DESIGN PORTFOLIO

Joeun Yook
University of Toronto | Engineering Science

Before you read

The purpose of this design portfolio is to showcase both myself and the outcomes of my design activities throughout my first year in the University of Toronto Engineering Science program, designed for an external audience.

The portfolio begins by introducing my positionality to engineering design. This is followed by an overview of the primary design activities I have engaged in so far. These include participation in the UTWind (University of Toronto Wind Turbine Team), the Praxis I project, the CIV102 Bridge Project, and the Praxis II project. A summarized description of each design process and the work involved will be provided.

Although the high level objective of this portfolio is to document my design work and showcase my relevant skills and experiences, the content is written in a generic and straightforward way to suit an external audience not familiar with the Engineering Science program. This design portfolio is intended to be added to my personal website, while satisfying all the assessment criteria outlined in the ESC102 design portfolio instructions.

Ⅰ. Positionality

Engineering Student vs Student engineer?

At the beginning of the semester, I strongly identified myself as an "engineering student" rather than a "student engineer." This distinction came from my belief that my engineering values and decisions were not fully embedded in my designs, primarily because my designs were based on mimicking or integrating existing ideas.

1. My Belief in Engineering

If asked to choose between identifying as an "engineering student" or a "student engineer," I would undoubtedly describe myself as an engineering student. This is due to my limited experience in studying engineering courses. The engineering designs I create are primarily based on mimicking or integrating existing ideas, meaning my values and decisions are not yet fully embedded in these designs. My understanding of “Engineering Design”

Figure1 : Initial position statement

I still believe that I am closer to being an engineering student, but I would like to clarify that I now believe the terms "engineering student" and "student engineer" refer to similar roles; the difference lies mainly in the depth of engineering knowledge and proficiency in integrating and applying ideas.

At this point, I would like to define relevant terms in my words.

Definition of Engineering and Engineering Design

➔ Engineer: A person who performs engineering design to solve real-life technical problems by integrating and applying numerous existing technical discoveries.

➔ Engineering Design: Technical calculation and optimization aimed at qualitative performance and intention, *where the reasoning is often not apparent to regular stakeholders but adheres to all standards while achieving maximum functionality.*

By the definition of an engineer provided above, engineers are people who use existing ideas; therefore, I can also characterize myself as a “student engineer”.

Author’s Value & Biases

The author’s value and biases can be summarized as following

Belief

1. Acknowledging that I am still an engineering student, I find that learning engineering knowledge and technical skills from sources not only limited to coursework but also from a design team is preferable for my development as an engineer.(1)
2. I can utilize all the existing engineering ideas that proficient engineers have verified, and even implementing the same function can still be considered 'engineering design' by the definition of an engineer provided above. (2)
3. As a first-year student, I lack engineering knowledge and oftentimes unaware of the existence of the applicable engineering techniques during the design process. In this case, providing alternative justification at the first-year level should be done without hesitation. (3)
4. The purpose of engineering design is not to explicitly showcase our capabilities, as was required for assessment purposes in the ESC102 course. Instead, its goal is to ensure functionality without issues, allowing users to remain unaware of the engineering concepts involved based on the definition of “engineering design” above. (4)

* Numbers in the bracket () will be used for the future reference

Value

- **Design Implementation:** Prioritize phenomenal engineering designs over conceptual ones. Evaluate designs dichotomously—either functioning or not—based on constraints, rather than merely adjusting functionality.
- **Clarity and Usability:** Ensure designs are straightforward for stakeholders, not through simplicity of operation, but by inherently solving complex issues within the design itself.

Biases

1. The author believes engineers often derive ideas from existing designs, which is considered preferable.
2. The author believes that a "null solution" is often the best approach for a first-year engineering student if the research on existing designs is thorough, except in cases where the community or the opportunity is specific (and usually not recognized by the majority), which was the case for praxis II communities.

