Energy Saving Devices – design by CFD and Model Testing

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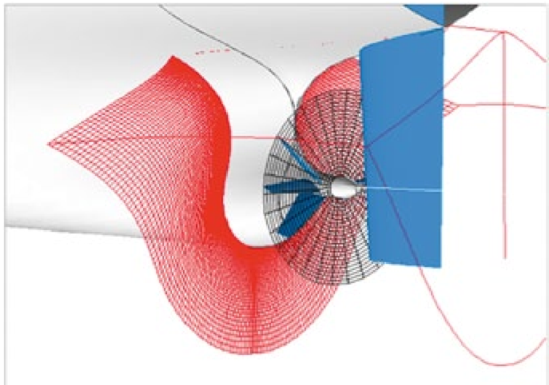
With environmental concerns becoming the most important issues facing the shipping/shipbuilding industry today, SSPA has witnessed strong demand for the development of energy saving devices (ESD). SSPA envisions that the demand will be greater to respond to the new requirements as set by the upcoming IMO regulation on energy efficient design index (EEDI). Most ESDs are used to enhance the flow into the propeller, aimed at increasing propulsion efficiency as well as reducing energy loss. The design of ESDs requires knowledge of flow mechanism around ESD and highly advanced Computational Fluid Dynamics(CFD) simulation coupled to accurate model testing. SSPA has been involved in many joint research projects in developing energy saving solutions. This article is a short summary of one of most successful developments of energy saving devices.

Various energy saving devices can be applied, but the practically applicable devices should be simple, relatively cheap to install, easy to maintain and most importantly, the ESD design should have a solid scientific background. Daewoo Shipbuilding and Marine Engineering Co. Ltd (DSME) has developed the pre-swirl stator (PSS) in cooperation with SSPA; SSPA tested most of DSME's designed PSSs over the past 10 years. The PSS is a device mounted on the boss end of the hull in front of the propeller and is designed to generate pre-swirl flows in order to gain a favorable interaction with the propeller action that improves propulsive efficiency and results in power reduction.

Optimisation investigation says four blades

Three to six blades have been investigated in various configurations on single screw ships over the years and the stator configuration selected from the optimisation investigation typically has four blades with a diameter equal to the propeller diameter. This has become the standard configuration for a wide range of hull types including VLCCs, Tankers, Bulkers, Ro-Ro ships and Containerships. The DSME PSS has been successfully applied to various ship types, with an average gain of 4 percent on propulsion power achieved in model tests and confirmed in sea trial tests.

PSS mounted on ship model for testing.



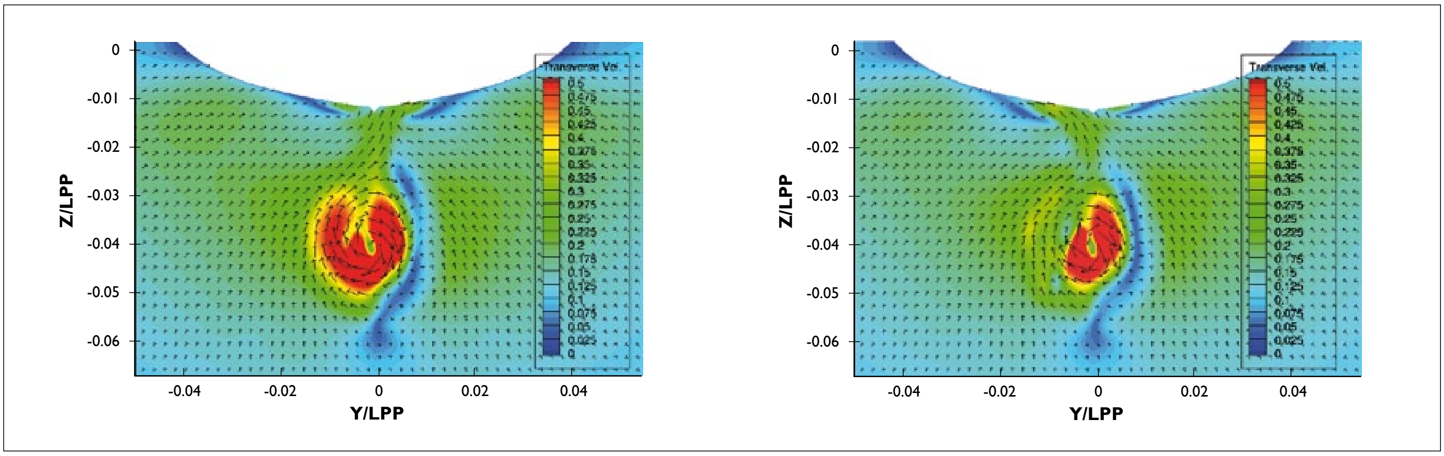
PSS model set-up for CFD computation.

The configuration process

The optimum configuration of PSS is determined based on CFD computations and tank tests. A wide range of design parameter variation studies was performed first by SHIPFLOW computation and the most promising configurations were selected for the final confirmation by model tests.

