Design Project 1 – Renewable Technology Challenge

ENGINEER 1P13 – Integrated Cornerstone Design Projects in Engineering

Tutorial 06

Team Tues-46

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Submitted: November 2, 2022

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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.

Ross Anderson 400436568

(Student Signature) *

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.

Rumaisa Asif 400461729

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(Student Signature) *

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Victor Bannayan 400395223

Victor Banayan

(Student Signature) *

Problem Statement

Team 46 was tasked with the EWB Humanitarian Aid Mission. The finalized problem statement was: "Design a wind turbine blade that is low cost, durable and readily manufacturable by local citizens, for turbines that will be built in Quetzaltenango, Guatemala. These blades will help generate energy for simple electrical devices." While progressing within the research of the project, a list of critical objectives was established, related to the blade's construction. These included considerations of the blade being low-cost, easy to manufacture, and weather resistant. Additional considerations with regards to the material selection included the weather of Guatemala, the resources of local villagers, and the economic conditions of the city. Constraining the design was that the blade's deflection had to between 8.5mm and 10mm.

Main Body

Justification of Technical Objectives and Material Performance Indices

Initially, it was determined that the main objectives for the blade design should be low-cost, ease of manufacturing, and durability. The blade must be low cost for EWB to help the most people with a limited budget. Also, the blade should be easy to produce by the locals since they are not trained for advanced manufacturing. Lastly, the blade must be durable so that little maintenance is required, maximizing the electricity generated over time. The reasoning behind low cost being the primary objective was that the humanitarian aid mission would have a limited budget. Furthermore, the turbines only needed to power small electrical devices, so it would be ideal to not overdesign the blade. Since the blades will be produced locally on a small scale, the blades shouldn't require too much work or advanced techniques to manufacture, therefore the secondary objective was minimizing manufacturing energy. Using these objectives, the materials property indices for stiffness and strength and were then used to find possible material options for the blade design.

Conceptual Design – Justification of Selected Material

Although the decision matrix resulted in a two-way tie between wood (typical along grain) and low alloy steel, the winner was chosen to be steel. Steel was chosen over wood because the blades being low-cost was prioritized in the specified scenario, for which low alloy steel vastly outperforms wood as seen in [1, Fig. 3]. Low alloy steel also managed to score high in criteria like material availability, weather resistance and aerodynamic properties, important for the blade design as seen in Table 1. With regards to material availability, all three materials can be locally sourced, as Guatemala has impressive yearly steel production [2]. Maintenance is one area where steel fell flat compared to the alternatives presented, as wood or bamboo can be patched with minimal tools and training, but steel requires access to a welder. Wind turbines should produce electricity efficiently, meaning the blade needed to have low drag. Steel is ideal for this, as on the molecular level, it doesn't have nearly as many scars, holes or chips like wood or bamboo might [3, Fig 1] [4, Fig. 2], and thus would result in a more aerodynamic blade out of the factory.

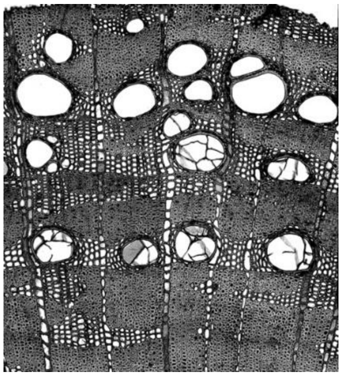


Figure 1. Wood as seen under an electron microscope

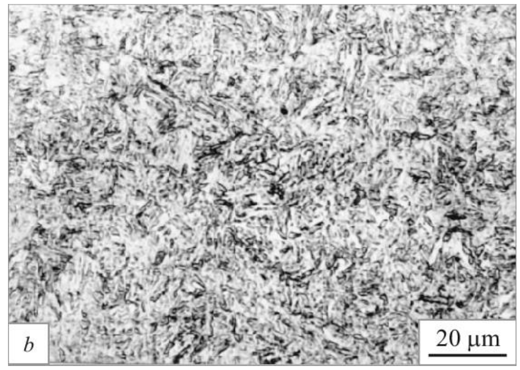


Figure 2. Low alloy steel as seen under an electron microscope

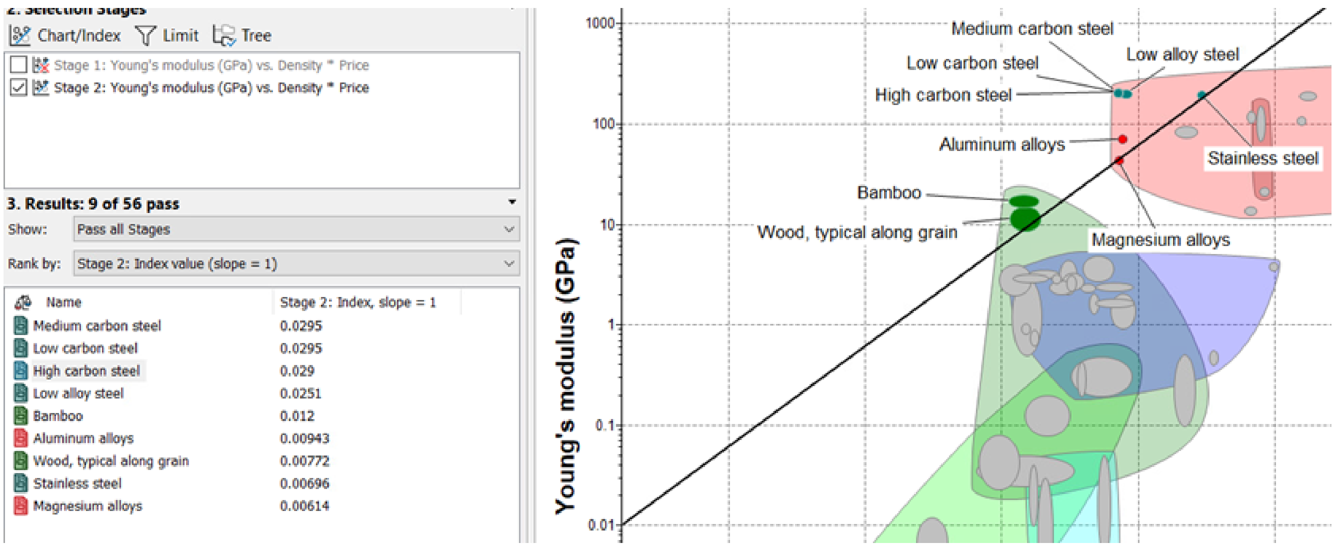


Figure 3. MPI showing the top 5 materials of E, density, and price (steels counted as one) [1]

Table 1: Material Decision Matrix [5]

	Material 1: Steel (Low alloy)	*Material 2: Wood, typically along grain*	*Material 3: Bamboo*
Cost	5	1	2
Energy to Manufacture	2	5	1
Local material availability	4	5	4
Weather resistance	4	3	1
Ease of maintenance	2	5	4

Drag and aerodynamic effectiveness	5	3	1
TOTAL	22	22	13

Design Embodiment - Justification of Solid (CAD) Modelling

In order to determine ideal thickness for the blade in accordance with the maximum deflection constraint of 10mm, a stress analysis simulation was run for a turbine blade model in Autodesk Inventor. The blade was given the material of low alloy steel. After testing various thicknesses for the blade, it was found that a thickness of 25mm produced a maximum deflection of 9.661mm, (see [1, Fig. 4]), which was sufficiently below the threshold without being so low that it would use an unnecessary amount of material. It was concluded that this should be the ideal thickness for the blade design as it struck a good balance between material use and strength.

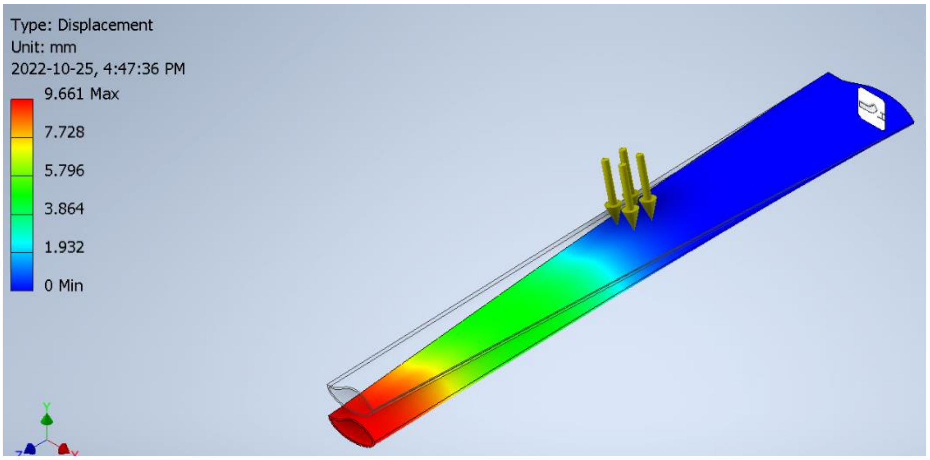


Figure 4. Deflection simulation for low alloy steel turbine blade with thickness of 25mm

Concluding Remarks – Reality Check

It can be concluded that in different situations, a variety of factors must be considered to truly analyze what will affect the way in which the problem, objectives, and constraints are defined. For example, in the EWB scenario, there were many factors to consider such as the location and economic situation of the city, as well as the ability of the locals to locate materials and assemble the blade. This shows that design considerations can be a lot more complex than what they seem when first analyzed. In order to maximize time as an engineer, one must utilize their time wisely and establish better scheduling, prior to the design studios milestones for future reference. This is especially important, as it can help not only prepare for future design studios, but also get ahead in the given project. In sum, one can conclude that they have learned a tremendous amount in the brief time that project one took to complete and now have a solid foundation to bring to future projects and the workplace for co-ops.

