McMaster University

ENG 1P13 P1 Project Module

Project One - Renewable technology challenge: Mechanical design of turbine blades in renewable wind technology

Table of Contents

Project Summary

In Project One, you will be in an engineering design team that contributes to green (renewable energy) technology. As part of a larger engineering group, your team particularly will be focusing on designing a turbine blade component inside a wind turbine, by considering its mechanical properties and performance. Although your team's design will focus on a blade as the main component, having knowledge of wind turbine, in general, as a technology and its design considerations of wind turbine is inevitable to be successful in your turbine blade design.

Your team will also explore the design of this turbine blade through the three levels of the Engineering Design Process. First, you will explore the technology and learn about the design specifications of wind turbine. You will also focus on determining the design requirements (i.e. function, constraints, and objectives) of wind turbine as well as its main component (turbine blade), in one of the four assigned scenarios (more details will be given for each scenario):

- Renewable Energy for a Large Population
- Engineers Without Border (EWB) Humanitarian Aid Mission
- A Roof Generator
- A Pioneer in Clean Energy

Second, you will then develop a conceptual design by selecting the suitable materials for this turbine blade based on the design requirements and top objectives considering the mechanical properties/ performance. Finally, you will develop a design embodiment through CAD modelling to determine the suitable blade dimensions to withstand the design load requirement.

Your team will be exploring the suitable "material choice" and CAD modelling for a turbine blade. Through this project, your team will acquire knowledge in using Engineering Computational Design Tools for material selection (ANSYS-Granta EduPack) and CAD modelling (Autodesk Inventor) for your proposed designs.

Timeline

WEEK	DATE	DESIGN STUDIO AGENDA
3	Sept 24 – 30	Milestone 0 and 1 (Problem Statement)
4	Oct 1 – 7	Milestone 2 (Problem Statement Refinement)
5	Oct 8 – 9 and 19 – 21	Milestone 3A (Conceptual Design) Milestone 3B (Design Embodiment) – during Lab
6	Oct 22 – 28	Milestone 4 (Finalized Design + Social Learning Exercise)
7	Wed. Nov 4	final deliverable

TEAM FORMATION

Assigned teams of 4 students

SUMMARY OF PROJECT OBJECTIVES

Working in a team of 4 students, you will be required to:

1. *Identify* the suitable objectives (using an objective tree) of the assigned design scenarios in terms of mechanical performance
2. Using ANSYS-Granta EduPack, *identify* suitable material(s) and/or alloys for manufacturing the turbine blade
3. Using Autodesk-Inventor, *design* a solid model with dimensions (i.e. airfoil thickness) that will satisfy the design requirements for this turbine blade
4. *Justify* how your final design meets the needs of the application with suitable technical objectives

SUMMARY OF PROJECT DELIVERABLES

The following is a brief summary of Project One deliverables:

Project Entry Research Memo: Each team member is required to complete a brief pre-project literature research memo (1 page long). Completion of this summary is required to access your gradebook on Avenue.

Administrative Responsibilities: Each team member is assessed individually based on specified criteria related to a team-based approach to learning.

Project Milestones: There will be 4 milestones required to be completed:

- → 0: Project Management
- → 1: Problem Statement
- → 2: Problem Statement Refinement
- → 3A: Conceptual Design
- → 3B: Design Embodiment
- → 4: Finalized Design

Final Deliverables: At completion of Project One, your team must complete a Design Summary:

- → **Finalization of problem statement**: define the suitable function, constraints, and objectives of this project, and develop an objective tree for the specific scenario assigned to your team
- → **Justification of high level and technical objectives** of the project for the specific scenario assigned to your team
- → **Summary of material selection:** describe how your team selects your chosen material

→ **Summary of CAD modeling (embodiment design)**: determine the sheet thickness requirement of the turbine blade if manufactured from your chosen material
→ Complete a peer-learning summery

SUMMARY OF PROJECT GRADING BREAKDOWN

Project 1 is worth **10% of your overall ENGINEER 1P13 grade (i.e., 10 marks out of 100**). Each deliverable is associated with 1 of 4 course modules (C – Computation, G – Graphics Design, M – Materials, P – Profession and Practice). Table 1 outlines the breakdown of Project 1 marks by course module. Table 2 lists each deliverable, the number of marks available for that deliverable, and the module associated with that deliverable.

Table 1. Breakdown of Project 1 marks by course module

COURSE MODULE	AVAILABLE MARKS
Computation (C)	-
Graphics Design (G)	0.5
Materials (M)	8.5
Profession and Practice (P)	1.0

Table 2. List of deliverables

Deliverable	Deadline	Marks	Weight	Module
Admin Responsibilities	–	P/F		P
Milestone 0	End of DS-3 (Wk-3)	P/F		P
Milestone 1 (Individual)	End of DS-3 (Wk-3)	0.5	5%	M
Milestone 1 (Team)	End of DS-3 (Wk-3)	1.0	10%	M
Milestone 2 (Team)	End of DS-4 (Wk-4)	1.0	10%	P
Milestone 3a (Individual)	End of Wk-5 Lab-B	1.0	10%	M
Milestone 3a (Team)	End of Wk-5 Lab-B	2.0	20%	M
Milestone 3b (Team)	End of DS-5 (Wk-5)	0.5	5%	G
Milestone 4 (Individual)	End of DS-6 (Wk-6)	1.0	10%	M
Milestone 4 (Team)	End of DS-6 (Wk-6)	1.0	10%	M
Design Summary	Wed. November 4th	2.0	20%	M
Learning Portfolio	Wed. November 4th	P/F		P
Self- and Peer-Evaluation	Wed. November 4th	P/F		P

Introduction

Wind turbine technology is currently one for the most effective renewable energy technologies. The turbine blade of a wind turbine acts like an airfoil to convert wind energy (or mechanical energy) into electrical energy. However, wind turbine can sometimes be subjected to extreme weather. In the case of a windstorm, wind speed can reach about 70 m/s, causing the turbine to be highly stressed. This mechanical loading during a storm can cause the turbine blade to deflect, see Fig.1. If designed improperly, the turbine blade may deflect too much – either causing damage to the rotor or interfering with the wind tower. In the extreme, the bending load may also cause the turbine blade to fail in yielding/fracture. Fig. 2 shows two real life examples of the fracture of a wind turbine. As a result, the mechanical design of the stiffness and strength of a wind turbine blade is crucial to the overall design of a wind turbine. Both the stiffness and strength of a wind turbine blade are mainly governed by the properties of the material that has been chosen for manufacturing the blade, as well as the final blade geometry.

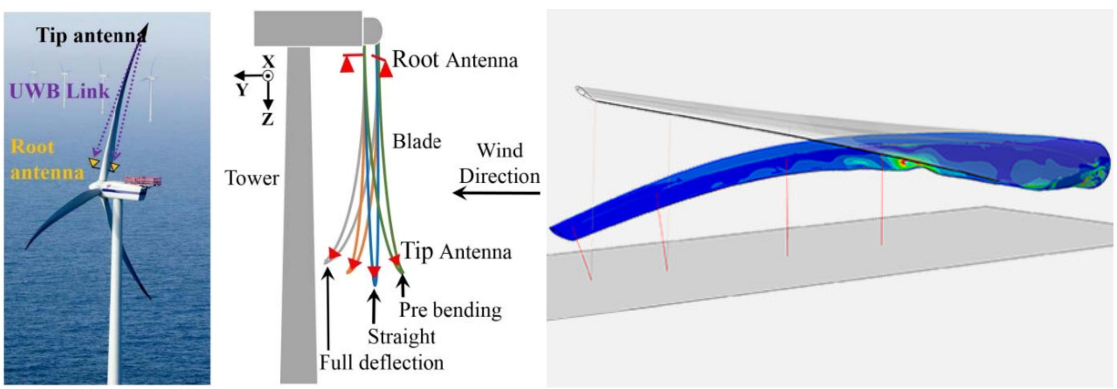


Figure 1. Diagrams of a wind turbine blade subjected to deflection from strong winds.

Figure 2. Images of fracture failure in wind turbines.