This type of CFD computation is a very challenging task as this requires full simulation of POW, resistance and self-propulsion tests with a high level of accuracy that is capable of predicting small differences in flow characteristics, as well as the relative ranking of propulsion efficiency due to the small variation of a design parameter setting of PSS. Extensive internal SSPA research work has been performed in this area in 2009-2010 to investigate the limit of SHIPFLOW prediction accuracy for self-propulsion test simulations. Promising results were obtained for a containership and a VLCC. The coupling between the potential-flow based method and RANS code proved to be a sufficiently complete and accurate approach for predicting the thrust, torque and rotation rate for the propeller in order to achieve the correct ranking between different design alternatives.

The figure above illustrates the calculation model set-up for SHIPFLOW computation; the overlapping grid technique with structured components was used to achieve high quality cells for the background hull and appendages. The overlapping grids consists of one back ground grid with an additional refinement covering the stern of the ship and six component grids for four pre-swirl stator blades, one propeller and one rudder.



Rotational energy behind the ship without PSS (left) and with PSS (right).

The SHIPFLOW part of the process

SHIPFLOW simulation was carried out in two steps. In the first step, a base reference computation was made for the base PSS configuration selected; the 4-bladed stator was initially set at what was tentatively expected to be the optimum configuration. The effect of PSS on the improvement of propulsion efficiency was investigated through detailed analysis of local flow quantities around the stator blades.

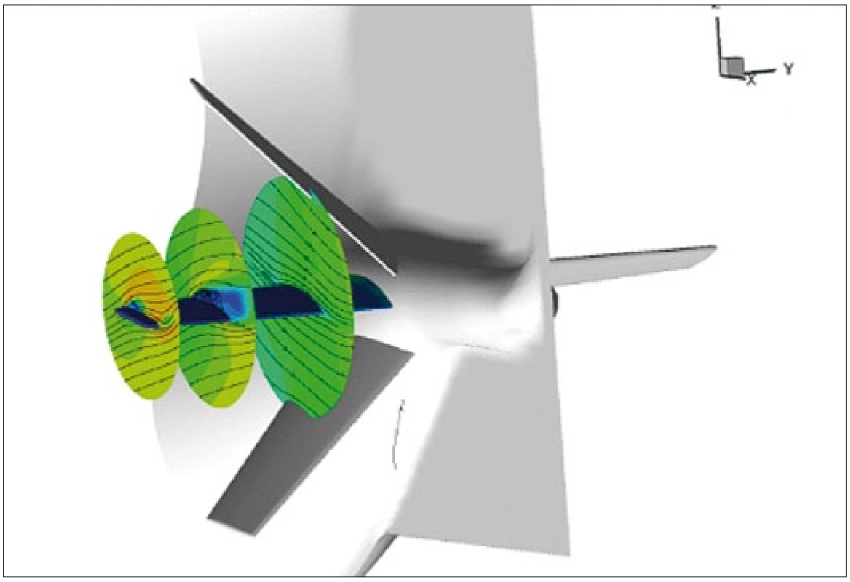
More as a pre-optimisation study in the second step, a systematic computation was made for stator blade pitch angle variations and the two most promising PSS design alternatives were selected for further confirmation through tank tests.

Energy loss reduced

By putting the PSS in front of propeller, more rotational flows are generated, particularly on the port side and the rotational energy loss is reduced in the propeller's slipstream. This can be also seen clearly from the comparison of velocity distribution from self-propulsion velocity distribution behind the propeller in the figure above. The distribution of rotation velocity components behind the propeller are plotted for the bare hull and for the base PSS configuration. It is clear that the loss of rotating energy is considerably diminished by the stator.

The figure below shows how the flow direction changes due to the lift generated by the stator. The lift is developed mainly by the mid to outer part of blade (some separation occurs due to high angle of attack locally in the mid-span) while there is no significant effect on lift by the inner part of the blade.

Change of Flow direction due to lift generated by stator blade.



Computation results confirmed

Based on the evaluation of power gain and detailed analysis of flow characteristics, four (4) of the most promising PSS configurations are selected and tested. The table below indicates that an approximate 5–6 % power gain can be achieved by the best PSS as compared to the bare hull. SHIPFLOW computation was able to correctly predict the relative ranking for all PSS configurations tested. CFD simulation coupled to model testing can be a cost effective approach to develop an ideal configuration of ESDs for the future…

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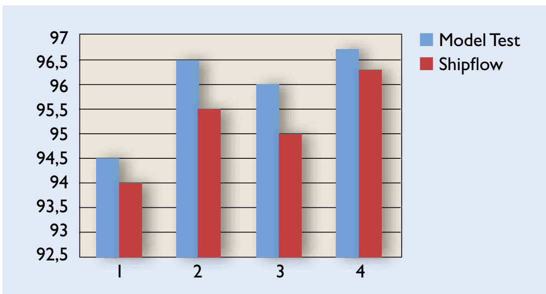

Energy gain predicted by CFD (left) and model test (right) for different PSS configurations.