Reference List

[1] Ansys Granta EduPack software, ANSYS, Inc., Cambridge, UK, 2022(www.ansys.com/materials)

[2] "Guatemala Exports By Category," *Trading Economics*, 2022. [Online]. Available: https://tradingeconomics.com/guatemala/exports-by-category. [Accessed: Oct. 28, 2022]

[3] K. Ziemińska, "Wood Under the Microscope," *Arnoldia*, vol. 76, no. 2, pp. 18–22, 2018 [Online]. Available: https://arboretum.harvard.edu/stories/wood-under-the-microscope/. [Accessed: Oct. 28, 2022]

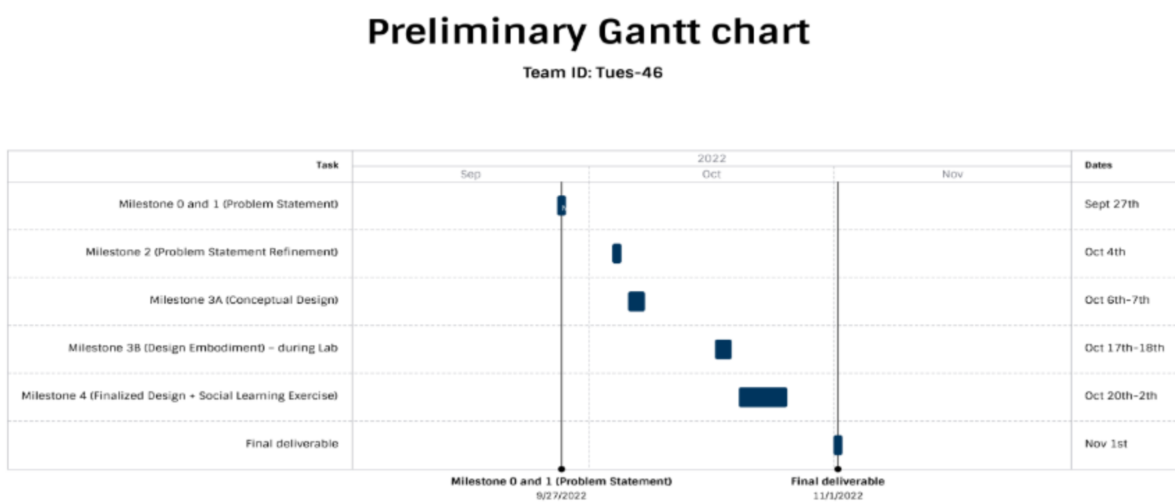
[4] Z. Janjušević, Z. Gulišija, M. Mihailović, and A. Patarić, "Effect of Tempering on Mechanical Properties and Microstructure of a High-Strength Low-Alloy Steel," *Metal Science and Heat Treatment*, vol. 56, no. 1–2, pp. 81–83, May 2014, doi: 10.1007/s11041-014-9708-y. [Online]. Available: https://www.researchgate.net/publication/271740200_Effect_of_Tempering_on_Mechanical_Properties_and_Microstructure_of_a_High-Strength_Low-Alloy_Steel. [Accessed: Oct. 28, 2022]

[5] McMaster University, "ENGINEER 1P13 – Project One: Renewable technology challenge," *avenue.cllmcmaster.ca/*, 2022. [Online]. Available: https://avenue.cllmcmaster.ca/d2l/le/content/486894/viewContent/3857187/View. [Accessed: Oct. 31, 2022]

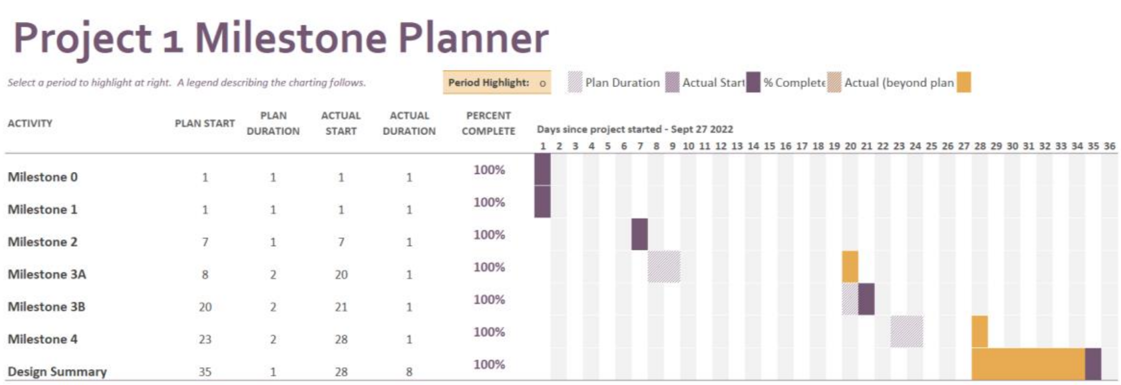
Appendices

Appendix A: Project Schedule

Preliminary Gantt Chart



Final Gantt Chart



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0	1	1	1	1	100%
Milestone 1	1	1	1	1	100%
Milestone 2	7	1	7	1	100%
Milestone 3A	8	2	20	1	100%
Milestone 3B	20	2	21	1	100%
Milestone 4	23	2	28	1	100%
Design Summary	35	1	28	8	100%

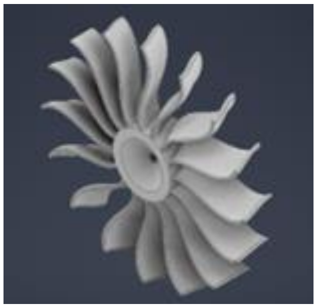
Logbook

Overall, the team was able to efficiently complete most milestones of project 1 within the allotted time during design studio, however time was occasionally taken outside meetings to complete certain tasks.

-*All meetings were held in person*

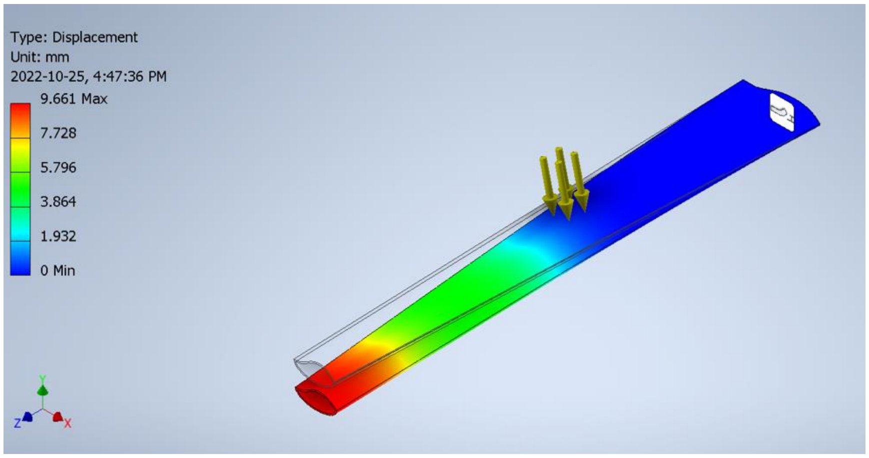
Milestone 3B (Oct 18, 2022): 1 hour

-The team took time outside of the design studio to complete the "Blow us away" challenge. While the main section of milestone 3B was completed in studio, extra time was allocated to create an interesting design for this challenge, in which the result from engaging collaborative teamwork is shown as follows.



Milestone 4 (Oct 25, 2022): 30 minutes

-This was not necessarily a meeting, however, extra time was taken right after the studio ended, to create the most properly refined deflection obtainable. Originally, issues were encountered with the models used, and some material properties indicated, so troubleshooting occurred in this meeting to ensure everything provided in the final milestone 4 submission was up to par, and contained all the correct designs, and material properties.



Final deliverable (Oct 28, 2022) - 3-4 hours

-This section was where the majority of post-design studio meeting time occurred. The team handled this deliverable in 3 waves.

1) Originally, the project was read individually, followed by cooperation with team members to understand and organize what should be put onto the deliverable, where it was meant to be put and where to obtain the visual aids and statistics from. An example of this was understanding that justifying the materials involved

the material properties, charts taken from Granta, and an explanation based on the specified scenario to reciprocate why a specified material was chosen. This work was further organized into sections.

2) Information was gathered for each section from: previous milestones, saved files, images and applications such as inventor and Granta, and collectively added to the deliverable, so the visual aids could accompany the paragraphs written.

3) Finally, the deliverable was written and reviewed, where corrections were made to grammar and phrasing, as well as double checking all numbers and statistics provided. This acted as a final checkpoint to ensure the deliverable was completed properly and was not missing anything.

Note: Wave 3 was done online without meetings, while the main meeting of this deliverable was for the first 2 waves, where all the planning and supplementation of information and extra documents such as photos occurred.

