ASHESI UNIVERSITY

INTELLIGENT WIND TUNNEL DESIGN

CAPSTONE

B.Sc. Mechanical Engineering

Michael Kissi Danquah

2019

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CAPSTONE

Capstone Project submitted to the Department of Engineering, Ashesi University in partial fulfilment of the requirements for the award of Bachelor of Science degree in Mechanical Engineering.

Michael Kissi Danquah

2019

DECLARATION

I hereby declare that this capstone is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:

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Candidate's Name:

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Date:

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I hereby declare that preparation and presentation of this capstone were supervised in accordance with the guidelines on supervision of capstone laid down by Ashesi University.

Supervisor's Signature:

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Supervisor's Name:

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Date:

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Acknowledgements

I give unparalleled reverence to Almighty God for providing me life to complete this project. I am very grateful to my supervisor, Dr. Heather Beem, for her interest in the project, inspiration and readily available support throughout the project duration. I am also thankful to the Ashesi University engineering department for providing me with the resources to complete the project. Finally, I want to express profound appreciation for my family for the love they continue to give me.

Abstract

A Wind tunnel is a mechanical assembly used to analyze the behavior of air flow and the effects they have over objects. Using a wind tunnel, one can control the stream conditions which influence forces on the test object. Through the calculations of the forces on the model, one can anticipate the forces on the full-scale test object. In the beginning, wind tunnels were used to utilized to comprehend and improve the execution of airplanes. Over the years, cars, bridges, and building were studied using wind tunnels.

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Chapter 1: Introduction

1.1 Background Information

In the engineering design process, testing is inevitable, and advices the necessary steps to be taken to get a system to its desired state. Design and manufacturing of systems that interact with wind involve the study of the aerodynamic principles that govern the operation of the system. Fluid mechanics theories and design parameters are tested out on full-scale prototypes or scale model prototypes of the product or system under study.

A wind tunnel is a device used in creating a simulated environment for testing prototype structures. The wind tunnel allows for a direct translation of test parameters from a scale model to the actual product or system because of the fluid mechanics property known as the Reynolds number. The Reynolds number is based on the characteristic geometry of the body being tested, thus allowing for a scale model to be used to represent the actual product or system.

Products or systems that are tested in wind tunnels range from cars, aircrafts, skyscrapers, bridges, etc. The common theme within these mechanical systems is their interaction with fast-flowing air, whether they are stationary or mobile. So far as wind tunnels are concerned, the speed of winds around (external flow) or within (internal flow) are categorized mainly under low or high.

1.2 Project Aims and Objectives

The main aim of this project is therefore to design and build a wind tunnel that can be used in conjunction with the Fluid Mechanics and Applications course in Ashesi University. In line with this, the specific objectives of this project are as follows:

- To determine the effect the honeycomb structure has on a wind tunnel

- To model the wind tunnel using internal flow design principles

1.3 Expected outcomes of project

It is expected that after the wind tunnel is built and tested, it can be used for experiments involving flow visualization for the Fluid Mechanics and Applications course in Ashesi University.

1.4 Significance of Project

In the first run of the Fluid Mechanics and Applications course, experiments involving the visualizing of flow and testing of airfoils could not be performed due to the lack of a wind tunnel. The presence of a wind foil on the Ashesi campus will make theory learnt in class more meaningful. In addition, this feat will make Ashesi a center of research for projects involving wind testing as there are very few wind tunnels in Ghana.

1.4 Research Methodology

Data for this project will be obtained mainly from primary and secondary sources. Primary data experiments and secondary from journal articles, books, other project documentations and any other related documents.

1.5 Project Scope

This project will focus primarily on the design and implementation of wind tunnels in its first phase. The second phase will focus on testing the wind tunnel to determine if it matches the standard of other wind tunnels around the world.

1.6 Thesis Chapter Outline

Chapter one constitutes the main introduction to the problem and the project (background information, aims and objectives of the project, expected outcomes of the project, the significance of the project, research methodology, project scope, and the chapters outline).

Chapter two comprises a more extensive literature review on wind tunnel design and manufacture.

Chapter three consists of the methodology, material selection process, design and the mathematical model used for forecasting the design

Chapter four comprises the implementation of the project.

Chapter five centers on the results of all experiments conducted.

Chapter six will look at the summary and conclusion of the project.

Chapter 2: Literature Review

2.1 Overview

This section provides a detailed look into understanding how wind tunnels work.

2.2 Wind Tunnel Model Parameters

Wind tunnels are one of the many devices or methods used to obtain experimental information for solving both hydrodynamic and aerodynamic problems. Low-speed wind tunnels can easily be made during the early stages of a design thinking cycle as they can provide large amounts of consistent data and contain the full complexity of real fluid flow. They are known to be accurate devices for conducting research and obtaining data in design designs based on aerodynamics; economical and respond quickly during use. Wind tunnel experiments are conducted using scale models of wind tunnels. These models are characterized by certain parameters which are used to effectively predict the nature of full-scales models. These parameters for dimensionless coefficients that appear in the non-dimensional form of the fluid dynamics equations. These are Froude number, Reynolds number and Mach number [1].

