Senior Design Group #5:

Enhanced Agility of MAV's Using Adaptive Structures

Deliverable 4: Final design Report

Due: December 3, 2010

Client: Dr. Benjamin Dickinson

Advisor: Dr. William Oates

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Executive Summary

Research in adaptive structures is a very cutting edge and mostly undiscovered field at this point. Adaptive structures or smart materials can be used for a variety of applications including; CPU's, avionics, and consumer products. Smart materials are defined as a material that will significantly change one or more of its properties when exposed to external stimuli(2). The materials include, but are not limited to piezoelectric, dielectric elastomers, and shape memory alloys.

The Air Force Research Laboratory (AFRL) at Eglin Air Force base has contracted senior design group five in order to test whether or not the flight characteristics of a Micro Aerial Vehicle (MAV) can be changed by using adaptive structures. In the past our client, Dr. Benjamin Dickinson, has done research using a basic elliptical frame with a dielectric elastomer placed on top. This experiment concluded that the delay time for stall was increased at higher angles of attack and also that the lift coefficients increased compared to the base line. See figure

The initial testing has proven that there is a basis for furthering this research. The AFRL has contracted the group to continue Dr. Dickinson's research. The main component of this project is the testing of various electrode placements and their resulting change in flight characteristics. In order to record these results the group has scheduled time at the University of Florida's REEF facility outside of Eglin Air Force base. Here the concept designs will be tested for lift and drag coefficients, as well as rolling moments. Further testing will be done in flow visualization to provide qualitative evidence of the changes inherent in the flow field due to wing displacement. Although stress and fatigue testing need to be done before the prototype can be used in the field, the client is more focused on the limitations of this application.

Along with electrode variation the group must also design a suitable connection system for the testing equipment at the REEF facility. This design must prevent all arcing to the measuring device. These designs will be done with Wildfire's Pro Engineering software. The specific dimensions for the wing and test platforms will be used to ensure compatibility. Due to low forces of lift no FEA will be done on the wing components themselves. Also the project advisor Dr. William Oates specified that the FEA on the smart material has already been done and not pertinent for the project.

Needs Assessment

The applications for low Reynolds number (less than 10^5) micro aerial vehicles(MAV's) are essentially limitless. They can be used for surveillance, surveying, reconnaissance, and many other objectives. There is a lack of knowledge into the behavior of these vehicles due to their size and air speed. In order for the field to advance, better designs that will result in more stable and agile flight are necessary to increase the dependability of these vehicles. The use of smart materials is perfect for an application such as this in that they do not require the use of mechanisms to function.

Problem Statement

Low Reynolds number MAV's can be somewhat undependable due to the fact that their implementation is relatively cutting edge. Much is not understood about aerodynamics in the transitional phase of flow (between laminar and turbulent) such as this. In order for MAV's to prove themselves viable useful steps must be taken towards improving their performance.

Justification/Background

The client of this project is Dr. Benjamin Dickinson, a materials researcher for Eglin Air Force base. MAV's are still very much in the developmental stages and much is to be learned about their flight characteristics. The MAV itself will need to be agile and durable enough to navigate various obstacles and the inherent forces therein. The flight environment should be able to range from high heat conditions such as deserts to dark cold wet conditions such as caves. This project calls for the implementation of adaptive structures in order to improve flight characteristics.

Even though the field is very new there have been a number of innovations and papers published. Many studies that have already been done are modeled after natural phenomena such as avian and insect flight. Many of these solutions have worked but are strictly limited to unfixed "flapping" flight, which can be a nuisance while trying to fly through places with low clearance. Others have tried to meet the challenge by using adaptive structures to change the wing geometry resulting in increased performance. Another problem that must be solved is managing the deformation in the way that the polymer does not lose its elasticity which all membranes are subject to when put under fluctuating stresses. This can either be done by finding a material that hinders this behavior, or by implementing a quick inexpensive way to change the material out between flights.