3. While valuing teamwork and communication highly, the author believes that such abstract and universal values should not be the focus in this design portfolio, as the primary objective here is to document design work.

Ⅱ. UTWind - Designing a Wind Turbine

Background

UTWind (University of Toronto Wind Turbine Design Team) designs small-scale wind turbines for participation in the International Small Wind Turbine Contest (ISWTC) held in Amsterdam, Netherlands.

Team

The team comprises five subsystems: Aerodynamics, Mechanical, Control System, Power System, and Sustainability. I have been working as a mechanical team member, focusing on pitch system and blade design since September 2023. I had the privilege to participate in ISWTC in the Netherlands as one of the nine competition team members in the first week of July 2024. The competition team includes Dhara Patel (Power System Co-Lead), Robert Zhao (Aero Lead), and Justin Ding (Mechanical Co-Lead).

High-Level Objective

Contribute to UN Sustainable Development Goal 7.1 by providing accessible and reliable energy to Potiskum, Nigeria.

Key Requirements for design

- Wind turbines with a swept diameter of 1.6m.
- DC voltage output between 0 to 60V and current output between 0 to 20A.
- Both horizontal and vertical axis wind turbines are permitted.

Design Process & Design Product

Since the entire design process is extensive and the author contributed to a very small portion of it, only the author's specific contributions will be discussed to explain how positions/values are affected. All technical engineering design justifications are listed in the official UTWind Final Report. The wind turbine for the 2024 contest has not been assembled yet.

Skills learned

-Software : SOLIDWORKS, Ansys, PrusaSlicer

-Concept : Pitch system, Usage of coupling & bearings, Machining, Material selection, Making composite mold from 3D printed pattern.

My Contribution & Role of Positionality

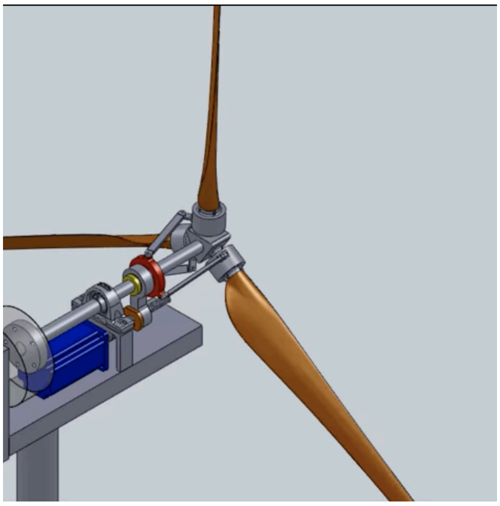
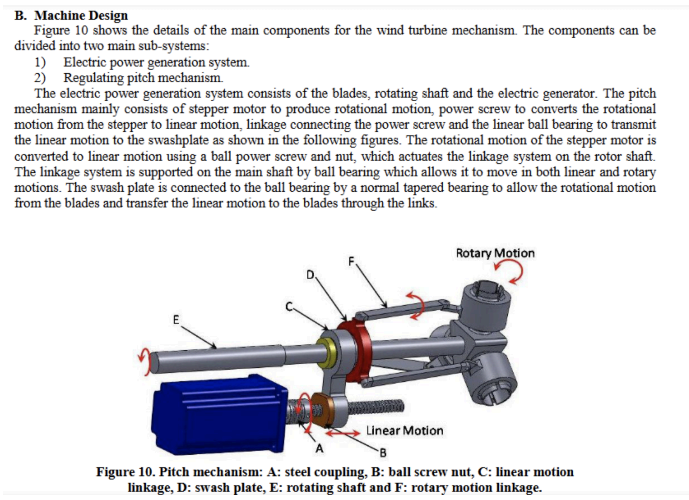


Figure 2: Existing pitch system

https://www.youtube.com/shorts/M6pPLfNrM4c



B. Machine Design

Figure 10 shows the details of the main components for the wind turbine mechanism. The components can be divided into two main sub-systems:

1) Electric power generation system.
2) Regulating pitch mechanism.

