has 48 node with a Intel Pentium IV 3.2 GHz processor for each node. About a parallel method, a structured grid block is decomposed into several multi blocks and 1 cpu for each block is allocated[3]. Examining the parallel performance, the speedup test is performed with a simple ship hull, series60. The fully non-linear free-surface flow around a series60 hull is simulated and consistence/convergence of parallelized solution is investigated.

The parallelized WAVIS code is applied to a self-propelled LNG carrier ship. WAVIS uses the cell-centered finite volume method for discretization of the governing equations. Convection terms are discretized using the third order QUICK scheme and the central difference scheme is utilized for diffusion terms. To ensure divergence-free velocity field, the SIMPLEC method is employed. The realizable k-ϵ turbulence model with a wall function is employed for the turbulence closure. The free surface is captured with the two-phase level set method[4] and body forces are used to model the effects of a propulsor without resolving the detail blade flow. The propeller forces are obtained using an unsteady lifting surface method based on potential flow theory[5].

The numerical procedure followed the self-propulsion model experiment based on the 1978 ITTC (International Towing Tank Committee) performance prediction method. The self-propulsion point is obtained iteratively through balancing the propeller thrust, the ship hull resistance and towing force that is correction for Reynolds number difference between the model and full scale. The unsteady lifting surface code is also iterated until the propeller induced velocity is converged in order to obtain the propeller force. The self-propulsion characteristics such as thrust deduction, wake fraction, propeller efficiency, and hull efficiency are compared with the experimental data of the practical container ship[6]. The present paper shows that the hybrid parallelized RANS and potential flow based numerical method is promising to predict the self-propulsion parameters of practical ships as a useful tool for the hull form and propeller designs.

