Group 5

Enhancement of MAV's using adaptive structures

3rd Deliverable: Concept Generation

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Introduction

The objective of this project is to enhance the flight performance characteristics of micro air vehicles by employing the use of adaptive structures or smart materials. Below is a list of preliminary concepts based on the groups knowledge of thermal fluids design and smart materials.

Concept 1

To enhance the agility of Micro Air Vehicles (MAV's) it is first helpful to understand ways to improve the agility of a sphere. Causing a turbulent boundary layer to form on the front surface of a sphere significantly reduces a sphere's drag. For a given sphere diameter, a designer has only two options encourage this transition, either to increase the speed of the flow over the sphere to increase the Reynolds number beyond transition or to make the surface rough in order to create turbulence (which is often referred to as "tripping" the boundary layer.) For practical purposes, in the case of a sphere, increasing the velocity is insufficient to exceed the transition Reynolds number, which leaves tripping the boundary layer as the only realistic alternative to reducing the drag.

The most dominant form of drag on spherical shapes is caused by pressure drag, while more streamlined shapes like the airfoils used on wings are dominated by a different kind of drag called skin friction drag. These streamlined bodies have a teardrop shape that creates a much more gradual adverse pressure gradient and this less severe gradient promotes attached flow much further along the body that eliminates flow separation, or at least delays it until very near the trailing edge. The resulting wake is therefore very small and generates very little pressure drag.

Some types of devices commonly used on wings create a similar effect to the dimples used on golf balls. Though these wing devices also create turbulence in order to delay flow separation, the purpose is not to decrease drag but to increase lift and one of the most popular types of these devices is the vortex generator. These vortex generators are often placed along the outer portion of a wing in order to promote a turbulent boundary layer that adds forward momentum to the flow.

Vortices are quite common in aerodynamics. Probably the most well-known and significant of these are the trailing vortices that are seen coming off the tips of wings in flight. These vortices are not desirable because they create a type of drag known as induced drag, or that drag induced by a surface generating lift (like a wing). However, vortices very similar to trailing vortices can also be used to produce beneficial effects, and one of the methods used to create beneficial vortices is the vortex generator.

When an aircraft flies at high angles of attack, the airflow over the wing can become detached, or it stops following the shape of the wing. When this happens, the lift produced by the wing will suddenly and rapidly decrease, and the wing is said to be stalled. When the flow separates from the wing, it usually means the air is moving too slowly, or there isn't enough energy in the flow to keep it moving. Since vortices are energetic, they can be used to put energy back into the flow to keep it moving in the desired direction. This is what vortex generators are designed to do.

Vortex generators are simply small rectangular plates that protrude above the wing surface and they look small wings jutting up perpendicular to the wing itself. As air moves past them, vortices are created off the tips of the generators just like the trailing vortices mentioned earlier. These vortices interact with the rest of the air moving over the wing to speed it up and help reduce the possibility of separation. Often times in actual airplanes, multiple sets of vortex generators are used along the outer wing with one set located near the leading edge with others placed just before the ailerons. The generators on planes serve to break up the shocks formed at transonic speeds thereby delaying the effects of separation. The generators located just ahead of the ailerons on the wing also help improve the effectiveness of these control surfaces at low speed or high angle of attack. Because Micro Air Vehicles typically do not have these kinds of control surfaces, one set of vortex generators at the leading edge seems practical and efficient.

Concept 2

A related device that is most commonly used on high performance fighters is the leading edge extension (LEX), which can theoretically be used as an adaptive structure to Micro Air Vehicles. Both the vortex generator and the LEX are primarily used to delay the flow separation that occurs when operating at high angles of attack near stall. As angle of attack increases, the adverse pressure gradient along the airfoil becomes increasingly stronger. Once the stall angle is reached, the gradient becomes so strong that it forces the flow to separate resulting in a loss of lift or control effectiveness. The advantage of devices like vortex generators and leading edge extensions is that they force the flow to remain attached at higher angles of attack and increase the stall angle. This improvement gives planes likes fighters greater maneuverability while increasing the safety of commercial airliners.

On airplanes these LEX devices are called fences and can be seen on most examples of the F-18 Hornet from the A/B models through the C/D. These surfaces are basically flat plates mounted on the upper surface of the LEX near the junction with the main wing.

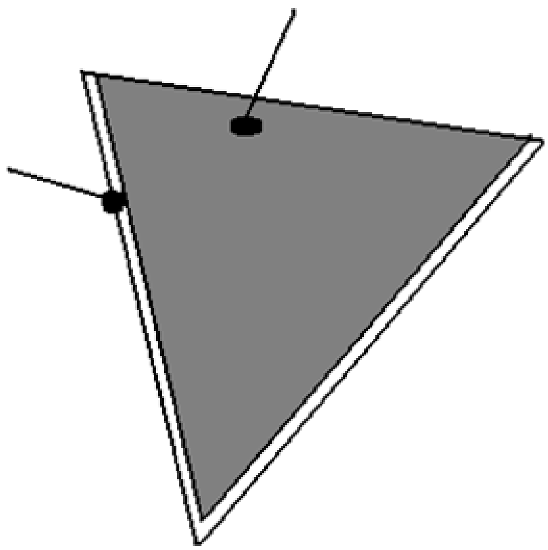
A leading edge extension is designed for the same purpose as the Vortex Generator - to create a strong vortex that increases the stall angle of a wing. The LEX achieves this behavior in the same way trailing vortices are created on a wing.

