ENGINEERING

Project One – Renewable technology challenge:

Mechanical design of turbine blades in renewable wind technology

ENGINEER 1P13 – Integrated Cornerstone Design Projects

Tutorial T09

Team Thurs-50

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Academic Integrity Statement

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

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Finalized Problem Statement

Design a mechanism's blade that will be used in a system for a wind farm to generate electricity in Sweden. The blade should capture wind and convert it into electricity that will be used to provide power to multiple cities while being cost-efficient and a clean source of energy to help reduce Sweden's greenhouse gas emissions. The system's blade should be durable, efficient, lightweight, and have a low maintenance cost. The system's blade should be able to supply energy to multiple cities by maximising its output of power. It should also minimize production energy and carbon footprint. It must weigh below 8000 kilograms, use a plastic coating, be longer than 50 meters and have an airfoil shape. The mechanism's blade should be resistant to harsh changes in weather, meaning it should also be corrosion, water, and temperature resistant.

Design Summary

Justification of Technical Objectives and Material Performance Indices

As our scenario of a pioneer in clean energy suggests, we were required to come up with a design solution to reduce net emissions of greenhouse gases for Sweden to zero by 2045. The wind turbines are also required to be efficient enough to provide power for multiple cities. Keeping these in mind, we came up with our objective tree which mostly focused on efficiency, low maintenance cost, and lightweight [1] as shown in Figure 1. Wind turbines must be lightweight to operate at maximum efficiency by eliminating air resistance as much as possible [1]. This is because it helps them move faster, which helps create more wind power [1]. Keeping in mind that our design tries to portray a means of trying to maximize energy production to be available to all the cities we brought about changes in blade design by making it longer in length and giving it an airfoiled-shape [2]. In addition, we also used an appropriate number of blades for our turbine to balance out air resistance [2]. Based on these factors from the objective tree we came up with our primary and secondary objectives which were minimization of carbon footprint and production energy both of which contribute to our scenario by eliminating greenhouse gas emissions and increasing efficiency. Minimizing the energy required to create the material for the blade will help cut down on further emissions of greenhouse gases and reduce waste. Therefore, our MPI's of both stiffness and strength contribute to our scenario.

