Developing and Implementing a Wind Turbine Based Laboratory Design Experiment for First Year Engineering Students

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Abstract –

A two week Wind Turbine based laboratory design experiment was developed and implemented by the First Year Engineering Program at the The Ohio State University. This lab series, incorporated aspects of active learning and team work in an inverted class room environment. Students, in groups of four, performed experiments to study the physical properties of the wind and the wind turbine. Students also had the opportunity to design and test their wind turbine blades. Contained in this extended abstract are details of how the lab was implemented, how we believe the learning objectives were met and some of the results which were observed.

Introduction –

The First Year Engineering Program at The Ohio State University has long recognized the significance of renewable energy sources and the importance of getting young Engineers excited and involved in understanding how these sources of energy can be harnessed. The newest lab added in a sequence of laboratory experiments which included the Fuel Cell Lab and the Solar Cell Lab is the Wind Turbine Lab. The aim of this lab was to help students recognize the benefits of wind energy as an energy resource, identify effective ways of producing energy from the wind and establish current limitations.

This two week laboratory design experiment fits into the overall theme of the First Year Engineering Program by incorporating active learning and teamwork in an inverted classroom framework. This hands on laboratory experiment was aimed at giving students an insight into engineering in the real world and hopefully help students realize that engineering can be fun. In week one, students in groups of four, studied physical characteristics of the wind, the relationship between the velocity of the wind and pressure, how to determine the power available in the wind and how all these factors are applicable to a wind turbine. Week two was the design phase of the lab, where students designed their own turbine blades and determined which one of the four blades generated the most power. They also analyzed the influence of number of blades, blade orientation and pitch angles in determining over all power output and efficiency.

Inverted classroom philosophy -

Different students have different learning styles. Some students might be *Dependent Learners* and require a lot of attention from Instructor, some might be *Collaborative Learners* who learn the best in a collaborative, team based environment and some others might be *Independent Learners* who learn the best independently on their own. Expecting students to choose classes based on their learning styles or having instructors change their learning styles to suit all students may not be a viable option[1]. However, in this age of technology where lectures can be taped, and classroom presentations can be made available to students before class, inverting the classroom can be made appealing to all types of learners[1].

Simply put, inverting the classroom is bringing events that are traditionally done outside of the classroom to the classroom and viceversa[1]. This laboratory experiment and many courses in the First Year Engineering Program use this inverted class room philosophy.

Prior to the first lab, students are required to go through a Preparation document, watch a video, go through the procedure for the lab and take a quiz which tests their preparation level. Prior to the second lab, each student is responsible for coming up with a design for a wind turbine blade from research they perform outside of class.

Active Learning and Team Work in Engineering –

Active learning in general can be 'defined as any instructional method that engages students in the learning process.'[2]This includes all learning activities that are introduced in the classroom.

Studies shows that active learning in combination with team work in the form of Collaborative and Cooperative learning can prove to be effective[2,3]. This was a key aspect that was kept in mind when work the Wind Turbine lab was being developed.

Students in this lab series are responsible for their own work while also being a part of the team. Individually, they review material, come up with a design before the second lab and submit a report a week after the second lab which includes individual components designed to test their individual understanding. As a group, students learn to use the equipment (Figure 1 and Figure 2), take readings of velocity, pressure and power in the first week and try to optimize the efficiency of their chosen design in the second week. They also work on the group section of the report which includes a real world problem which they are required to solve. In all, the lab accomplishes the important task of building team working skills while also ensuring that individuals are evaluated on their understanding of the concepts involved.

The Wind Turbine Lab –

Materials and Tools Used –

The lab itself consists of the following constituent parts-

1. DC Power Supply
2. Glass Wind Tunnel with a Wind Source
3. Manometer
4. Display board using an Arduino Microcontroller
5. Wind turbine with pre manufactured blades
6. Balsa Wood
7. Hubs with 30˚ and 45˚ pitch angles (manufactured using a 3D printer)

In addition a cutting knife was provided to students to design their wind turbine blade.

A set up of the lab with all its constituent parts is shown in Figure 1 and Figure 2.