The high pressure air from the lower surface of the LEX rolls around the edge to the lower pressure region on the upper surface and this motion induces a rotation on the air flow causing it to roll up into a strong vortex. The strength of the vortex grows as angle of attack increases, and the high-speed vortex helps keep the air flow attached to the surface of the wing beyond the normal stall angle. The quantitative effect of this type of structure being implemented to Micro Air Vehicles can be calculated and visualized using computational fluid dynamics (CFD) software.

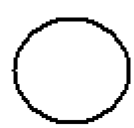
Concept 3

The delta wing concept is a continuation of Dr. Oates and Dr. Dickinson's research. It will consist of a rigid frame made of some light weight nonconductive material in the shape of a V. The frames cross section will be circular in nature. The VBH Tape will then be stretched over the frame with an electrode on either side of the tape, which will be the control surface of the wing. The main focus of this design will be to evaluate how the "adaptive structure" performs when not bounded on all side, as well as how much displacement can be achieved in an irregular shape. The design should have very low drag due to the profile being similar to that of a flat plate.

VBH Membrane



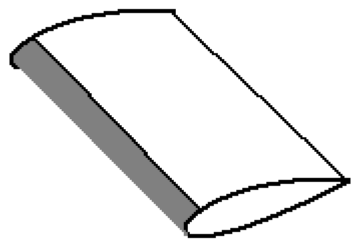
Rigid Frame



Frame Cross Section

<u>Concept 4</u>

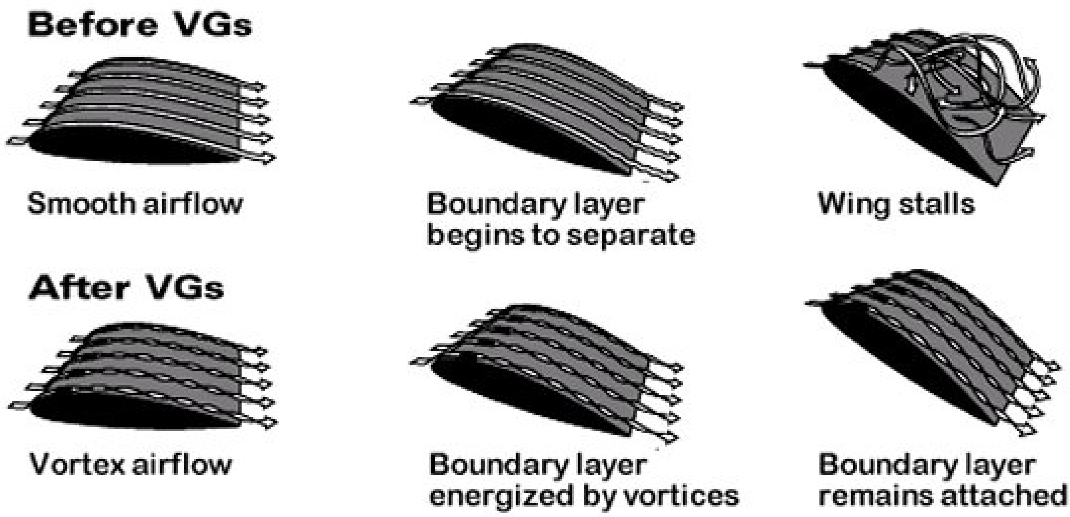
This design is an adaptation of last year's senior design project. The main focus of this design is to reattach flow, and increase the angle where stall occurs. Instead of having the RHB Tape father back on the top control surface of the wing, the leading edge will be made of RHB Tape, or some other adaptive structure. Also, the wing shall be made of a lighter material instead of aluminum in order to decrease weight and cost.



Concept 5a

This concept employs the use of a shape memory alloy. Although these materials often require a large and cumbersome power source, the properties of these materials are ideal for this application. In this concept the leading edge of the wing will be constructed of a shape memory alloy. These materials are built to retain a shape when put under and electric field. Once the field is removed the wing will go back to its original shape (flat). Although these alloys are usually very expensive, they are known to be the most dependable and durable through multiple cycles.

This concept will employ the use of vortex generators much like the first concept. As stated before, vortex generators are used to reattach turbulent flow on the trailing edge of the wing. By reattaching the flow one is able to reduce the drag coefficient and increase lift properties. The alloy will be imprinted with a series of ridges along its length. When the electric field is activated the ridges will rise and promote attached flow on the trailing edge of the wing as shown below (aerospaceweb.org)



Concept 5b

This concept, like concept 5a, will use vortex generators. In this concept however, the ridges will be formed using VBH tape with an exoskeleton structure placed over it. This concept will produce results much like concept 1, but will not require the use of multiple electrodes and power sources. By placing the exoskeleton on top of the VBH tape the design places boundary conditions on how much the tape can expand. This is a cheaper, and lighter version of concept 5a, but it also sacrifices its dependability.

Bibliography

1) aerospaceweb.org. Date accessed October 9,2010.