2.3 Types of Wind Tunnels

There are two basic types of wind tunnels which form the two types of test-section structures. These however do not influence the types of wind tunnels made as all wind tunnels are made using numerous variations of specific features. These two are closed circuit and open circuit wind tunnels and the test-section structures are closed and open test-sections.

The air flowing through a closed-circuit wind tunnel continuously recycles with little or no replacement of air with its environment. Most closed-circuit wind tunnels have a single return, though there are wind tunnels with both annular and double returns. Unlike the open circuit wind tunnel, closed circuit wind tunnels may have either an open test-section or a closed test-section based on the experimental program being considered. Below is a figure of a closed-circuit wind tunnel [1].

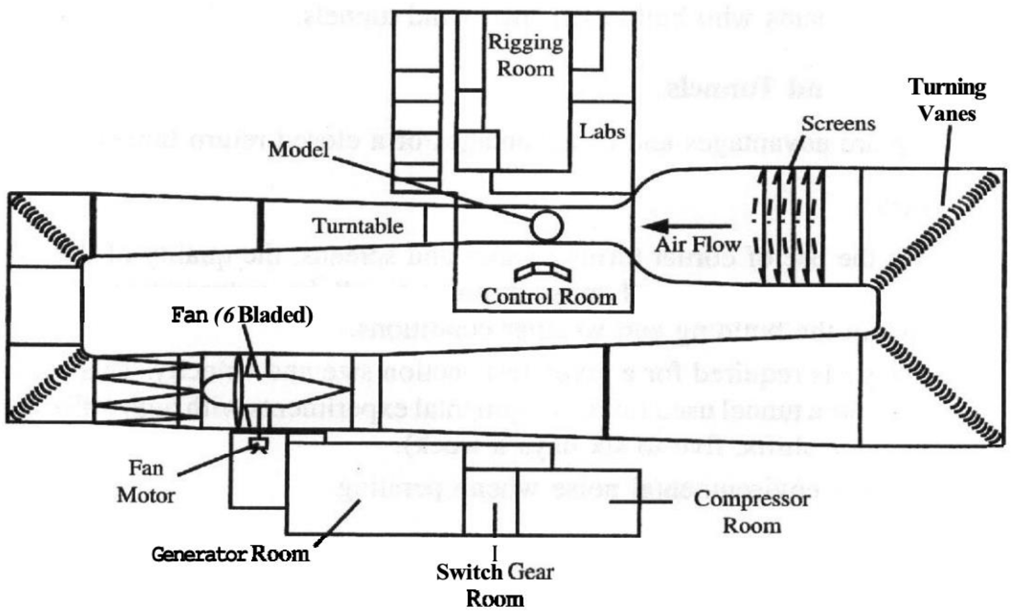

Figure 2.1: A closed circuit wind tunnel, Defense Establishment Research Agency @ERA), 13 X 9-ft tunnel in Bedford, England.

There are advantages and disadvantages of the closed-circuit wind tunnel. These are listed in the table below.

Table 2.1: The advantages and disadvantages of the closed-circuit wind tunnel

Advantages	Disadvantages

The environmental noise during operation is less.	Tunnels used widely for the running of internal combustion engines or smoke flow visualization experiments must have a way to be purged.
The flow quality can be properly controlled via the use of screens and comer turning vanes. In addition, the flow quality will be independent of the weather conditions surrounding the wind tunnel as well as other activities surround the wind tunnel.	Tunnels with heavy utilization may have to include an air exchanger or another method of cooling.
The energy required for a given size of the test-section and its velocity is less. Such a feature is important for tunnels which will be heavily used.	High initial costs due to comer vanes and return ducts.

Closed circuit wind tunnels of large sizes, with an external balance, and working on the open test-section configuration tend to have a solid boundary since they must withstand high wind intensities. Many of the closed-circuit tunnels working under the open-test configuration experience severe problems with flow fluctuations and they require extensive corrective actions

The air flow through an open circuit wind tunnel fundamentally flows in a straight path from the entrance through a narrowing to the test section. This is followed by a diffuser, a fan section, and an exhaust of the air. This wind tunnel may have a test section consisting of solid boundaries (closed jet or National Physical Laboratory (NPL) type) or no solid boundaries (open jet or Eiffel type). Below is a plan view of an open circuit tunnel with a closed jet [1].