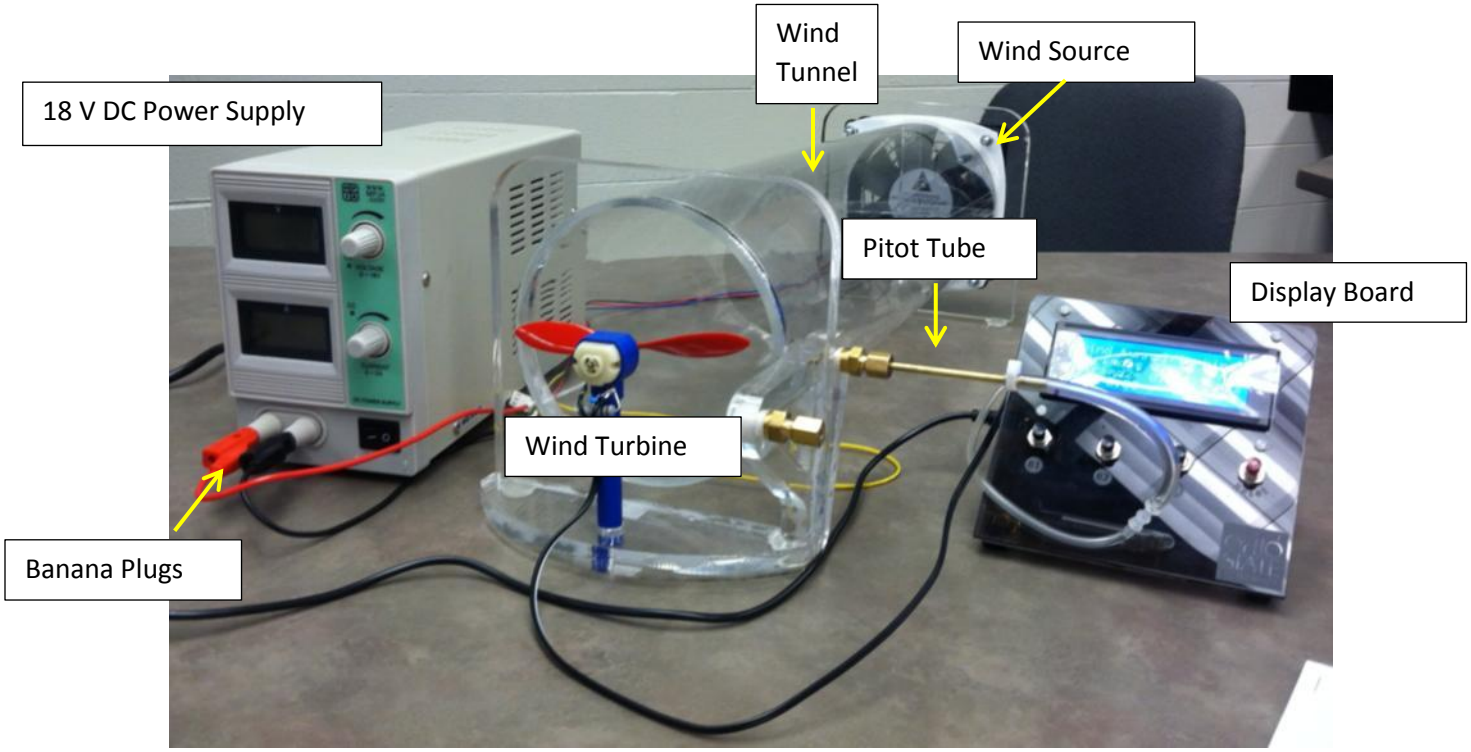

Figure 1: Set up of the Wind Turbine lab

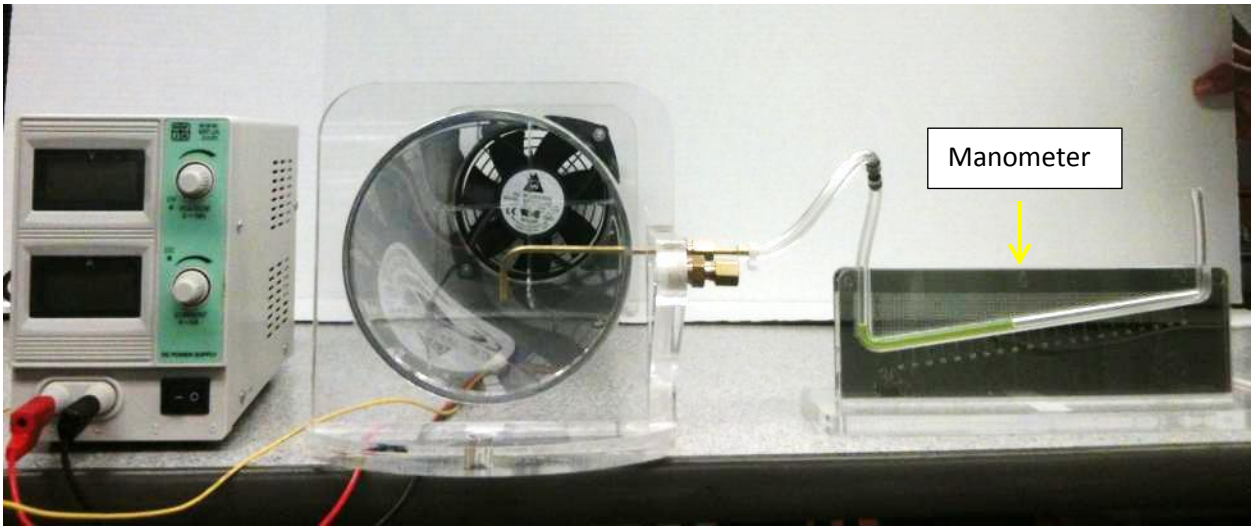

Figure 2: Setup with Manometer

Week 1 -

The Wind turbine laboratory begins even before students arrive in class. Before the start of class, students are required to read through a preparation document, familiarize themselves with the procedure and watch a video which introduces them to wind turbines.

While in their groups, students start week 1 by observing the equipment provided to them. The first half of the lab involves studying the characteristics of the wind. They first use the manometer to measure the pressure difference and understand the relationship between velocity and change in pressure. After this, they estimate the power available in the wind using

$P = \frac{1}{2}\rho A v^3$ where,

ρ is the density of air at standard temperature and pressure, 1.29 kg/m^3
A is the cross-sectional area in m^2
v is the velocity of the wind in m/s

They also calculate the volumetric flow arate and mass flow rates using the appropriate formulas.

In the second half of week 1, they connect the provided wind turbine and measure the power it produces for increasing wind velocities. They do this for both a turbulent and a laminar flow. A laminar flow is generated in the wind tunnel by the use of a glass "X" shaped Wind Vane.

Week 2 -

Prior to coming to the lab for Week 2, each student is required to develop a design for a wind turbine blade. Students come up with this design based on mandatory outside class research regarding wind turbine blade designs. They are asked to validate the reason for their choice in the individual section of the report which they submit a week after lab 2.

Students start Week 2's lab by constructing their individual Wind Turbine blade based on their design. They then test each design to find the design that generates the maximum power. They then use this selected design and record the power generated by varying the number of blades, the orientation of the blades, and the pitch angle. The aim of this lab, was to give students a feel of 'real' engineering and help them realize how varying different parameters affect the overall output. In the report they are required to identify, the configuration which gave them the most power and efficiency.

Conclusions and Future Work –

The Wind Turbine Lab was successfully introduced to over 2000 students at The Ohio State University and its regional campuses in Autumn Semester of 2012. We believe that this lab experiment can be introduced as a standard part of any introductory engineering curriculum which incorporates active learning. Brief student surveys have found that many students appreciate the learning outcomes of the lab and feel like they did a 'real' engineering project.

However, to truly understand and assess the success or failure of a project, a quantitative analysis is mandatory and work is now underway to ensure that such an analysis using a Likert type scale is conducted in the upcoming Autumn Semester.

Bibliography –

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