Chisachi KATO LAB.

[Numerical simulation of unsteady fluid flows], [Research on energy conversion systems]

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Thermal Energy Conversion Systems

Department of Mechanical Engineering

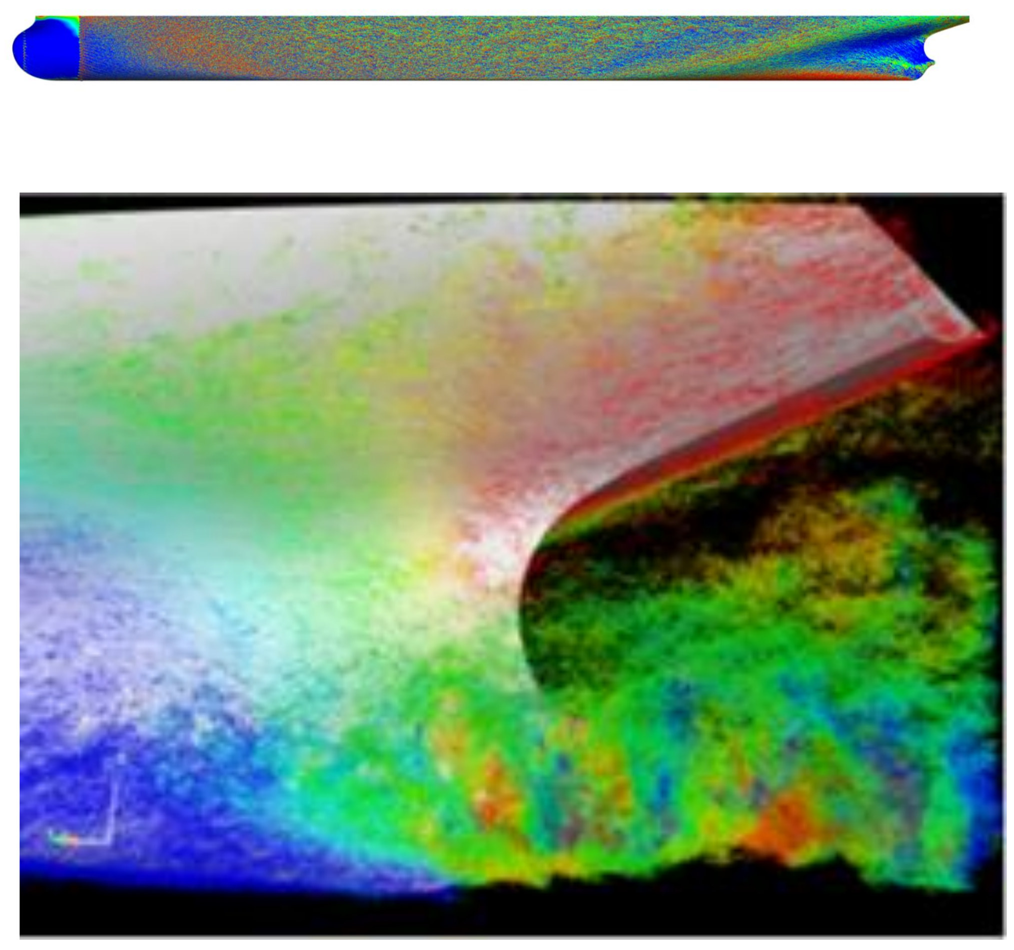
Numerical simulation of unsteady fluid flows

Fully resolved LES as an alternative to towing tank resistance tests

The demand for towing tank tests has been increasing due to the requirements of the EEDI*1 imposed by IMO*2 as a measure for controlling CO_2 emissions from ships. Although numerical simulations by RANS (Reynolds-averaged Navier-Stokes) have been widely used in the early stage of hull design, the prediction accuracy has to be further improved for such simulations to become a complete alternative for towing tank tests. In particular, for resistance tests and self-propulsion tests, the relative error to the experimental data has to be reduced to within 1%. By tuning the turbulence models, RANS simulations may provide such accuracy. But, it seems difficult for RANS simulations to always guarantee such accuracy for different types of ships.

With the recent speed-up of high-end computers, fully resolved large eddy simulation (LES), which directly computes the streamwise vortices in the turbulent boundary layer (TBL), is expected to become feasible within a few years. Fully resolved LES provides almost the same accuracy as DNS (Direct Numerical Simulation) and will probably achieve simulations with a relative error of 1% or smaller.

*1 Energy Efficiency Design Index, *2 International Maritime Organization



Flow field around a ship.

Computations of cavitating vortex rope by using LES

The operation of a turbine at part load or at full load conditions changes the axial and tangential velocity distributions at the inlet of the draft tube, inducing the development of the well-known vortex rope. The volume of the vortex rope is changing over time resulting in a pressure variation that can be felt throughout the power plant. It is thus primordial to predict accurately the dynamical behavior of the vortex rope in order to avoid that the Eigen frequency of the vortex rope reach the Eigen frequency of the hydraulic system. Therefore, the challenge is to predict accurately the behavior of the flow field, which requires to take into account the cavitation phenomenon.

Cavitating and precessing vortex rope downstream of a Francis turbine.

Research on energy conversion systems

Research of ultra micro gas turbines

The recent appearance of humanoid robots and the explosive spread of portable devices have led to expectations for the development of compact and lightweight portable power supplies. Power supplies in the form of ultra micro gas turbines (UMGT) with impellers of several mm to several tens of mm in size are thought to be promising candidates in terms of both output density and energy density.

AA battery sized gas turbine.