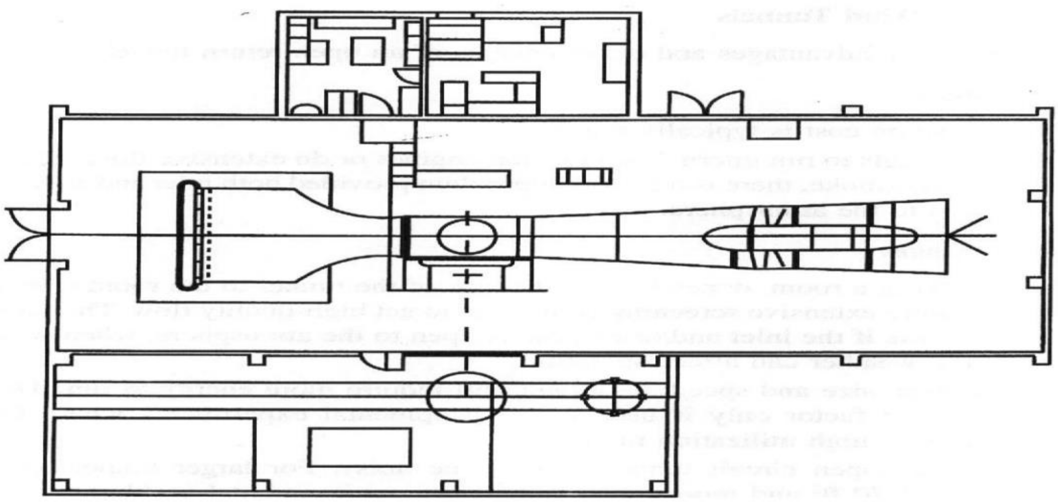

Figure 2.2: Plan view of an open circuit wind tunnel (Diamler-Benz Aerospace Airbus, Bremen, Germany).

There are advantages and disadvantages of the open circuit wind tunnel. These are listed in the table below.

Table 2.2: The advantages and disadvantages of the closed-circuit wind tunnel

Advantage	**Disadvantage**
Wind tunnels used for running internal combustion engines or smoke flow	Are generally noisy. For larger tunnels, the noise may cause environmental problems, and/or require extensive noise

visualization tests do not experience purging problems provided the inlet and the exhaust are open to its surroundings.	treatment of the tunnel and surrounding room.
Wind tunnels used for running internal combustion engines or smoke flow visualization tests do not experience purging problems provided the inlet and the exhaust are open to its surroundings.	Depending on the room size and the tunnel size, that is if it's placed in a room, it may require extensive screening at the inlet to produce high-quality flow. The same may be true if the inlet and/or exhaust is open to the atmosphere, when wind and cold weather can affect operation.
Cost of building the wind tunnel is less compared to the closed wind tunnel, hence is ideal for universities, schools and research exercises where utilization is high.	The tunnel will require more energy to run based on the given test-section size and the speed. This becomes a factor to be considered only if the tunnel is to be used for developmental experiments with high utilization rates.

Open circuit tunnels operating using the open test-section structure need an enclosure around the test section to prevent the drawing of air into the tunnel via the test section instead of the inlet. For large-sized closed-circuit tunnels with an external balance, the open test section tends to have a solid boundary. This is done to shield the external balance from the wind.

Several closed-circuit tunnels which operate using open test-sections have experienced severe flow fluctuation problems. These problems require deep post-construction diagnostics and corrective actions.

2.4 Applications of Wind Tunnels

There are about 7 main applications of wind tunnels. These are:

- Aeronautical Wind Tunnels – a wind tunnel for producing a controlled stream of air to study the resistance to moving air on aircraft models.
- Smoke Tunnels – a wind tunnel in which the movements of air are observed by releasing smoke filaments at specific points.
- Automobile Wind Tunnels - a wind tunnel made up of a test section where a model or vehicle can be mounted and viewed whilst air is either blown or sucked over it by a fan or several fans.
- Aeroacoustic Wind Tunnels – a wind tunnel that provides forward flight conditions in an anechoic environment for the Aeroacoustic testing of propeller and rotor concepts including isolated components and integrated propulsor-airframe.
- Water Tunnels – a wind tunnel used for testing the hydrodynamic behavior of objects immersed in flowing water
- General-Purpose Wind Tunnels – a wind tunnel used to test a wide range of vehicle-related experiments and continue to be the best available for a range of special-purpose experiments that have not spawned their own specially designed aerodynamic facilities.

- Environmental Wind Tunnels – a wind tunnel used to determine wind loads on buildings, soil erosion, snow drifts, air pollution dispersion patterns, flow patterns near building complexes and others.

Chapter 3: Design

3.1 Overview

This chapter details the fluid-dynamics design of an open-loop wind tunnel for aerodynamic analyses. The design specifications and requirements of the wind tunnel to be built and the mathematical model that forecasts its design are detailed out systematically.

3.2 Review of Existing Designs

Open-circuit wind tunnels are relatively easy to construct that closed-circuit wind tunnels, mainly because closed-circuit wind tunnels require a return vane for the air to be circulated inside the system, whereas the open-circuit wind tunnels draw air from the environment and release it back into the environment. However, open-circuit wind tunnels perform better in maintaining an overall internal wind tunnel temperature around that of the ambient temperature, whereas closed-circuit wind tunnels accumulate heat over multiple cycles and affect the overall boundary layer characteristics of a test sample [2].

Although the existing open-circuit wind tunnels have the above advantages over the closed-circuit wind tunnels, they use the same flow visualization techniques. There are two main categories of flow visualization; namely, surface flow visualization and flow field visualization [1]. Although, technically surface flow is also a flow field, the two terms are used to distinguish between on-body and off-body fields. In on-body or direct-surface flow visualization where the agent of visualization is applied on the surface of the test sample, tufts, oil flow, ink dot, china clay, and liquid crystals are used. For off-body visualization, where the agent of visualization is carried in the air particles and flows over the test sample, smoke injection, helium bubbles and streamers are used [1].