In Project One, your team will have the opportunity to design a turbine blade component of a wind turbine based on the mechanical requirements specified by your engineering supervisor. In this project, you will determine what the “most desirable” materials for your blade design are based on an assigned engineering scenario (i.e. **conceptual design**). An image of the material selection design tool, ANSYS-Granta EduPack, is shown in Fig. 3a. The most suitable material for each scenario should have high strength and stiffness, but it can also be compact, lightweight, economical, or sustainable (depending on the specific scenario your team is assigned). After selecting the most suitable material for manufacturing, your team will then refine the design by developing the most effective geometry (e.g. through CAD modelling) for the turbine blade given the specific application (i.e. **design embodiment**). An image of the solid modelling design tool, Autodesk Inventor, is shown in Fig. 3b. Your final design of the turbine blade must withstand the mechanical loading conditions of the turbine blade given by your supervisor (i.e. **functional constraints**), but it should also satisfy a set of **design objectives** given by the application or your potential clients. The project objectives of your design are therefore governed by the engineering scenario your team has been assigned.

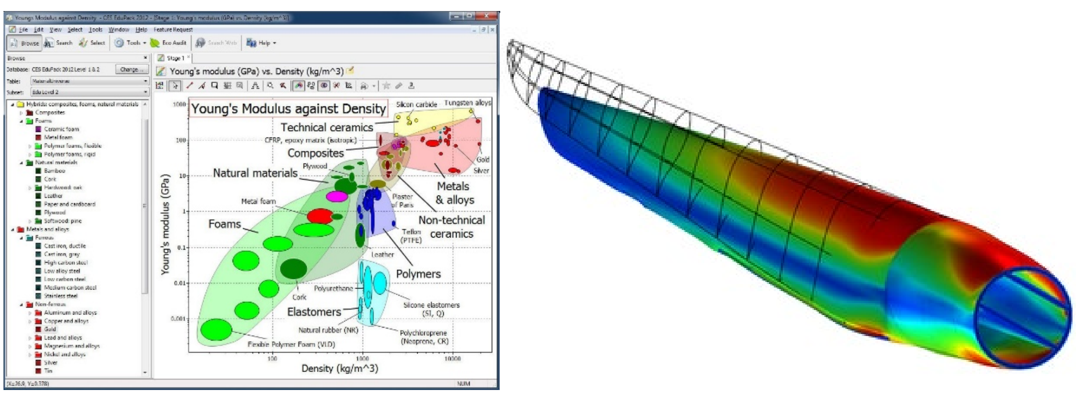


Figure 3. a) ANSYS-Granta EduPack image, and b) Autodesk Inventor image.

Design Specification

In this project, your team will be designing a turbine that acts like an airfoil to convert wind pressure into mechanical movement of the rotor. In this design, the external dimensions (length *L*, blade width *b*, and blade height *a*) have been restricted, see Table 1 and Fig. 4 (the restrict dimension the blade will be provided later in Milestone 3B and 4 of this document). However, the material choice of the turbine blade and the air foil thickness *t* remain unknown. The turbine blade needs to design to survive a windstorm where the blade will be subjected to a distributed pressure *p* caused by a wind speed of v = 70 m/s. Assuming the density of air is ρ = 1.2 kg/m^3, the wind pressure the turbine blade is subjected to can be expressed as:

$$p = \frac{1}{2}\rho v^2 \approx 3000 \text{ Pa} \quad (1)$$

When the turbine blade is subjected to the above loading, it will deflect and experience an internal bending stress. The first design requirement is that the maximum deflection δ of the turbine blade must be less than a threshold of δ^* = 10 mm, i.e.:

$$\delta < \delta^* = 10 \text{ mm} \quad (2)$$

The second design requirement is that the turbine blade needs to withstand the pressure load without yielding.

$$\sigma < \sigma_y \quad (3)$$

where σ_y is the yield strength of the material.

The material chosen and the final thickness of the turbine blade of your design will be based on the above design requirements as well as your team's set of design objectives. Your design objectives will depend on the specific engineering scenario your team is assigned, see next section.

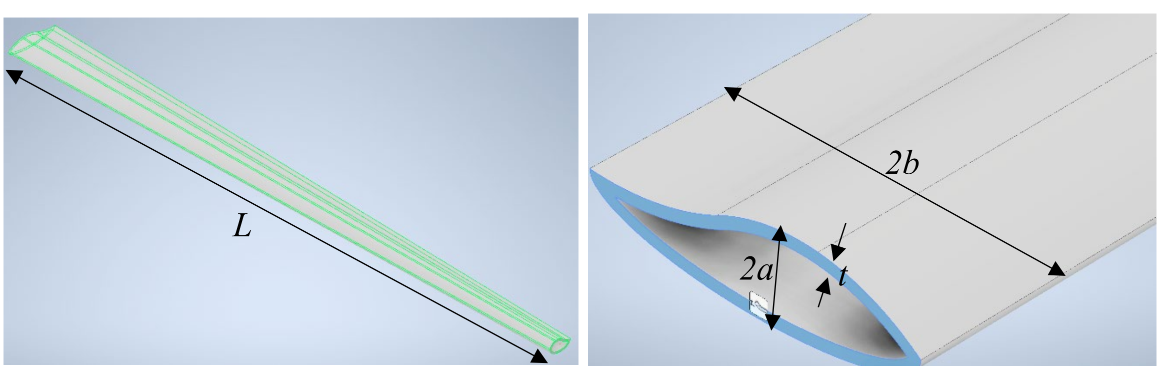


Figure 4. a) Schematic diagram of a turbine blade and b) its cross section.

Table 1. Geometrical parameters of the turbine blade

Blade external width, 2*b* (m)	Fixed
Blade external height, 2*a* (m)	Fixed
Blade external Length *L* (m)	Fixed
Blade deflection *t* (mm)	Free to adjust

Design Scenarios

Scenario 1: Renewable Energy for a Large Population

A large Canadian hydro company has contracted you, a professional engineer, to design wind turbines for their new wind farm in Wolfe Island. The main objective of this wind farm is generating large amounts of electric power for the neighboring city of Kingston, Ontario. To fully take advantage of the wind pressures in the area, turbine blades should minimize inertia to maximize efficiency. As this wind farm will be the primary source of energy for nearby cities, the turbines must be durable and have a long lifespan. Your task is to generate an efficient design for the wind turbine used in this wind far.

Source:

[1] miningandenergy.ca, 'Top wind farms in Canada', 2019. [Online]. Available: https://www.miningandenergy.ca/energy/article/top_wind_farms_in_canada. [Accessed: 24 – July - 2020].

Scenario 2: EWB Humanitarian Aid Mission

You are a part of a group of volunteer engineers in Engineers Without Borders (EWB) that is designing a simple wind turbine for the Guatemalan city of Quetzaltenango. This Guatemalan village is currently off the grid and EWB aims to build a wind turbine that can provide enough energy to power simple electrical devices like LED lights. Once the design is finished, local village workers will assemble multiple units of these simple turbines. The design must be simple enough so that it can be assembled from widely available materials. At the same time, the turbines should be long lasting and require little maintenance. Your task is to design a simple wind turbine design that is suitable for easy assembly by village locals.

Source:

[2] wired.com, 'Engineers Without Borders Bring Tech to Villages Without Power', 2008. [Online]. Available: https://www.wired.com/2008/03/engineers-without-borders-bring-tech-to-villages-without-power. [Accessed: 24 – July - 2020].

Scenario 3: The Roof Generator

Calgary, known for its "chinook blows", is one of Canada's windiest large cities. Although these winds may often be destructive, residential homeowners want to take advantage of these strong winds to reduce their electricity bills. Demand for roof wind turbines is on the rise. A start-up business has contracted you, a professional engineer, to design a new mini wind turbine that can be easily installed on a residential roof. In designing this new wind turbine, space considerations must be made. This is especially important if houses are closely packed (such as in a semi-detached or row house). When installed on a roof, it must not collide with neighboring turbines or roofs. Your task is to design a suitable wind turbine that can be installed on most residential housing roofs for homeowners that want to reduce their electricity bills.

Note: For consistency, all teams will be expected to use the same external geometrical parameters (see Table 1 on the previous page) for the CAD modelling. You may imagine that when the final turbines are produced for residential home applications, they would in fact be scaled down to lower dimensions.

