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Optimization of Suction Control on an Airfoil Using Multi-island Genetic Algorithm

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Abstract

To overcome the disadvantage of large suction requirements, the suction control for drag reduction is optimized. Computational fluid dynamics (CFD), in conjunction with multi-island genetic algorithm (MIGA), is employed to achieve the optimization. An E387 airfoil is employed as the physical model. The suction location and mass flux of a slot are set as the design parameters. The goal is to minimize both the airfoil drag and suction requirement by identifying the optimal suction location on the upper airfoil surface. The effects of different numbers of suction slots were investigated. Results show that the suction control for drag reduction could be optimized using MIGA. For a single-suction slot, the reduction in airfoil drag is up to 8.3%, and the mass flux of a slot reaches the lower limit of the optimization interval. The increase in suction slot number results in a better drag reduction effect, which is accompanied by larger suction requirement and slower convergence. The main reason for airfoil drag reduction is the decrease in the pressure drag.

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Keywords: Multi-islands genetic algorithm; suction; drag reduction; numerical simulation

Nomenclature

c	airfoil chord length
C_d	drag coefficient of the airfoil with suction
C_l	lift coefficient of the airfoil with suction
C_{d0}	drag coefficient of the basic airfoil without suction

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C_{l0}	lift coefficient of the basic airfoil without suction
x/c	normalized chordwise location
x_u/c	normalized chordwise location of upstream slot
x_d/c	normalized chordwise location of downstream slot
φ	mass flux of suction slot
φ_u	mass flux of upstream suction slot
φ_d	mass flux of downstream suction slot
φ_{sum}	sum of mass flux

1. Introduction

As global environmental awareness increases, fuel consumption that causes air pollution is expected to be reduced [1]. Specifically, the aviation industry aims to reduce energy consumption to cut operating costs. Reducing drag is crucial to reducing the cost of fuel energy.

Drag-reduction control includes passive and active drag reduction. Although passive drag reduction, which includes ribelts and large eddy breakup, is easy to apply, its effects are observed only at the design points. Active drag reduction, which can be effective in a more extensive design range, may be an alternative remedy [2].

Suction is a popular method of active drag-reduction control. Employed to reduce friction drag, suction is also called laminar flow control. Suction can delay the occurrence of transition and extend the laminar flow area by suppressing the development of boundary layer disturbances [3]. As the turbulence friction drag is greater than laminar friction layer, the expansion of laminar flow area means the reduction of friction drag. Furthermore, suction is an effective method to cut down pressure drag caused by flow separation. Prandtl[4] was the first researcher to control the flow separation through suction. The effect of suction involves the removal of decelerated fluid particles from the boundary layer [5].

Suction control has been studied extensively through experiments and numerical simulation [6-10]. The suction location and suction flow rate are critical parameters in determining the effects of suction. However, the suction location is generally identified through experience or tests, which cannot be optimal for drag reduction. As a result, the drag reduction objective may not be achieved or a large amount of suction requirement is inevitable to reduce drag. Thus, suction control must be optimized.

The goal of the present study is to improve the drag reduction effect of suction and reduce the suction requirement by optimizing the suction location and suction flow rate. CFD, in conjunction with MIGA, is employed to optimize the suction design. All the work has been conducted with a Reynolds number of 1.17×10^6 based on the airfoil chord at an angle of attack of 4° .

2. Mathematical Method

2.1. Physical model and Computation method

An E387 airfoil was employed for numerical simulation. The suction slot with a constant width of 61.5 mm was located on the upper airfoil surface. The location of the slot is defined by x/c, where x is the location of the trailing edge of the slot and c is the length of the airfoil chord. Two cases, depending on the number of slots, were studied. Two different physical models are shown in 错误!未找到引用源。.

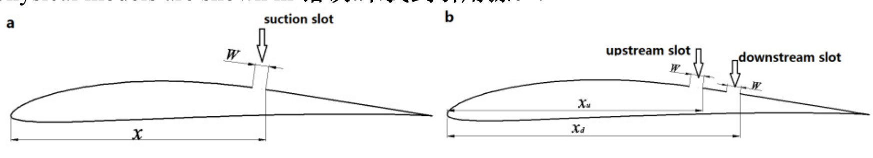

Fig.1.Schematic suction model for E387 airfoil(a) single slot; (b) double slot.