Data recording and analysis is very important in the engineering testing process, and the fluid mechanics/dynamics field is an ever-growing field because of the extensive amount of data base and analysis being created by the day. In existing wind tunnels, the data recording techniques available range from the simplest, and least permanent which is observation with the eyes, to the more complex as Digital Particle Image Velocimetry, which uses powerful-processor computers to store and analyze flow visualization data from a series of images and provide charts on the velocity profile of the flow [3].

The Intelligent Wind Tunnel Design will be an open-circuit wind tunnel that will use smoke injection for flow visualization. The addition to the project will be a data recording and analysis system that will use still and moving images to generate live-updates of the velocity field of the flow around the test sample.

3.3. Thesis Design Objectives

The project is aimed at creating an instructional wind tunnel that will be used in Ashesi University for fluid mechanics/dynamics tests. It will use low-cost materials to provide a certified facility that will not be limited only to airfoil sections, and simple-geometry objects, but also capable of providing tests on scale model of external flow structures like cars, airplanes and buildings, provided the Reynolds numbers the models are very low [1].

Moreover, the project is aimed at obtaining air flow in the test section that is as near as possible to a parallel steady flow with uniform speed throughout the test section.

Also, the Intelligent Wind Tunnel is aimed at providing a built-in data recording and analysis system that will generate information on velocity field and boundary layer characteristics of any test conducted.

3.4. Design Decisions

The first step in any wind tunnel design is to specify the shape and dimensions of the test section depending on the type of tests to be conducted with the wind tunnel.

The Intelligent Wind Tunnel design will be an open-circuit wind tunnel for use in conducting fluid dynamic experiments on airfoil sections and a range of objects of varying aerodynamic geometries.

To ensure an easier build and control of the test section, an open test section with a square cross-sectional area will be used. The test-section-length-to-hydraulic-diameter ratio will be 2. Moreover, since the wind tunnel will accommodate a wide range of instructional-level and project prototype-level aerodynamic objects, the test section will have a 35cm-square cross-sectional area, and a length of 70 cm.

The dimensions of the other sections of the wind tunnel will be drawn from the dimensions of the test section:

- The area ratio of the larger end to the smaller end of the diffuser will be 2. The cone angle will be 3^{o} [4], yielding a diffuser section length of 144cm, about 2 times the test section length.
- The contraction cone or nozzle will have an area ratio of 7 [4], between the inlet and outlet.
- The settling chamber will have a length of 16cm, which will house a honeycomb and two turbulence control screens.

- The wind tunnel will be made modular based on its individual sections. This will allow for easy replacement and maintenance of any faulty section, or customization of the wind tunnel based the user requirements.
- Also, an extractor fan will be used instead of a blower fan in the drive section to ensure that turbulence in the tunnel is easily managed.

Moreover, smoke will be the primary mode of visualization of the flow. For phase 2 of the project, a computer-vision-based system will provide digital flow visualization.

3.5. Project Schedule

As per every Engineering project, it is essential to create a schedule that the entire project will be guided by. The project schedule also puts the project tasks in modules or milestones that are guided by a timeline to keep the project on the track of a successful completion. The project schedule for the Intelligent Wind Tunnel Design can be seen in Figure 3.1.