Appendix C: Comprehensive List of Sources

[1] "Wind Energy Solutions," *Wind Energy Power Systems & Solutions GE Renewable Energy*. [Online]. Available: https://www.ge.com/renewableenergy/wind-energy. [Accessed: Sep. 20, 2022]

[2] "Leading wind turbine blade design and technology," *Wind Turbine Blade Design & Technology | GE Renewable Energy*. [Online]. Available: https://www.ge.com/renewableenergy/wind-energy/leading-wind-turbine-blade-technology. [Accessed: Sep. 20, 2022]

[3] Alternative Energy Tutorials, "Wind turbine blade design, flat, bent or curved," *Alternative Energy Tutorials*, Jan. 07, 2022. [Online]. Available: https://www.alternative-energy-tutorials.com/wind-energy/wind-turbine-blade-design.html. [Accessed: Sep. 20, 2022]

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[6] P. J. Schubel and R. J. Crossley, "Wind Turbine Blade Design Review," *Wind Engineering*, vol. 36, no. 4, pp. 365–388, Aug. 2012, doi: 10.1260/0309-524X.36.4.365. [Online]. Available: https://doi.org/10.1260/0309-524X.36.4.365. [Accessed: Sep. 26, 2022]

[7] P. Gipe and E. Möllerström, "An overview of the history of wind turbine development: Part II–The 1970s onward,"

[8] C. Phelps, J. Singleton, R. Bhaskaran, and A. Zehnder, "Wind Turbine Blade Design," 2011 [Online]. Available: https://courses.edx.org/assets/courseware/v1/b345b75023f9be9e65d220987a5ed0f7/asset-v1:CornellX+ENGR2000X+1T2018+type@asset+block/blade_design_calvin_john.pdf. [Accessed: Sep. 26, 2022]

[9] P. Brondsted and R. P. L. Nijssen, *Advances in Wind Turbine Blade Design and Materials*. Jordon Hill, UNITED KINGDOM: Elsevier Science & Technology, 2013 [Online]. Available: http://ebookcentral.proquest.com/lib/mcmu/detail.action?docID=1574945. [Accessed: Sep. 25, 2022]

[10] N. Buckney, A. Pirrera, S. D. Green, and P. M. Weaver, "Structural efficiency of a wind turbine blade," *Thin-Walled Structures*, vol. 67, pp. 144–154, 2013, doi: https://doi.org/10.1016/j.tws.2013.02.010. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0263823113000311. [Accessed: Sep. 25, 2022]

[11] K. Ziemińska, "Wood Under the Microscope," *Arnoldia*, vol. 76, no. 2, pp. 18–22, 2018 [Online]. Available: https://arboretum.harvard.edu/stories/wood-under-the-microscope/. [Accessed: Oct. 28, 2022]

[12] "Guatemala Exports By Category," *Trading Economics*, 2022. [Online]. Available: https://tradingeconomics.com/guatemala/exports-by-category. [Accessed: Oct. 28, 2022]

[13] Z. Janjušević, Z. Gulišija, M. Mihailović, and A. Patarić, "Effect of Tempering on Mechanical Properties and Microstructure of a High-Strength Low-Alloy Steel," *Metal Science and Heat Treatment*, vol. 56, no. 1–2, pp. 81–83, May 2014, doi: 10.1007/s11041-014-9708-y. [Online]. Available: https://www.researchgate.net/publication/271740200_Effect_of_Tempering_on_Mechanical_Properties_and_Microstructure_of_a_High-Strength_Low-Alloy_Steel. [Accessed: Oct. 28, 2022]

[14] McMaster University, "ENGINEER 1P13 – Project One: Renewable technology challenge," *avenue.cllmcmaster.ca*, 2022 [Online]. Available: https://avenue.cllmcmaster.ca/d2l/le/content/486894/viewContent/3857187/View. [Accessed: Oct. 31, 2022]

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Appendix D: Peer-learning interview

After a thorough discussion with a group that was assigned with scenario 1, widespread energy, one can gather that they had used a different and admittedly unique material of CFRP, epoxy matric (isotropic), and had different objectives compared to Team 46. The interviewed group's objective placed heavy requirements for an aerodynamic blade design, durability and minimized production energy. This was primary due to the need to produce a high functioning, widespread, long lasting and easily producible wind farm, that would contain many windmills in a wind farming plot of land. Aside from CFRP, the other top materials they considered included wood, and low alloy steel. Within their matrix, yield strength, a lightweight design, ease of production and weather & chemical resistance were also top considerations. After refinement, the thickness of their blade resulted with 53.05mm, yielding a maximum deflection of 9.99mm. Overall, their scenario was vastly different, as had varying objectives and functions that created notable differences between the 2 turbine blades, showing how the objective of a project guides one's decision making and design choices.

Appendix E: Design Studio Worksheets

Project One Milestone (Team) Worksheets

MILESTONE 0 (TEAM): COVER PAGE

Team ID: Tues-46

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Rumaisa Asif	asifr6
Victor Bannayan	bannayav
Anousha Amedi	amedia
Ross Anderson	anderr26

Insert your Team Portrait in the dialog box below

MILESTONE 0 – TEAM CHARTER

Team ID: Tues-46

Project Leads:

Identify team member details (Name and MacID) in the space below.

Role:	Team Member Name:	MacID
Manager	Anousha Amedi	amedia
Administrator	Ross Anderson	anderr26
Coordinator	Victor Bannayan	bannayav
Subject Matter Expert	Rumaisa Asif	asifr6

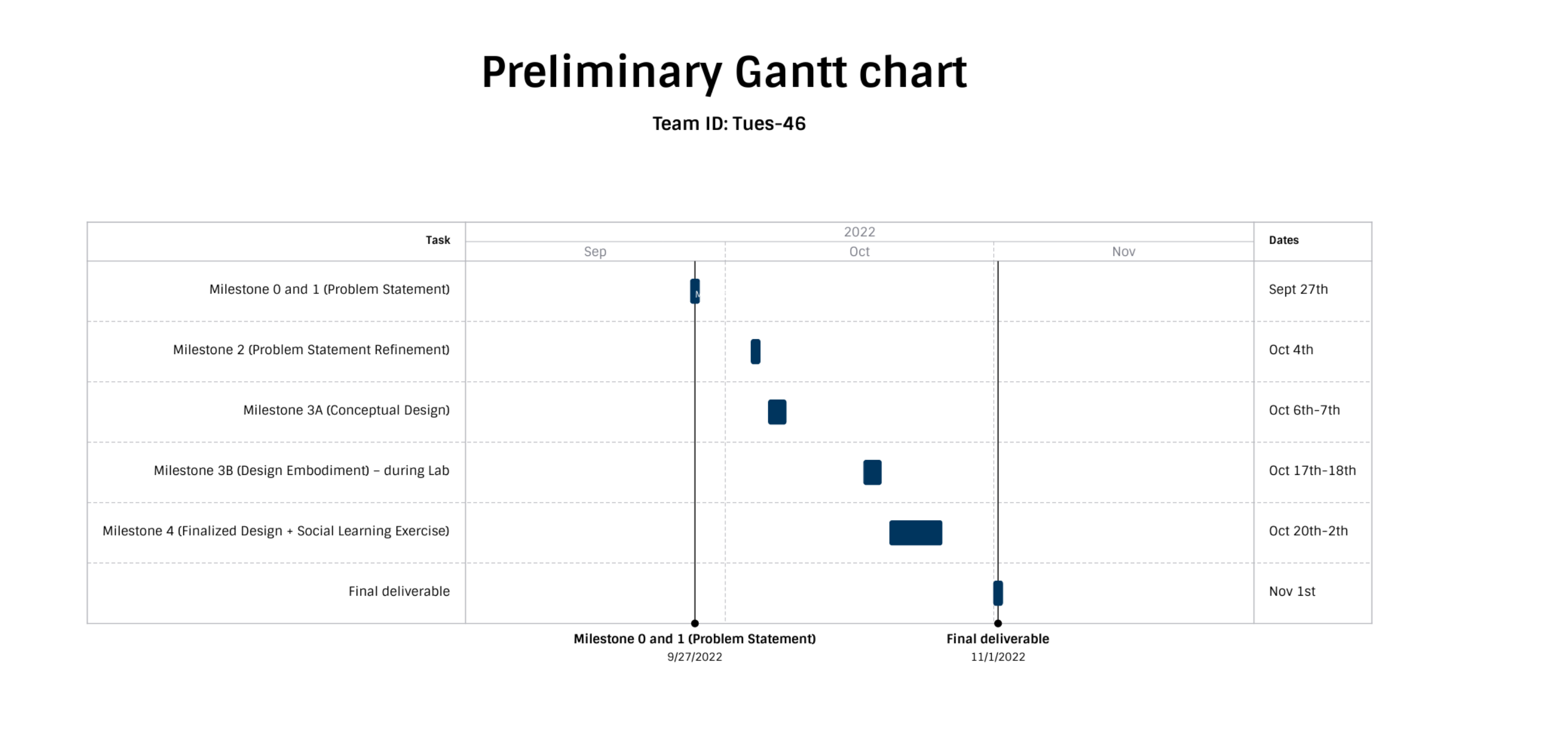
MILESTONE 0 – PRELIMINARY GANTT CHART (TEAM MANAGER ONLY)

Team ID: Tues-46

Only the **Project Manager** is completing this section!