Figure 1. Scenario 4 Objective Tree

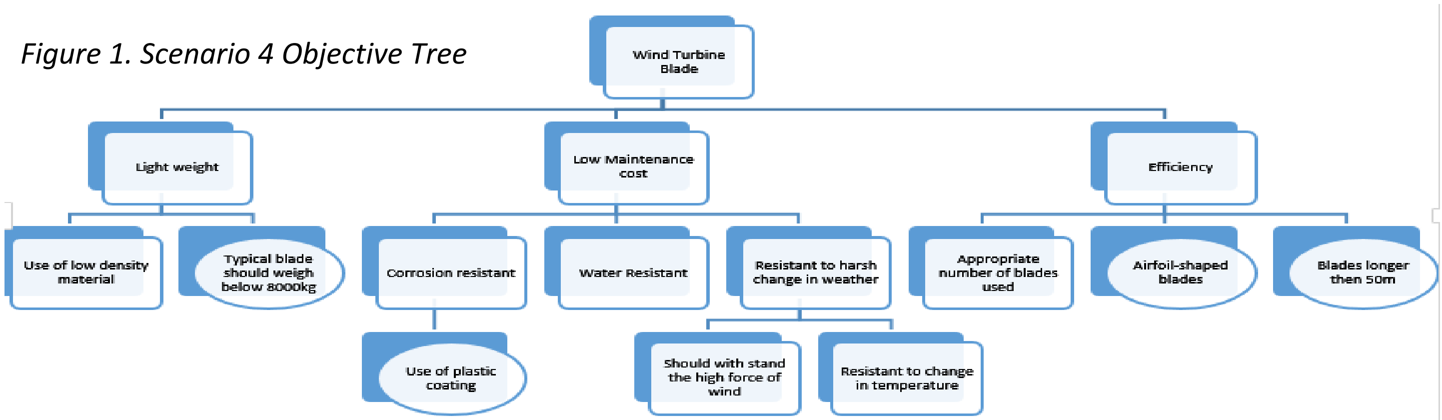

Table 1. MPI Selection

	Objective	MPI-stiffness	MPI-strength	Justification for this objective
Primary	Minimize carbon footprint	$MPI = \frac{E}{\rho CO_2}$	$MPI = \frac{\sigma_y}{\rho CO_2}$	The primary goal of this scenario, A Pioneer in Clean Energy, is to reduce the amount of greenhouse gases that are emitted. Sweden is aiming to reduce emissions to zero by 2045, so minimizing the carbon footprint will help us to reach this goal.
Secondary	Minimize production energy	$MPI = \frac{E}{\rho H_m}$	$MPI = \frac{\sigma_y}{\rho H_m}$	Minimizing the energy required to create the material for the blade will help cut down on further emissions of greenhouse gases and reduce waste, thus contributing further to the objective of clean energy production.

Conceptual Design – Justification of Selected Material

Depending on our selected primary and secondary objective we used the Granta Edu pack Software to list our top five materials depending on our MPI's. After ranking them on our individual materials ranking table we selected our top 3 materials based on the highest number of times they appear and the highest average ranking. This led us to our finding of wood, medium carbon steel and bamboo as out top 3 materials. We then assigned different criteria to our simple decision matrix of wood, medium carbon steel and bamboo. Out of all medium carbon steel proved to be the most reliable, durable and resistant to corrosion and hence got the highest total. Though it proved to be a little less environmentally friendly in the short term, its reliability and durability helps it last longer compared to wood or bamboo thus means less emission of greenhouse gases by medium carbon steel in the long-run as it wouldn't require less frequent replacing compared to the others. Therefore, we went with the one that came up with highest total in our simple decision matrix and contributes to our cause of reducing greenhouse gases to zero by 2045 by requiring less frequent replacements.

Table 2. Simple Decision Matrix

Simple Decision Matrix - Template			
	Material 1: Wood, typical along grain	*Material 2:* Medium carbon steel	*Material 3: Bamboo*
	Score	*Score*	*Score*
Chemical, weather, and/or corrosion resistance	2	5	2
Reliable	2	3	1
Environmentally friendly	2	1	2
Durable	3	5	1
TOTAL	9	14	6

Design Embodiment - Justification of Solid (CAD) Modelling

In milestone 3 and 4, we made a solid CAD wind turbine blade in Autodesk Inventor 2022. In milestone 4, we tested our blade in specified constraints to find the thickness of the blade with the help of the deflections of the blade which was required to be greater than 8.5 and less than 10 mm. Our Young's Modulus for medium carbon steel is 240 GPa which is greater than 100 GPa so, we found the deflection range using the deflection formulas and values given for the design of Blade A. We calculated deflection for thicknesses of 150 mm, 50 mm, 30 mm and 15mm. Then we found the range of the thickness for which the value of deflection was near 10 mm. To find the exact value of the thickness, we performed trials where we inputted the value of thickness from 30 mm to 15 mm and simulated our blade using Granta EduPack using medium carbon steel as the material while keeping the wider end of the blade fixed. We found out that at a thickness of 25 mm, the deflection was 9.435 mm which followed the thickness constraint.

Concluding Remarks

During this project, our team was able to design a wind turbine blade to help Sweden reduce their greenhouse gasses while continuing to provide energy to multiple cities, we created a design where we would minimize energy production and carbon footprint. While considering these objectives, we selected a material for the blade that satisfied the goals we wanted to achieve. Using the simple decision matrix, we decided that the most suitable material for our scenario would be medium carbon steel. After studying our scenario, we ensured that the material we selected was durable, corrosion, chemical, and weather resistant, and environmentally friendly in the long-run. A realistic consideration of this design would be testing exactly how long the blade would last using medium carbon steel without it becoming damaged to see how environmentally friendly it is in the long-run. Clean energy sources are becoming more prioritized as more countries around the world aim to reduce greenhouse gasses. As Sweden is aiming for this objective, we were given the chance to help determine a potential solution to this scenario.