The electric power generation system consists of the blades, rotating shaft and the electric generator. The pitch mechanism mainly consists of stepper motor to produce rotational motion, power screw to converts the rotational motion from the stepper to linear motion, linkage connecting the power screw and the linear ball bearing to transmit the linear motion to the swashplate as shown in the following figures. The rotational motion of the stepper motor is converted to linear motion using a ball power screw and nut, which actuates the linkage system on the rotor shaft. The linkage system is supported on the main shaft by ball bearing which allows it to move in both linear and rotary motions. The swash plate is connected to the ball bearing by a normal tapered bearing to allow the rotational motion from the blades and transfer the linear motion to the blades through the links.

Figure 10. Pitch mechanism: A: steel coupling, B: ball screw nut, C: linear motion linkage, D: swash plate, E: rotating shaft and F: rotary motion linkage.

Figure 3: Handbook of Figure 2

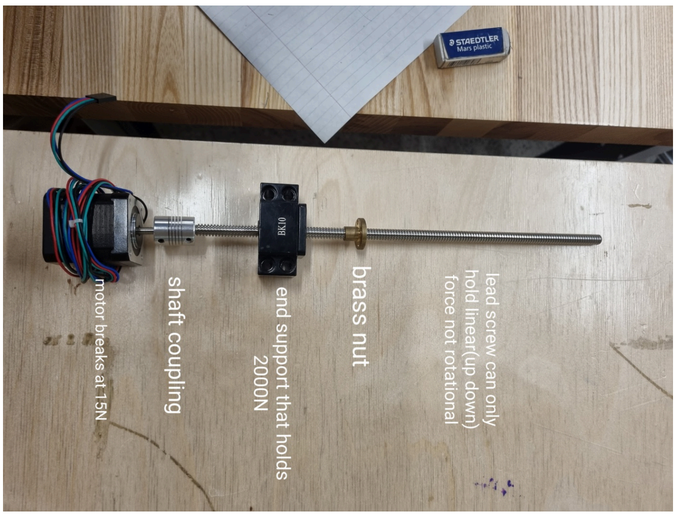


Figure 4: Lower section of Figure 3

(Blue part of Figure 3 is a motor at the leftmost side)

- Based on my belief (1), I learned to use various software programs—CAD (SOLIDWORKS), material analysis (Ansys), and 3D printing (Prusa Slicer)—through the design team outside of coursework. Credit goes to David Petriw(Mse 2T4) and Michael Jing (Mech 2T4) for teaching me.
- Based on my belief (2), the team adopted existing pitch system ideas (Figures 2 and 3) for our pitch system design, making slight modifications and verifications. One of my contributions, depicted in Figure 4, was to add an end support to accommodate the force exerted on the motor to the existing system

Ⅲ. CIV102 Bridge Design and Construction

Background

The project involved optimizing the cross-section of a girder bridge in a civil engineering course. Starting with an initial design (design 0), the goal was to enhance the bridge's capacity to support a locomotive train using permitted construction materials. Team members included Divya Roy and Md Ahnaf Zafir, who transferred to Civil Engineering after the bridge project.

Objective

To optimize the geometric parameters of the bridge's cross-section, maximizing strength while minimizing material usage.

Key Requirements

The design considerations included:

- Flexural tension and compression
- Bending moment
- Shear and glue shear of the matboard
- Euler buckling
- Thin plate buckling (cases 1, 2, 3)
- Critical shear buckling

Safety factors and failure loads were to be determined using both manual calculations and computational methods (MATLAB or Python).

Final design product and outcome

The optimized bridge withstood loads up to 840N, significantly improving from the initial 441N failure load. Since the bridge had a weak connection point (the project was intentionally designed to give a shorter matboard than the bridge length) failure at the connection point was also considered. Despite these measures, the bridge ultimately failed due to insufficient glue coverage, which was anticipated due to the minimal amount of glue provided.

