Concept Generation and Selection

EML 4551C – Senior Design – Fall 2011 Deliverable

Team # 13

Joseph Cognato (1)
Jonathan Glynn (1)
Matthew Hartman (1)
Ramon Villarreal (2)
1. *Department of Mechanical Engineering, Florida State University, Tallahassee, FL*
2. *Department of Mechanical Engineering, Universidade Federal de Itajubá, Itajubá, MG*

Project Sponsor
Mary Brogan Museum

Project Advisor(s)

Dr. William Oates, PhD
Department of Mechanical Engineering

Reviewed by Advisor(s):

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Introduction

This project is commissioned by the Mary Brogan Museum and is headed by Dr. Oates of FAMU-FSU College of Engineering. The actual tasks given to Group 13 serve as a continuation of a previous project that was left incomplete. The initial product that is to be expanded upon currently has all the required physical components and assembly to provide air flow through a display case. This "wind tunnel" display is meant to be added to the Museum's exhibit upon the completion of the senior design course with which we are enrolled. Previous groups have had trouble finding a strong direction on how to present aerodynamic properties in the current display; we hope to not only determine how best to demonstrate such properties, but to also complete the display and present it to the Mary Brogan Museum.

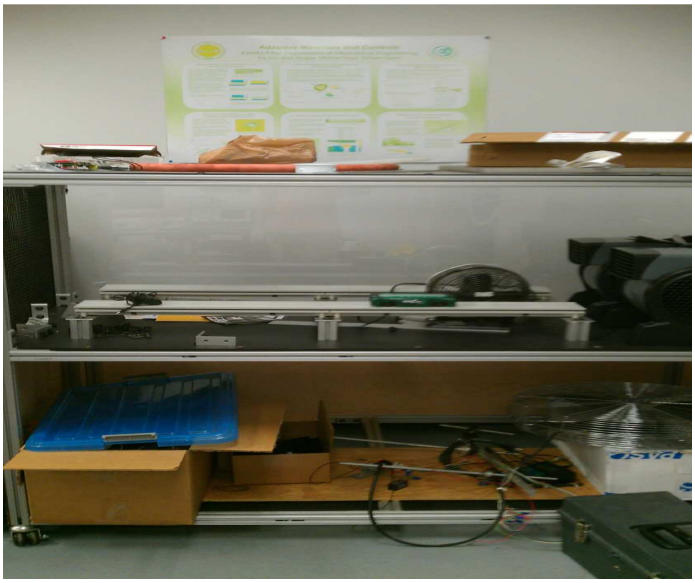

Figure 1 - Current Wind Tunnel

Product Specifications

The purpose of this project is to expand upon an existing display model so that it can be used in the Mary Brogan Museum. This display is meant to demonstrate properties of air flow and what affects/relevance such properties may have to young students. The display structure and basic materials are already present and assembled; as well as the fans that will be used to move the air through the display. What we are meant to add are mechanisms with which the air flow leaving the fans can have some demonstrate-able effect. The exact properties that we are to

demonstrate were not explicitly stated but the inherent limitations of both the size of the display and the speed of the air leaving the fans should serve as a strong enough limitation.

Along with the mechanisms inside the display we are also tasked with creating an interactive visual display to accompany our presentation. The display should server to engage any user/viewer, and to add a more detailed visualization and explanation as to what is being shown. The quality of the visual display will be heavily limited by our budget and will take up the major portion of it.

It is important that our display be geared for the understanding and interest of young students from k-12; and that this display server as a motivator for future scientists and engineers, or just to inform young minds as to what forces drive the world we live in.

Current Situation

This display is already built which saves us a great deal of time when it comes to implementing the flow visualization tank. The wind tunnel is compact and light which allows for easy transportation and storage. The current assembly has sufficient fans by which to conduct many simple demonstrations. The wind tunnel is not complicated enough to deliver clean/laminar flows and therefore will need to rely on simple qualitative experiments. With air as the working fluid and without having complicated flow visualizations the wind tunnel will allow for very low maintenance and very simple operation, which are both very important aspects of our final design specifications.