Last year a design group used an electrically actuated elastomer in order to deform the wing geometry in an advantageous way. In theory applying an electric potential across this membrane will cause the membrane to deform in a convex fashion. The results of this experiment in this instance were less than desirable do to an in proper placing of the membrane. The client, Dr. Dickinson, has done further work using a basic elliptical frame with a dielectric elastomer used for the top surface. By changing the geometry of the wing Dr. Dickinson was able to produce an increase in the lift coefficient of around 30% at low speeds (See figure 1).

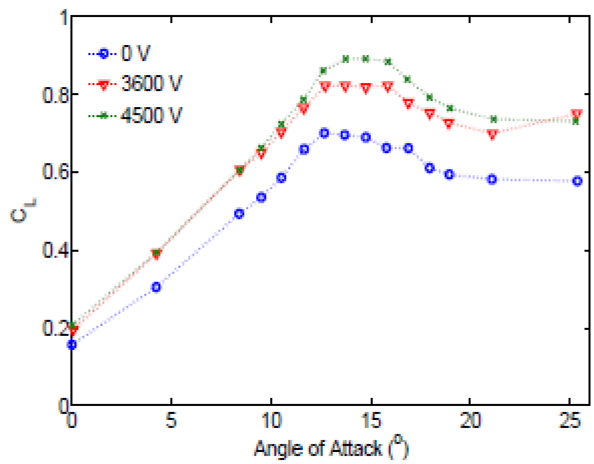

Figure 1- Lift Coefficient vs. Angle of Attack for wind speeds of 6 m/s. (Dickinson/ Oates)

Figure 1 shows that the greater the applied voltage to the membrane the larger the gain in lift. The figure below shows the wings deformation at the peak lift coefficient for (a) 0 Volts and (b) 4500 Volts.

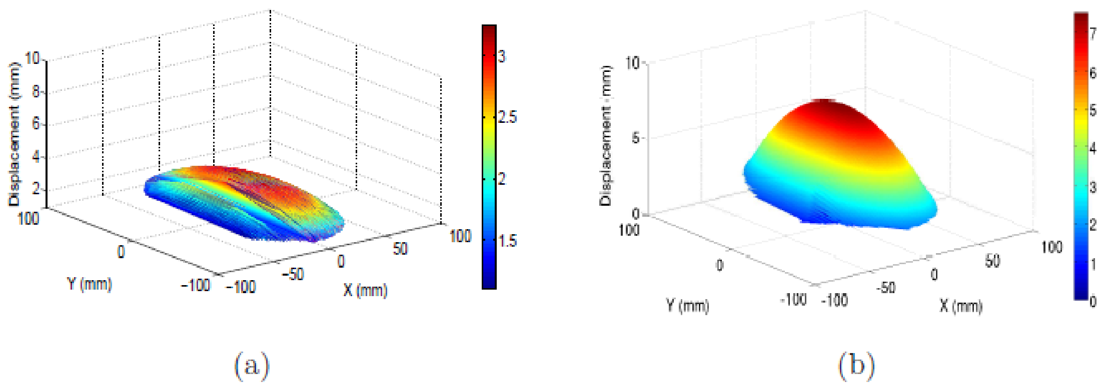

Figure 2- Shows the deformation of the wing membrane at the peak C_L for (a) O V and (b) 4500 V.(Dickinson/Oates)

There are a variety of adaptive materials that can be used for this project. Placing no limitations on the power source normally leaves the design very open ended, but the client has specified that a dielectric elastomer is to be used to continue the work that has been done earlier.

Objective

Enhance the aerodynamic properties of fixed wing MAVs at low air speeds (5-10 m/s)using a dielectric elastomer. The ultimate goal of the project is to prove that adaptive structures integrated into an airfoil are a viable way to improve or change the flight characteristics of MAVs. The enhancement of MAV's can be, but is not limited to , increased lift coefficient, better flow attachment, or decreased stall speeds. This will be done by varying the electrode geometries of the elastomer. It is the intention of this group to provide empirical results if these enhancements with a budget of two thousand dollars.

