Design of Open-water and Wake-adapted Optimum Propellers Based on a Vortex Lattice Lifting-Surface Model

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ABSTRACT

A new design procedure has been proposed for optimum marine propellers operating in uniform and radially non-uniform inflows based on a vortex lattice lifting-surface model (VLM). The procedure consists of two stages. In the first stage, the optimum circulation distribution along the radius is determined by using the NACA a=0.8 camber line. For a given design thrust coefficient, iterations start with the pitch profile when the blade loading is zero; the maximum camber at each radius is made dependent on the pitch by requiring that the local inflow is tangent to the camber line at the leading edge. For each blade section, the pitch angle and correspondingly the maximum camber are successively varied and the variations in efficiency are evaluated by means of an in-house vortex lattices code, the SPROP30. When the thrust is lower than required, the pitch angle is increased from root to tip, where the pitch increment at each radius is proportional to the amount of variation in efficiency evaluated previously. The maximum pitch increment is successively halved when the design thrust value is approached. The optimum circulation distribution is obtained when the design thrust value is achieved with a given tolerance.

In the second stage, the optimum circulation distribution obtained in the first stage is used to design the pitch profile and camber surface geometry with a prescribed loading distribution along the chord (NACA a=0.8 in this work). For a set of assumed pitch profile and camber surface geometry, the circulation distribution over the camber surface is computed by means of the VLM, and used to update the camber surface geometry by the Newton-Raphson iterative scheme according to the differences between the computed and the prescribed circulation distributions.

The proposed method has been applied to the design of a highly skewed propeller. Compared with the prototype propeller, the efficiencies of optimum propellers redesigned increase 3.9% in open-water and 4.6% in radially non-uniform inflows, respectively.

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