Source:

[3] ec.gc.ca, 'Wicked Winds from the West', 2017. [Online]. Available: https://ec.gc.ca/meteo-weather/default.asp?lang=En&n=774B5B53-1. [Accessed: 24 – July - 2020].

Scenario 4: A Pioneer in Clean Energy

Sweden is a global leader in the shift to clean renewable energy. As of 2018, 54% of Sweden's energy is produced from renewable resources. By 2045, Sweden aims to reduce its net emissions of greenhouse gases into the atmosphere to zero. Working with the Swedish Wind Energy Association (SWEA), your company has contracted you, a professional engineer, to design a cleaner sustainable wind turbine. This design is to be used to create multiple units for a new wind farm. In addition, these turbines must be able to efficiently provide power to multiple cities. Your task is to design a clean wind turbine to generate large amounts of power.

Source:

[4] clickenergy.com.au, '12 Countries Leading the Way in Renewable Energy', 2017. [Online]. Available: https://www.clickenergy.com.au/news-blog/12-countries-leading-the-way-in-renewable-energy. [Accessed: 24 – July - 2020].

[5] sweden.se, 'Towards 100% renewables', 2020. [Online]. Available: https://sweden.se/nature/energy-use-in-sweden. [Accessed: 24 – July - 2020].

[6] community.ieawind.org/, 'Wind Energy in Sweden', 2017. [Online]. Available: https://community.ieawind.org/about/member-activities/sweden. [Accessed: 24 – July - 2020.

a)

b)

c)

d)

Figure 5. Application examples of (a) Scenario 1, (b) Scenario 2, (c) Scenario 3, and (d) Scenario 4.

TITLE:	Scenario 1, Renewable Energy for a Large Population	Scenario 2, EWB Humanitarian Aid Mission	Scenario 3, The Roof Generator	Scenario 4, A Pioneer in Clean Energy
OVERVIEW	You have been contracted by a large hydro company to design durable wind turbines that generate large amounts of electric power for the entire city of Kingston, Ontario. To fully take advantage of the wind pressures in the area, your turbine blades should minimize inertia to maximize efficiency.	The Guatemalan city of Quetzaltenango is currently off the grid and your volunteer group, Engineers Without Borders (EWB), aims to build a wind turbine that can provide enough energy to power simple electrical devices like LED lights. The design must be simple enough so that multiple units can be assembled from widely available materials by local workers. At the same time, the turbines should be long lasting and require little maintenance.	Residential homeowners want to take advantage of the strong winds to reduce their electricity bills in Calgary. You have been contracted to design a mini wind turbine that can be easily installed on a residential roof. Space considerations must be made since some houses are closely packed and the roof turbine must not collide with neighboring turbines or roofs.	Sweden aims to reduce its net emissions of greenhouse gases to zero, by 2045. Working with the Swedish Wind Energy Association (SWEA), you have been contracted to design wind turbines in a new wind farm. The wind turbines must be clean and sustainable while efficiently providing power to multiple cities.
TASK:	Design efficient wind turbines to be built in the nearby Wolfe Island wind farm	Design a simple wind turbine design that is suitable for easy assembly by village locals	Design a suitable wind turbine to be installed on residential housing roofs for homeowners	Design a clean wind turbine to generate large amounts of power

Figure 6. A summary of all four design scenarios

Project One Schedule of Activities

Week #	Date	Activity	Complete **BEFORE** Design Studio	Complete **DURING** Design Studio
Wk-3	Thurs Sept 24 – Wed Sept 30	**Milestone 0** • Determine and document administrative responsibilities for each team member	***Individual***: Review the Administrative Responsibilities section of the P1 Project Module	***Team***: Complete Team Charter worksheet (Milestone Zero Team Worksheet)
		Milestone 1 • Problem Statement and Objective tree	***Individual***: Complete pre-project research memo	***Team***: Complete initial problem statement and objective tress of a wind turbine for 4 different engineering scenarios
Wk-4	Thurs Oct 1 – Wed Oct 7	**Milestone 2** • Refined problem statement and metrics	***Team:*** N/A	***Team***: Complete refined problem statement of wind turbine, design requirement of wind turbine bladed of a specific scenario, design objectives of a turbine blade, and the metrics of the design objectives
Wk-5	Thurs Oct 8 – Wed Oct 21	**Milestone 3A** • Conceptual design – material selection	***Team:*** Learn how to use Granta EduPack as a design tool for material selection (in materials science lab #1)	***Individual***: Complete material selection process ***Team***: Complete problem definition of a turbine blade for material selection, compare material alternative, select the more suitable material your turbine blade should be made of
Wk-5	Thurs Oct 8 – Wed Oct 21	**Milestone 3B** • Design embodiment	***Team:*** N/A	***Team***: Complete deflection calculation, CAD drawing of a turbine blade, and deflection simulation turbine blade CAD file
		***Milestone 3B** is completed during Wk-5 Lab-B*		

PROJECT ONE SCHEDULE OF ACTIVITIES

Week #	**Date**	**Activity**	Complete **BEFORE** Design Studio	Complete **DURING** Design Studio
Wk-6	Thurs Oct 22 – Wed Oct 28	**Milestone 4** • Finalized design and social learning	***Team:*** N/A	***Team*:** Estimate the thickness requirement of the turbine made of your chosen material, refine the thickness requirement based on deflection simulation turbine blade CAD file, and interview another team with a different assigned scenario and take note of what you have learned.
Wk-7	Wed Nov 4	**Final deliverable** • Design summary	***Team:*** N/A	***Team*:** Include the following in your Design Summary: finalized problem statement of the turbine blade deign, justification of technical objective and material performance index, justification of selected materials, justification of solid (CAD) modelling, and peer-learning interview summary

Project One Deliverables

MILESTONE ZERO: TEAM DEVELOPMENT AND PROJECT PLANNING

Assessment Type: Team
Time Allotted: Week 3 Design Studio (DS-3)
Submission Deadline: End of DS-3

Objectives and Requirements

For Milestone Zero, your team is required to formally document your team's personnel and the administrative roles and responsibilities each member will take on for the duration of the project. This formal documentation process is in the form of a **Team Charter**. Complete your charter on the *Team Charter* worksheet. Your worksheet must include the following:

1. **Team Personnel**: Record each team member's name (preferred name) and MacID in the Team Personnel table on the **Milestone 0 Cover Page worksheet** located in the *Wk-3 (Fall) – P1 Milestone 0 Worksheets TEAM.docx* document.
2. **Team Portrait**: Take a screenshot of your team during a virtual meeting. Ensure your camera is turned on so we can see you! Be creative! Include your photo on the **Cover Page worksheet**.
3. **Project Leads**: *As a team*, come to an agreement on who will take the **Lead** for each administrative task (**M**anager, **A**dministrator, **C**oordinator, **S**ubject Matter Expert)
   → Record each team members name next to their assigned role in the *Project Leads* table on the **Team Charter worksheet**.
      - For a team of 5 students, there will be **two (2) Subject Matter Experts**
      - Otherwise, there can only be one team member for each role

   → Give consideration to each team member's administrative portfolio to ensure team members have the opportunity to take on different roles across projects
   → Each team member must sign next to their name, indicating their acceptance of the expectations and responsibilities specific to their assigned role
      - Refer to the *Administrative Roles and Responsibilities* section

Submission Details

1. **Each Team Member**: upload screenshots of your *Team Charter* worksheet (all pages) to your **online web Portfolio**.
   → Photos should be uploaded to the *Milestones* subpage under the *Project-1* Page, and captioned "*Milestone 0 Worksheets*"
   → Click "Publish" on the top-right corner of the browser to reflect your changes online

2. **Project Administrator ONLY**: save your Milestone 0 *Cover Page* and *Team Charter* worksheets (both pages) as a single PDF, and submit it to the *Avenue Dropbox* titled **P1 Milestone 0**
   - → Use the following naming convention: **Team#_P1_Milestone0.pdf**
   - → This is a *team* submission that is the responsibility of the project *Administrator*
     - Submit all files as a **Group** on Avenue
   - → Files missing from your submission will not be graded. **No exceptions**!

