Propeller Tip Vortex Cavitation Mitigation by Using Roughness

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Tip vortex cavitation is usually the first type of cavitation that appears on a propeller. Therefore, it is considered as the main controlled cavitation characteristics in the design procedure of low-noise propellers, where their operating profiles require very low radiated noise emissions. The current study focuses on the possibility of adoption of roughness on blades in order to alter their tip vortex properties, and consequently mitigate their tip vortex cavitation [1].

The basic design of the selected propeller is from a research series of highly skewed propellers having a low effective tip load and are typical for yachts and cruise ships, where it is very important to suppress and limit propeller-induced vibration and noise. In this type of propellers, the main source of noise and vibration is the vortex cavitation in the tip region.

The tip vortex flows around the propeller are simulated by the two equation SST k-ω model on appropriate grid resolutions for tip vortex propagation, at least 32 cells per vortex diameter according to previous studies guidelines [2]. A curvature correction method is employed to prevent overprediction of turbulent viscosity in highly swirling tip regions [3].

The roughness is included in the simulations by employing two different approaches. In the first approach, rough wall functions are used to mimic the effects of roughness by increasing the turbulent properties in roughed areas. The second approach modifies the mesh topology by removing cells in roughed areas to create random roughness elements. While the first approach models the roughness effects, the second one actually includes their geometry into the simulations. However, as the roughness elements have very small sizes, resolving the flow around them demands a very fine mesh resolution. The comparison between the results of these two approaches will provide further insights regarding their level of accuracy and their related computational cost.

Roughness application on different blade areas, e.g. suction side, pressure side, close to the tip, leading edge, trailing edge, are considered. For each case, the interaction between vortices generated by roughness and their impact on the pressure field and the cavitation inception is highlighted. It is evaluated how roughness alters the vortical structures on the blade and as a result in the tip vortex region. The flow streamlines forming the tip vortex are investigated at different roughness conditions and are compared with the fully smooth blade results. The comparison provides further knowledge on how roughness changes the flow pattern around the blade tip and mitigates the cavitation. The propeller performance degradation in different roughness conditions is computed and by considering the tip vortex cavitation inception improvement, the most optimum roughness pattern is proposed.

REFERENCES

[1] C. Kruger, and N. Kornev, and L. Greitsch. Influence of propeller tip roughness on tip vortex strength and propeller performance. Ship Technology Research, 63(2):110–120, 2016.

[2] Asnaghi, A., Svennberg, U., and Bensow, R.E., 2018: “Numerical and experimental analysis of cavitation inception behaviour for high-skewed low-noise propellers,” Applied Ocean Research, 79:197–214.

[3] Asnaghi, A., Bensow, R.E., and Svennberg, U., 2017: “COMPARATIVE ANALYSIS OF TIP VORTEX FLOW USING RANS AND LES,” VII International Conference on Computational Methods in Marine Engineering, MARINE 2017At: Nantes, France.