References

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Appendix A – Supporting documents

Peer-Learning Interview

Our team interviewed design team Thurs-49. As our team was assigned scenario 4, we found that we had a few things that were similar and different compared to team Thurs-49’s scenario. We learned that team Thurs-49 are working on scenario 3, which is The Roof Generator. Their team explained that scenario 3 was about how residents in Calgary would like to utilize their strong winds and have wind turbines installed on their rooftops to work towards their goal to reduce electricity bills. Our scenario dealt with pioneering clean energy through a wind turbine that can help reduce Sweden’s greenhouse gas emissions and can produce electricity for multiple cities. For our primary objective we selected minimizing carbon footprint, and our secondary objective was minimizing production energy. Our team selected these objectives as Sweden aims to reduce their greenhouse gas emissions and use clean energy, which can be done through these objectives. The primary objective they selected was minimize mass. They chose this objective as these wind turbines will be installed on rooftops and the rooftops will be required to withstand the weight of the wind turbines, which also meant that it would need to be lightweight but also heavy enough to keep its ground on the roofs. The secondary objective they selected was minimize cost. They selected this as their secondary objective because the wind turbines are going to be mass produced, so it would be ideal if the cost production was minimized so it would be affordable for Calgary residents. These were different compared each other's objectives as our scenarios are aiming to achieve different goals. Our top three material finalists were wood, typical along grain, medium carbon steel, and bamboo. Team Thurs-49’s top three material finalists were aluminum alloys, bamboo, and high carbon steel. Both of our teams had some type of steel and bamboo in our top materials, and we both selected steel as our final material. Our team selected medium carbon steel, and team Thurs-49 selected high carbon steel. Both of our teams picked the steel because it was environmentally friendly in the long-term, strong, durable, reliable, and good under weather conditions. These factors were things that both scenarios looked for to determine the final material for the wind turbine blade. In terms of our refined thicknesses and final deflections, both of our teams had a refined thickness of 25 mm and had very similar final deflections of 9.43 mm (for team Thurs-49) as shown in Figure 2, which is the deflection simulation done in Granta EduPack, and 9.435 mm (for our team).

