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Vertical Take-off with Artificial Airflow

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VERTICAL TAKE-OFF WITH ARTIFICIAL AIRFLOW

by

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Abstract

Vertical Take-off with Artificial Airflow

Vertical take-off has been a capability available only to military aircraft due to the design utilized. However, if the design incorporated artificial airflow over the aircraft wings, then vertical take-off becomes a possibility for aircraft varying from general aviation to small jets. In order to determine the most efficient wing for vertical take-off, multiple airfoils with different characteristics and airflow configurations were designed and tested. For each airfoil, the coefficient of lift was to be calculated and recorded in order to determine which airfoil had the greatest capability for vertical take-off. However, the airfoil/airflow design utilized in the tests did not create enough lift to measure. Although the tests appear to have ended in failure, there was one important trait that was effectively proven. This trait was the fact that there was a pressure drop over the top of the airfoil, which meant that the airfoil was generating lift. This trait has lead to plans for future designs and testing.

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Definitions

artificial airflow – *Airflow caused by something other than movement through the air*

chord line – *An imaginary line drawn from the leading edge to the trailing edge of a wing*

commercial aircraft/aviation – *Aircraft that fly for compensation or hire (airlines, cargo carriers, charter, etc)*

general aircraft/aviation – *Aircraft owned by individuals that do not fly for compensation or hire*

leading edge – *The front edge of an airfoil (the 'leading' part of the wing)*

stall – *A condition of flight where the airflow over the wing is disturbed, or becomes separated, resulting in a loss of lift*

symmetrical airfoil – *An airfoil design where the shape of the airfoil above and below the chord line is the same*

trailing edge – *The back edge of an airfoil (the 'trailing' part of the wing)*

Abbreviations

C_L – coefficient of lift

Introduction

Preface

The capability to take-off and land vertically has been a trait that has intrigued aviators and engineers for many years. An airplane with this capability would have fewer limitations in regard to minimum speeds, take-off and landing distances, and even the necessity of a runway. At this point in time, the only aircraft capable of vertical take-off and landing include helicopters which utilize the spinning rotor blades to generate lift and military airplanes which utilize directional thrust. However, neither feature can be utilized effectively and efficiently for general and commercial aircraft. The solution to this problem is artificial airflow.

At this time, the concept of artificial airflow has been incorporated into military airplanes to slow the onset of a stall. Slowing, or even preventing, the onset of a stall means that lift is being increased by artificial airflow. However, artificial airflow has not yet been utilized as anything more than an airflow supplement. The following research explores this concept with the intent of determining the likelihood that it can be utilized to permit vertical take-off and landing by aircraft in general and commercial aviation.

Purpose

At this time, airplanes require runways and landing strips that can vary in length from 75 feet to over two miles. For many airplanes, this required element drastically reduces the available selection of airfields that can be utilized. The purpose of this research is to find a way to reduce the necessary length of the landing field to permit aircraft to take-off and land at more airfields, and some aircraft may not even require an airfield.

Development

General Information

Airfoils, when moving through the air, generate lift through Bernoulli's Principle (Figure 1). Bernoulli's Principle, also described as the venturi effect, states that as the velocity of a fluid

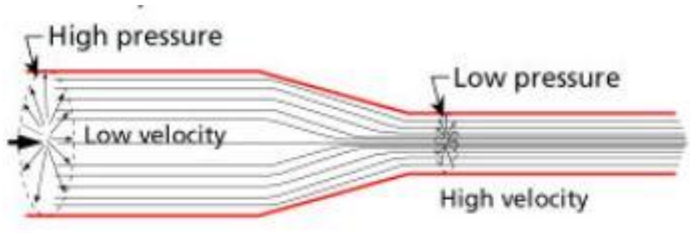

Figure 1. The venturi effect and Bernoulli's Principle, andreakb.wordpress.com/

(in this case air) increases the pressure of the fluid will decrease (and vice-versa). A venturi, a tube with a constriction in the center, is used to facilitate this increase in the velocity of the airflow.

To create lift, an airfoil is shaped like half of a venturi (Figure 2). The shape of the airfoil is used to increase the velocity of the airflow over the surface of the wing, therefore resulting in a decrease of pressure. The result of this decrease in pressure is lift.

