ENGINEERING

McMaster University

Project One – Renewable technology challenge:

Mechanical design of turbine blades in renewable wind technology

ENGINEER 1P13 – Integrated Cornerstone Design Projects

Tutorial 02

Team Mon-31

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Table of Contents

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

Our engineering scenario was the EWB Humanitarian Aid Mission. In this scenario we were responsible for creating some wind turbines that can power simple electrical devices in the Guatemalan city of Quetzaltenango [1]. They want it to be a simple build with easily available materials and the turbine to be durable. For our problem statement we said that the turbine should be made from easily accessible material that is simple to assemble and fix. Therefore, our three main objectives for our turbine blade are that it is simple/easy to set up, durable/long-materials and low-cost. The function of the blade is that it must be made of durable and accessible materials and must be made from low-cost materials. The main engineering constraints are that the deflection of the blade would have to be less than 10 mm. The high-level objectives are that it is lightweight, durable, easy to repair and accessible.

Justification of Technical Objectives and Material Performance Indices

Based on our EWB Humanitarian Aid situation, we created an objective tree that perfectly embodied the criteria for this scenario. From our objective tree, we were able to conclude that our main priorities were cost efficiency, accessibility to material, durability and most importantly, we had to ensure that the parts being used required little effort to put together while setting up the wind turbine. Based off of our priorities from the objective tree, we were able to form our decision matrix, which included durability, lightweight, accessibility to material, and easy reparation; also, we were able to determine that we had to minimize cost and production energy [2], which gave us our equations to determine the MPI, thus helping us come up with the possible materials for the wind turbine using Granta software [3]. Using our criteria ranking and decision matrix, we were able to assign the materials wood (typical along the grain), bamboo, and low alloy steel a numerical value of 34, 29, and 36 respectively, so that we could easily decide which material would be most beneficial for our situation. From our decision matrix, we were able to agree that the low alloy steel was able to meet our objectives. Even though it is not as lightweight and accessible to the villagers as bamboo and wood, it is durable and easy to fix.

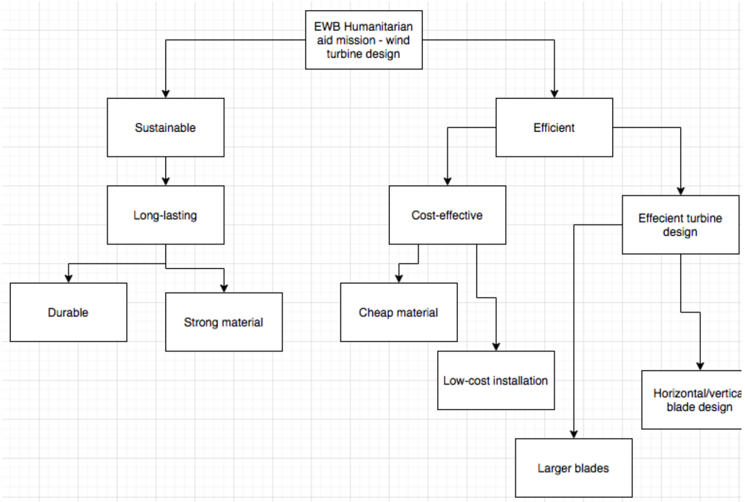

Figure 1: The EWB Humanitarian Aid objective tree

Criteria Ranking

	Lightweight	*Durable*	*Easy to repair*	Accessibility	**Weight factor**
Lightweight	1	0	0	0	1
Durable	1	1	1	1	4
Easy to repair	1	0	1	0	2
Accessibility	1	0	1	1	3

Decision Matrix

	Weight factor	*Wood, typical along grain*		*Bamboo*		*Low alloy steel*	
		Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Lightweight	1	3	**3**	5	**5**	2	**2**
Durable	4	3	**12**	2	**8**	5	**20**
Easy to repair	2	2	**4**	2	**4**	4	**8**
Accessibility	3	5	**15**	4	**12**	2	**6**
TOTAL			**34**		**29**		**36**

Figure 2: The criteria ranking and decision matrix

Conceptual Design - Justification of Selected Material

The final material chosen for the wind turbine blade is low alloy steel. This was done through the following series of steps. First, the primary and secondary objectives were listed, and the MPI-stiffness and MPI-strength formulas were chosen accordingly. The primary objective is to minimize the cost, as this turbine is being designed for villagers who may not have enough money to afford expensive materials. The secondary objective is to minimize production energy. This will make it easier for people to build more wind turbines when needed. Based on this information, MPI charts were made using the Granta software [3] to aid in the selection of the final material. Each team member completed one chart, using the 4 MPI formulas that were finalized. For each chart, the top five materials were selected. Then, according to this, the top three were selected. The three finalists were wood (typical along grain), bamboo, and low alloy steel. Finally, a decision matrix was used to determine the final material (as stated above, this material is low alloy steel). This material was the most durable out of all the materials, which means it can be used for a long time, ultimately reducing long-term costs. If the material is damaged during use, it can be easily repaired or replaced. Bamboo and wood may be more accessible; however, these materials are more susceptible to damage, leading to more costs in the long run. This will ensure the people living in this Guatemalan village can use these wind turbines for a long time.