Full Name of Team Manager:	MacID:
Anousha Amedi	amedia

Preliminary Gantt chart



MILESTONE 1 (TEAM) – COVER PAGE

Team Number: Tues-46

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Ross Anderson	anderr26
Rumaisa Asif	asifr6
Anousha Amedi	amedia
Victor Bannayan	bannayav

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-1 grade.

MILESTONE 1 (STAGE 1) – INITIAL PROBLEM STATEMENT

Team ID:	Tues-46

Stage 1: Initial Problem Statement:

What is your first draft of the problem statement? Keep it brief and to the point. One or two sentences should be enough. **For this initial problem statement, you should be focusing on the main function(s) of the wind turbine.**

We are seeking to produce electricity in an ecofriendly, sustainable, and easily scalable way for certain communities of people by converting kinetic energy from the wind to electrical energy via electromagnetic induction.

MILESTONE 1 (STAGE 3) – REFINED OBJECTIVE TREES

Team ID: Tues-46

For each engineering scenario, you will be submitting a modified/revised objective tree agreed upon by the group. Each branch of objective trees should have a minimum of 3 layers. This can be hand-drawn or done on a computer.

Engineering Scenario #1

The title of the scenario

Renewable energy for a large population.

Team objective tree diagram for scenario #1

Please insert a copy of the refined and finalized team objective tree for scenario #1.

Team ID: Tues-46

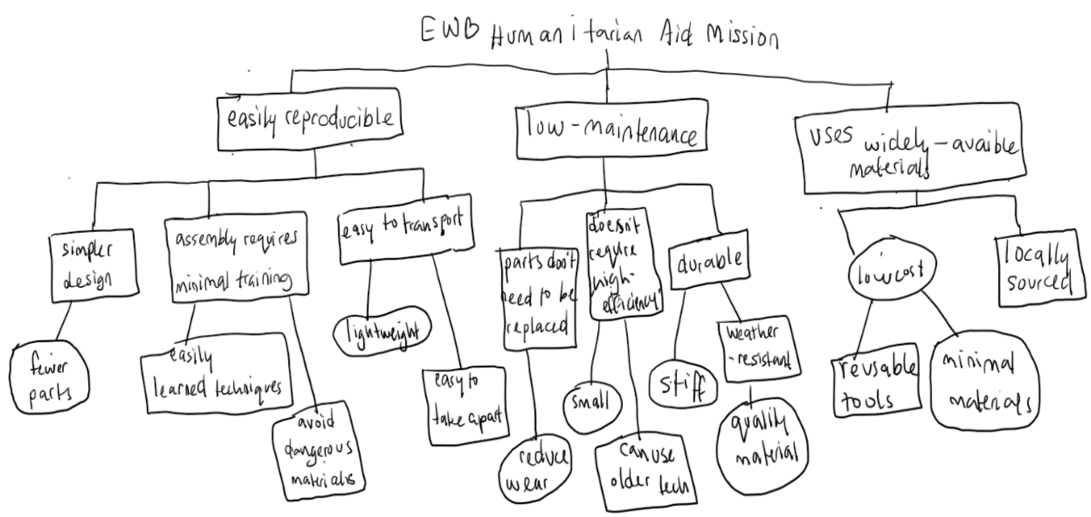
Engineering Scenario #2

The title of the scenario

EWB Humanitarian Aid Mission

Team objective tree diagram for scenario #2

Please insert a copy of the refined and finalized team objective tree for scenario #2.


EWB Humanitarian Aid Mission
easily reproducible
low-maintenance
uses widely-avaible materials
simpler design
assembly requires minimal training
easy to transport
parts don't need to be replaced
doesn't require high-efficiency
durable
low cost
locally sourced
fewer parts
easily learned techniques
avoid dangerous materials
lightweight
easy to take apart
reduce wear
small
can use older tech
stiff
weather-resistant
quality material
reusable tools
minimal materials

Team ID: Tues-46

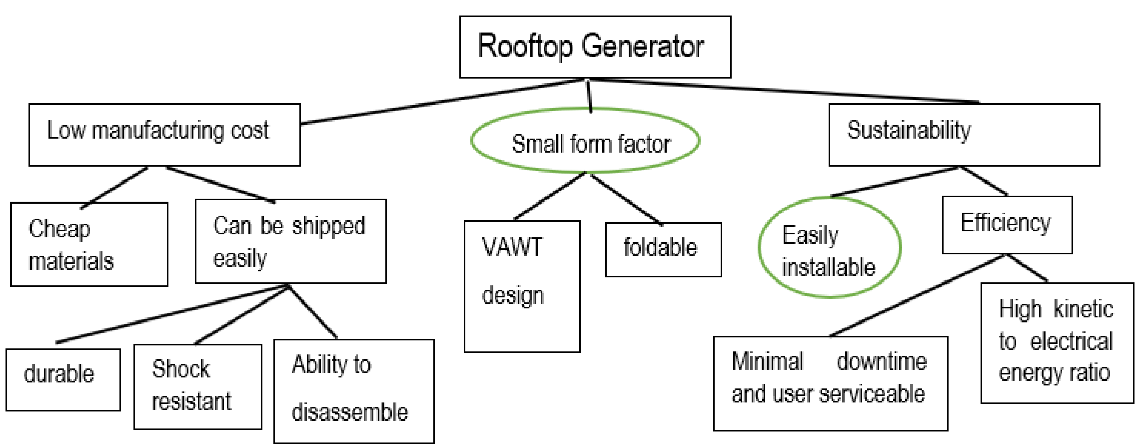
Engineering Scenario #3

The title of the scenario

The Roof Generator

Team objective tree diagram for scenario #3

Please insert a copy of the refined and finalized team objective tree for scenario #3.



Team ID: Tues-46

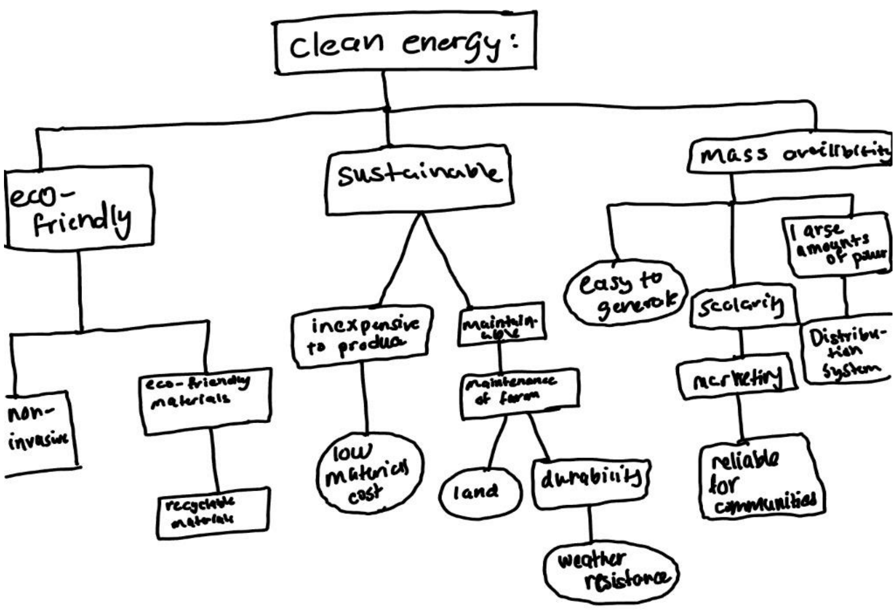
Engineering Scenario #4

The title of the scenario

A pioneer in clean energy

Team objective tree diagram for scenario #4

Please insert a copy of the refined and finalized team objective tree for scenario #4.



MILESTONE 2 (TEAM) – COVER PAGE

Team Number: Tues-46

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Anousha Amedi	amedia
Ross Anderson	anderr26
Victor Bannayan	bannayav
Rumaisa Asif	asifr6

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-1 grade.

MILESTONE 2 (STAGE 1) – REFINED PROBLEM STATEMENT FOR A WIND TURBINE

Team ID: Tues-46

The Title of The Assigned Engineering Scenario

EWB Humanitarian Aid Mission

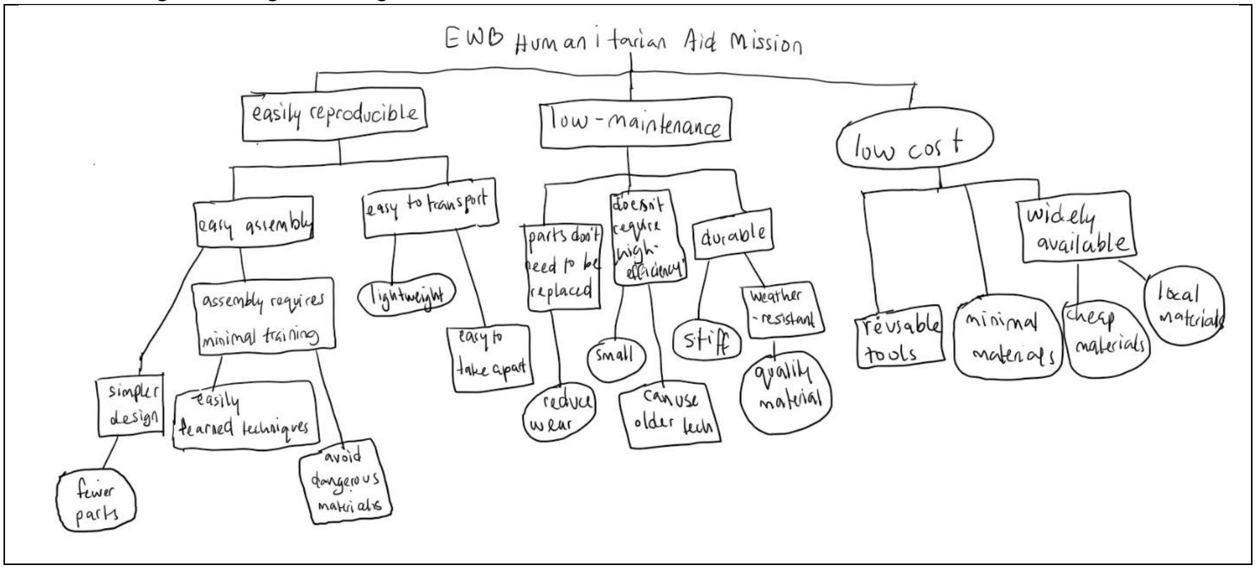
Write the Initial Problem Statement Below

→ This is a *copy-and-paste* submission of what you submitted for Milestone 1

We are seeking to produce electricity in an ecofriendly, sustainable, and easily scalable way for certain communities of people by converting kinetic energy from the wind to electrical energy via electromagnetic induction.

