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Shape optimization of two-dimensional cavitators in supercavitating flows, using NSGA II algorithm

R. Shafaghat [*,1], S.M. Hosseinalipour [2], N.M. Nouri [3], I. Lashgari [4]

Department of Mechanical Engineering, Iran University of Science and Technology, Iran

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ABSTRACT

The reduction of energy consumption of high speed submersible bodies is an important challenge in hydrodynamic researches. In this paper, shape optimization of two-dimensional cavitators in supercavitating flows is studied. A two dimensional supercavitation potential flow passes a symmetric two dimensional cavitator, which is placed perpendicular to the flow in a channel of infinite length and immediately a cavity is formed behind the cavitator. This is because of the generation of a gas or vapor cavity between the body and the surrounding liquid due to the change in a high speed flow direction passing the cavitator. Drag force acting on this supercavitating body dictates the thrust requirements for the propulsion system, to maintain a required cavity at the operating speed. Therefore, any reduction in the drag force, by modifying the shape of the cavitator, will lead to decrease this force. This study concentrates on the optimization of two dimensional cavitators in order to decrease drag coefficient for a specified after body length and velocity in a potential flow. To achieve this goal a multi-objective optimization problem is defined to optimize cavitator shapes in supercavitating flow. The so-called NSGA II (Non-dominated Sorting Genetic Algorithm) algorithm is used as an optimization method. Design parameters and constraints are obtained according to supercavitating flow characteristics and cavitator modeling and objective functions are generated using Linear Regression Method. The obtained results are compared with other classic optimization methods, like the weighted sum method, for validation.

1. Introduction

Supercavitation is the cavitation effects which create a large bubble of gas inside a liquid, allowing an object to travel at great speed through the liquid by being engulfed by the bubble. The creation of the cavity (i.e., the bubble) reduces the total drag on the object and this makes supercavitation an attractive phenomena. In recent years, supercavitation has attracted growing interest due to its potential for vehicle maneuvering and drag reduction. Many problems in cavitation (e.g., cavitating flows around hydrofoils and bodies of revolution, design of supercavitating foils, ventilated cavities, etc.) have been investigated in detail both experimentally and theoretically. However, there are still many more problems that require more careful research [1]. In the past, the hydrofoil propeller design philosophy was to avoid cavitation for a widespread range of operating conditions. However, nowadays demands for underwater vehicle speeds and higher propeller efficiency have made this design philosophy practically impossible to apply. The efficiency of a non-cavitating high-speed propeller is relatively low, due to the required large blade area that leads to high frictional losses. Therefore the two dimensional supercavitating hydrofoils with controlled amounts of cavitation are utilized for designing propellers with a small blade area. A numerical optimization technique is applied to the design of two-dimensional supercavitating hydrofoil sections (Fig. 1). The drag coefficient of a cavitator is one of the most important characteristics of supercavitating flows. Usually the drag can be characterized as pressure drag and viscous drag. In the case of supercavitation, the pressure drag is considerably much higher than the viscous drag, since the body does not come into contact with the fluid [15]. In a special cavity, the length of the drag coefficient is a function of cavitator geometric parameters. In order to find the best cavitator shape in special conditions, we have to use an optimization process.

2. Literature review

Early research on supercavitating flows was performed by Reichardt [1], who experimentally studied the axisymmetric supercavitating flows. Efros [2] employed conformal mapping techniques to investigate the supercavitating flow problems. Tulin [3] introduced the use of perturbation methods for examination of two

* Corresponding author.
E-mail address: rshafaghat@iust.ac.ir (R. Shafaghat).
1 Ph.D. Student.
2 Assistant Professor.
3 Assistant Professor.
4 MSc. Student.

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