Grading of Milestone Zero

Milestone Zero is graded on a **Pass/Fail** basis. Failure to submit all worksheets will result in a **10% deduction to your Project 1 grade**.

MILESTONE ONE: INITIAL PROBLEM STATEMENT & OBJECTIVE TREE

Assessment Type: Individual (Stage 0 and 2)+Team (Stages 1 and 3)
Time Allotted: Own Time (Stage 0) and Week 3 Design Studio (DS-3)
Submission Deadline: End of DS-3

Objectives and Requirements

For Milestone One, your team is asked to discuss and formulate an initial problem statement which defines the main function(s) of a **wind turbine**. The other outcome of this design studio is a set of clear objectives that can be considered for the design of a **wind turbine**.

Note: Your team will use this important information for the **wind turbine** design in the later weeks; there is no need to think of the final solution at this stage. A "solution-driven" approach to engineering often does not yield the best final design.

Note: You will be focusing only on a **wind turbine** in this milestone. For Milestone 2, you will focus more specifically on a wind turbine ***blade***.

1. **Stage 0 (Before DS-3)**: *Each team member* is required to write a *one-page* **literature research memo**. This research memo will be used to start your team activities during DS-3. The research assignment consists of four parts; 1) Introduction, summarizing the current state of wind turbine technology, 2) Design factors, including the potential consideration factors when designing a wind turbine in general and wind turbine *blade* (focused specifically on mechanical properties), and 3) References (following IEEE notation). Complete your research memo on the **Pre-Project Research Memo worksheet** located in the *Wk-3 (Fall) – P1 Milestone 1 Worksheets INDIVIDUAL.docx* document.

   ***Note: In order to learn how to write a research assignment, what resources to use, and, how to use IEEE format, please refer to the following documents in the **Week-2 > Lab B** folder on Avenue:

   - ENG1P13 – Design and Communication Workshop 1 – Slides
   - ENG1P13 – Guide to Citing in IEEE
   - RADAR for evaluating Information

2. **Stage 1 (During DS-3)**: As *a team*, *draft* an **initial problem statement** for the design of wind turbine. The initial problem statement should focus on the main functions(s) of the wind turbine, and not the turbine blade. Each team member's submitted *pre-project research memo* should serve as a guide for discussion. Complete your initial problem statement on the **Initial Problem Statement worksheet** located in the *Wk-3 (Fall) – P1 Milestone 1 Worksheets TEAM.docx* document.

3. **Stage 2 (During DS-3)**: *Each team member* is required to review the 4 different engineering scenarios outlined in the Project 1 module and create a **preliminary objective tree of a wind**

turbine *for one scenario*. The Project **Manager** will assign each team member one scenario. Give consideration to your discussions around each team members research memos as this may identify appropriate objectives of a turbine blade for your specific scenario. Each branch of your objective tree should have minimum of 3 layers. Complete your individual objective tree on the **Preliminary Objective Tree worksheet**, located in the *Wk-3 (Fall) – P1 Milestone 1 Worksheets INDIVIDUAL.docx* document.

→ In teams of 5, two members will be assigned the same scenario but should work individually

4. **Stage 3 (During DS-3):** As a *team*, come together and discuss each scenario. Review each team member's individual objective tree, provide feedback and finalize it as a team, creating a **refined objective tree for a wind turbine**. Each branch of your objective tree should have minimum of 3 layers. Complete your individual objective tree on the **Refined Objective Tree worksheet**, located in the *Wk-3 (Fall) – P1 Milestone 1 Worksheets TEAM.docx* document.

    → For a team of 5 students, two (2) students should be working on scenario 4 and submit their individual works separately.

    → Otherwise, there can only be one team member for each role

Note: Below is a quick guide that can be used to complete these tasks.

Function, constrains, and objectives:

Here is a reminder of some definitions:

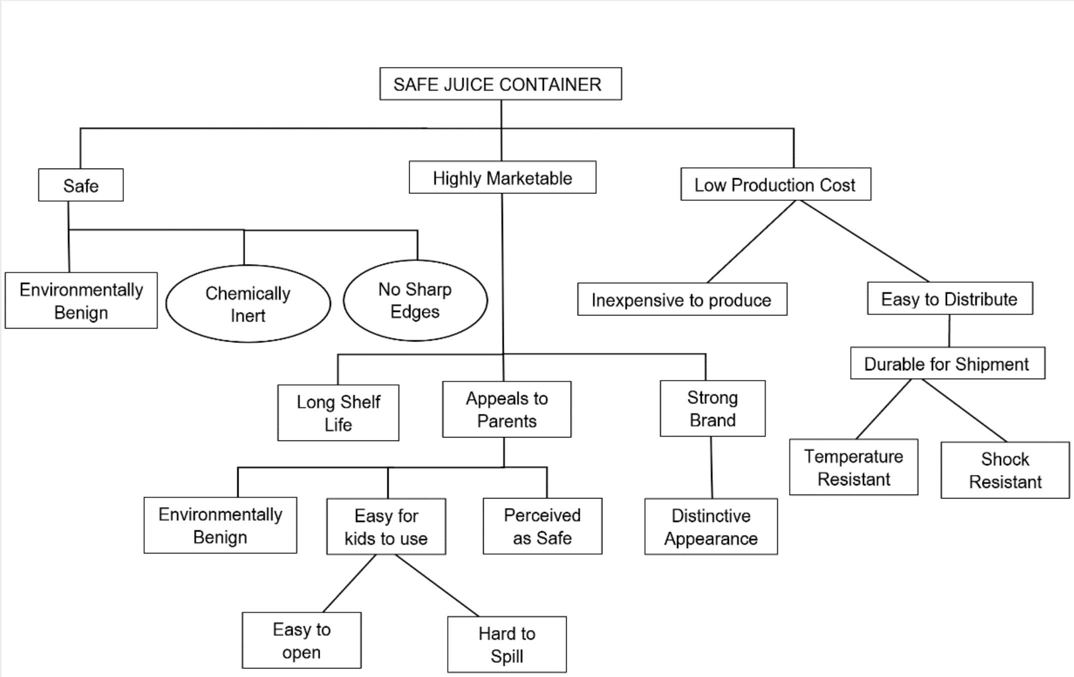
Function	"What does the component do?"
Constraints*	"What non-negotiable conditions must be met?" "What negotiable but desirable conditions ...?"
Objective	"What is to be maximized or minimized?" "What attributes are desirable?"

* It is sometimes useful to distinguish between "hard" and "soft" constraints. Dimension and Manufacturing Process might be absolute requirements (hard constraints); cost might be negotiable (a soft constraint).

Objective tree:

An **objective tree** is used to capture the criteria that the client/user would use to compare and contrast designs proposed by the designer. It is a visual representation of the relationships between objectives of a varying level of detail. An objective is a feature or behavior that the design should possess or exhibit. When in doubt: think adjectives!

Another way of looking at the objective tree is that reading from top to bottom answers the question of "**How** do we achieve the above goal?", e.g. how do we make a safe juice container. Reading from bottom to top explains "**Why** are we doing this?", e.g. why should a juice container be easy to open. Both questions should be answered with a new objective.



A **constraint** is defined as a limit or restriction on a design's behaviors or attributes. Often, stating a constraint can help you think about objectives to be placed on the tree. However, this does not imply that constraints can be copied word-for-word into an objective tree. Objectives and constraints must be clearly distinguished from each other on the tree. In the example above, the constraints (chemically inert and no sharp edges) are clearly distinguished by being **placed in an oval instead of a rectangle.**

Submission Details

1. **Each Team Member**:
   - Upload a ***.PDF** copy of *Wk-3 (Fall) – P1 Milestone 1 Worksheets INDIVIDUAL* document to the *Avenue Dropbox* titled **P1 Milestone 1 (Individual)**
     - → Use the following naming convention: **macID_P1_Milestone1.pdf**
     - → The Project Administrator must submit a copy as well
   - Upload photos of your Pre-Project Research Memo, Initial Problem Statement**,** Preliminary Objective Tree**,** and Refined Objective Trees worksheets to your **online web Portfolio**.