Skills learned

MATLAB, Civil engineering principles, Multivariable optimization through trial and error method

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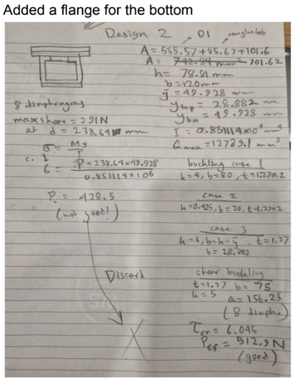
Role of positionality Based on my belief (3), our team realized that multivariable optimization was beyond our scope at the time, so we resorted to a trial and error method. To systematize our approach, we considered how each parameter influenced others. For instance, through observations and hand calculation, we observed that the initial failing load ratio of compressive to tensile force was approximately 1:5, both affected by y-bar. Consequently, we added multiple flanges to the top of the bridge to increase y-bar, enhancing the maximum compressive forces at the expense of tensile strength(Figure 5). Such adjustment between multiple parameters and verification using MATLAB code(Figure 6) almost doubled the bridge's maximum load from 441N to 840N, which was considered to be high compared to the other groups. Also, now at this point, having learned multivariable optimization in Calculus 2, I can feel that the number of applicable engineering techniques increases as I accumulate more engineering knowledge.

Increasing the breadth of the glue tab by 80 mm

Added a flange for the bottom



This will further strengthen the structure in terms of compression on the top flange and this also increases FOS for glue shear failure. This further raises the centroidal axis up to make the structure more efficient (The ratio of compressive strength to tensile strength is 1:5). We want to have most of the mass on the top by doing so.

Increase the number of diaphragms

Removed bottom flange

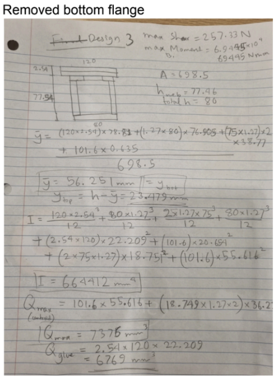


Figure 4

We can increase the P_{fail} for shear buckling, which lowers the plate length (a) and the critical shear buckling stress.

$\tau crit = 5\pi^2 E/12(1-\mu^2)\cdot((t/a)^2 + (t/h)^2)$

Changed the number of diaphragms from 8 to 9. The distance between the diaphragms was 150 mm. It uses more of the available matboard.

Bottom flange was removed because the bridge is more likely to fail due to compressive force rather than tensile force. Removing bottom flange increases y_bar, hence increasing the maximum compressive force the bridge can hold.

Figure 5 : Example of optimization step with hand calculation and justification

max_shear_x	291
maximum_trai...	419.3095
min_FOS	1.0483
min_FOS_case1	2.4142
min_FOS_case2	4.1042
min_FOS_case3	4.7737
min_FOS_case4	3.3278
min_FOS_com...	1.0483
min_FOS_glue	7.5725
min_FOS_shear	2.6987
min_FOS_tensi...	4.4074
minimum_fact...	1.0483
moment_envel...	*1x1201 double*
moment_vals	*1x1201 double*
Q_centroid	6192
Q_glue	4344
reason_for_fail...	"Yielding in Com...
shear_capacity	*1x1201 double*
shear_envelope	*1x1201 double*
shear_vals	*1x1201 double*
tensile_capacity	*1x1201 double*
u	0.2000
x_train_vals	*1x2057 double*
y_bar	41.4310

Figure 6 : Part of MATLAB code output to verify hand calculated values

Based on my value of 'Design Implementation,' this bridge design was deemed a failure in engineering due to its dichotomous evaluation—survive or fail. Therefore, a thorough review in engineering design is essential. According to my definition of engineering design, 'the reasoning behind the design is often not apparent to regular stakeholders but adheres to all standards while achieving maximum functionality.' On the actual bridge, passengers crossing by train would likely be unaware of its design, which by definition is an engineering design. However, if regular stakeholders express concerns due to its failure in a design demonstration, it is not considered successful engineering design due to their skepticism about its functionality. As an engineer, thorough verification and validation are crucial when facing such failure in design. In this case, as a designer of the bridge, I would say the design process underwent rigorous mathematical verification; the only issue was the assembly due to limited glue availability."