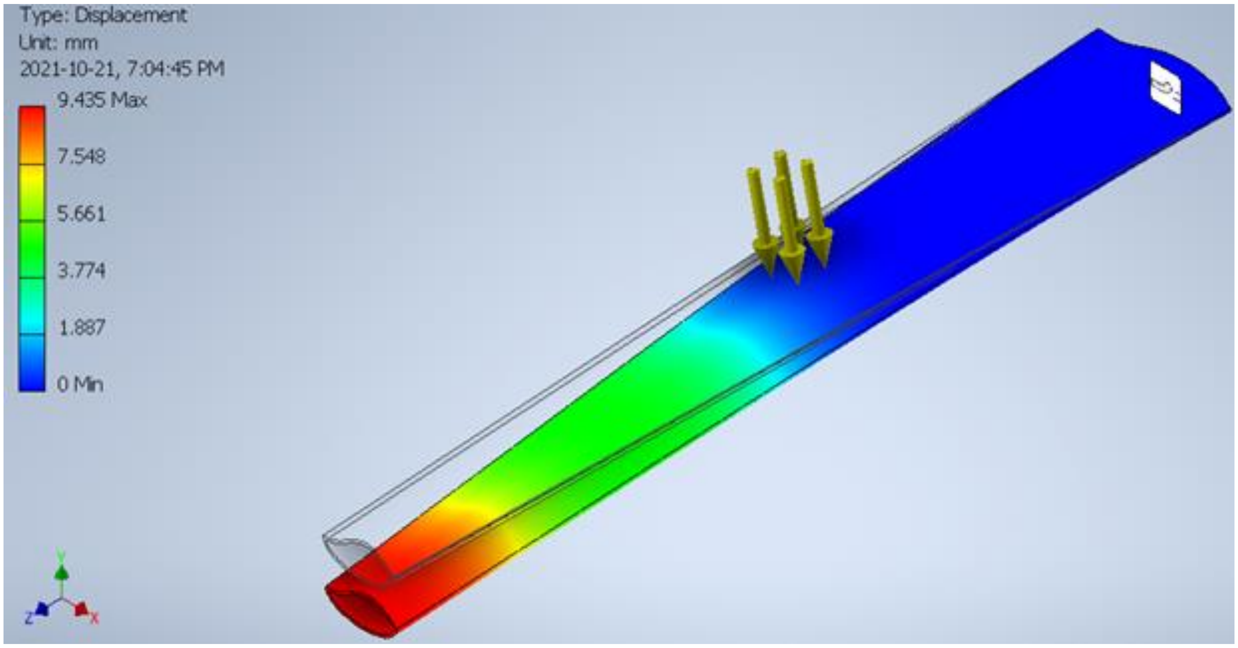
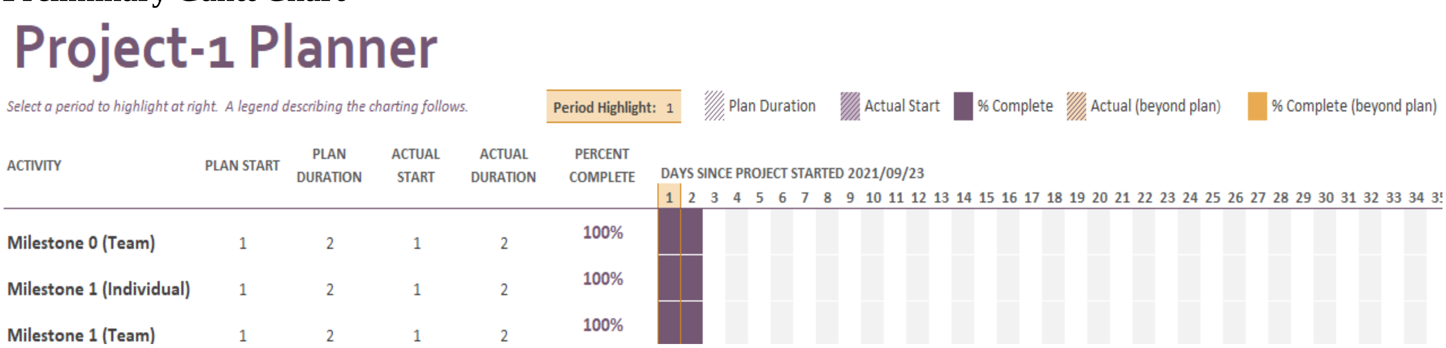


Figure 2. Blade Deflection Simulation

Appendix B – Project Schedule

Preliminary Gantt Chart



Project-1 Planner

Select a period to highlight at right. A legend describing the charting follows.

Period Highlight: 1 | Plan Duration | Actual Start | % Complete | Actual (beyond plan) | % Complete (beyond plan)