→ Photos should be uploaded to the *Milestones* subpage under the *Project-1* Page, and captioned “*Milestone 1 Worksheets*”

→ Click "Publish" on the top-right corner of the browser to reflect your changes online

2. **Project Administrator ONLY**:
    - Upload a ***.PDF** copy of *Wk-3 (Fall) – P1 Milestone 1 Worksheets TEAM* document to the *Avenue Dropbox* titled **P1 Milestone 1 (Team)**
        → Use the following naming convention: **Team#_P1_Milestone1.pdf**

        → This is a *team* submission that is the responsibility of the project *Administrator*
        - Submit all files as a **Group** on Avenue

        → Files missing from your submission will not be graded. **No exceptions**!

Grading of Milestone One

Milestone One is worth **1.5/10 marks of your total Project 1 grade (15%)**. Each team member will receive their own grade for Stage 0 and 2 of the Milestone. All team members will receive the same grade for Stages 1 and 3 of the Milestone.

MILESTONE TWO: REFINED PROBLEM STATEMENT AND METRICS

Assessment Type: Team
Time Allotted: *During* Week 4 Design Studio (DS-4)
Submission Deadline: End of DS-4

Objectives and Requirements

At the beginning of Design Studio 4, your team will be assigned one scenario. You will be working on this scenario only for all the activities of Design Studio 4.

1. **Stage 1 (During DS-4):** As a *team*, review the objective tree created in Milestone 1 for your ***assigned*** scenario and revise it if required. Based on the finalized objective tree, and the overall understanding of your scenario, *your team is required to* **refine your problem statement for the design of a wind turbine**.
   → Your *refined* problem statement should include more than main function(s)
      - You should also include the important objectives and constraints of the design

   → Complete your *finalized objective tree* for your assigned scenario as well as your *refined problem statement* on the **Refined Problem Statement for a Wind Turbine worksheet** located in the *Wk-4 (Fall) – P1 Milestone 2 Worksheets TEAM.docx* document.

> **Note on your *Refined* Problem Statement:** Recall the initial problem statement completed for Milestone 1. Now that you have been assigned ***one*** scenario, your team is required to generate a more *detailed* and *specific* problem statement. This will be referred to as a **refined problem statement.** This will clearly define and communicate the problem your team is focusing on and it will most likely contain a few sentences.
>
> Your refined problem statement should address and include:
> - Who? (the user/client)
> - Where? (the environment in which it will be used)
> - Why? (the reason for solving the problem)
> - What? (the key objectives that should be considered for your design)
>
> REMINDER: **Do not** include the *How*? (i.e., the process/path your team will use to solve the problem)

2. **Stage 2 (During DS-4)**: As a *team*, **establish a set of design requirements for a turbine *blade***, based on your *assigned* scenario. Your set of design requirements, described in detail below, are meant to inform decisions on the *mechanical design of a turbine blade*. This stage includes the following activities:

→ **Stage 2A**: As a *team*, **define a problem statement for the design of a wind turbine blade**. Definition of your problem statement should follow a discussion of the design considerations, including the functions, constraints, and objectives of turbine blade, based on your *assigned* scenario. Complete your *turbine blade* problem statement on the **Design Requirements for a Turbine Blade worksheet** located in the *Wk-4 (Fall) – P1 Milestone 2 Worksheets TEAM.docx* document.

→ **Stage 2B**: As a *team*, **create an objective tree for the wind turbine blade**, based on your *assigned* scenario. Each branch of your objective tree should have at least 3 layers. Complete your *turbine blade* objective tree on the **Design Requirements for a Turbine Blade worksheet** located in the *Wk-4 (Fall) – P1 Milestone 2 Worksheets TEAM.docx* document.

> Up to this point, we have focused on the design of a wind turbine. For Stage 2 of this Milestone, and moving forward, you are now tasked with narrowing the design space, focusing on the **mechanical design of a turbine *blade*** for a wind farm. These activities are meant to inform design decisions for your turbine blade material selection and design embodiment (i.e., overall shape), which will take place in the coming weeks

3. **Stage 3 (During DS-4)**: As a *team*, review the objective tree you created for a turbine blade in Stage 2B. Focusing on the *mechanical properties* of the blade, **select the top 3 objectives of your turbine blade design**. List your top 3 objectives, including a rationale behind each selection, on the **Selection of Top Objectives worksheet** located in the *Wk-4 (Fall) – P1 Milestone 2 Worksheets TEAM.docx* document.

4. **Stage 4 (During DS-4)**: As a *team*, **generate a set of metrics for your turbine blade**. These metrics are meant to evaluate the top 3 objectives you identified in Stage 3. List the metrics for each objective on the **Metrics worksheet** located in the *Wk-4 (Fall) – P1 Milestone 2 Worksheets TEAM.docx* document. Below are some guidelines meant to help you complete this task.

Metrics:
Objectives, or design goals, are the desired attributes of the design (i.e., what the design will "be" and what qualities it will have). Objectives allow exploration of the design space to select amongst alternatives that are at least acceptable or satisfactory.

How do you know how to evaluate the objectives in different design alternatives?

- Metrics help measure the degree to which objectives are achieved
- Metrics can be specific, **quantifiable**, and include units of measurement when applicable
- Metrics can also be **qualitative** in cases where there is no direct measurement available

Example of Establishing Metrics for a Given Objective:

Objective: Device should be Easy to Use

Metric: Rating of how long an average user takes to learn the device

- Let's select a range from 0 (worst) to 100 (best)

Units: Number of minutes it takes for an average user to learn to use the device

- 0-2 Minute(s): 100 points
- 2-4 Minutes: 75 points
- 4-10 Minutes: 50 points
- 10-15 Minutes: 25 points
- 20+ Minutes: 0 points

Submission Details

1. **Each Team Member**:
   - Upload photos of your Milestone worksheets (*Refined Problem Statement for a Wind Turbine*, *Design Requirements for a Turbine Blade*, *Selection of Top Objectives for a Turbine Blade* and *Metrics*) worksheets to your **online web Portfolio**.
     - → Photos should be uploaded to the *Milestones* subpage under the *Project-1* Page, and captioned "*Milestone 2 Worksheets*"
     - → Click "Publish" on the top-right corner of the browser to reflect your changes online
2. **Project Administrator ONLY**:
   - Upload a ***.PDF** copy of the *Wk-4 (Fall) – P1 Milestone 2 Worksheets TEAM* document to the *Avenue Dropbox* titled **P1 Milestone 2 (Team)**
     - → Use the following naming convention: **Team#_P1_Milestone2.pdf**
     - → This is a *team* submission that is the responsibility of the project *Administrator*
       - Submit all files as a *Group* on Avenue
     - → Files missing from your submission will not be graded. **No exceptions**!

Grading of Milestone Two

Milestone Two is worth **1/10 marks of your total Project 1 grade (10%)**. All team members will receive the same grade for the Milestone.

MILESTONE THREE-A: CONCEPTUAL DESIGN – MATERIAL SELECTION

Assessment Type: Individual (Stage 2)+Team (Stages 1 and 3)
Time Allotted: *During* Week 5 (lab-B)
Submission Deadline: End of Week 5

Objectives and Requirements

For Milestone Three-A, you are required to perform a material selection for a turbine blade, based on your *assigned* scenario. Using a material performance index (MPI), you are required to rank which materials (i.e. "material candidates") have properties most suitable for a particular application.