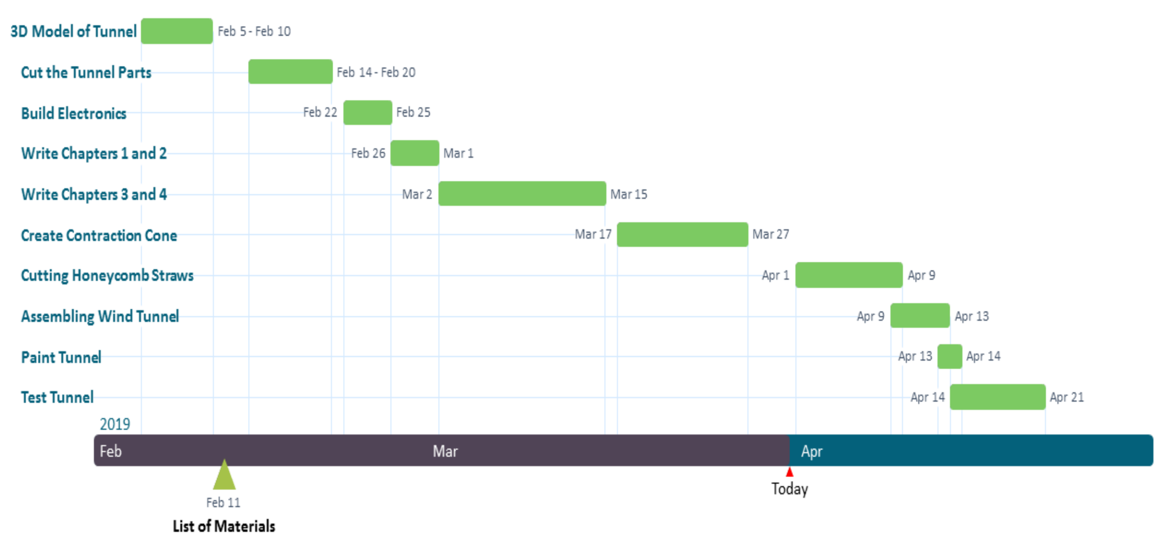

Figure 3.1: Project Schedule

3.5.1. User Requirements

The Intelligent Wind Tunnel will be an integral part of the Ashesi University Engineering facilities. It will be used in the Fluid Mechanics course during lab sessions to run fluid dynamics tests, thus providing visual learning aids for the course. Students can also use the wind tunnel to test their end of semester and capstone projects, so long as the project needs the use of the wind tests. The primary user of the Intelligent Wind Tunnel (IWT) facility is any member of the Ashesi community who desires to conduct fluid dynamics tests within the scope of the tunnel's capabilities. The user requirements of the IWT are as follows:

- Rapid and Robust – The IWT should be able to run complete test cycles without continuous user intervention. It should also be used without the need for much maintenance or repairs.
- User-Friendly – The IWT should require minimal training to operate.
- Affordable – The IWT should be built with readily available and affordable, but suitable materials to yield a less costly but effective facility.
- Versatile – The IWT should allow for customization and easy interfacing with peripheral devices that can share data with the IWT system.

The IWT user requirements will be described by the ASSURED criteria,

- **A**ffordable
- **S**ensitive
- **S**pecific
- **U**ser – friendly

- **R**apid
- **R**obust
- **E**quipment Free
- **D**eliverable to end user.

3.5.2. System Requirements

- The IWT's sections should be in detachable and reconfigurable modules
- The background noise level of the IWT must be sufficiently low
- The IWT must have a large test section with uniform high-speed steady wind flow
- The IWT must house a computer system for data acquisition and analysis
- The IWT must have a control and display unit for the user adjust the orientation of a test sample and be able to see the scientific significance of such changes on the display.
- The IWT must run of a 220-volt AC power source
- The facility must have a constant smoke injection throughout a complete run
- The laboratory must be well ventilated for safe smoke ejection

3.6 Materials

The materials that will be used in the construction of the IWT should be low cost and readily available to permit the completion of the project in the given timeline. Below are the materials and components used:

- Plexiglass sheet

- Alucobond sheet
- Extractor fan
- Adhesive rubber gasket
- Silicone
- Dual-Range Force Sensor
- Multimeter
- Variable AC transformer
- Anemometer
- Metal Mosquito mesh
- 1-inch iron L-bars
- Galvanized steel sheet
- Bolts and nuts and rivets
- Spray paint
- Smoke injector

3.7 Design Iterations

The IWT will go through two major design iterations. Two iterations will be done on the contraction cone, while holding all the other sections of the wind tunnel constant. The contraction cone iteration will be realized first in 3D-CAD models. The first model will be a square cross-sectional area contraction cone, which will be ideal for very low-cost manufacturing because four-sided plane sheet of affordable and rigid material such as Alucobond or plywood can be used. However, this model will be liable to early boundary layer separation in the nozzle [2]. The second model will be a contraction cone with a silhouette that will be defined by fifth order Bell-Mehta polynomials [2]. This model of the contraction cone will produce the best result in maintaining the desired boundary layer thickness in the nozzle.

Chapter 4: Implementation

4.1 Overview

This chapter details the methods and techniques used in developing the design model and the construction of the IWT. The implementation of the project will cover the mechanical design and fabrication of the wind tunnel.

4.2. Mechanical Design

The mechanical design section will involve the fluid mechanics principles that will be used to model each section, namely: test section, diffuser, nozzle, settling chamber and drive section. Additionally, it will entail the steps taken in fabricating each section respectively.

4.2.1 Test Section

The fundamental parameters for designing the test section will be the shape, dimensions and the wind speed. The test section will be made to have a square cross-section, with height and width of 0.35 m. Also, the wind speed of the test section will effectively be 25 m/s.

In determining the length of the test section, the hydraulic diameter must be first determined. Given the width and breadth of the test section above, the hydraulic diameter can be calculated using equation 1 [1] below:

$$D_h = 2\sqrt{A / \pi} \qquad (1)$$

Where A is the cross-sectional area of the test section.

Early research suggest that the ideal test section length must be in the range of 0.5 - 3 times its hydraulic diameter [1]. This length range will satisfy the condition that the air flow exiting the nozzle will be 0.5 times the hydraulic diameter to become almost uniform.

Furthermore, a longer test section (that is, more than 3 times the equivalent hydraulic diameter) could increase boundary layer thickness leading the boundary layer to detach at the test section exit.

In this project, the length of the test section will be set to twice its hydraulic diameter. This test section size will allow for a wide range of test sample sizes. Also, the square cross-section ensures relatively easy fabrication.

Moreover, the design of the test section involves the use of transparent material to allow test sample observation, and a door for placing and accessing the sample.

4.2.1 Nozzle or Concentration Cone

The nozzle will increase the velocity of the air from the settling chamber through its narrow outlet into the test section. According to [4], a wind tunnel nozzle increases the average wind speed by factors ranging from 6 to 10.