Overall Concept Design

The design for this project is a simple one. The design consists of one, major, non moving part. The frame for the wing is a simple ellipse with major and minor axis equal to twenty centimeters and ten centimeters respectively. A pre-stretched segment of VHB tape will be placed on the top side of the frame. Either side of the tape will be covered in carbon grease. This grease acts as an electrode and can be varied so that desirable flight characteristics can be changed. Once a voltage is applied across the electrodes the tape will deform. Figures one and two below show the basic concept of the elastomer without a voltage applied(figure 3) and with a voltage applied (figure 4).

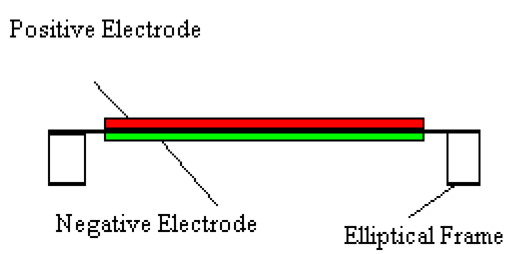

Figure 3- Basic wing cross section without an applied voltage

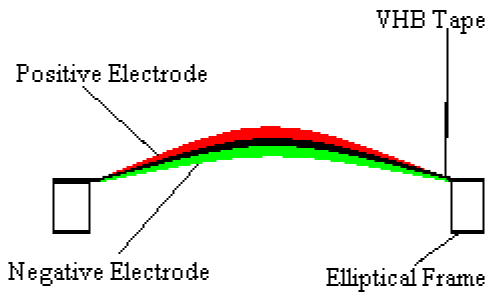

Figure 4- Basic wing cross section with voltage applied

Constraints

The client for this project, Dr. Ben Dickinson has provided a basic wing frame structure for the group to use. Because this project is based on a technology that is characterized by a lack of knowledge and experimental data, the client's main request is to test whether or not dielectric elastomers are a viable material for enhancing the flight characteristics of MAV's. The elastomer specified for use by the client is VHB (Very High Bonding) 4910. This elastomer is very easy to find and cheap, which makes it ideal for this project. The power source used will not exceed 4500 volts in order to ensure safe operation and limit arcing. The group must also design a suitable connector for the testing platform to ensure that the lab equipment does not sustain any damage.

Materials

The materials for this project were mostly specified by the client. The dielectric elastomer that is to be used is VHB (Very High Bonding) 4910. This material is relatively cheap and can be bought in bulk. This material also gives one of the most reliable deformations of all materials considered for use. Basing the design on this material meets the specification that the wing must be easily replaceable.

In order for this VHB tape to undergo a deformation it must be subject to an electric field. Unfortunately using a fixed electrode hinders the deformation of the elastomer, and usually results in failure. In order to account for this blow out problem the group has decided that carbon grease will be used as the electrode. Using dielectric carbon grease ensures that the voltage applied is even distributed throughout. A thick even coat of the grease will ensure that the VHB is not exposed upon deformation.

The wing frame itself is made of an Al6061 to prevent deflection while under strain from the elastomer. The connectors must be insulating to prevent arcing to the valuable testing equipment in the lab. Delrin plastic, characterized by its resistivity to deflection and electrical current make it an ideal candidate for these parts.

Electrode Test Configurations:

For this project we are focusing on two main implementations of electrode placement on the wing platform, which leads to two test configurations. The first test configuration which we are interested in is placement of the electrodes on the leading edge of the wing (Figure 4).

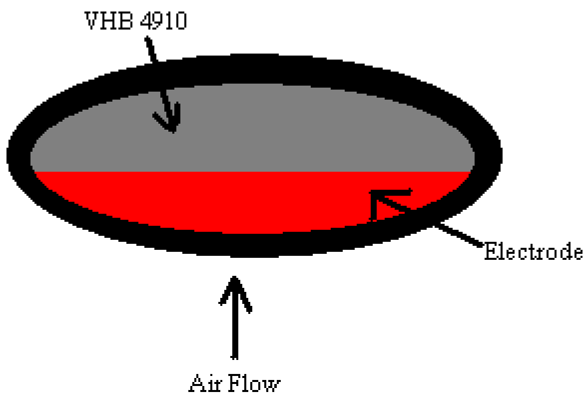

Figure 4- Shows the leading edge test configuration.