Ⅲ. ESC101 on campus garbage bin design

Background

The team identified overflowing garbage bins as one of the opportunities on the University of Toronto campus. A solution to this was systematically identified based on FDCR steps (the FDCR design process is explained in the Design Handbook).

Teammates Jeffrey Klinck, Aydin Yousaf, Trevor Orlando (all EngSci 2T7)

Objective Redesign the garbage bin system at the University of Toronto St. George Campus to effectively manage waste overflow, enhance cleanliness, and meet the specific needs of stakeholders including students, faculty, and maintenance staff.

Primary design decisions and design product

Design : Garbage bin lid compressor

1. A garbage compressor system was adopted
2. The compressor is added only to the lid of the current garbage bin, not to the entire garbage can.
3. Compressor will be operated using a stepper motor and lead screw.

Final design product was represented as a low fidelity physical prototype where rotation in lead screw in the middle results in the compress of the garbage.

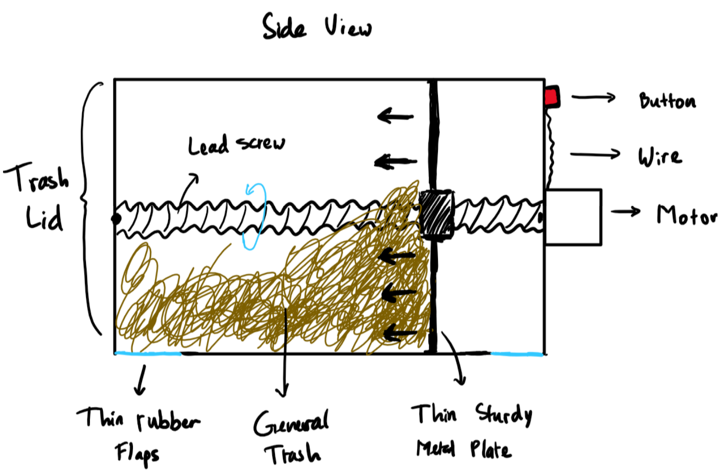


Figure 7 : Sketch of the sideview

Figure 8 : Prototype:Lid with compressor

Skills learned FDCR(Framing, Diverging, Converging, Reframing) process

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Role of positionality

Based on my value Clarity and Usability, a motor system was adopted instead of manual compression to ensure that stakeholders, especially students, do not have to worry about whether the garbage bin will overflow or when to compress it. Therefore, an automated compressor was chosen. To increase implementation time, the design is applied only to the separable lid part of the garbage bins currently used by the University of Toronto.

Ⅲ. ESC102 - Cordage Maker for Basket Weaving Community

Background

Design opportunities from communities within the Greater Toronto Area (GTA) were explored, and a project from the Toronto basket weaving community was selected after the Praxis II teaching team reviewed the request for proposal. The primary opportunity comes from community members with arthritis who experience pain during various stages of basket weaving.

Objective Create a device that reduces the arthritis-related pain affecting a beginner weaver's ability to make cordage

Teammates Sasha Mee, Mario Arambula, Princess Akinolaore (all EngSci 2T7)

Primary design decisions and design products

Design : Cordage Maker

1. Combines four different cordages into one thick cordage.
2. Features two ergonomic handles on opposite sides; the first handle twists all four cords individually, while the other combines them.
3. Adjustable in length to accommodate different user needs.
4. Incorporates an inner gear system to enhance functionality.