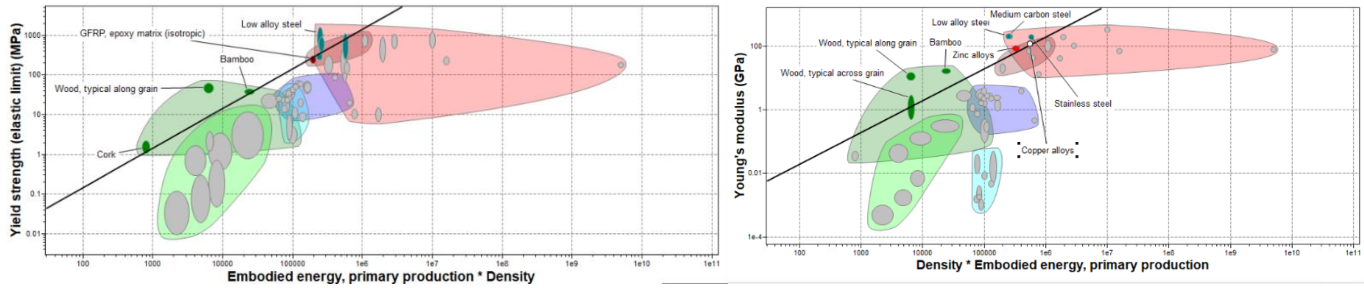

Figure 3-4: Some Grant charts for the MPI equations showing that wood, bamboo, and low alloy steel were some of the recurring materials.

Design Embodiment – Justification of Solid (CAD) Modelling

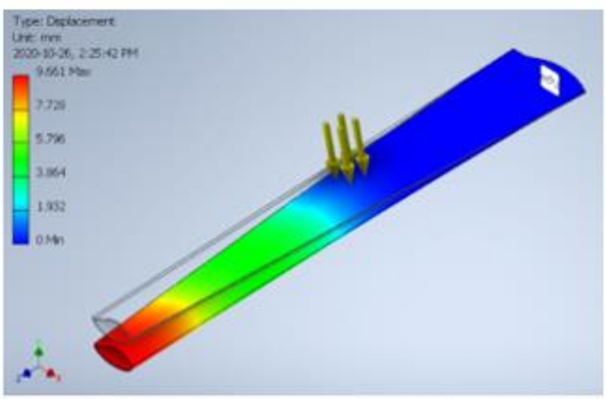

Figure 5: Final deflection simulation from inventor

Based on our calculations for the estimated deflection in milestone 4, we noticed that our actual thickness would have to be bigger than 15mm and smaller than 50mm for the deflection to be between 8.5mm and 10mm. In our calculations, the deflection for the thicknesses of 15mm, 30mm, and 50mm were 14mm, 7.96mm, and 5.5mm, respectively. For our first attempt, we tried the 30mm thickness in the Autodesk Inventor simulation [4]. This thickness gave us a deflection of about 8.3mm, which was very close to the required deflection. In our next trial, we tried to use the value of 25 as our thickness, and it gave us a deflection of about 9.7mm, which was in the desired range, so it qualified to be an appropriate thickness.

Concluding Remarks – Reality Check

In this project we learned many valuable things that we can bring forward to other projects in the future. We learned about administrative roles and how to work in a team environment, which can help us create trust that we will do what our responsibilities entail. Secondly, we learned how to assess a problem and how to create a problem statement. We learned about material properties and how important it is for material simulations to be conducted. Also, we were introduced to objectives, functions, constraints and means of design and how they influence and are incorporated in an objective tree. In the future, some engineering considerations that are worth exploring include the tower of the wind turbine and how it could be built to perform the best when keeping the ideas of the scenario in mind, as well as possibly different types of wind turbines such as vertical and horizontal wind turbines, taking into consideration how well they work in following a given objective.

Appendix A – Peer learning discussion summary

During our peer discussion, we met with group Mon-32. Their scenario was the Pioneer in Clean Energy, which means they had to create a clean wind turbine which creates lots of power. Mon-32's main priorities were concerning the turbine efficiency and carbon footprint, while we were focused on durability and accessibility to material. Although our priorities were much different from each other, both of our teams had chosen very similar materials. Mon-32 had picked a low carbon steel, while we decided to go with low alloy steel. Since these materials are so like one another, we both got similar thickness and deflection values for our turbine. Both of our groups even had the same second and third choices for material. Along with this, we both had also used the minimizing production energy equation for our strength and stiffness design. Overall, this peer interview showed us that although our main targets while building the wind turbine might be different, all wind turbines have similar goals which is providing adequate power for daily usage.