The goal of this test configuration is to increase the lift of the wing platform as well as increase the critical angle of attack. The parameters that will be varied are the thickness of the electrode, the applied voltage, as well as the angle of attack. Ultimately we would like to optimize the thickness of the electrode and the applied voltage in order to achieve the maximum lift as well as highest critical angle of attack.

The second test configuration we are interested in can be seen below in Figure 5.

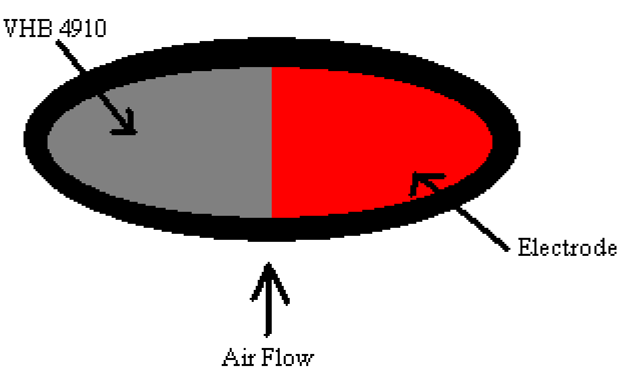

Figure 5- Shows the roll test configuration.

The focus of this configuration is to test the viability of using a dielectric elastomer as a control surface in a MAV. The theory is that when a voltage is applied to the electrodes, it will change the aerodynamic properties of one side of the elliptical wing enough to induce roll. As in the leading edge configuration, the thickness of the electrode, as well as the applied voltage will be varied in order to optimize the desired result.

Prototyping

The group is scheduled to commence building at the beginning of spring 2011. This build will consist of construction of six working prototypes. Due to the materials volatility three of each of the aforementioned electrodes (leading edge and rolling applications) will be built for testing. The building phase is still in the developmental stages. In order for the material to reach its full potential it must be pulled to 300% strain before it is fixed to the wing frame. This pre-stretching must be done with the upmost care to ensure that the membrane does not rupture. A ruptured membrane will result in a catastrophic failure or blowout which can set the testing back. The REEF facilities will only be available for a week building six models will ensure that testing will continue should two or three models fail.

Cost Analysis:

Part	Material	Vendor	QTY.	Part Cost	Total cost
Frame Connector	Al 6061	eMachineShop.com	2	$20.00	$40.00
Elliptical Frame	Al 6061	eMachineShop.com	6	$20.00	$120.00
Sting Connector	Sting Connector	McMaster-Carr	1	$7.20	$7.20
Actuating Material	3M-VHB	McMaster-Carr	2	$28.32	$56.64
Amplifier	x	Emco	1	$166.00	$166.00
Transportation	Gasoline	Gas Station	40	$2.79	$111.60
	Total Cost				$501.44

Spring Proposal:

Once the materials arrive in the spring we will begin by building our working prototypes. We will then practice straining the VHB tape to 300% and applying it to the elliptical wing. Once the application of the VHB tape to the elliptical wing has been optimized, we will then proceed to practice applying the carbon grease to the fully assembled testing platform, as well as placing the wires through which the voltage will be applied. Also during this time we will be testing to see how common oils used in smoke wire flow visualization react with the VHB tape in order to prepare for the flow visualization testing. We want to get the best results possible and in order to insure this; we need to make sure that oil and dielectric elastomer will not have any types of chemical reactions in the testing.

We will then be conducting experiments using the low speed wind tunnel located at the REEF facility owned by the University of Florida. We will be varying several parameters which include wind tunnel velocity, angle of attack, as well as the voltage being applied to the electrode.

We also plan to conduct the aforementioned flow visualization using equipment located at the Fsu-Famu College of Engineering. We will be varying the applied voltage, as well as the angle of attack in these test.

Works Cited

1) Dickinson, Benjamin. Oates, William. "Aerodynamic Control of Micro Air Vehicle Wings Using Electroactive Membranes". © August 2010.
2) "Dielectric Elastomers" http://en.wikipedia.org/wiki/Dielectric_elastomers. Accessed November 20, 2010.

Appendix:

Assembly and Drawings