→ Recall: an MPI is a numerical index that evaluates how well a material performs in regard to a single **function**, **constraint**, and **objective** for a given engineering application
  - We will discuss the derivation of an MPI in both lectures and lab activities

→ A total of 10 possible material performance indices (MPIs) will be provided by your IAIs
  - This includes different combinations of **constraints** (stiffness- and strength-limited) and **objectives** (lightweight, compact, economical, low energy in manufacturing, and low carbon footprint in manufacturing)

> During one of the Wk-4 labs (Materials Science #1), the IAI's will walk you through an example of material selection process in designing a lightweight turbine blade for a stiffness-limited design. The Wk-4 lab is meant to prepare you for Milestone 3A by helping you become familiar with:
> → The concept of function, constraints, and objectives,
> → Translating qualitive design statement into physical equations of material selection,
> → Deriving a material performance index (MPI), and
> → Selecting a material using the ANSYS-Granta EduPack material selector (Figure 7)

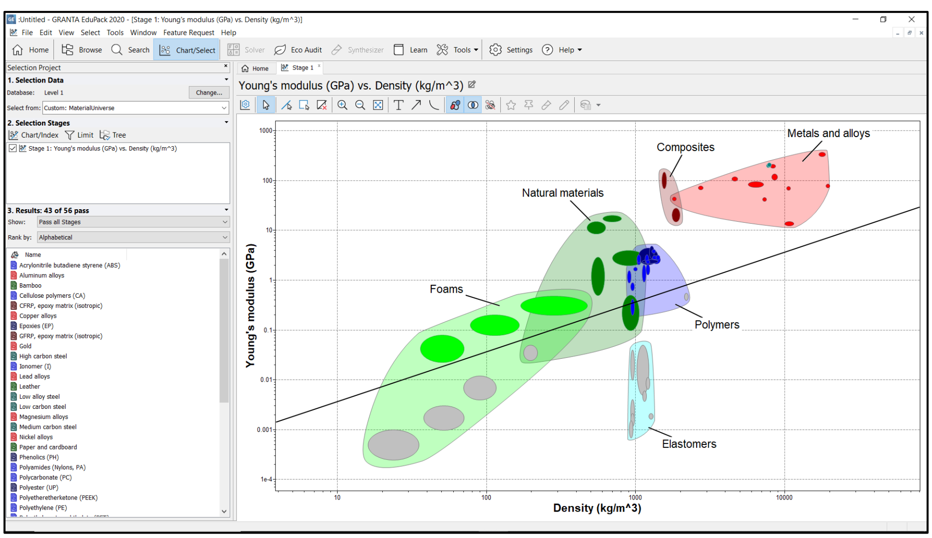


Figure 7. A screen of the Granta Edupack interface

***IMPORTANT*: You will only have access to Granta-EduPack for Project 1 in today's 3-hour lab. Thus, make sure you save all work by print page to pdf in the EduPack software.**

1. **Stage 1 (During Wk-5 Lab-B)**: As a *team*, discuss and determine one primary objective and one secondary objective for your *assigned* scenario. *For each objective* (2 in total), **your team is required to list the Material Performance Index (MPI)** for 2 assigned constraints: *stiffness-limited design* and *strength-limited design*. List the MPI for each objective and each assigned constraint (4 MPI's in total) on the **Material Selection: Problem Definition worksheet** located in the *Wk-5 (Fall) – P1 Milestone 3A Worksheets TEAM.docx* document.
   → For each objective, write a short justification for why these objectives are the most suitable objectives for your assigned scenario

   NOTE: A list of MPIs will be given to you. You do not need to derive the MPIs for this Milestone.

2. **Stage 2 (During Wk-5 Lab-B)**: Each *team member* is required to **perform a materials selection for *one* MPI identified in Stage 1**, using the ANSYS-Granta EduPack material selector.
   → **Save a PDF of the material property chart** for your assigned MPI. Insert a screenshot of the material property chart on the **Material Selection: MPI and Material Ranking worksheet** located in the *Wk-5 (Fall) – P1 Milestone 3A Worksheets INDIVIDUAL.docx* document.
   → **Rank the top 5 materials for your assigned MPI**, based on your material property chart. List the top 5 materials on the **Material Selection: MPI and Material Ranking worksheet** located in the *Wk-5 (Fall) – P1 Milestone 3A Worksheets INDIVIDUAL.docx* document.

   IMPORTANT NOTE: **For teams of 5**, two members will create a material property chart for the same MPI but should work individually and submit their individual works separately.

   Please note the following when using the ANSYS Granta EduPack material selector:
   → The material database should be **LEVEL1** and should *exclude* any ceramics and cast irons
   - Ceramics and cast iron are too brittle for use in any structural application such as a turbine blade
   - The concept of brittleness is beyond the scope of Project One

3. **Stage 3 (During Wk-5 Lab-B)**: As a *team*, you are required to consolidate your rankings, narrow down the material candidate list, and discuss additional engineering considerations (beyond mechanical performance) that may be relevant to your *assigned* scenario.

→ **Consolidate your individual material rankings from Stage 2**. List the rankings for each team member on the **Material Selection: Material Alternatives and Final Selection worksheet** located in the *Wk-5 (Fall) – P1 Milestone 3A Worksheets TEAM.docx* document.

→ **Narrow down the material candidate list to 3 finalists** based on the rankings for all MPI's. For each finalist, save the material datasheet as a PDF and distribute amongst all team members. Record the 3 finalists on the **Material Selection: Material Alternatives and Final Selection worksheet** located in the *Wk-5 (Fall) – P1 Milestone 3A Worksheets TEAM.docx* document.

→ **Evaluate your material finalists** against the objectives, constraints and any other criteria you think is important. As a first step, weigh the relative importance of your criteria (i.e., your objectives and constraints). Perform an evaluation using the Decision Matrix provided to you, **selecting one material to pursue further**. Complete the **criteria ranking** and **Decision Matrix** on the **Material Selection: Material Alternatives and Final Selection worksheet** located in the *Wk-5 (Fall) – P1 Milestone 3A Worksheets TEAM.docx* document.

- Discuss and justify your selection, giving consideration to the MPI ranking and any other relevant considerations. The textbox below lists examples of some criteria you may consider. Please note that this list is just a guideline and some of the items might not be relevant to your *assigned* scenario.

Recommended material properties:

→ Young's Modulus E (GPa)

→ Yield Strength σ_y (MPa)

→ Density ρ (kg/m^3)

→ Price C_m (USD/kg)

→ Embodiment Energy H_m (MJ/kg)

→ Specific Carbon footprint CO_2 (kg/kg)

Submission Details

1. **Each Team Member**:
    - Upload a ***.PDF** copy of the *Wk-5 (Fall) – P1 Milestone 3A Worksheets INDIVIDUAL* document to the *Avenue Dropbox* titled **P1 Milestone 3A (Individual)**
        - → Use the following naming convention: **macID_P1_Milestone3A.pdf**
        - → The Project Administrator must submit a copy as well
    - Upload photos of your *Material Selection* worksheets to your **online web Portfolio**.
        - → Photos should be uploaded to the *Milestones* subpage under the *Project-1* Page, and captioned "*Milestone 3A Worksheets*"
        - → Click "Publish" on the top-right corner of the browser to reflect changes online
2. **Project Administrator ONLY**:
    - Upload a ***.PDF** copy of the *Wk-5 (Fall) – P1 Milestone 3A Worksheets TEAM* document to the *Avenue Dropbox* titled **P1 Milestone 3A (Team)**
        - → Use the following naming convention: **Team#_P1_Milestone3A.pdf**
        - → This is a *team* submission that is the responsibility of the project *Administrator*
            - Submit all files as a **Group** on Avenue
        - → Files missing from your submission will not be graded. **No exceptions**!

Grading of Milestone Three-A

Milestone Three-A is worth **3/10 marks of your total Project-1 grade (30%)**. Each team member will receive their own grade for Stage 2 of the Milestone (1/10 marks). All team members will receive the same grade for Stages 1 and 3 of the Milestone (2/10 marks).

MILESTONE THREE-B: DESIGN EMBODIMENT

Assessment Type: Team
Time Allotted: Design Studio (DS-5)
Submission Deadline: End of DS-5

Objectives and Requirements

For Milestone 3B, you are required to: 1) **estimate the deflection of a turbine blade during a windstorm**, 2) **create a solid model of a standard turbine blade with assumed thickness *t*** (using Autodesk Inventor), and 3) **perform a deflection simulation** to determine the blade deflection more accurately.

1. **Stage 1 (During DS-5):** As a *team*, **estimate the maximum deflection of a turbine blade** with an idealized elliptical cylinder geometry according to Eq. (1).

$$\delta = \frac{pbL^4}{4EI} \quad \text{(1a);}$$

$$I = \frac{\pi}{4}[a^3 b - (a-t)^3(b-t)] \quad \text{(1b);}$$

where δ is the deflection of the beam, *E* is the elastic modulus of an assumed material (brass), *p* is the wind pressure in MPa, ***b* is the half width** of the blade, ***a* is the half height** of the blade, *L* is the length of the blade, *I* is the moment of inertia, and finally *t* is the thickness of the blade.