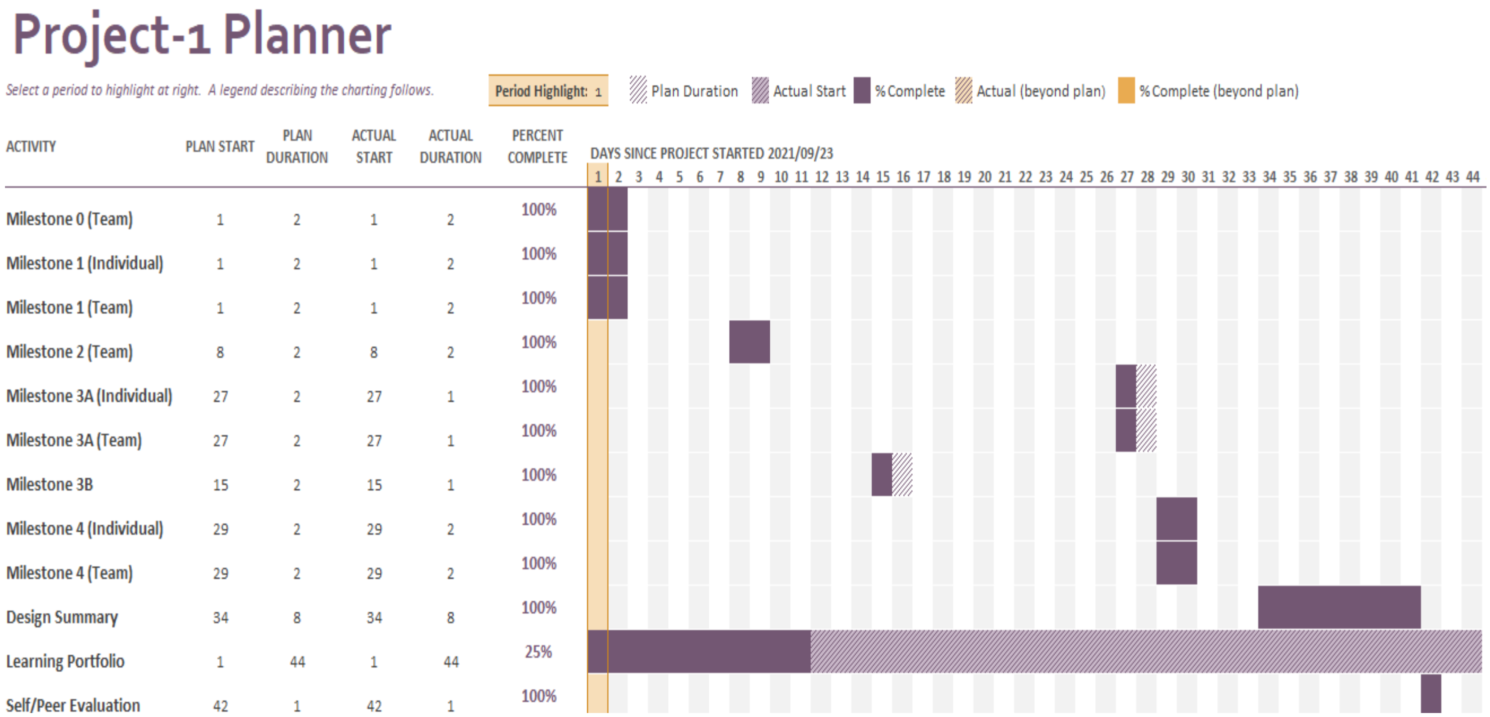
DAYS SINCE PROJECT STARTED 2021/09/23

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0 (Team)	1	2	1	2	100%
Milestone 1 (Individual)	1	2	1	2	100%
Milestone 1 (Team)	1	2	1	2	100%

Figure 3. Preliminary Gantt Chart

This is the Project 1 planner we used to organize when we would complete each milestone and how long it should take us to complete it.

Final Gantt Chart



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0 (Team)	1	2	1	2	100%
Milestone 1 (Individual)	1	2	1	2	100%
Milestone 1 (Team)	1	2	1	2	100%
Milestone 2 (Team)	8	2	8	2	100%
Milestone 3A (Individual)	27	2	27	1	100%
Milestone 3A (Team)	27	2	27	1	100%
Milestone 3B	15	2	15	1	100%
Milestone 4 (Individual)	29	2	29	2	100%
Milestone 4 (Team)	29	2	29	2	100%
Design Summary	34	8	34	8	100%
Learning Portfolio	1	44	1	44	25%
Self/Peer Evaluation	42	1	42	1	100%

Figure 4. Final Gantt Chart

This is the completed Project 1 planner where you can see the duration of each milestone, when, and how long it took to complete each task.

Logbook of Additional Meetings and Discussions

Date:	Duration:	Topics:	Format:
Sept. 23, 2021	90 mins	Milestone 1 - Worked on our initial problem statement and refined objective trees	Online
Sept. 30, 2021	45 mins	Milestone 2 - Finished the refined problem statement, top objectives	Online
Oct. 21, 2021	50 mins	Milestone 4- Completed deflection calculations and finished using the simulation to calculate thickness	Online

Table 3. Logbook of Additional Meetings and Discussions

This table displays the additional meetings we had outside of the assigned design studios to complete any work and discuss topics. All of our extra meetings were held online through Microsoft Teams.