ENGINEERING

McMaster University

Project One – Renewable technology challenge:

Mechanical design of turbine blades in renewable wind technology

ENGINEER 1P13 – Integrated Cornerstone Design Projects

Tutorial 07

Team 03

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Table of Contents

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Executive Summary

Our team was assigned the task of modeling a turbine blade specialized to capture high winds on the roofs of resident houses in the urban area of Calgary. House owners want to utilize the high winds to produce energy lowering the overall electric consumption per house [1]. Our team were with faced unique constraints that consider the occupied space of the blade, to understand that there may be multiple turbines and that they should not collide with each other. Henceforth, we condensed the problem into this problem statement, to be able to generate more than enough energy in all types of climate conditions and withstand high levels of windspeeds at different altitudes while maximizing cost efficiency. There were three main objectives that were agreed upon by the group: efficiency, durability, and safety. Efficiency is the reason for the product to exist which is to be a sustainable substitute for their current source of electricity. By maximizing efficiency, electricity output will also be maximized. The second objective, durability, reflects the high winds that Calgary faces. If the blades are too brittle, then they are going to fold under the pressure of the wind. Although, if the material and the blade had a high-level stiffness, then it can withstand the high winds. The last objective, safety, is the concern to the client. Since these turbines are placed on the highest part of the house, they could be a hazard to the house owner, neighbours, and the surrounding area. The potential risks include catching on fire, breaking, destroying property, and injuring the customer or bystanders. The functions lay on the same lines as our objectives, to capture the wind which turns the turbine blades, thus allowing the generator to provide electrical energy to the customer.

Design Process

Justification of Technical Objectives and Material Performance Indices:

Using an objective tree decide the material of the blade, a flow chart was derived into four main objectives, each with three to four levels of specifications. The flow chart helped us to identify objectives needed for the optimal material for our scenario: affordability, efficiency, safety, and durability. Since these turbines will be most likely mass produced, the affordability must be at a reasonable price. The selected material must be durable enough to maximize efficiency. By maximizing the durability, we not only maximize the efficiency, but also the safety of the turbine. This means that we would need a material with a high Young's modulus while not forgetting other factors such as high yield strength and a low specific carbon footprint. Four MPIs were chosen, two based on durability and two based on their carbon footprint. Each team member was assigned one of four MPI requirements and used GRANTA to find the top five materials [2]. Filtering out uncommon materials, we found out that stainless steel, low alloy steel, and medium carbon steel were the most favorable materials. Using a decision matrix based on our top three materials, low alloy steel became the most ideal material.

Conceptual Design ─ Justification of Selected Material

Individually, each member was tasked to create a graph of their given equation using GRANTA [3], implementing the specific constraints of their equation while also excluding ceramics and glasses, and cast irons. (Figure 1) Considering that a large Young's modulus will not bend as easily, the top five materials were selected from each graph from the top of the graph and collaboratively the common top three materials were selected: Stainless steel, low alloy steel and medium carbon steel. To further refine the list, a decision matrix was used to filter through to find the most optimal material. The material had to be lightweight, compactible, easy to instal, safe and efficient. Some of these criteria were hard to give a number to, so we used properties of each material to decide. The safety of the material considered the process it took to create it. The installation considered the weight since it must be brought up to the roof. Efficiency was decided by comparing their Young's modulus and melting points. Finalizing our decision, low alloy steel was the most optimal material based on the density, strength, and carbon footprint. While low allow steel does not have the highest density, in terms of the strength and the production of the material, it was concluded that low alloy steel was more efficient than stainless steel and medium carbon steel while also having the lowest carbon footprint of the three materials.

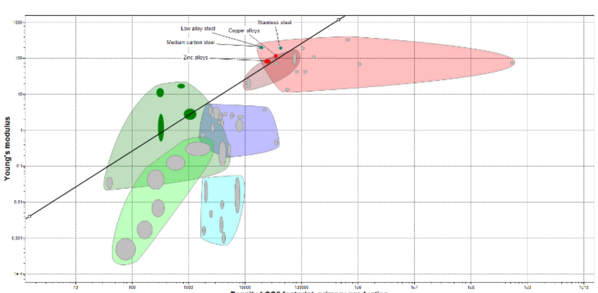


Figure 1 – Material Selection Graph (MPI = $\frac{E}{p\ CO_2}$)

Design Embodiment – Justification of Solid (CAD) Modeling

Using low alloy steel metal as our reference, we had to measure the deflection of the turbine blade based on various assigned thicknesses. Since low alloy steel's Young's modulus is greater than 100 GPa [3], our deflection formula was based on compliant materials. Values of 0.8m, 0.378m and 8.5 m were used for the half width, half height and length, respectively. Using the calculated deflection values for 15mm, 30mm, 50mm and 150mm, deflection simulations were performed in Autodesk Inventor to find the thickness for that satisfies the constraint 8.5mm to 10 mm of deflection. First verifying our calculations using the simulator, we found the range of our constraint. Using values between 15mm and 30mm, trial and error was used to close on our constraint. This brought us between 26mm and 28mm, having deflection of 9.592 mm and 8.83 mm. accordingly. Keeping our scenario in mind, we decided that minimizing the deflection would optimize the efficiency, durability, and safety of our turbine blade. Thus, the thickness 28mm was the optimal choice.