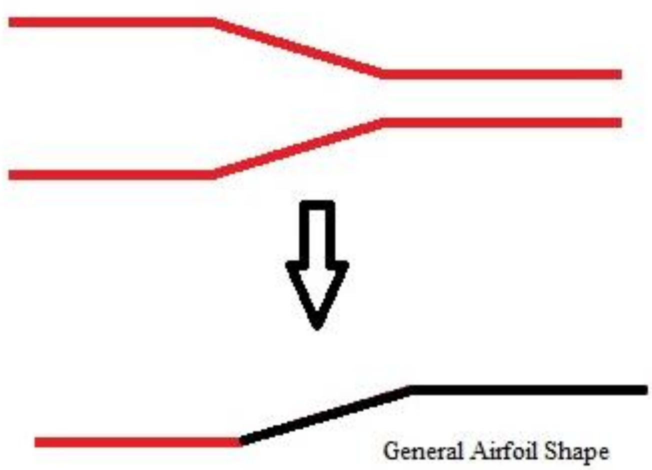

Figure 2. Venturi to Airfoil

Concept Formation

The concept of using artificial airflow that is restricted, at least mostly, to the upper surface of the wing came from the fact that a wing generates lift on both the upper and lower surfaces (Figure 3). Because of this fact, airfoils have taken on many different characteristics to reduce the negative lift induced on the lower surface of the wing. However, as long as air is being displaced and directed under the wing there will be negative lift reducing the total net lift acting on the airfoil. By directing the flow of air over the airfoil without letting air move under the airfoil, the net lift will be the same as the lift acting on the top of the airfoil.

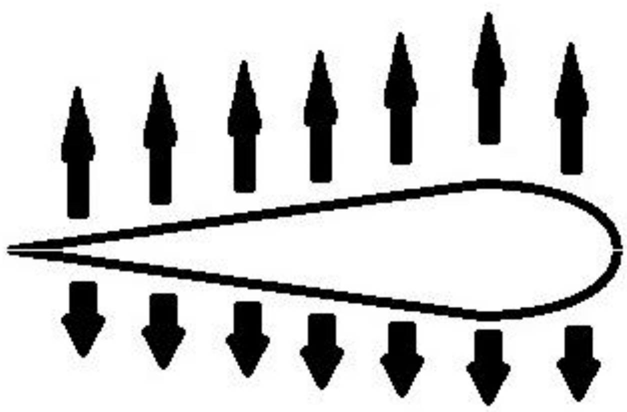

Figure 3. Negative lift

Test Plan

After the concept was formed, the test plan began taking shape. The test would utilize several different symmetrical airfoil configurations with differing characteristics (see Table 1).

Airfoil #	Nozzle Position	Slot	Airfoil #	Nozzle Position	Slot
1	Forward	*No*	**7**	On & under slot	*Yes*
2	At	*No*	**8**	On slot & At	*Yes*
3	Aft	*No*	**9**	On slot & Aft	*Yes*
4	Forward & At	*No*			
5	Under slot	*Yes*			
6	On slot	*Yes*			

Table 1. Airfoil configurations

The airfoils would be mounted to a test jig and the airflow directed over the surface from the locations listed in the above table. As each location was tested, the airspeed and lift (in pounds) would be noted and used to determine the C_L (see Equation 1). After all the airfoils were tested, the C_L from the airfoils would be compared to conclude which configuration would best serve the purpose of vertical take-off.

$$C_L = 2L/\rho V^2 A = L/qA$$

where

CL is the *coefficient of lift*	**V** is *true airspeed*
L is *lift*	**A** is the *planform area*
ρ is *air density*	**q** is *dynamic pressure*

Equation 2. The coefficient of lift

Design Process

The airfoils were designed to incorporate an internal airflow manifold and flush nozzles (see Figure 4) to prevent the necessity of using externally mounted nozzles or fans that would add excess weight and cause issues with airfoil balance. To facilitate the manifold, the symmetrical airfoils were required to be cut in halves. Using a hot wire and jigs, the airfoils were cut out of foam before being sanded smooth and measured to ensure the correct measurements were maintained through the process.