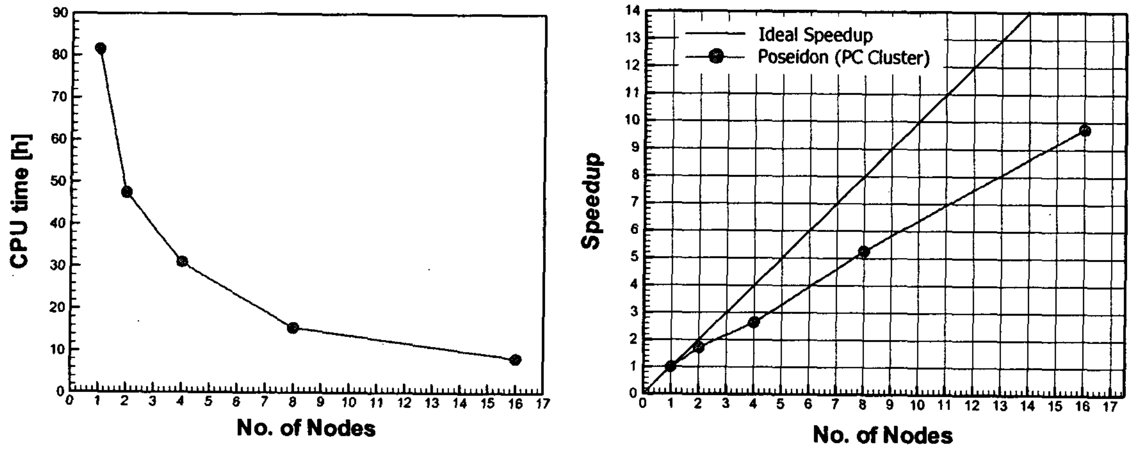

Fig. 1 speedup test of parallelized WAVIS code

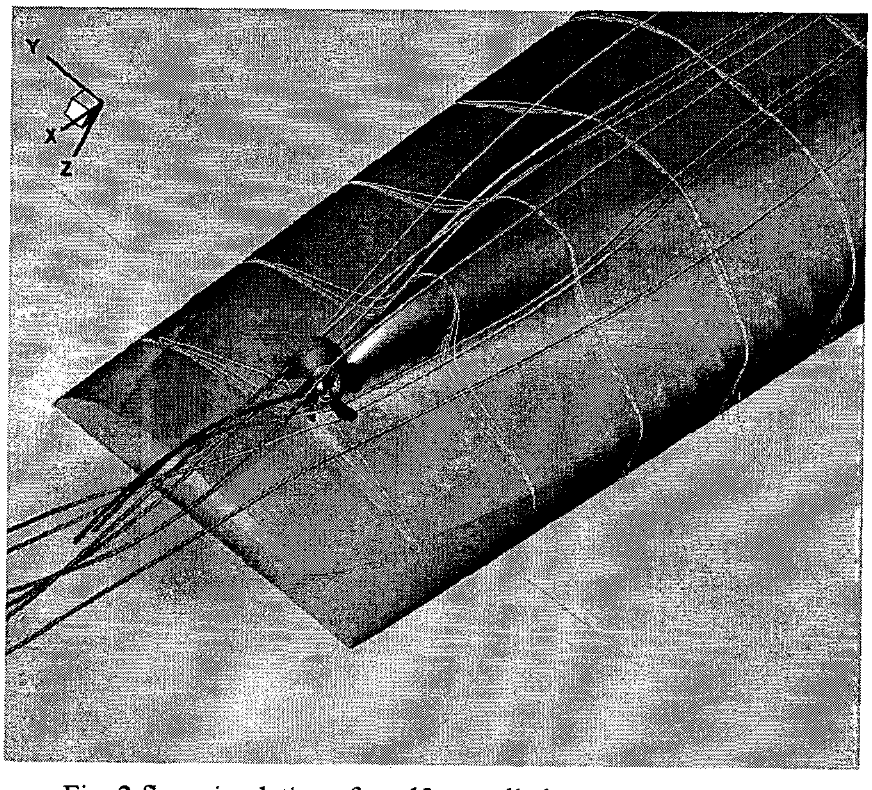

Fig. 2 flow simulation of a self-propelled container ship(KCS)

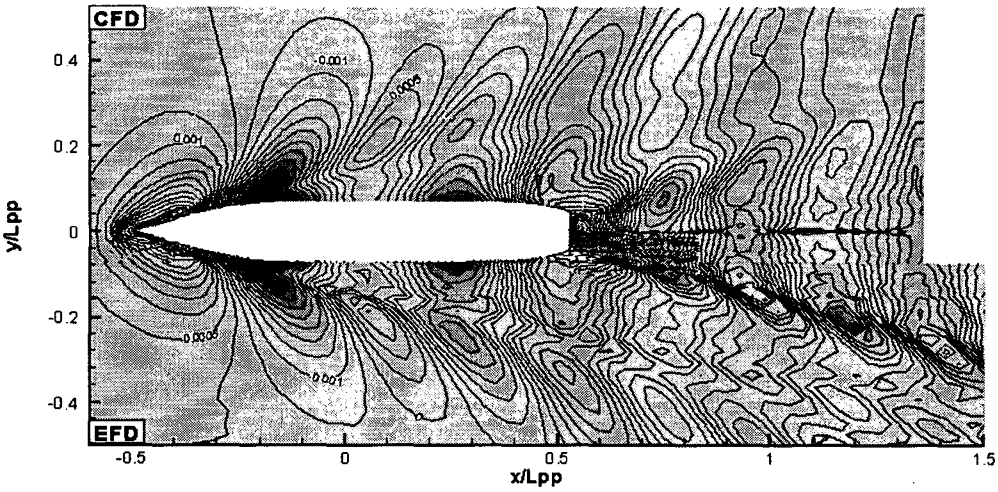

Fig. 3 comparison of wave pattern

REFERENCES

[1] Kim, W. J. and Van, S. H.(2000), "Comparisons of turbulent flows around two modern VLCC hull forms", *Proceeding of a Workshop on Numerical Ship Hydrodynamics: Gothenburg 2000.*

[2] Kim, W. J., Kim, D. H., and Van, S. H.(2002), "Computational study on turbulent flows around modern tanker hull forms," *International Journal for Numerical Methods in Fluids, Vol. **38**, No. 4, 2002, pp. 377-406.*

[3] William Gropp, Ewing Lusk, Anthony Skjellum (1999), *USING MPI: Portable Parallel Programming with the message-passing interface*, (2nd Ed), The MIT press, Cambridge, Messachusetts

[4] Sussman, M., Fatemi, E., Smerera, P., and Osher, S. (1997), "An improved Level-Set method for incompressible two-phase flows," *Computers and Fluids, Vol. 27, No. 5-6, pp. 663-680*

[5] Kerwin, JE and Lee, CS (1978). "Prediction of steady and unsteady marine propeller performance by numerical lifting surface theory," *Trans. SNAME, Vol. **86**, pp. 218-258*

[6] Van, S. H., Yim, G. T., Kim, W. J., Kim, D. H. , Yoon, H. S., and Eom, J. Y. (1997), "Measurement of flows around a 3600TEU container ship model," *Proc. of the Annual Autumn Meeting, SNAK, Seoul, pp. 300-304 (in Korean).*