Finalized Objective Tree of Wind Turbine for Your Assigned Engineering Scenario

→ Please insert a copy of your finalized team objective tree of a wind turbine for your assigned engineering scenario.



Refined Problem Statement:

→ Write the refined problem statement for the design of a wind turbine based on your assigned scenario.

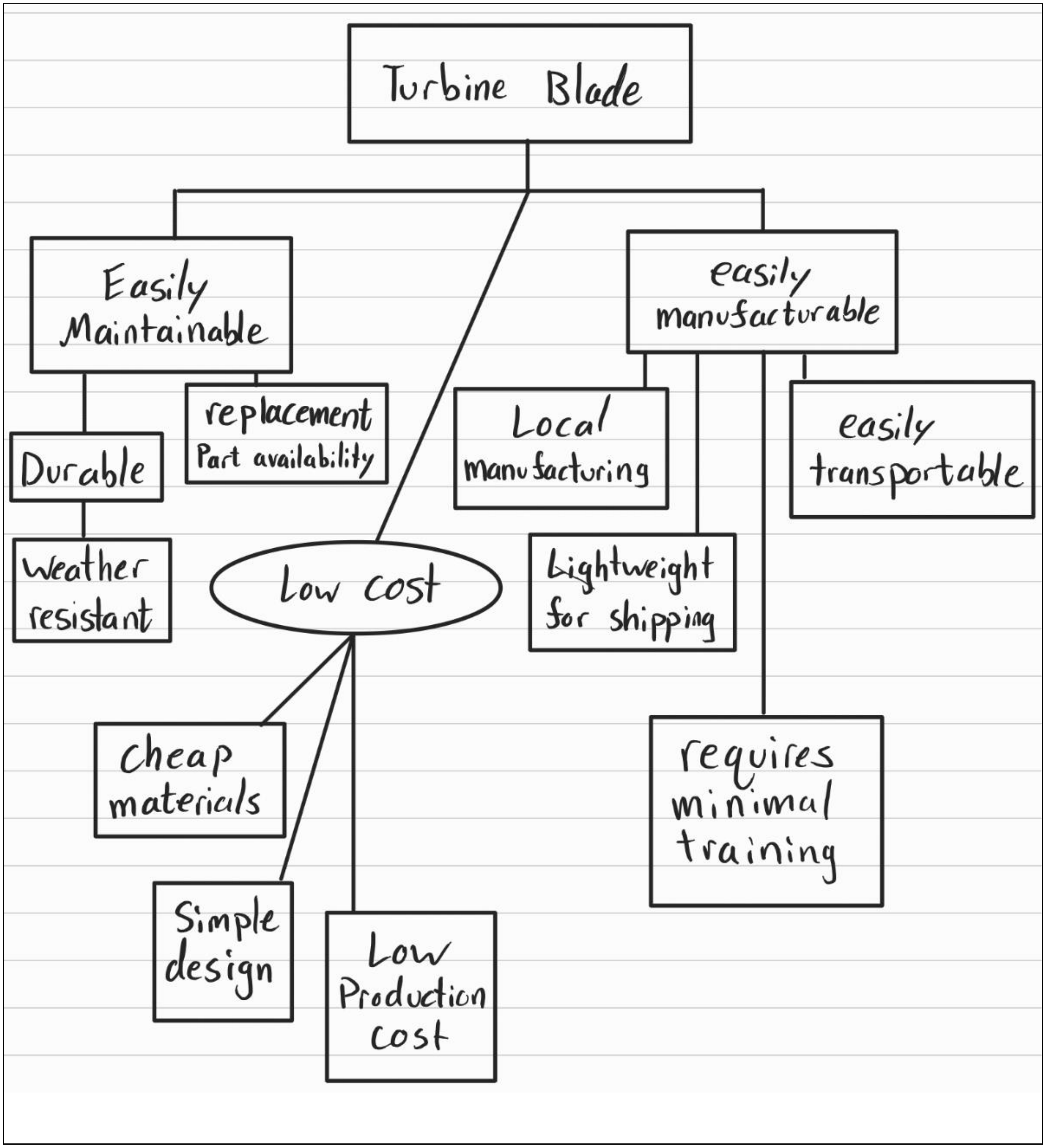
We are seeking to produce electricity in a cost effective, sustainable, and easily transportable way for the impoverished community of Quetzaltenango, Guatemala to improve their quality of life.

MILESTONE 2 (STAGE 2) – DESIGN REQUIREMENTS FOR A TURBINE BLADE

Team ID: Tues-46

Objective Tree of turbine blade for assigned engineering Scenario

→ Please insert a copy of your team objective tree for the design of a turbine blade based on your assigned engineering scenario.



Turbine Blade Problem Statement:

→ Write a complete problem statement for the design of a turbine *blade* based on your assigned engineering scenario.

We are looking to design a wind turbine blade that is low cost, durable and readily manufacturable by local citizens, for turbines that will be built in Quetzaltenango, Guatemala. These blades will help generate energy for simple electrical devices.

MILESTONE 2 (STAGE 3) – SELECTION OF TOP OBJECTIVES FOR A TURBINE BLADE

Team ID: Tues-46

List the top three objectives of a turbine blade for your assigned engineering scenario

1: Low cost

2: Manufacturing time

3: Durability

Include a rationale for selecting each of these objectives

→ Write *maximum* 100 words for each objective

Objective 1: Low cost

Rationale: The blades must be of low cost to accommodate the conditions of the local people of Quetzaltenango, Guatemala. This is pertinent, as our task is to design blades which are economically accessible for the local quality of life for the people of the village.

Objective 2: Manufacturing time

Rationale: The blades must be able to be manufactured quickly by locals. This is so they can be rapidly deployed across an array of turbines, and excess stockpiled if an active turbine needs a new blade installed in the case of breakage.

Objective 3: Durability

Rationale: The blades must be durable so that they require little maintenance and can last a long time. This is necessary due to the locals not having the ability to constantly repair and maintain the blades. The durability can be measured by yield strength of the major material the blade is made of.

MILESTONE 2 (STAGE 4) – METRICS

Team ID: Tues-46

For your selected top three objectives fill out the table below with associated metrics (including units) for each objective.

Objective 1:	Low cost
Unit/Metric:	Money [Canadian Dollars ($)]

Objective 2:	Manufactuing time
Unit/Metric:	Time [Hours (hrs)]

Objective 3:	Durability
Unit/Metric:	Yield Strength [Pascals (N/m^2)]

MILESTONE 3A (TEAM) – COVER PAGE

Team Number: Tues-46

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Anousha Amedi	amedia
Ross Anderson	anderr26
Victor Bannayan	bannayav
Rumaisa Asif	asifr6

Any student that is ***not*** present for their scheduled Lab-B session will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-1 grade.

MILESTONE 3A (STAGE 1) – MATERIAL SELECTION: PROBLEM DEFINITION

Team ID: Tues-46

1. Copy-and-paste the title of your *assigned* scenario in the space below.

EWB Humanitarian Aid Mission

2. MPI selection
   → List one primary objective and one secondary objective in the table below
   → For each objective, list the MPI
   → Write a short justification for your selected objectives

	Objective	MPI-stiffness	MPI-strength	Justification for this objective
Primary	Minimize Cost	E/pC_m	σ_y/pC_m	These blades are meant for a small village in Guatemala with limited money, hence the cost of materials must be minimized.
Secondary	Minimize production energy	E/pH_m	σ_y/pH_m	Since the blades will be produced locally on a small scale, the blades shouldn't require too much work or advanced techniques/technology to manufacture.

MILESTONE 3A (STAGE 3) – MATERIAL SELECTION: MATERIAL ALTERNATIVES AND FINAL SELECTION

Team ID: Tues-46

Document results of each team member's materials selection and ranking on the table below.

- All different types of steel (carbon steels, alloy steels, stainless steels) have very similar Young's moduli. **For this stage in Project 1, please group all variations of steels into one family as "steel"**. Please put **steel** in your material ranking list only once and indicate in a bracket which steels made the top ranks.