Figure 2 - Current Wind Tunnel

Electrolysis

This display will use water as a medium by which hydrogen bubbles will be used to track the flow of the water as it travels over different shapes. Water can be used as a substitute to air as electrolysis is a much cleaner and lower maintenance method than injecting smoke or other air visualization methods. Instead of requiring foreign substances in the working medium electrolysis uses the elements already present and doesn't require additional systems to support the visualization. What is necessary for electrolysis visualization is to move the test section in the fluid rather than the other way around. This requires motors by which to move the test section and any necessary light sources.

To create the hydrogen bubbles that are used to visualize the flow a current is run from a copper anode through the water to a platinum cathode. The platinum is only 25 microns in diameter by which very small bubbles are created. These small bubbles are necessary to eliminate the buoyancy of the bubbles which allows for an accurate representation of the flow. A light source is used to scatter off of the bubbles and create a contrast with which the pattern of the flow can be observed.

This design is robust and out of all the flow visualizations methods is the most stable, only maintenance is minor maintenance of the materials and filling and draining the tank. There is not much flexibility on what types of test sections can be used in the tank due to the fact that the section needs to be anchored behind the wire and must be symmetrical. There is also a very large current that is put through the water in the tank which can be hazardous to the touch.

Figure 3 - Towing Tank

Display

The display plays an important role in our project since we want to create something interactive, easy to use and didactic. That only will be possible with a display that can combine these three together. Using a touch screen monitor to control the system with the less complication possible, meaning that would have few buttons and will request no explanation of how to use, will facilitate the use of the experiment. Also will be an interesting and fun enough to get people's attention. Showing quick explanations about what is happening so it doesn't get boring and exposing the effects caused by changes made by the user, will facilitate the comprehension of fluid dynamics in a fun and interactive experiment.

Figure 4 - LCD Touch Screen

Concept Generation

Concept 1 - Smoke

The main idea of our project is to allow the comprehension of air flow's physics, so a good and clear visualization of it is necessary. The smoke can perfectly fulfill this task since it exposes the air flow lines besides being a really cool and interesting experiment that can get everyone's attention. Some advantages of using smoke will be that it helps people to visualize what is really happening around anybody that it's put inside the wind tunnel. Changing the bodies will show the flow property of outlining the bodies. Also, since it helps the visualization of the flow, it also helps in the comprehension of the phenomenon. Finally, we already have the basic structure of the wind tunnel and wouldn't be a big of a change to put smoke in it. On other side, there are some disadvantages such as the smoke machine would need someone constantly adding fluid and one of the customer's requirements is that the experiment must not need any maintenance. The cost is also something to look for since this tracer would cost 4000 dollars and the fluid would have to be change at least once a week, meaning a cost of another 60 dollars weekly. A certain smoke control system inside the wind tunnel would be necessary since the smoke cannot come out of the wind tunnel. Finally, due to the dimensions of our wind tunnel and the need of using air, creating a laminar flow so we have a clear visualization is very hard and we would need to change the structure that is already built.

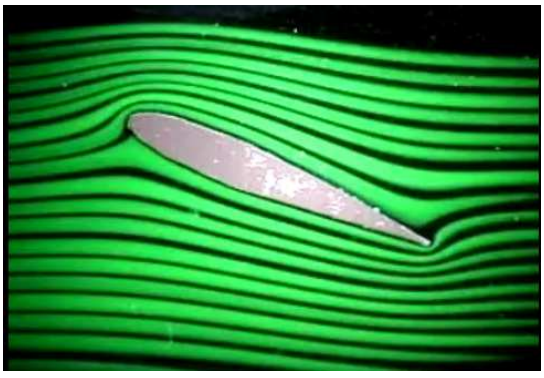

Figure 5 - Smoke Visualization over Airfoil

Concept 2 - Carts

For this concept our team will supply multiple different attachments that are able to be placed on traditional carts to interact with the air flow. The carts will be stationary on the track with an airfoil or different geometric shape (circle, square, or a triangle) attached to the top of the cart so as the fans generate more flow the carts will be able to move and increase in speed based on the attachment used. This concept allows for a lot of interactive play with kids of all ages as well as helps the user understand which shapes can cause more drag and thus causing the cart to move faster. The concept gives a good visualization for drag forces but is unable to actually display the flow of the air. The concept is also very cost efficient in that it only requires few pieces to be implement. A big issue with this idea is that the user would actually need access to the wind tunnel so that could cause some safety issues if someone could have access to the wind tunnel.