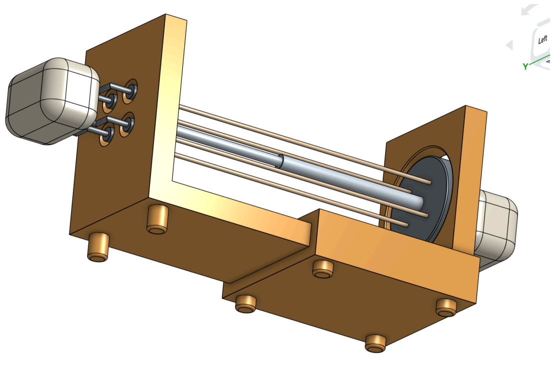

Figure 9 : CAD of cordage maker

Figure 10 : Physical prototype

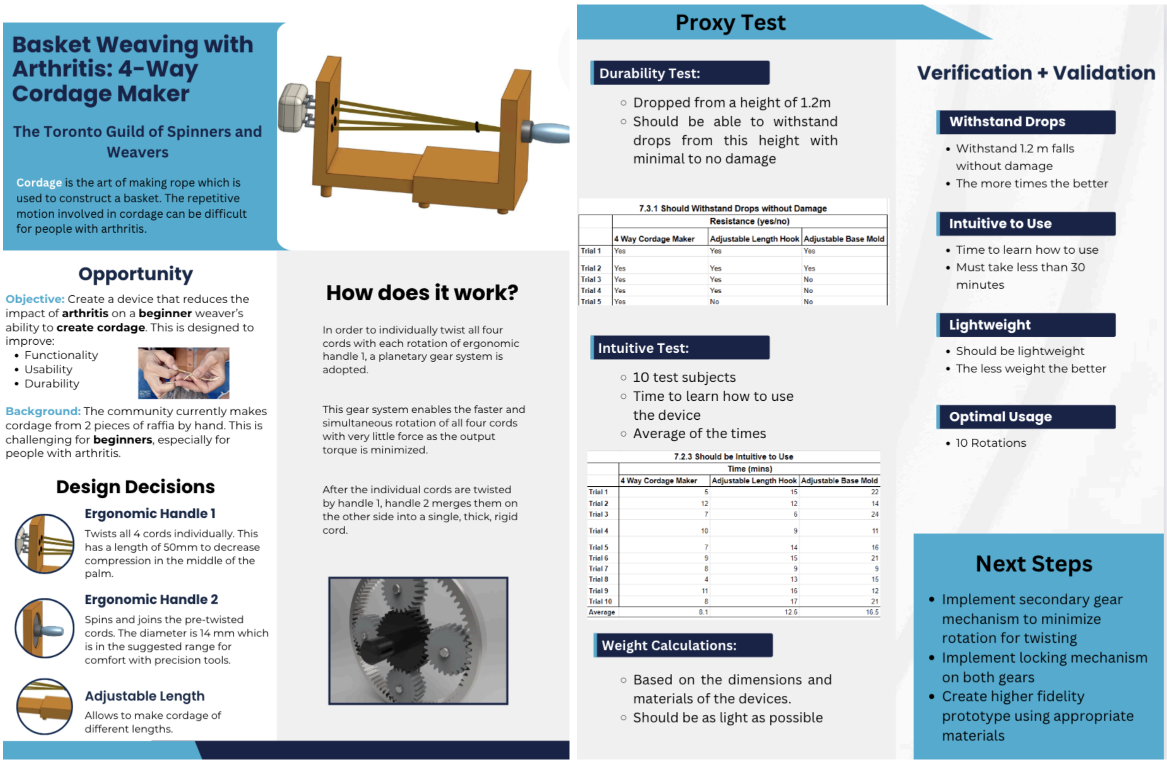

Figure 11 : Praxis II one pager of the design

Skills learned CAD(Onshape)

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*Note : The role of positionality is detailed in the "Assessment' section of the "Design Handbook".