Consolidation of Individual Material Rankings					
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
MPI 1: E/pC_m	Steel (medium carbon, low carbon, high carbon, low alloy, stainless)	bamboo	Aluminum alloys	Wood, typical along grain	Magnesium alloys
MPI 2: σ_y/pC_m	Steel (low alloy, high carbon, low carbon, stainless)	Aluminum alloys	Zinc alloys	Copper alloys	Magnesium alloys
MPI 3: E/pH_m	Wood, typical along grain	Steel (Low carbon, low alloy, medium carbon, high carbon, stainless steel)	Bamboo	Zinc alloys	Copper alloys
MPI 4: σ_y/pH_m	Wood, typical along grain	Steel (Low alloy steel, high carbon steel, medium carbon steel, Low carbon steel, Stainless steel)	Bamboo	GFRP, epoxy matrix (isotropic)	Paper and cardboard

As a team, fill out the table below and narrow down the possible materials for your assigned scenario by choosing the 3 materials which showed up the most across all MPI rankings in the table above.

- For this stage in Project 1, if **"steel"** is one of your three material finalists, please specify which steel your team chose to continue with, based on which showed up the most in your team's consolidated table.
- Remember to save the datasheets of all 3 material finalists

Narrowing Material Candidate List to 3 Finalists	
Material Finalist 1:	Steel (Low alloy)
Material Finalist 2:	Wood, typical along grain
Material Finalist 3:	Bamboo

Team ID: Tues-46

As a team, compare material alternatives and make a final selection based on either a simple decision matrix or a weighted decision matrix (up to your team to decide)

→ As a team, consider *at least* 3 additional criteria that are relevant to your assigned scenario and discuss your 3 materials finalists for each criterion

- Feel free to pause at this stage and do some quick research on the materials finalists
- You may refer to the material finalists' datasheets for any relevant information that will enable your discussion.
- To help you come up with your additional criteria, below are some question prompts that you may consider. Please note that you are not limited to these suggestions, and they may or may not be relevant to your assigned scenario

Additional Criteria	**Possible question prompt**
Ease of access to material	Is the material easy to source in the country, are there tariffs due to international trade policy?
Chemical, weather and/or corrosion resistance	Will the material degrade over time (e.g. due to chemical resistance, corrosion resistance, fatigue resistance)?
Ease of maintenance	Consider maintenance if the part got damaged. Based on the material, is it easy to fix or will the entire part need replacement?

→ Remember that:

- Your MPI ranking takes into consideration both material and mechanical properties relevant to the objectives of your assigned scenario.

- Your additional considerations should not include previously evaluated objectives e.g. If minimizing the carbon footprint was either your primary or secondary objective, then it not be an additional criterion

→ Compare the material alternatives and make a final selection based on either a simple decision matrix or a weighted decision matrix (up to your team to decide)

- *Applies to a weighted decision matrix only:* choose a range for the weighting (e.g., 1 to 5) for each criterion. The higher the number on the weighting, the more important that criterion is.
- Choose a range for the score (e.g., 1 to 5) for each material on each criterion. Give each material a score based on how successfully it meets each criterion. The higher the score, the better the material is for that criterion.
- Add additional rows as needed.
- Add up the total score for each material alternative.

Fill one of the following templates only:

Simple Decision Matrix - Template			
	Material 1: Steel (Low alloy)	*Material 2: Wood, typically along grain*	*Material 3: Bamboo*
Cost	5	1	2
Energy to Manufacture	2	5	1
Local material availability	4	5	4
Weather resistance	4	3	1
Ease of maintenance	2	5	4

Drag and aerodynamic effectiveness	5	3	1
TOTAL	22	22	13

→ State your chosen material and justify your final selection

Justification	
Chosen Material:	Steel (Low Alloy)
Our decision matrix resulted in a two-way tie between wood along the grain and low alloy steel. Our decision of choosing steel over wood stems primarily from the critical need for a low-cost material in our specified scenario, for which low alloy steel vastly outperforms wood. Low alloy steel also manages to score high in certain criteria such as material availability, weather resistance and aerodynamic properties, all of which are very important for our blade design. With regards to material availability, while it is true that both wood and bamboo could be grown and harvested locally, steel can be procured from local manufacturers on a moment's notice, as the country of Guatemala has impressive yearly steel production. Moreover, although steel can rust if not treated, it would still have significantly better resistance to the elements than either wood or bamboo, as these could rot and fall apart over time, and their yield strengths are significantly lower than low alloy steel. Furthermore, maintenance is one area where steel falls flat compared to the alternatives we chose, as it's easy to patch or swap out chunks of wood or slabs of bamboo with minimal tools and training, and steel would require access to a welder, not to mention the additional manpower needed to move the mass. Inherently, wind turbines should produce electricity and to do this efficiently, the blades need to have low drag which implies a smooth surface. Steel is ideal for this, as on a microscopic level, it won't have scars, holes or chips like wood or bamboo might, and thus would result in a more aerodynamic blade out of the factory.	

Summary of Chosen Material's Properties

Material Name	Average value
Young's modulus E (GPa):	205
Yield strength σ_y (MPa):	1034.5
Tensile strength σ_{UTS} (MPa):	1249.5
Density ρ (kg/m^3):	7800
Embodiment energy H_m (MJ/kg)	31.05
Specific carbon footprint CO_2 (kg/kg)	2.49

MILESTONE 3B (TEAM) – COVER PAGE

Team Number: Tues-46

Please list full names and MacID's of all *present* Team Members

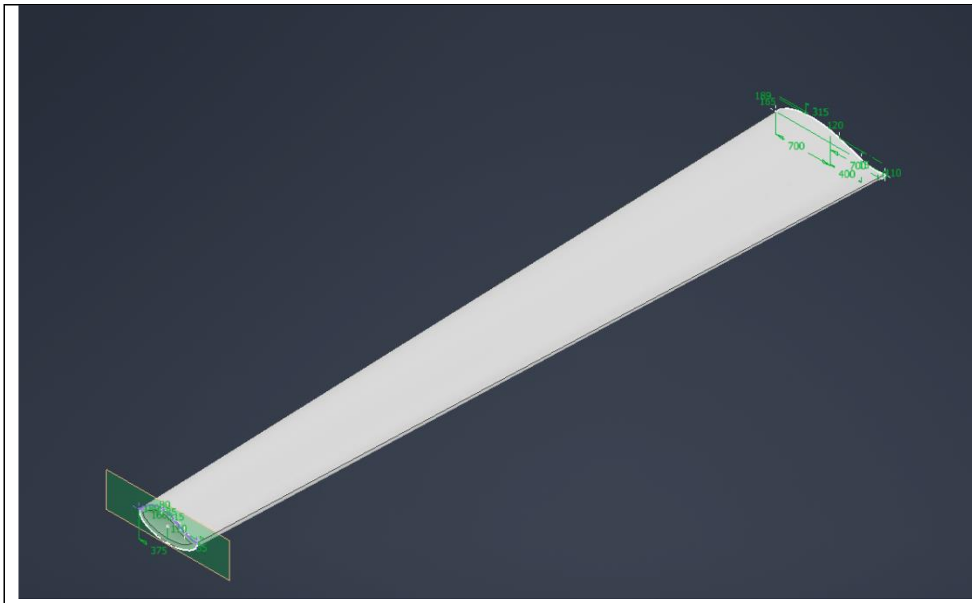
Full Name:	MacID:
Victor Bannayan	bannayav
Rumaisa Asif	asifr6
Ross Anderson	anderr26
Anousha Amedi	amedia

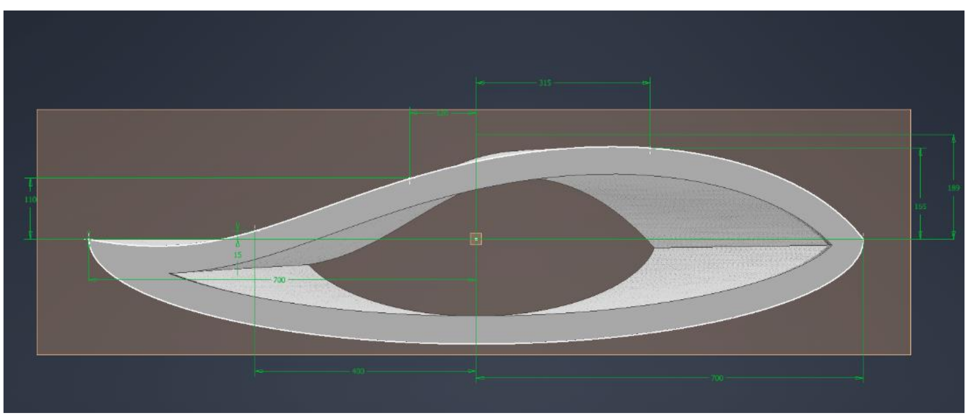
Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-1 grade.