The uniformity, and not just the velocity of the air flow in the test section is highly dependent on the design of the nozzle. It is important that either of the adverse pressure gradient at the entrance or exit of the nozzle does not grow beyond control, causing the boundary layer to separate [1]. If the boundary layer were to separate, it will lead to a degradation of the air flow in the test section, an increase in the drive power required and noise.

To ensure flow uniformity in the test section, whilst meeting the wind speed requirement, careful attention will be paid to the design of the nozzle. This makes the nozzle the most difficult section to design and build as will be seen in the fabrication section later.

The first step in designing nozzle will be specifying the contraction ratio. The contraction ratio is determined from the ratio of the inlet cross-sectional area to the exit cross-sectional area. Bell and Mehta [2] suggest the use of a contraction ratio between 6 and 10 for a low speed wind tunnel. For this project, a contraction ratio of 7 will be used, making the inlet cross-section area 0.92 m square.

The nozzle outlet will be coincident with the inlet of the test section and will have the same dimensions as it. The shape of the nozzle will be based on Bell and Mehta's [2] 5th order polynomial given by:

$$y = a\delta^5 + b\delta^4 + c\delta^3 + d\delta^2 + e\delta + f \quad (2)$$

where $\delta = \frac{x}{l}$ (3)

and $y = h$ (4)

l is the total axial nozzle length, while h is half the cross-section side length.

Thus, $0 \le x \le l$ (5)

The Bell-Mehta fifth order polynomial coefficients will be determined by substituting the boundary conditions values into equation (2). Equations (6) to (11) show the boundary conditions.

$$\delta = 0,\ y = y_o \quad (6)$$

$$\delta = 1,\ y = y_1 \quad (7)$$

$$\delta = 0,\ \frac{dy}{d\delta} = 0 \quad (8)$$

$$\delta = 1, \ \frac{dy}{d\delta} = 0 \quad (9)$$

$$\delta = 0, \ \frac{d^2y}{d\delta^2} = 0 \quad (10)$$

$$\delta = 1, \ \frac{d^2y}{d\delta^2} = 0 \quad (11)$$

The Bell-Mehta fifth order polynomial is among four nozzle shapes namely, third order polynomial, fifth order polynomial, seventh order polynomial and matched cubics [2]. The fifth order polynomial yields the best result per their research.

The length of the nozzle can be determined from the relation given below that states that the ratio of the total nozzle length to the height of the nozzle inlet cross-section should be about 1 (refer from equation (12) and figure 1) [2].

$$\frac{l}{2y_o} \cong 1 \quad (12)$$

In their experiments, Bell and Mehta [2] determined that an $L/2y_o$ ratio less than 0.667 causes the air flow to detach close to the nozzle exit, whereas a value greater than 1.79 increases the boundary layer thickness.

For this project, the $L/2y_o$ will be set to 0.9, making the nozzle length 0.828 m.

The shape of the nozzle was realized in SolidWorks by inputting equation (2) and using the boundary values (see figure 1).