> *Note 1*: be sure to use **SI units** for your calculation
> *Note 2*: You do not need to understand the physical meaning of the mechanics equation. **Formula's like this will be provided to you for any assessments**. Please do not stress about them.

Pressure *p* (MPa)	0.003 MPa (assume wind speed of 70 m/s and density of air is 1.2 kg/m^3)
Elastic modulus, *E* (GPa)	120 GPa (assumed to be brass)
Blade half width, *b* (m)	0.375 m
Blade half height, *a* (m)	0.189 m
Blade external length, *L* (m)	8.5 m
Blade sheet thickness, *t* (m)	0.05 m (or 50 mm)

2. **Stage 1 (During DS-5): As a *team*, create a solid model of a *standardized turbine blade*.** The standardized turbine blade (Figure 8) has fixed dimensions (*a, b, t*, and *L*). Complete your solid model in Autodesk Inventor 2021.
   → Your TAs and IAIs will be grading you and providing feedback along the way

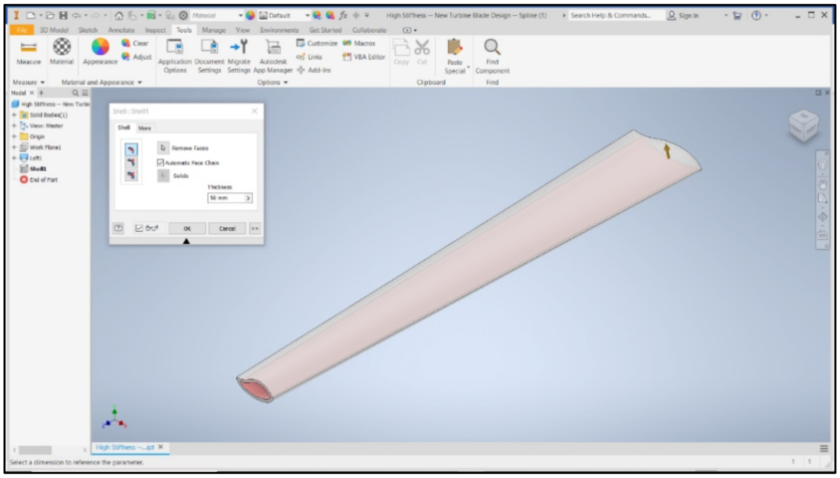


Figure 8. CAD design of a "standardize turbine blade".

3. **Stage 1 (During DS-5):** As a *team*, **perform a deflection simulation of your modelled standardized turbine blade** with a *predefined geometry* (e.g. sheet thickness of t = 50 mm) and an assumed material (***brass***). Complete the deflection simulation in Autodesk Inventor.

Submission Details

1. **Each Team Member**:
   - Upload photos of your *Design Embodiment* worksheet to your **online web Portfolio**.
     → Photos should be uploaded to the *Milestones* subpage under the *Project-1* Page, and captioned "*Milestone 3B Worksheets*"
     → Click "Publish" on the top-right corner of the browser to reflect your changes
2. **Project Administrator ONLY**:
   - Upload a ***.PDF** copy of the *Wk-5 (Fall) – P1 Milestone 3B Worksheets TEAM* document to the *Avenue Dropbox* titled **P1 Milestone 3B (Team)**
     → Use the following naming convention: **Team#_P1_Milestone3B.pdf**
     → This is a *team* submission that is the responsibility of the project *Administrator*
       - Submit all files as a *Group* on Avenue
     → Files missing from your submission will not be graded. **No exceptions**!

Grading of Milestone Three-B

Milestone Three-B is worth **0.5/10 marks of your total Project-1 grade (5%)**. All team members will receive the same grade for all three stages of the Milestone.

MILESTONE FOUR: FINALIZED DESIGN AND PEER INTERVIEW

Assessment Type: Individual (Stage 1)+Team (Stages 2 and 3)
Time Allotted: Design Studio (DS-6)
Submission Deadline: End of DS-6

Objectives and Requirements

Recalling that the outcome of Milestone 3A was to select the material for the turbine blade, Milestone 4 requires that your team **determine the geometry requirements of the turbine blade, specifically the required sheet thickness**. The sheet thickness must satisfy the stiffness design constraint: *the blade's maximum deflection must be less than 10 mm*. In other words, the turbine blade must not have a deflection δ of more than a threshold of δ^* = 10 mm (i.e. $\delta < \delta^*$). Your team will interview another team that has been assigned a different scenario than yours. From this interview, you will learn from your peers about a design with different objectives.

1. **Stage 1 (During DS-6):** Each *team member* is required to **estimate the deflection of a turbine blade** using one of the 4 air foil thicknesses outlined in Table 1 (i.e., each team member should calculate deflection with on of the following values of *t*). In all cases, the estimation of turbine blade deflection should be based on your selected material. Document your work on the **Finalized Design: Estimate Thickness Requirement worksheet** located in the *Wk-6 (Fall) – P1 Milestone 4 Worksheets INDIVIDUAL.docx* document. You should dedicate approximately **15 minutes** to this stage of the Milestone.

   (For a team of 5 students, two (2) students should be working on t_4 and submit their individual works separately.)

2.

Table 1. Assigned air foil thicknesses for calculating deflection

t_1	15 mm
t_2	30 mm
t_3	50 mm
t_4	150 mm

Your estimation of turbine blade deflection is based on the following equations:

$$\delta = \frac{pbL^4}{4EI} \quad \text{(1a);}$$

$$I = \frac{\pi}{4}\left[a^3 b - (a-t)^3(b-t)\right] \quad \text{(1b);}$$

where δ is the deflection of the beam, *E* is the elastic modulus of your chosen material, *p* is the wind pressure in MPa, ***b* is the half width** of the blade, ***a* is the half height** of the blade,

***L* is the length of the blade**, *I* is the moment of inertia, and finally *t* is the thickness requirement of the blade.

The values of the turbine blade external dimensions (i.e., ***a***, ***b***, ***L***) are determined from Table 2 below. The values you select will *depend on the Young's module of your team's chosen material*. Specifically, **select Design A if Young's Module is *greater than or equal to* 100 GPa**. Alternatively, **select Design B if Young's Module is less than 100 GPa**.

Table 2. Criterion and Geometrical parameters of the blade Design A and Design B

	Design A – stiff materials	**Design B – compliance materials**
Criterion	If: $E \geq 100$ GPa	If: $E < 100$ GPa
Applied Pressure, p (MPa)	0.003 MPa	0.003 MPa
Elastic modulus, E (GPa)	Based on material ($E \geq 100$ GPa)	Based on material ($E < 100$ GPa)
half width, b (m)	0.375 m	0.8 m
half height, a (m)	0.189 m	0.378 m
length *L* (m)	8.5 m	8.5 m

3. **Stage 2 (During DS-6):** As a *team*, **refine the thickness requirement of the turbine blade to satisfy the deflection constraint** (i.e. $\delta < \delta^*$, where δ^* = 10 mm). Based on the design you selected from Table 2 (i.e., Design A if $E \geq 100$ GPa or Design B if $E < 100$ GPa), open the corresponding turbine blade solid model in Autodesk Inventor (i.e., either Blade-Design-A.ipt and Blade-Design-B.ipt). Using Inventor's built-in deflection simulation, run a simulation, continually iterating by either increasing or decreasing the thickness *t* of the blade until the design constraint is satisfied. Document your work on the **Finalized Design: Refine Thickness Requirement worksheet** located in the *Wk-6 (Fall) – P1 Milestone 4 Worksheets TEAM.docx* document. You should dedicate **60 minutes** to this stage of the Milestone.

> *Note*: Your final blade thickness should be based on the deflection simulation results
> → Do not over- or under-design the turbine blade
> → Please state the necessary final thickness *t* to the nearest +/- 1 mm
> → You will be penalized if your final design is too thin or too thick.

4. **Stage 3 (During DS-6):** As a *team*, you are required to **interview another team that has been assigned a different scenario**. You will be assigned a team to interview by your TA. You are required to document what you have learned based on the interview (i.e., both the similarities and differences in your designs) on the **Peer Interview worksheet** located in the

Wk-6 (Fall) – P1 Milestone 4 Worksheets TEAM.docx document.. You should dedicate approximately **30 minutes** to this stage of the Milestone.