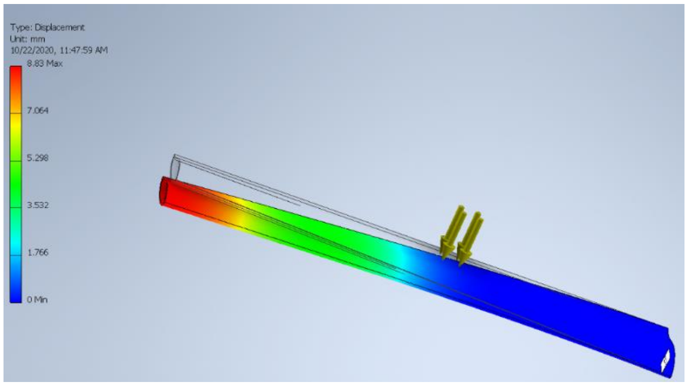


Figure 2 ─ Deflection simulation at 28 mm

Concluding Remarks – Reality Check

Finalizing our culmination of our project, to create a roof turbine generator that can generate sufficient energy in all types of climate conditions, wind pressure and altitudes whilst maximizing the cost efficiency, a thorough knowledge of a wind turbine is needed. Together as a team, it was concluded that there were certain objectives and constraints that were needed to be considered before choosing the material and design. Recognizing the strong winds in Calgary, we determined that the material used should acknowledge our objectives and constraints. In other words, a firm metal that that does not bend in high pressure and does not erode over time due to extreme weather conditions. Contemplating how thick the blade should be, once again considering the high-pressured winds, we decided that a thickness that minimizes the deflection would be most optimal. In this project we determined the material and thickness of the turbine blade, however, further research is needed to fully initialize the project. We would need to explore different types of mounting and the sizes of the wind turbine. Since the turbine will be attached to the roof of the houses, we must consider the weight the entire turbine. The mounting and size will affect how sturdy the turbine will be and if it will be sustainability throughout the years. Creating an environmental-friendly and affordable turbine that can be mass-produced onto homeowners' roofs, not only pleases the consumers but also makes the world greener.

Appendix A – Peer learning discussion summary:

Near the end of our first project, we had the opportunity to have a formal discussion with another team. The discussion regarded similarities and differences along with additional topics brought up regarding project one. Our team was paired up with the "Thurs-04" group, where we had an insightful and productive conversation. The other team's scenario was "A Pioneer in Clean Energy" [4] which was completely different from our scenario, the roof generator. Their primary goal was being environmentally friendly which commenced a multitude of diverse discussion points since our primary goal was to be durable to resist the high-pressured winds. Since their primary focus was being environmentally friendly, the environmental impacts that go into production of the materials of the blade itself was always at thought. Despite the contrasted scenarios, we ended up having the similar objectives, which resulted in minor differences in our projects. Our common objectives were that the blade needed to be efficient and durable, which were at utmost importance. Our material selection also resulted in the same material list. The most favourable material that transpired through the material selection process was low alloy steel. The justification for the other group was that it was the material with one of lowest carbon footprints, while keeping a high Young's modulus and density, alongside the material being relatively reusable. The other favorable material was medium carbon steel, which was also in our top three materials. The reasoning for our similar material selection, stems from having common objectives. The discussion was incredibly productive since we brought up the topic of external factors that could affect our primary objectives and how to possibly counteract them. For example, rust was one of the main topics for this discussion and how it is a detrimental factor to the durability with regards to our chosen material. At first glance the project appeared to be rather austere, but after indulging in a more in-depth dialogue and analysis we realized that the project has a plethora of factors that challenges our ideas. At the very end of the group discussion, we also touched upon topics within the scope of teamwork; decision making strategies and how to maximize effectiveness with regards to working in a group. This is a vital component to any group project that must be addressed and is considered the formula for success. The opportunity to have a discussion with other groups was an experience and beneficial in many ways.