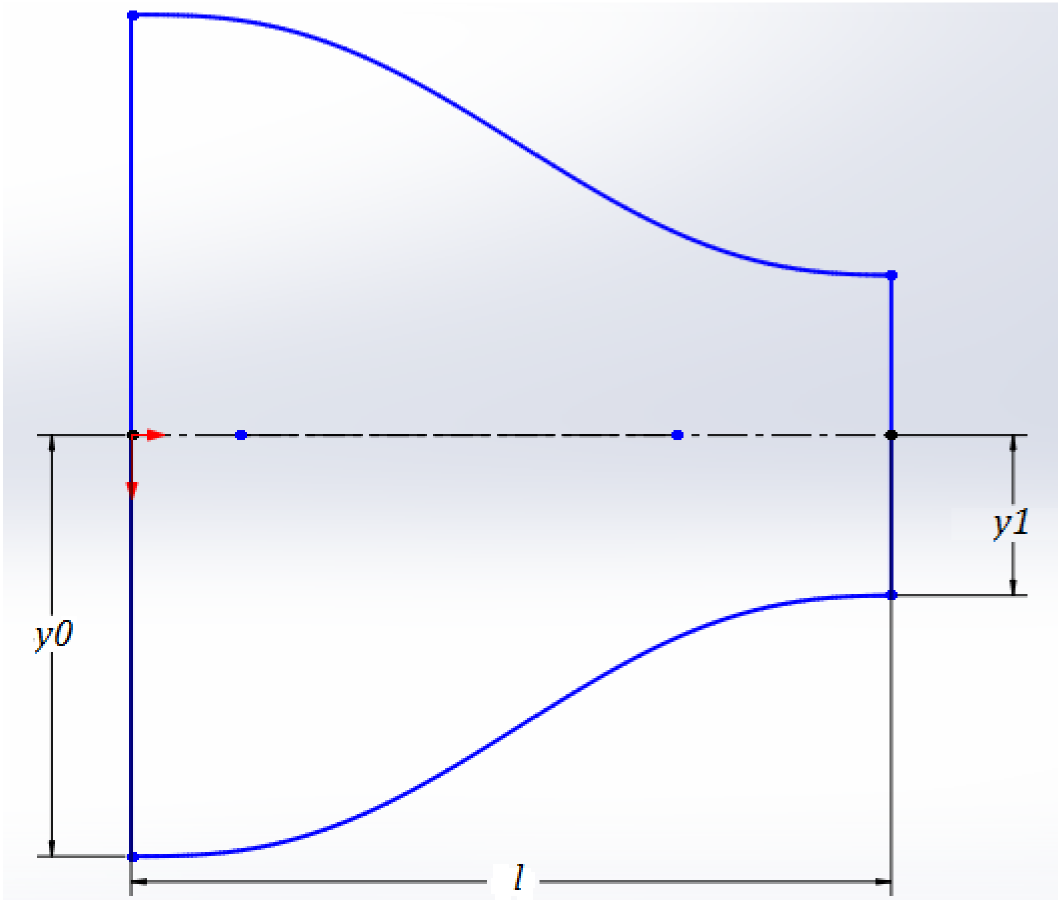

Figure 4.1: Fifth order polynomial nozzle shape

4.2.2 Diffuser

The diffuser will extend from the downstream end of the test section to the drive section. Since the inlet of the diffuser will be coincident with the outlet of the test section, its inlet diameter will be 0.35 m.

The other parameters to consider in the design of the diffuser are the area ratio, diffuser angle and diffuser cross-sectional shape [4].

The area ratio of the inlet cross-section and the outlet cross-section will be used to determine the outlet diameter of the diffuser. From the expert literature [1], the area ratio must be in the range of 2-4. An area ratio greater than 3 might cause irregular flow velocity, and an area ratio of less than 2 will cause an increase in the overall dimension of the wind tunnel, thus, the cost for construction.

For this project, the area ratio of the diffuser will be set to 2, giving the outlet diameter a dimension of 0.50 m approximately.

The equivalent diffuser angle is defined as follows [1]:

Let R_1 be one-half the diffuser inlet hydraulic diameter D_1. Let R_2 be one-half the outlet hydraulic diameter D_2 and A_r (Area ratio) be A_2/A_1 (thus, A_1 is the inlet area and A_2 is the outlet area). Then the equivalent diffuser expansion angle will be given by:

$$\theta_d = \tan^{-1}\left(\frac{R_2 - R_1}{L}\right) \tag{13}$$

The conical angle will be 3^{o}, making the length of the diffuser 1.44 m.

4.2.3 Settling Chamber

The settling chamber will extend from the front of the wind tunnel to the inlet of the nozzle. It will have a constant cross-section having the same dimensions as the nozzle inlet cross-section. The settling chamber will serve the purpose of housing a honeycomb and a screen to reduce the turbulence in the test section, as they are appropriately termed as flow straighteners.

The length of the settling chamber will be advised by the length of the honeycomb and the spacing between the honeycomb and the screen. It is thus appropriate to determine the design of the honeycomb and screen to arrive at the length of the settling chamber.

The honeycomb will reduce the turbulence in the test section in the horizontal or x-component of the air flow velocity [1]. The honeycomb has little effect on streamwise velocity because the pressure drop through a honeycomb is small [5].

The main design factors for the honeycomb are honeycomb length (L_h), cell hydraulic diameter (D_h), and porosity (β_h) [4]. The honeycomb porosity is defined as the ratio of the actual flow cross-section area (A_f) over the total cross-section area of the settling chamber (A_t) (refer from equation 14).

$$\beta_h = \frac{A_f}{A_t} \tag{14}$$

The honeycomb length and the hydraulic diameter are given in equation 15 from Mehta and Bradshaw [4].

$$6 \le \frac{L_h}{D_h} \le 8 \tag{15}$$

Also, $\beta_h \ge 0.8$ (16)

For this project the honeycomb parameters are detailed in table 4.1.

Table 1. Honeycomb parameters

Table 4.1: Honeycomb parameters

Parameter	Value	Unit of Measurement
Cell Diameter	9	mm
Sheet Metal Thickness	0.06	mm
Roughness	15	µm
Length	60	mm

Thus, the length of the honeycomb, as advised by Mehta and Bradshaw [4] will be 60 mm.

Screens mainly reduce stream-wise velocity fluctuations, with minimal effect on flow direction [4].

For an effective reduction in turbulence, a screen must have a porosity in the range 0.58 – 0.8 [1]. Screen porosity values over 0.8 are not suitable for good turbulence control, while values below 0.58 lead to flow instability.

For this project, a screen porosity of 0.60 will be used, and the settling chamber will be designed to allow the removal and replacement of the screen. Early research suggests the spacing of the screen from the honeycomb so that the pressure drop in the air flow does not create instability in the flow [1]. To keep the settling chamber short to cut down cost, a spacing of 0.1 m will be used. This will give the settling chamber an overall length of 0.16 m.

4.2.4 Drive Chamber

The drive section will be designed to house the fan. It will extend from the outlet of the diffuser to the back of the wind tunnel. The cross-section of the drive section will be 0.5 m by 0.5 m, with a length of 0.18 m.

The figure below shows the SolidWorks 3D model.