> *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

Submission Details

1. **Each Team Member**:
   - Upload a ***.PDF** copy of *Wk-6 (Fall) – P1 Milestone 4 Worksheets INDIVIDUAL* document to the *Avenue Dropbox* titled **P1 Milestone 4 (Individual)**
     - → Use the following naming convention: **macID_P1_Milestone4.pdf**
     - → The Project Administrator must submit a copy as well
   - Upload photos of your **Finalized Design and Social Learning** worksheets to your **online web Portfolio**.
     - → Photos should be uploaded to the *Milestones* subpage under the *Project-1* Page, and captioned "*Milestone 4 Worksheets*"
     - → Click "Publish" on the top-right corner of the browser to reflect your changes online
2. **Project Administrator ONLY**:
   - Upload a ***.PDF** copy of **Wk-6 (Fall) – P1 Milestone 4 Worksheets TEAM** document to the ***Avenue Dropbox*** titled **P1 Milestone 4 (Team)**
     - → Use the following naming convention: **Team#_P1_Milestone4.pdf**
     - → This is a *team* submission that is the responsibility of the project *Administrator*
       - Submit all files as a **Group** on Avenue
     - → Files missing from your submission will not be graded. **No exceptions**!

Grading of Milestone Four

Milestone Four is worth **2/10 marks of your total Project-1 grade (20%)**. Each team member will receive their own grade for Stage 1 of the Milestone. All team members will receive the same grade for Stages 2 and 3 of the Milestone.

FINAL DELIVERABLE – DESIGN SUMMARY

Assessment Type: Team
Time Allotted: Own Time
Submission Deadline: Nov 4th, 2020.

Final Submission: Design Summary

To summarize your achievements, you are asked to compile a ***maximum 3 pages*** *Design Summary.* Your Design Summary is based on materials you have already drafted in previous Milestones.

> You are required to complete your *Design Summary* using the template Word document that has been provided to you on Avenue-to-Learn
> - **Content > 4-Design Projects > Student Resources >** *1P13_Project_Report_Template.docx*
>
> Follow the template formatting explicitly!

that includes the following sections based on materials you have already drafted in the previous project milestones.

1. **Finalized Problem statement**: In one paragraph, briefly describe the nature of your engineering scenario and the problem definition of your **Turbine Blade** design, which includes concepts such as function, engineering constraints, and high-level objectives.
2. **Justification of Technical Objectives and Material Performance Indices**: In one paragraph, briefly summarize the objective tree, objective matrix, and how your team determined the relevant material performance indices (MPIs) for your engineering scenario.
3. **Conceptual Design – Justification of Selected Material**: In one paragraph, briefly summarize the material selection process. Justify how the chosen material satisfies the project objectives.
4. **Design Embodiment – Justification of Solid (CAD) Modelling**: In one paragraph, briefly summarize the analytical calculation and deflection simulation in Autodesk Inventor. Justify how the chosen turbine blade thickness satisfies the stiffness-limited design constraint (i.e. maximum deflection less than 10 mm).
5. **Concluding Remarks – Reality Check**: In one paragraph, briefly state what you have learned, a bring home message, and a short discussion of additional engineering considerations that are worth exploring in the future.
6. **Appendix A – Peer-learning interview**: In one paragraph, summarize what you have learned from another design team working on another engineering scenario (i.e. similarities/differences).
7. **Appendix B –** References (if necessary).

8. **Appendix C** – Project Gantt chart: create a bar chart that illustrates a project schedule of each members.

> **IMPORTANT NOTE 1**: For Project-1, you are ***not required*** to write an *Executive Summary*. In the provided template, you should include your **Finalized Problem Statement** in place of the Executive Summary.

> **IMPORTANT NOTE 2**: The 3-page limit includes text and images, but does not include the cover page, references, and appendix.

.Submission Details

1. **Project Administrator ONLY**:
   - Upload a ***.PDF** copy of your Design Summary to the *Avenue Dropbox* titled **P1 Design Summary**
     - → Use the following naming convention: **Team#_P1_DesignSummary.pdf**
     - → This is a *team* submission that is the responsibility of the project *Administrator*
       - Submit all files as a ***Group*** on Avenue
     - → Files missing from your submission will not be graded. **No exceptions**!

Grading of Design Summary

The Design Summary is worth **2/10 marks of your total Project-1 grade (20%)**. All team members will receive the same grade for the Final Deliverable.

LEARNING PORTFOLIO ENTRY

Assessment Type: Individual
Time Allotted: Own Time
Submission Deadline: Wednesday November 4th, 2020

Objectives and Requirements

Complete your **online web Portfolio** for Project-1, by uploading all worksheets and photos outlined in the previous pages, as well as documentation of any progress, rough work or extra content.

Submission Details

Each Team Member: ensure your online web Portfolio is complete and up to date

→ Photos and images should be uploaded to the appropriate subpage under the P1 Page
- Milestone worksheets (*Milestones* subpage)
- Final submission content (*Final Deliverables* subpage)
- Extra documentation (*Log Book* subpage)

→ Click "Publish" on the top-right corner of the browser to reflect your changes online
  → Remember, you need to do this *every time* you make changes to your website

→ *You do not need to resubmit any work already submitted!*

Grading of Learning Portfolio

Your Learning Portfolio is graded on a **Pass/Fail** basis. Any team member who does not complete their learning portfolio will be penalized 5% of their Project-1 grade.

SELF-AND PEER-EVALUATION

Assessment Type: Individual
Time Allotted: Own Time
Submission Deadline: Wednesday November 4th, 2020

Objectives and Requirements

Each team member is expected to contribute equitably and effectively to the team's overall performance, throughout the duration of the project. This contribution is evaluated through both a ***self-evaluation*** and a ***peer-evaluation***. There are 3 components to the Evaluation:

(1) Individual Evaluation: Each team member will be asked to evaluate themselves and their peers on the following dimensions:

→ Contributing to team's work
→ Interacting with teammates
→ Expecting quality
→ Having relevant KSAs (Knowledge, Skills, and Abilities)

(2) Team Evaluation: Each team member will be asked to evaluate the overall team and their project experience on the following dimensions:

→ Working together in the Future
→ Team Conflict
→ Team Satisfaction
→ Psychological Safety

(3) Peer-to-Peer Comments: Each team member will be asked to provide comments to their peers based on the project experience. You are expected to adhere to the following:

→ Before you start writing, reflect on the project experience and evaluation you just completed.
→ Comments should include both positive feedback and constructive criticism.
→ Constructive criticism should not be overtly negative, should not include profanity, should be given with a purpose, and should focus on what your peer can do to improve in the future.

While writing Peer-to-Peer comments, consider the following resources:

- → **Belbin Team Roles Inventories:** This inventory recognizes that every team member brings different strengths and weaknesses to the team. Consider using the language and inventories in this document to provide feedback to your team members and yourself
  - Belbin Inventories Reference Article
- → **Constructive Criticism:** These websites provide tips and tricks on what should be included in constructive criticism.
  - 6 Ways to Make Feedback Constructive
  - What is Constructive Feedback + Examples

Submission Details

Self and Peer Evaluations will be completed through a website called **CATME** (Comprehensive Assessment of Team Member Effectiveness). You will receive email prompts to your McMaster email from CATME when a Peer Evaluation is ready to complete and when the results are ready to view.

In the **Getting Started** folder on **Avenue to Learn** there is a CATME document you can refer to for resources and an overview of the software.

Grading of Self- and Peer-Evaluation

Each team member will have a peer-evaluation score calculated as part of the self- and peer-evaluation. Depending on your own self-evaluation and your team members peer-evaluation, your peer-evaluation score can ***add or deduct*** a maximum of 5% towards your overall Project-1 grade.

Team members are expected to take the self- and peer-evaluation process seriously. This is an important learning opportunity in terms of being able to evaluate one's own work as well as give and receive feedback on the work of others. It is not intended as an exercise in padding each other's marks! Team members may be expected to justify their peer evaluation scores in a meeting with the Course Instructors, individually or as a team. Failure to justify your peer evaluation may result in an adjustment to your peer-evaluation score.

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