Appendix B – References:

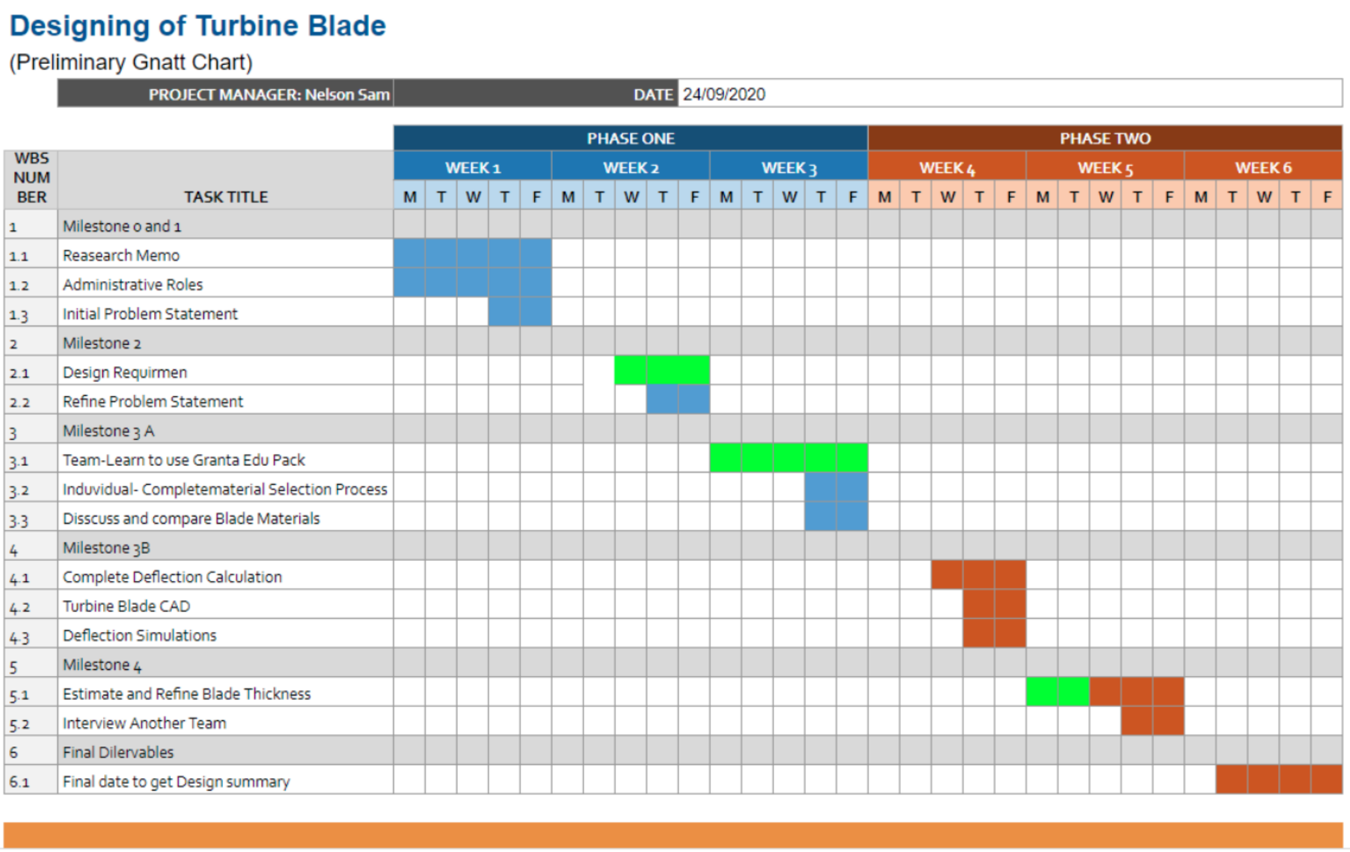
[1] "Design objectives will vary depending on your assigned scenario", Class notes for 1P13, Department of Engineering, McMaster University, Fall, 2020

[2] "The 5 MPIs for stiffness design", Class notes for 1P13, Department of Engineering, McMaster University, Fall, 2020

[3] Ansys Granta EduPack software, Granta Design Limited, Cambridge, UK, 2020 (www.grantadesign.com).

