Aaron Rapaport's Engineering Project Portfolio

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April 2, 2019

Abstract

This is a living document detailing my personal and extracurricular engineering projects. This document and the associated video and picture gallery at this Google Drive link will be updated regularly. The most recent modification date will be reflected above.

1 Airplane Design Team Experience

I joined the Union College Aero Team in my first year as an undergraduate. As a part of the team I have been a manufacturer, served as Vice President, and I currently serve as President and Team Captain. In my last two years I have been responsible for components of aerodynamic, structural, avionics, and manufacturing design.

1.1 SAE Aero Design West 2018-2019

Figure 1: The Union College 2019 Aero Competition Plane

This year we succeed in redesigning our aircraft with several innovative changes that have improved performance and reduced weight. Our 2019 competition plane incorporates a fully 3D printed fuselage and nose cone, a T-tail, high lift under-cambered wings, and friction fit carbon fiber rods that hold everything together. Collectively, these design features have succeed in minimizing weight while maximizing aerodynamic performance and assembly speed.

While I was involved in every part of the design and most manufacturing processes this year, I was specifically responsible for designing and manufacturing the wings and the connections holding them together.

Figure 2: The Stages of Wing Manufacturing

1.2 SAE Aero Design West 2017-2018

On the 2018 Competition Team, I served as a Vice President and was responsible for implementing aerodynamic stability features and developing our wing manufacturing process. I helped implement the shift from balsa to foam wing construction. Foam provided us the ability to successfully manufacture complicated wing profiles more precisely. Filling the entire wing volume with an isotropic, homogeneous material significantly improved the wings' impact strength. As a result, our planform held up significantly better during landings and test crashes.

1.3 SAE Aero Design East 2016-2017

When I first joined the Union College's Aero Team as a first-year, I mostly learned manufacturing techniques and did some independent research to gain the design and manufacturing skills. At the end of the year, I pursued leadership roles on the team, hoping to improve inclusiveness of new team members and to take on design responsibility myself.

2 Airplane Free-Building

2.1 Experimenting with True-Camber Foam-board Wings

I made my own true-camber foam wings, closely based on the "Experimental Airlines" design which produces a clean, continuous, airfoil.

Figure 3: True Camber Foamboard Wings

A "true camber" foam wing is different from other foamboard wings. Some wings, like in Figure 4 below, are shaped by creating a series of connected, flat strips of foamboard to form a top surface. However, in Figure 3 the top surface is completely uninterrupted. This generates a continuous camber line which is referred to as "true camber".

2.2 Developing a Modular, Folding Flying Wing

After building a few flying wings out of foamboard I decided to start developing one myself. The point of my design is to create a plane that folds into a significantly smaller volume than it occupies during flight, has an easily accessible electronics bay, and most importantly, is cut continuously out of a single sheet of foam-board.

I like that everything is connected by the paper from the same sheet of foam-board because it doesn't force me to rely solely on taping or another connection method to hold the wings together, but can still be modular by folding along the paper connecting the left and right wings.

The wing segments in this design are loosely based on the foam wing manufacturing style adopted by "Flite-Test", where the top shape of the wing is created by a series of planar surfaces that approximate the shape of a continuous wing. This model also implements a sweep and tapering.

Figure 4: The shell of a folding flying wing cut out of a single sheet of foam-board

3 Thesis Concept

3.1 P-Factor Compensation in Small, High Acceleration Propeller Aircraft

First Written On: 03/27/2019

For my Mechanical Engineering Thesis at Union College I plan to explore something that is relevant to my interests and has not been thoroughly explored before. I have noticed that every time I take on designing a new propeller aircraft, I am faced with compensating for propeller-factor with no usable information on how to predict its effects on the plane.

For context, propeller factor or "P-factor" is a term that refers to the induced yaw that occurs when a rotating propeller is inclined at some angle of attack in an oncoming flow. This becomes significantly more apparent when an aircraft is accelerating into an oncoming flow. P-factor yawing occurs because at an angle of attack, one side of the propeller is moving into the oncoming flow faster than the other. For a high thrust to weight ratio plane at a high enough acceleration this can lead to rapid yawing that causes a significant air velocity difference between the left and right wings. This leads to rolling during takeoff and can result in a crash.

3.2 Conventional Compensation

Typically, P-factor is adjusted for by inclining the motor at a slight angle to adjust for the airspeed difference between the two sides of the propeller. This solution becomes problematic because there is only sparse math and empirical data to help predict the the P-factor phenomena and none of it is really applicable to small aircraft. At the moment we only have the experience of hobbyists who say that a compensation angle of 3-5 degrees opposite the direction of the induced yaw tends to work. While I have done some basic empirical verification of compensation angle choices, choosing that angle in the first place is guesswork.

3.3 Preliminary Project Plan

I want to develop a project that explores the P-factor phenomenon by testing a variety of motor-prop combinations. Using a rotational and linear accelerometers, I will gage the effects of P-factor under different accelerations with different propeller pitches, diameters, and net thrusts. After collecting this preliminary data, I plan to develop a detailed table of adequate compensation angles for different motor-prop combinations by experimentally determining each compensation angle.

3.4 Auxiliary Goals

The angle compensation tests will yield information on the how the yaw forces change with respect to P-factor correction angle and the propeller's angle of attack. With this information, I hope to gain some understanding of this fluid mechanical phenomena that will allow for the development of equations that generally predict behavior. Using these equations, it may be possible to gain more understanding of the mechanics driving P-factor. This will at the very least, be applicable to small unmanned aircraft that need high overall performance, acceleration, and power efficiency.

4 Inkjet Printing Nanomaterial Films

My research is in Inkjet Printing Solar Cells from Organic nanomaterials. We are developing a technique to deposit high resolution films with a commercial, Epson, inkjet printer. By depositing nanomaterials in a layered set of films we can cast an organic bulk heterojunction that can separate charge and generate power.

I have been working on this project under the advisory of Professor Michael E. Hagerman since November of 2017 and working in the Hagerman Lab since April of 2017.

4.1 Materials

The Bulk Heterojunction Organic Solar Cell design involves several printed nanomaterials. The heterojunction, which preforms the charge separation, contains an electron conductor, a hole conductor, and a photoactive cromaphore. The photoactive layer is sandwiched between a cathode and an anode that, for the Hagerman-Kelbeck design can consist of carbon nanotubes or aluminum for the cathode, and Indium Tin Oxide.