Figure 6 - Cart used in Wind Tunnel

Concept 3 - Hand

A different concept compared to actually using an airfoil is to allow access to the wind tunnel and have a user use their hand in place of an airfoil. The air box can have an opening that allows for the user to place their hand into the experimental area and the user then specifies the speed to which they want to flow to act at and uses their hand to feel the different drag and lift forces. The benefit of allowing the user to actually put their hand in the air box is that it lets their hand feel the different forces acting on their hand rather than being told the forces acting on an air foil. The hand concept allows for a tactile response to the forces within the air box, the user feels the change in lift and drag as they change the angle of their hand. The hand idea is also very cost effective in that our team don't need to purchase anything from a third party, all that is necessary is just making modification to the air box. The issue again is safety, if the user is allowed within the air box it could cause technical issues if they decided to touch or move things that are supposed to be. Another rising issue is that the fluid flow isn't actually visualized again, it is only felt.

Figure 7 - Hand Acting as Airfoil

Concept 4 - Airfoil

A staple in visualization of air flow is airfoils; they are used in most wind tunnels to show different pressure regions as the angle of attack changes. For our wind tunnel it is no different, our team will use a simple wind design attached to a rotatable pin which is also contained within a sliding mechanism. The rotatable pin allows for the user to change the pitch angle so that different wakes and pressure differences may be experienced. The sliding mechanism allows for the airfoil to rise and fall as the pitch angle is changed so that the user is able to see the different lift forces that are applied with the different pitch angles. The only issues is since the flow isn't laminar the airfoil has to be adjusted to mostly turbulent flow. This concept allows for a lot of user interactions with the possibilities to adjust the pitch, it also is a very simple concept when it comes to doing air flow. Another benefit is the low maintenance cost of the idea, because there isn't anything that needs to be up kept. An issue with concept is the lack of streamlines that can't be shown so that different wakes due to different pitch angles can't be shown. Also the airfoil isn't going to be switched with another one so there is no variety in using the airfoil; as always space in the air box is also an issue.

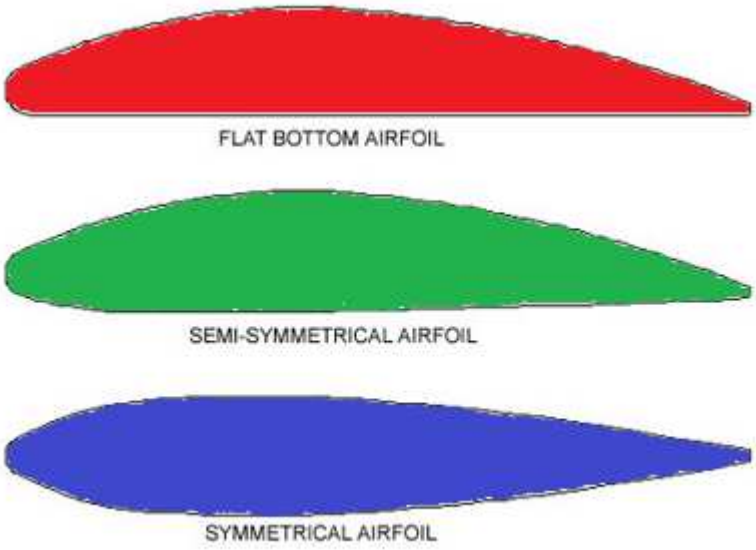

Figure 8 - Various Airfoil Designs

Concept 5 - Wake Visualization

The concept of a wake is hard to display without any smoke or lasers so a possible way to allow for wake visualization is to use an actuator and place it behind the airfoil, or what whichever device is creating a wake, and once the turbulent flow vibrates the metal beam the frequency is found and from there a voltage is produced. From that voltage we can display it on the led screens and show that there is a wake created behind the air foil. The concept is able to show the users that an actual wake is created behind different objects, as well as slows for an interactive component with the wakes. An issue with the concept is the space it will take up in our air box might cause issues with other types of visualizations that are going on. The actuator also requires electrical connections which might be an issue within the air box. Without test the actuator our team is unsure if the frequency produced will be significant enough to produce a usable voltage