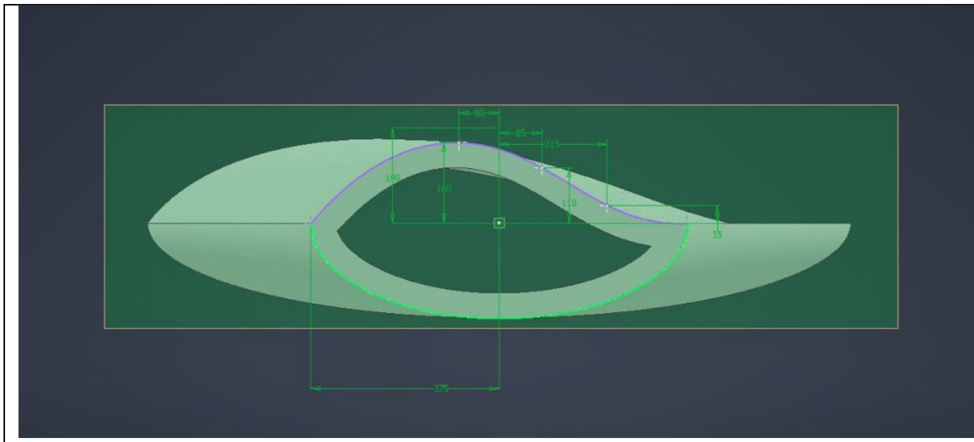
MILESTONE 3B – DESIGN EMBODIMENT

Team ID: Tues-46

1. Solid Model of Turbine Blade



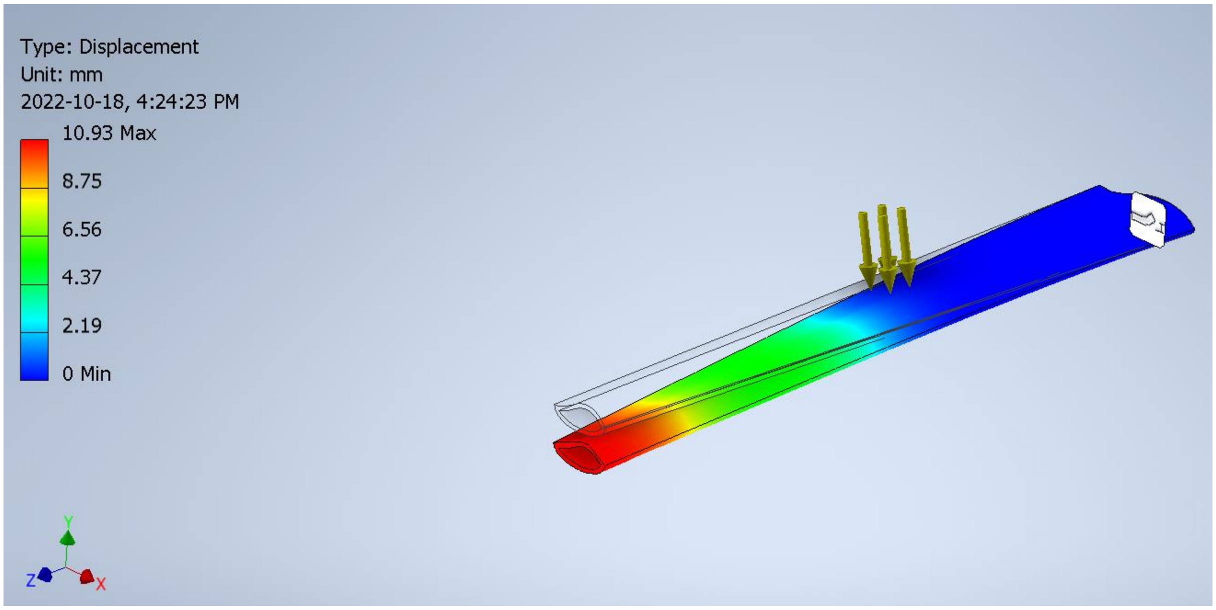


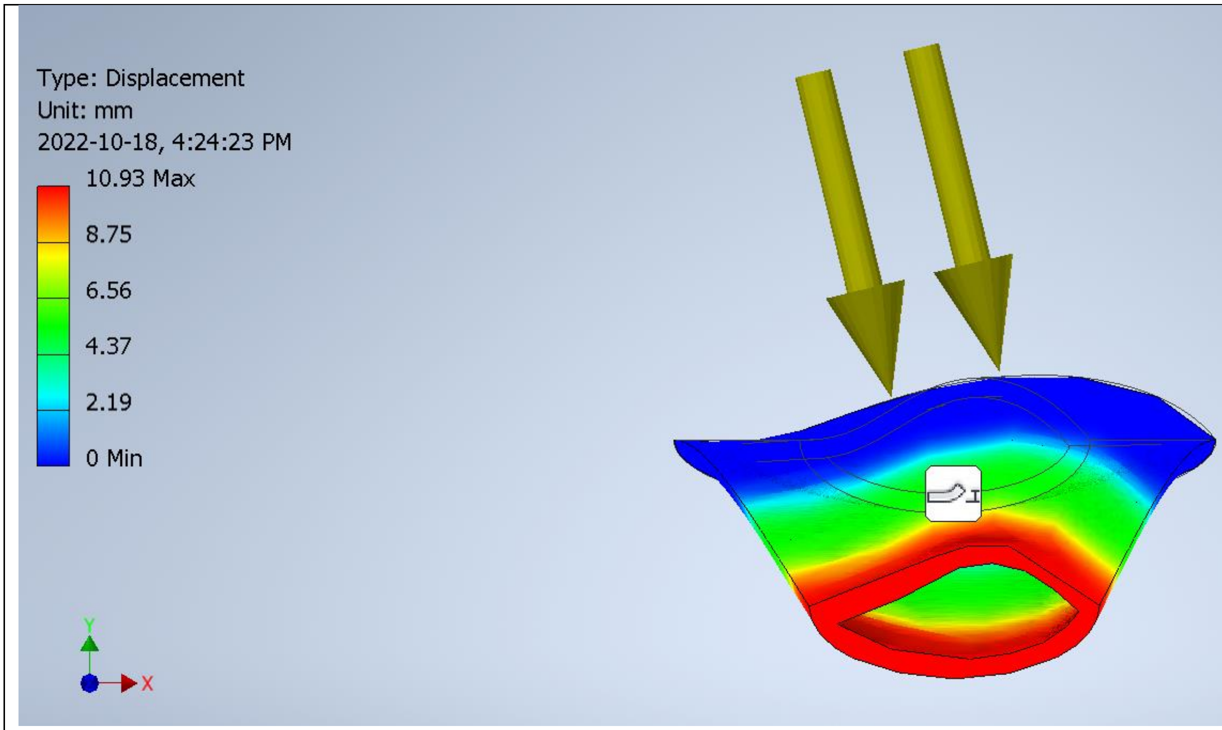


Team ID:	Tues-46

2. Deflection Simulation

Simulated deflection δ (mm):	10.93mm
Insert screenshots of your team's deflection simulation and provide evidence of the simulated deflection.	

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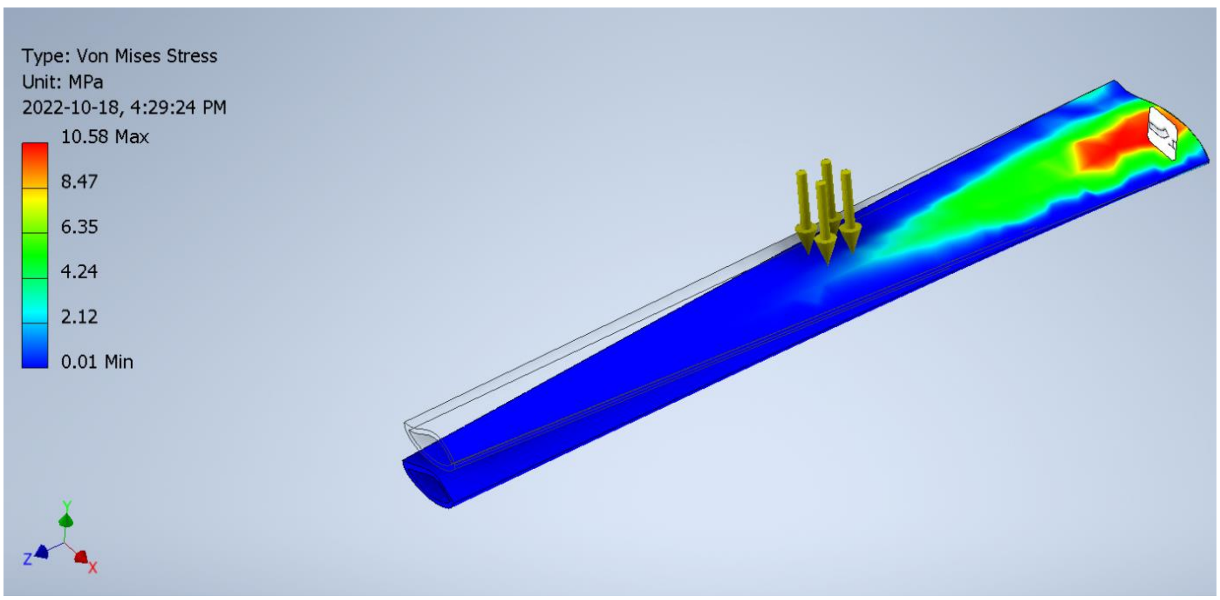
X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Unit: MPa
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10.58 Max
8.47
6.35
4.24
2.12
0.01 Min
Y
Z
X

BONUS: BLOW US AWAY (TEAM) – COVER PAGE

Team Number: Tues-46

Please list full names and MacID's of all *present* Team Members

Full Name:	**MacID:**
Victor Bannayan	bannayav
Anousha Amedi	amedia
Rumaisa Asif	asifr6

BLOW US AWAY! CHALLENGE WORKSHEET

Team ID: Tues-46

1. Solid Model of Turbine Blade

Insert an isometric pictorial of your team's solid models in multiple views (please show evidence of accurate CAD modeling by showing measurements).

