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Studying the Effect of the Trailing Edge Blowing of NACA0018 Airfoil on the Aerodynamic Performance

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Abstract

The flow control around the airfoil is widely investigated and utilized in the aircraft industry. The benefit of reducing the separation effect and its impact on the aerodynamic performance made the effort on this area is more desirable as this will impact to enhance the flight control as well as to reduce the fuel consumption during the flight. In this paper, the flow control using leading-edge blowing technique has been conducted for NACA0018 airfoil at Reynolds number 6.85 and 13.7 × 10^5. A CFD analysis has been conducted to examine several flight parameters and blowing speed to explore the benefit of using the blowing in this wing section. The results indicate that the lift coefficient can be enhanced to be increased by 4-6% as compared with no blowing case. However, this increase ratio is affected by the operational Reynolds number and blowing ratio. Higher speed means less benefit from blowing within the limit of blowing ratio of 1.

The benefit of using the blowing could come with an increase in the drag at some angle of attack. It is noticed that the blowing technique can generate positive pitching moment at lower angle of attack and can reduce the negative moment when the separation is happening at higher angle of attack. Also, the lesson learned in this paper is that the blowing benefit is more pronounced when the flight is under low Reynolds number environment.

Keywords: Airfoil, Trailing edge, Blowing, CFD.

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1. Introduction

The flow over airfoil has been studied over the last hundred years when the flying vehicle become widely used. Several studied are devoted on enhancing the aerodynamic performance of the wing section toward increasing the ability of lifting the airplane and also to reduce the required thrust to drive the aircraft with less fuel [1-3]. Also, the stability of airplane was the major concern to offer a safe flight and increase the maneuverability of the plane [4, 5]. One of the most effort on enhancing the aerodynamic performance was the flow control around the airfoil to reduce the drag as well as increasing the lifting force. Likewise, the main focus was to avoid the separation of the flow at higher angles of attack. Furthermore, controlling the flow also can be facilitated to adjust the laminar flow region over the airfoil to overcome the laminar separation before it happens during the flight [1, 6].

The flow control around wing section can be classified as passive and active types [2, 7, 8]. The passive control approach includes any mean of flow controlling that not requiring any auxiliary device/power or control loop. The second category is the active flow control in which the process requires auxiliary device as well as power / control loop [9]. One of the passive flow controls is using sucking or blowing air on the surface of the wing section at a location that may delay the separation in the flow or to induce the flow transition from laminar to turbulence flow before it normally happened and ended with laminar separation [10, 11]. Also, in some research area, inducing transition was conducted using vortex generators such as rough surface or fins at the upper and/or lower surface of the wing section.

The aim of flow control is usually needed when the flow is prone to separation at some flight condition such as that flight condition requiring high lift forces at low velocity (low Reynolds number) in the take-off and landing time. However, some maneuverability required to increase or decrease the speed during flight [12, 13].

Several studies such as in references [11], [14-16] investigated the suction and blowing flow control in some popular NACA symmetrical airfoil such as NACA 0012 and NACA0015. The results indicated that the lift generated could be increased to 93% in some cases. However, this increase is not constant with changing the angle of attack and Reynolds number. Each airfoil section can behave differently affected by several flow and geometric parameters. Also, the location of the blowing/suction flow control could serve particular design target and leading to a scarifying in some aerodynamic performance parameters [17-19].

A CFD analysis study was conducted by NASA to evaluate the benefit of blowing air at some locations in the upper surface of a NACA0018 wing section [20]. They used a wing-span wise slots to be pressurized by blowing air to induce the transition (from laminar to turbulence) at the upper surface. The results indicate an increase in the lift and decrease in the drag due to eliminating the laminar separation.

As the NACA0018 airfoil has a thicker wing section (18% of the wing chord), it is desirable to be used in aircraft wings to accommodate the structure elements, payload and fuel/battery. Its aerodynamic performance is good in term of