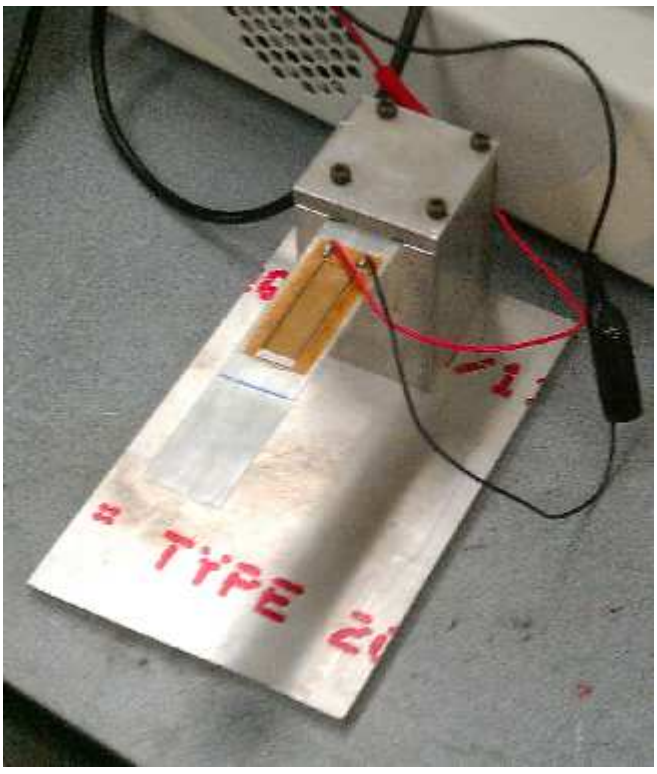

Figure 9 - Wake Actuator

Concept Selection

		Cost	Maintenance	Space	Robust	Edu.	Simple	safety	Total
	Weight	0.1	0.25	0.1	0.1	0.25	0.15	0.05	10
Phase 1									
	Air Box	10	9	10	10	7	10	8	8.9
	Towing Tank	1	7	2	8	10	8	5	6.8
Phase 2									
	Smoke	3	1	4	9	10	9	7	6.05
	Cart	8	8	8	7	7	9	9	7.85
	Hand	10	10	8	10	6	10	2	8.4
	Airfoil	6	9	6	8	9	7	8	7.95
	Actuator	8	9	7	8	5	5	8	6.95
	10=good	1=bad							

The decision matrix above takes into account all the specifications that are deemed necessary to this project. The first was the cost of implementing each idea. The sponsor does not want to spend a large sum of money therefore; simple inexpensive visualizations should be used. Another major point is that the display should require little to no maintenance. If at all possible keep the maintenance to an annual checkup. Since the wind tunnel is already built the space for the devices is limited. The main point of this project is for it to get used repeatedly by people so being robust must be considered. The display must also be able to teach the user the concept that is trying to be presented. Finally, keeping the wind tunnel simple and not over complicating anything and safe are the final criteria. The matrix itself is a two phase matrix. The first phase was to decide between the towing tank or stay with the current design. The second are the various ideas to demonstrate different flow characteristics.

Conclusion

Through the use of the decision matrix, we are able to compare which of the concepts we would like to put into place in the wind tunnel. Although we would like to implement all of them, due to our space limitation and budget it is wiser to only select a few and stay with the current set up. The best would be to place a smoke device into the tank but due to how short the box is the required distance to achieve laminar flow within the box is not possible. Having low

friction carts with different geometric shapes attached to the top of them would be a good candidate. There is little maintenance in this idea other than a possible realignment and the affect of drag on the shapes will be clearly seen. Being able to physically place the hand into the box would be a great way to feel the difference in pressure depending on how the hand is angled. However, this is a big safety concern so more background and testing will need to be done. The airfoil would be a good way to show the effect of lift. Also, by allowing the user into change the pitch of the airfoil this concept would be very interactive. The actuator may take up a lot of space and there are still some unanswered questions. The most important is if there is enough turbulence behind an object in the wind tunnel to create enough voltage.

After careful consideration, the current wind tunnel will be used. The concepts that we will by placing into the box will be the cart, airfoil, and actuator. Using these will allow should allow for enough space. The visual display will be a LCD touch screen. This will serve as an additional educational tool once the proper software is installed. Finally, we will continue to look into ways in which to allow users to use their hands to feel what is going on.