Macro-Surface Modifications of Subsonic Flow on Airplane Winglets

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Abstract

Airplane winglets are used to improve the efficiency and noise or vibrations of fixed-wing aircraft. In this paper, the surface modification involves alteration on surface's features to improve the performance of a product is being conducted. The surface modification was implemented on winglet surface in order to investigate whether the modified winglets provide better performance or not compared to the conventional wing designs. Two types of models were used which is a rectangular plane and airplane winglet, each with different types of surface modifications. For rectangular plane, four surfaces were introduced which is smooth plane, dimpled plane, riveted plane and extruded rivet plane. As for winglets, three surfaces were used which is the smooth winglet, dimpled winglet and riveted winglet. The parameters used for the simulations were based on the actual cruising flight and zero degree angle of attack. From the results, both show that the surface with rivets is better. The flow trajectories show that the flow velocity across riveted surface modified winglet is 5% higher than the smooth conventional winglet.

Keywords: winglet, surface modification, subsonic flow

1. Introduction

Airplane is a heavier-than-air powered fixed-wing aircraft that is propelled forward by thrust generated by the jet engine or propeller. An airliner is a type of airplanes commercially used for transporting passengers and cargo and is operated by airlines. Some of the famous airliners are Boeing 747, McDonnel Douglas MD-11 and Airbus A320.

Aerodynamic are the study of forces and the resulting motion of objects through the air. It can be classified into two types of flow, external and internal aerodynamic. External aerodynamics is the study of flow around solid objects of various shapes such as evaluating lift and drag of an airplane.

Wingtip device or also known as winglet was designed to improve the efficiency of fixed-wing aircraft by lowering the lift drag caused by wingtip vortices. It reduced the lift induced drag caused by wingtip vortices [1]. Winglets improve efficiency by diffusing the shed wingtip vortex, which then reduces the drag due to lift and improves the wing lift over drag ratio winglets increase the effective aspect ratio of a wing without adding greatly to the structural stress and hence necessary weight of its nature [2]. Winglet also reduces vibrations and noise greatly compared to those not having one.

In 1897, British engineer Frederick W. Lanchester conceptualized wing end-planes to reduce the impact of wingtip device. Later in 1976, Richard Whitcomb, a Langley Research Centre aeronautical engineer evaluated and tested winglet concept intensively. Whitcomb showed that winglet could improve airplane range by 7% at cruise speed [3].

Flight tests conducted on Boeing 737-400 shows 7% of drag reduction. Theoretical predictions indicate that the configuration would have only a 1-2% improvement and a wind tunnel tests shown only 2% drag reduction[4][5]. The first industrial application of the winglet concept was in sailplane where The Pennsylvania State University (PSU) 94-097 airfoil was designed for high performance sailplanes[5][6]. Throughout the years, improvements have been done on the winglets and now, Airbus has come out with new designed winglets called Sharklets equipped on A320 which save fuels as much as 3.5% on long routed of around 3000 NM[7]. Some of other winglets designs used are blended winglets and wingtip fences used by Boeing, Falcon 2000 and Airbus.

Surface modification is alteration on the features of a surface, like dimples and rivets. Research shows that dimples and rivets can be combined to gain improvements on airplane's fuselage [8]. One of the