Team ID: Tues-46

2. Justification

The objective of out scenario is to first and foremost minimize cost, with a secondary objective to have the blades locally produced. In order to achieve these goals, we needed to find a material that was simultaneously cheap and able to be worked with by local laborers with minimal training. Through the use of GRANTA and ranking the top materials, we settled on using steel as it's by far the cheapest material and also has the other benefit of being malleable and workable with low-tech tools. Thus, our wind turbine design reflects these choices accordingly. Our blade design and by extension turbine as a whole, fits within the HAWT designation of turbine designs, wherein the axis of rotation of the turbine is parallel to the ground. HAWT designs are simpler and less prone to failure than the VAWT counterparts, while producing power more efficiently when the wind speed/direction remains somewhat constant. By looking at the weather patterns of Quetzaltenango, Guatemala, we saw that these two factors were both true, further reinforcing our confidence in the HAWT design. The primary reason our blades are curved on multiple axis is to maximize the torque generated on the turbine without complicating the design with yaw-adjustable blades. An airfoil design to the blades creates a region of low pressure above the blade and high pressure below the blade, creating lift and thus torque. In conclusion, our blade/turbine design was a combination of material factors, local climate, and simplicity.

MILESTONE 4 (TEAM) – COVER PAGE

Team Number: Tues-46

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Ross Anderson	anderr26
Rumaisa Asif	asifr6
Anousha Amedi	amedia
Victor Bannayan	bannayav

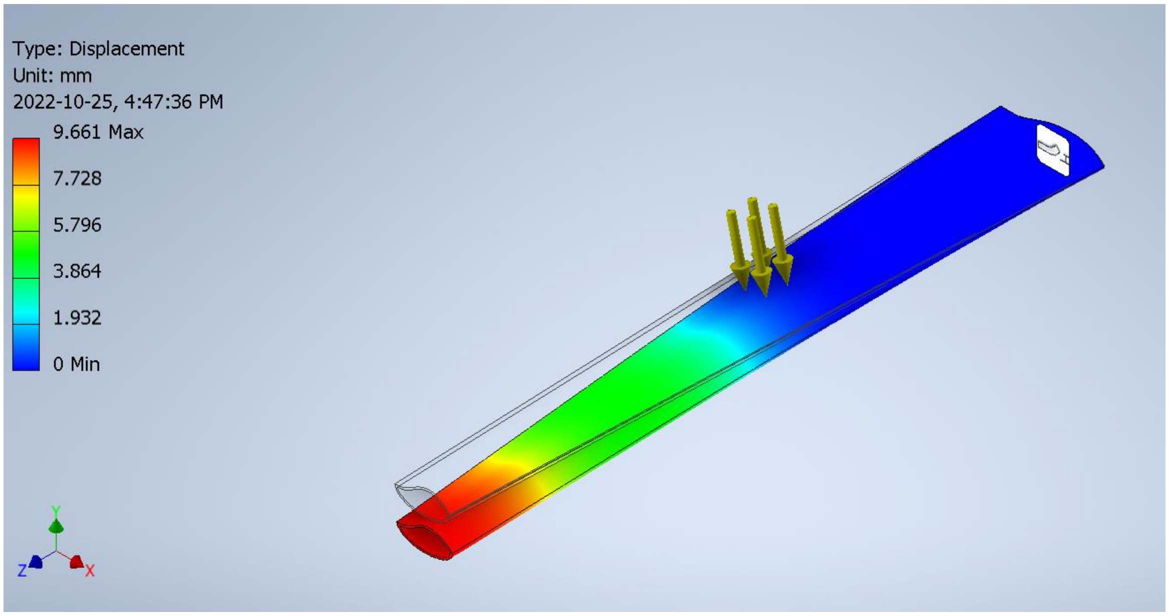
Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-1 grade.

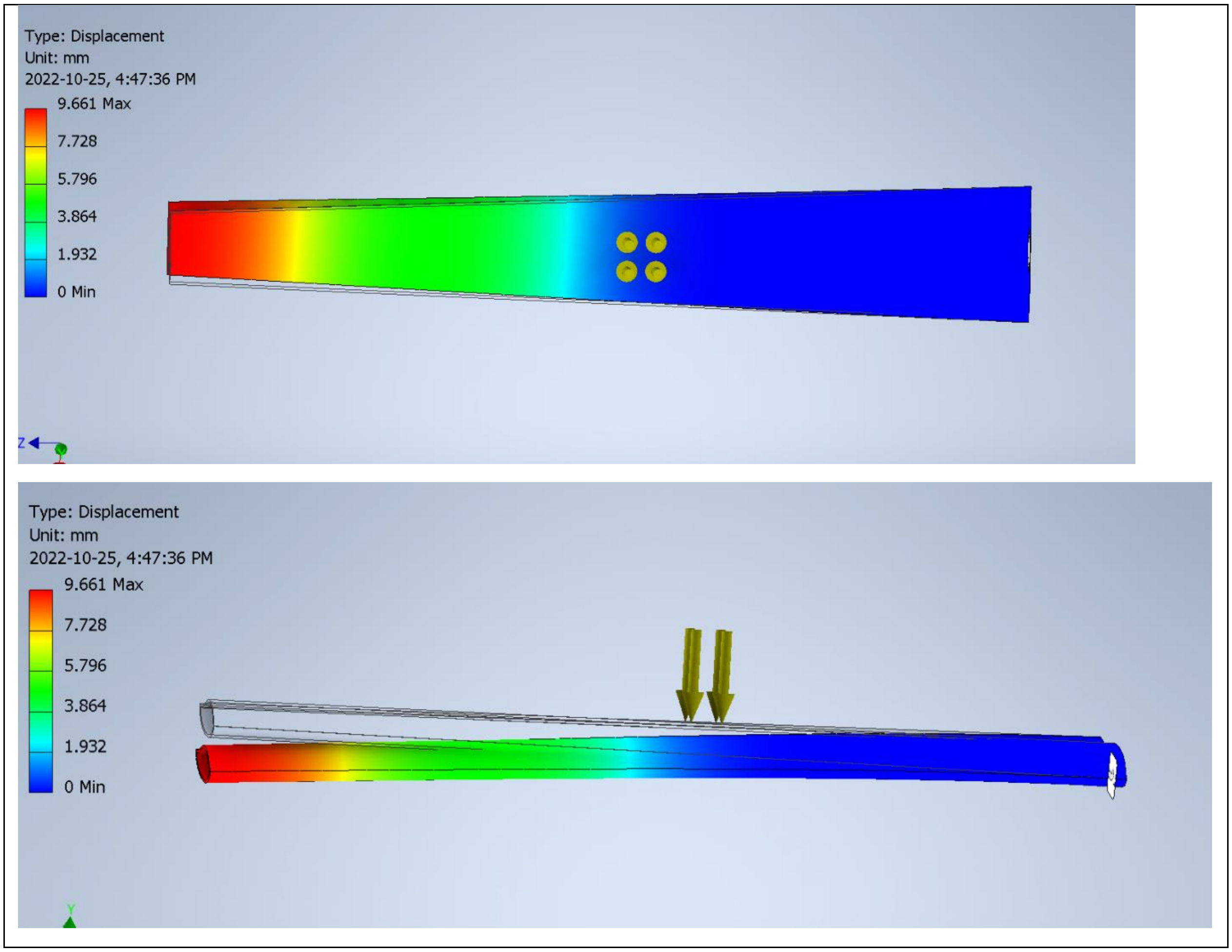
MILESTONE 4 (STAGE 2) – REFINE THICKNESS REQUIREMENT

Team ID: Tues-46

1. Refine Thickness Requirement to Satisfy Deflection Constraint

Refined turbine blade thickness *t* (mm):	25

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Unit: mm
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Type: Displacement
Unit: mm
2022-10-25, 4:47:36 PM
9.661 Max
7.728
5.796
3.864
1.932
0 Min

MILESTONE 4 (STAGE 3) – PEER INTERVIEW

Team ID: Tues-46

1. Peer Interview Notes

Discuss what you have learned from another group.

We learned from our peer review group who was tasked with scenario 1, widespread energy, that they had used a different and admittedly unique material of CFRP, epoxy matric (isotropic), and had different objectives compared to ours. Their group's objective placed heavy requirements for an aerodynamic blade design, durability and minimized production energy. This was primary due to the need to produce a high functioning, widespread, long lasting and easily producible wind farm, that would contain many windmills in a wind farming plot of land. Aside from CFRP, the other top materials they considered included wood, and low alloy steel. Within their matrix, yield strength, a lightweight design, ease of production and weather & chemical resistance were also top considerations. After refinement, the thickness of their blade resulted with 53.05mm, yielding a maximum deflection of 9.99mm. Overall, their scenario was vastly different than ours and had different objectives and requirements that created notable differences between our 2 turbine blades, showing how the objective of a project guides your decision making and design choices.

Main objectives:

Aerodynamic, minimize production energy, durable

Material: CFRP (carbon fiber), epoxy matrix

Other materials considered: Wood, Low alloy steel

Decision Matrix considerations: Strength, lightweight, ease of production, chemical and weather resistance

Thickness: 53.05mm, max deflection: 9.99 mm

Note: Please be mindful that you are expected to write a short reflection on what you have learned from the other team in your final deliverable.

Tues-46_P1_Milestones