Introduction Draft

Aircraft efficiency is greatly determined by the aircraft’s body and wings ability to move through the air with minimal drag while producing sufficient lift for flight. Aerodynamic drag can be broken into two categories: drag due to pressure gradients and drag due to friction. Pressure drag, is primarily caused by the low pressure wake an airfoil creates upon boundary layer separation with the wings trailing edge. This wake tends to become larger at high speeds or high angles of attack, thus increasing the pressure drag on the wings. In order to prolong boundary layer separation and thus reduce the size of the low pressure wake it may be possible to create a wing surface that acts as a vortex generator; creating turbulent flow at the boundary in order to delay separation and reduce pressure drag. A wing that is able to prolong boundary layer separation in this way could allow commercial aircraft to operate more efficiently and allow for improved maneuverability in military aircraft. Conventionally, a vane type vortex generator has been used for this purpose, however, the device height on conventional vortex generators is quite large and causes the wings to incur additional device drag in order to maintain their lift properties. In this experiment alternative methods of surface vortex generation will be tested in an attempt to improve upon current aircraft wing efficiency.

Conventional vortex generators have device height h, on the order of boundary layer thickness. They are generally a vane which protrudes normal to the surface and at an angle β in order to produce the desired turbulent layer. Due to there height, the device drag on these vortex generators is relatively high, so it is likely that a more efficient method of reducing boundary layer separation could be achieved. It is suggested by Rubiat et al. and Livya et al. that concave dimples on a wing surface may lead to the production of low pressure regions which can fight boundary layer separation while incurring much less device drag. It is also possible that an outward dimple with a smoother shape could have a similar effect to traditional vane style vortex generators, some possible dimple shapes are proposed in the work of Lin and Srivastav , while converting less forward momentum into unrecoverable turbulent energy. This experiment will be focussed on attempting to determine a dimple arrangement and shape which reduces boundary layer separation over a large range of angles of attack while minimizing the effects of device drag caused by the vortex generators.

In this experiment, the use of dimples as a form of vortex generator resisting boundary layer separation on lift producing airfoils will be investigated experimentally. In order to produce the airfoil models that will be used in this experiment Autodesk Fusion 360 will be used to produce 3-D models to be 3-D printed in PLA material for testing. The base airfoil will being tested will be following the NACA 0018 architecture throughout all tests. A control model with no dimpling will be produced alongside models with both concave and convex dimples in a variety of arrangements. Once the models have been printed they will each be tested in two ways, first in a sub-sonic wind tunnel over a range of airspeeds and angles of attack, then in a liquid flow employing dye lines to view fluid paths. The wind tunnel test will be used to determine lift to drag ratios for given speeds and angles of attack while the liquid flow test is meant to show where boundary layer separation first occurs on each model.

Works Referenced

Lin, John C. “Review of research on low-profile vortex generators to control boundary-layer separation.” *Progress in Aerospace Sciences,* vol. 38, no.4-5, 2002, pp. 389-420.

Livya, E., et al. “Aerodynamic Analysis of Dimple Effect on Aircraft Wing.” *World Academy of Science, Engineering and Technology International Journal of Aerospace and Mechanical Engineering*, vol. 9, no.2, 2015, pp. 350-353.

Mustak, Rubiat, et al. “Effect of Different Shaped Dimples on Airfoils.” *International Conference on Mechanical Engineering and Renewable Energy 2015 (ICMERE2015) 26 – 29 November, 2015, Chittagong, Bangladesh*.

Srivastav, Deepanshu. “Flow Control over Airfoils using Different Shaped Dimples.” 2012 International Conference on Fluid Dynamics and Thermodynamics Technologies (FDTT 2012). IACSIT Press, Singapore, 2012.