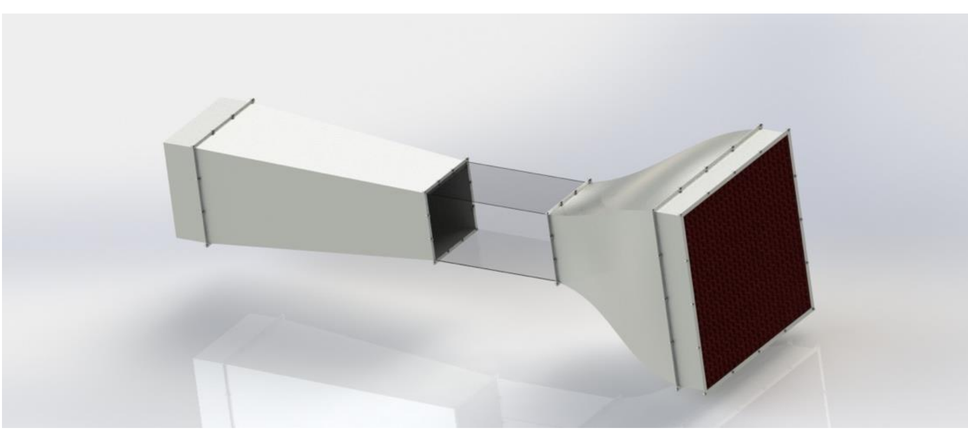

Figure 4.2: 3D model of wind tunnel

4.3 Fabrication

The test section will be built from plexiglass to allow for the user to observe the test sample. Epoxy glue will be used to hold the four sides of the plexiglass test section together. The 1-inch L-bars will be used at the inlet and outlet faces of the test section to strengthen it and allow for connecting it the other sections of the wind tunnel. The test section will also have flanges and windows to allow sample observations and introduce measuring tools.

The nozzle will be the most difficult to fabricate, so the section will be contracted to metal sheet benders in the Agbogbloshie, Accra, Ghana market. Fabricating will require the guidance of the project engineer for the completion of the part. It will be made from galvanized steel plating, and galvanized steel bars for a rigid frame.

The settling chamber, diffuser and drive section will be created from 3mm Alucobond sheets for the sides and galvanized steel angle bars for the frames.

The entire assembly will be done by holding the individual sections together by 8 mm bolt and nuts. Silicone sealants will be applied at the intersections to prevent air leakages.

Chapter 5: Result

The fabrication of the intelligent wind tunnel design was completed within the project duration. The following pictures illustrate the results obtained from implementing the design of the project.

Figure 5.1: The wind tunnel

Figure 5.2: The Electric fan

Figure 5.3: The front view

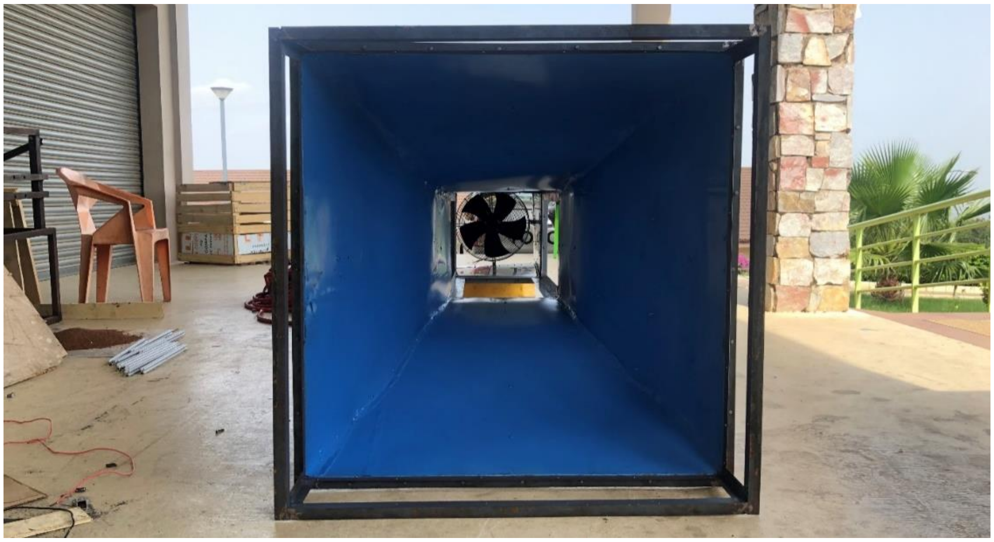

Figure 5.4: The front view after the frame for the honeycomb is attached

Figure 5.5: The side view

Chapter 6: Conclusion

6.1 Discussion

From the results obtained for the mechanical build, it shows the several fields that can be explored by continuing to improve on the wind tunnel facility to make it an educational standard facility.

6.2 Limitation

The list below shows the setback which served as limitations to the project

1. Unavailability of the honeycomb and the anemometer, limiting the test capability of the project

2. Short project duration - unable to test a sample before deadline

4. Limiting project to the mechanical construction, and not completing the electronics and computer programming aspects

6.3 Future Works

The list below shows several updates that can be added to the scope of the project.

1. Complete and attach measuring instruments on facility
2. Run the fan to measure out the wind speeds in the test section at different fan speeds
3. Test multiple samples and record data
4. Include flow visualization through smoke

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