High-Efficiency Optimization Design of Marine Propeller Based on P-System Diffusion Algorithm and Parameter Model

Long Zheng, Shunhui Chen, Hao Wang
School of Transportation, Wuhan University of Technology, Wuhan, Hubei, China

ABSTRACT

Based on a novel optimization algorithm called Diffusion Algorithm Based on P Systems (DAPS), we present a fast and reliable propeller optimization design method that uses the maximum thickness and chord length of the sections of the propeller blades as design variables. In order to predict the propeller performance efficiency, a kind of parametric model generates numerical models of the propellers. And a so-called method of SQCM method is used to get the pressure of the wing surface. SQCM uses source distributions (HESS and Smith type) on the wing surface and discrete vortex distributions arranged on the camber surface according to Lan’s quasi-continuous vortex lattice method (QCM). The parametric model uses seven functions to form the shape of the propeller, these functions are respectively the function of thickness distribution and camber distribution with respect to the chord coordinate ratio, and the function of the chord length distribution, pitch, skew and rake with respect to the camber coordinate ratio of the propeller blade. A kind of MUA4 propeller and a known bio-inspired propeller are selected as examples to be optimized are verified by Computational Fluid Dynamics (CFD). Our method can obtain a marine propeller with good hydrodynamic performance propellers in a relatively short period of time.

KEY WORDS: Propeller optimization; Parametric model; Computational Fluid Dynamics; Diffusion Algorithm Based on P Systems

INTRODUCTION

With the increasing pressure of the shipping economy and the baseline development around the world continue to develop various methods. Herath, MT et al presented a layup optimization algorithm for composite marine propellers (Herath, MT. et al, (2015)). Dai, C et al optimized the chord length and blade thickness distribution in order to minimize the propeller mass under the constraint of constant propeller efficiency (Dai, C. et al, (1994)). Taheri, R and Mazaheri, K developed a propeller design method based on a vortex lattice algorithm and optimized the shape and efficiency of two propellers using gradient-based and non-gradient-based optimization algorithms (Taheri, R and Mazaheri, K, (2013)). Wang, Chao et al combined the experimental design method, the Ellipsoidal Basis Function (EBF) neural network approximate model, and the genetic algorithm to propose a propeller optimization design method based on the neural network approximate model (Wang, Chao et al (2020)). Gao, Hongtao et al digitally studied the marine winglet propeller inspired by the winglet airfoil (Gao, Hongtao. et al, (2019)). Dang, J used a new blade section to be applied to the ship propeller, which reduced the cavitation volume on the suction side and increased the pressure side Initial cavitation margin (Dang, J, (2004)). Zhu, W et al got inspiration from the biological airfoil, starting from the biological airfoil to improve the performance of the propeller (Zhu, W. et al, (2019)). In addition, Gao, H et al proposed a newly designed winglet propeller (Gao, H. et al, (2019)). The tip of the winglet propeller is inclined to the pressure side. The main advantage of the winglet is that it can suppress the tip vortex cavitation, and when the blade is inclined toward the pressure side at a smaller angle, the development of the tip vortex cavitation will be reduced. Benini, E introduced a multi-objective optimization method that uses an evolutionary algorithm that maximizes efficiency and thrust coefficients with constraints determined by cavitation (Benini, E, (2003)). In addition, research on the parameters that affect the performance of the propeller is also important. Ghassemi, H et al numerically discussed the influence of the forward inclination angle on the characteristics of open water and the sound pressure level around the ship propeller (Ghassemi, H. et al, (2010)). With the development of time, several researchers have tried to apply new technologies such as artificial intelligence to ship propeller. Shora, Mohammad et al used the neural network (NN) model to predict the hydrodynamic performance of the propeller (Shora, Mohammad et al, (2018)). They regarded the pitch ratio, rake angle and skew angle, propulsion speed ratio (J) and cavitation numbers, propeller thrust,