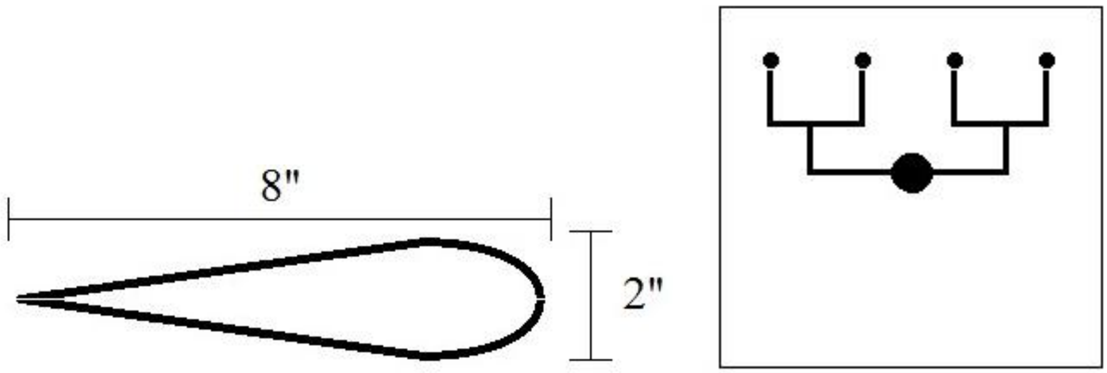

Figure 4. Airfoil - side view (left), Airfoil - internal manifold design (right)

Following the process of cutting and sanding the airfoil halves the first problem became apparent. The internal manifold was designed as passageways cut directly into the upper half of the airfoil. These passageways needed to be as close to the same size as possible to get accurate readings during testing, but cutting the passages was very difficult.

The first attempt to cut the passages was made using a hot pen. With the hot pen, there was no way to control the temperature or burn rate and the passages ended up different sizes (usually too big) or burned completely through the foam and the airfoil became unusable. Following the hot pen, a wire and drill bits were used to acquire more control over how much material would be removed and from where. First, the wire would be inserted into the foam to cut a pilot hole and prevent the drill bit from breaking out the top surface of the airfoil. This attempt worked much better than the previous, but the cuts were very rough (not conducive to smooth airflow) and the holes still ended up different sizes. The third, and final, attempt incorporated a rat-tail file and an etching pen. This solution gave the best control and the final product also had a smooth edge that would not hinder airflow.

While cutting out the manifold, another unforeseen problem arose. The airflow on those configurations using the nozzles positioned forward of the highest point did not direct the air back over the surface of the wing. Even with the etching pen, the nozzle passage could not be angled far enough to direct the airflow over the surface of the airfoil. To direct the airflow, an extra canal-like passage was cut into the top of the airfoil and tinfoil was used to get the required sharp angle.

The manifold area was sealed using tinfoil and the lower half of the airfoil (with a hole cut through the entire airfoil to attach the air source) was fastened in place with double-stick tape. A shop vacuum was used as the first air source and light-weight nylon tubing was used to connect the 2” diameter vacuum outlet to the ¾” diameter brass fitting that would fit tightly into the hole on the lower half of the airfoil. However, it quickly became apparent that the vacuum could not provide enough air volume or pressure to generate enough lift.

The second air source was compressed air. Two plastic step-down connectors were used to connect a hose to the airfoil. A valve in the system was used to control the amount of pressure fed into the airfoil to prevent blowing the airfoil halves apart.

Results

Using a high pressure air source gave much better results in the amount of airflow that was able to reach the trailing edge of the airfoil. Unfortunately, it still wasn’t enough to generate a measureable amount of lift. In order to ensure that there was indeed a pressure drop on top of the airfoil, a piece of paper was held over the airfoil and the manifold was pressurized. The paper was pulled down to the airfoil, proving that the pressure was dropping. While the pressure drop was not sufficient to generate a measureable amount of lift, design corrections and future plans were made to continue testing the artificial airflow concept.

Future Testing

Unfortunately, the design utilized in these tests did not generate sufficient lift to measure. However, by holding a piece of paper close to the airfoil as the air flowed across the top, the necessary drop in pressure was witnessed as the paper was pulled flush with the airfoil. The concept is sound, but the design needs to be changed.