Appendix B – References

[1] Al-Banna, Yasmin. “Wk-4 Design Studio (Fall) - P1 Milestone 2 Slides.” Engineer 1P13A, 5 Oct. 2020. McMaster University.

[2] Lucentini, Andrew. “Wk-5 Lab B (Fall) - P1 Milestone 3A Slides.” Engineer 1P13A, 9 Oct. 2020. McMaster University.

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

[4] Autodesk Inventor Professional, CA, USA, 2021 (https://www.autodesk.ca/en/products/inventor/overview).

Appendix C – Gantt Chart:

Preliminary Gantt Chart

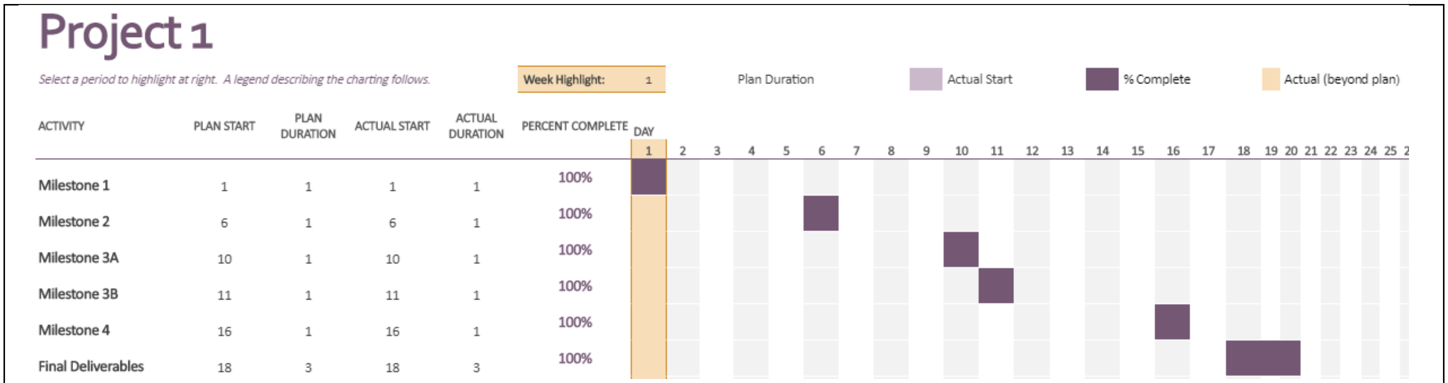

Figure 6: Preliminary Gantt chart for project 1

Final Gantt Chart

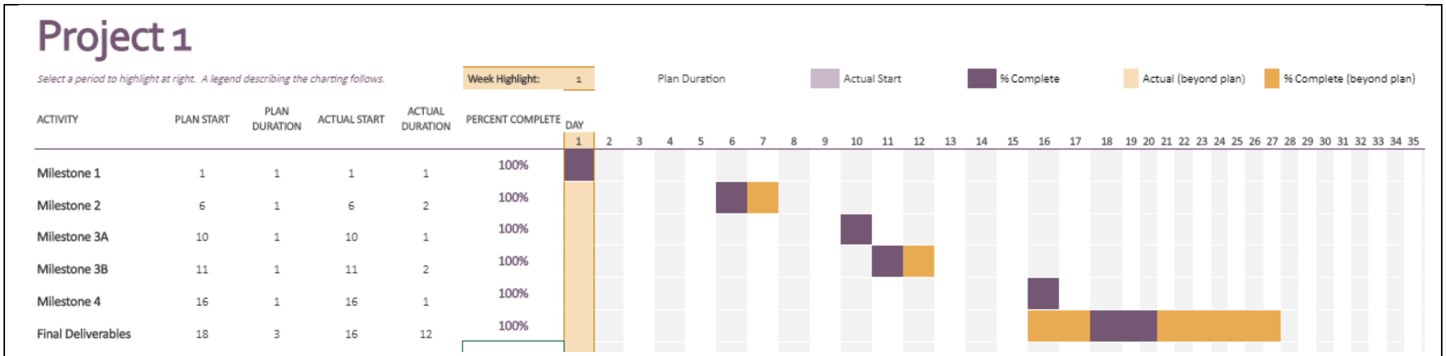

Figure 7: Final Gantt chart for project 1

Logbook

Table 1: Record of all meeting that took place outside of Design Studio

Meeting Date	**Meeting Purpose**
Monday, October 5	Finish Milestone 2 worksheet - Finish stage 4 (metrics) for each objective
Wednesday, September 27	Finish Milestone 1 team worksheet - Complete individual flowcharts - Create final team flowchart
Monday, October 19	Finish Milestone 3B worksheet - Finish simulation on wind turbine blade - Add screenshots and blade deflection values to worksheet
Saturday, October 31	Work on design summary
Sunday, November 1	Continue working on design summary
Friday, November 6	Final team meeting for design summary