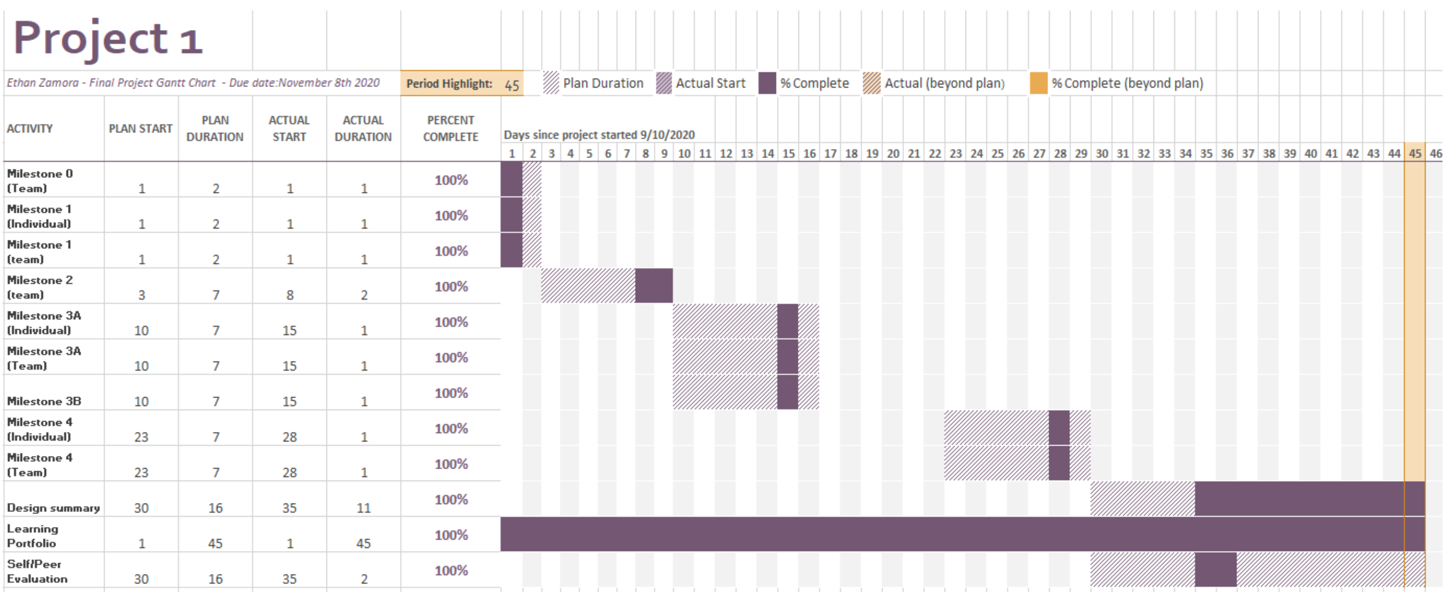
[4] "P1 Project Module", Class notes for 1P13, Department of Engineering, McMaster University, Fall, 2020

Appendix C – Project Schedule and Project Gannt Charts:



Project 1 – Logbook (Coordinator)

Date	Time	Assignment	Platform	Comments
Thurs. Sept. 24th	11:20-11:30am	Wk-3 (fall) P1 Milestone 1 (team)	Microsoft Teams: In our Thurs-03 channel	Spent an extra 10 minutes finishing our objective trees for our given scenarios.
Thurs. Oct. 8th	11:20-11:35am	Wk-5 (fall) P1 Milestone 3B (team)	Microsoft Teams: In our Thurs-03 channel	Spent 15 finishing our deflection simulation and adding a photo of our estimated deflection calculation.
Thurs. Oct. 22nd	11:20-11:35	Wk-6 (Fall) P1 Milestone 4 (team)	Microsoft Teams: In our Thurs-03 channel	Spent a few minutes adding in photos of our calculated deflections, alongside discussing our thoughts and ideas from the peer interview to finish the table of notes.
Sat. Oct. 28th	8:00-9:30pm	Final deliverable	Discord: 1P13 Design Studio voice chat	We spent an hour and a half discussing and working on the final deliverable in a shared document. The main topics we discussed were what parts of the final deliverable each group member would do, ultimately ensuring every member understands not only what to do but how to do it properly. We spent the majority of the hour and a half working on this assignment in our shared document.



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0 (Team)	1	2	1	1	100%
Milestone 1 (Individual)	1	2	1	1	100%
Milestone 1 (team)	1	2	1	1	100%
Milestone 2 (team)	3	7	8	2	100%
Milestone 3A (Individual)	10	7	15	1	100%
Milestone 3A (Team)	10	7	15	1	100%
Milestone 3B	10	7	15	1	100%
Milestone 4 (Individual)	23	7	28	1	100%
Milestone 4 (Team)	23	7	28	1	100%
Design summary	30	16	35	11	100%
Learning Portfolio	1	45	1	45	100%
Self/Peer Evaluation	30	16	35	2	100%

Appendix D – Source Material Database

Milestone 1: Pre-research memo

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