Design Changes

The changes that will be incorporated in future tests include using different materials, incorporating external nozzles (despite the extra weight and balance issues), and making the airfoil larger.

The foam that was used in these tests was chosen because of its light-weight characteristics, but the foam was difficult to work with. Making several airfoils of the same size and weight, as well as cutting the manifold the same for all the airfoils is almost impossible with foam. Future designs will utilize thin aluminum sheets that will be shaped into airfoils and the manifold will be made of light-weight tubing that can be moved between the different airfoils to test different configurations.

During this test, it became obvious that sufficient lift could not be generated if the nozzles were not utilizing the full deflection capability of the airfoil. Future airfoil designs will have moveable nozzles extending beyond the leading edge that will be able to stream air over the full length of the airfoil. This will result in the maximum deflection of air which will lead to a higher velocity over the airfoil and, therefore, a greater drop in pressure. These nozzles will be designed to be moveable so that when the design is incorporated onto an actual wing, the nozzles can be retracted out of the relative wind once the wing starts moving forward.

The final design change that will be incorporated in the next test is the size of the airfoil. The airfoils utilized in this test were only 8” X 8” with the thickest point being 2” (see Figure 4). In future tests, the airfoils will be a minimum of 18” X 12” with the thickest point being at least 5”. Increasing the size of the airfoil will allow more flexibility with the size of the manifold as well as the positioning, which will be important for balance issues.

Testing Changes

Aside from changing many of the design features used in this test, various test related changes will also be made. One major change that will be incorporated is the use of a wind tunnel with an integrated testing jig for the tests. Additional changes include the process for taking measurements and the air source control.

The biggest change made in future tests will be the use of a wind tunnel. The wind tunnel will permit testing in a sterile environment and will be built with an integrated testing jig. Integrating the test jig with the wind tunnel will ensure that each different airfoil is tested in the same position and with the same conditions. Also, the test jig will incorporate side baffles to prevent the higher pressure air under the airfoil from flowing to the low pressure area above the airfoil.

With the use of the wind tunnel, it will be possible to change how measurements are taken during the tests. During the previous tests, neither airspeed nor lift could be accurately measured simply because the scale was too small. With the wind tunnel, airspeed indicators can be installed and used to measure the airspeed at various points along the airfoil to get the most accurate reading possible. Lift will be measured more accurately by utilizing a more sensitive scale and making it possible to adjust the location where the measurement is being taken in order to get as close to the center of lift as possible.

The final change to the testing process will include a more reliable way to control the air source, which will still be compressed air. In order to test different airspeeds, the pressure of the air flowing from the source must be strictly controlled and the flow must be steady. Pressure gauges will be installed in the line leading to the manifold and a twist valve will be incorporated to control the amount of air flowing from the source.

Conclusion

The designs created and the tests performed to test the concept of artificial airflow were able to successfully show that the concept is sound. Although the tests yielded none of the expected numerical results, the problems and solutions gleaned from the process has lead to the planning of future tests that will lead to greater and greater results.

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Author's Biography

Born and, mostly, raised in Saint George, Utah, Rachel Jill Adams attended Dixie High School until her graduation in May 2007. While in high school, Rachel was part of Dixie High School's Honors Society and chose to maintain her honors status as she moved on to attend college at Utah State University in the Fall 2007 semester. Rachel simultaneously completed two Bachelor of Science degrees while attending Utah State University. Her primary degree was in Aviation Technology: Maintenance Management (with Honors) and her secondary degree was in Aviation Technology: Professional Pilot. Rachel will graduate at the end of the Spring 2011 semester after attending college for four consecutive years.

Following graduation, Rachel will travel back to Saint George, Utah and take over management for Aviation Services Group, LLC. Aviation Services Group, LLC is an aircraft avionics, maintenance, and paint shop that is partially owned by her father, Duane Adams. While managing the business, Rachel will be working to expand the business into a flight school which she will both manage and act as an instructor. Additionally, Rachel will be working to develop two computer programs to be used by aviation professionals and she will be continuing research into artificial airflow.