Abstract ID 1079

HYDRAULIC DESIGN AND OPTIMIZATION OF A LNG HYDRAULIC TURBINE RUNNER

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Keywords: LNG hydraulic turbines,DOE,RSM,NSGA-II,Optimization

Abstract: LNG hydraulic turbines used as the replacements of J-T valves play an important role in the LNG industry chain. In this study, an optimization method for hydraulic turbine impeller was established based on experimental design theory, the response surface approximation and genetic algorithm. This study focused on design optimization for the improvement of the performance of a LNG hydraulic turbine impeller by combining numerical analysis with DOE. The design variables of impeller are selected for the optimization process, and their effects were analyzed through Latin Hypercube Sampling method to select the final design variables that has major effects on the performance. Based on the chosen design variables, the design optimization is performed to select an optimized model through the RSM （response surface method） and NSGA-Ⅱ genetic algorithm.The structured grid system is generated through the ANSYS ICEM program. The dependence of the numerical predictions with respect to grid is analysed. When the mesh number is beyond 2.57 million, the head becomes stable. Thus the final grid number for calculation is selected as 2.89 million. The grid numbers for the computational domains are: guide vane 1.37 million, rotor 1.2 million, inlet and outlet 0.16 million, respectively.The CFD software ANSYS FLUENT 14.0 is used to calculate the 3D turbulence flow field of the hydraulic turbine. The flow is assumed to be steady, and the medium LNG is incompressible and viscous. The turbulence model RNG k-ε is chosen, and the interaction between rotor and guide vane is considered with the multiple reference frames (MRF) method. The coupling of pressure and the velocity is calculated with SIMPLEC algorithm, and the convection terms are discretized with the two order upwind scheme. The boundary conditions of the total pressure at inlet and mass flow at outlet were adopted.The efficient and head were chosen as objective functions, in the first step, the sensitivity of design parameters about hydraulic efficiency and head were analyzed, respectively. Then, the design parameters are chosen for the further optimization analysis. Response surface method (RSM) is used to obtain the explicit expression between the design parameters and the objective functions, then the NSGA-II genetic algorithm is used to obtain the Pareto Optimal Set of Multi-Objective Optimization. Finally, the head and hydraulic efficiency of the optimized model rise by 1.5% and 3.2%, respectively.