T.C. Yeditepe University

Mechanical Engineering Department

ME482: Design of Mechanical Systems

The Design of a Manual Battery Charger

Final Report

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Table of Contents

Table of Figures

1.Abstract

This project presents the design and simulation of a manual battery charging system powered by human force. The aim is to provide a portable and reliable solution for generating electrical energy in off-grid or emergency situations. A foot-pedal mechanism was selected as the core design due to its simplicity, durability, and effective energy conversion.

The mechanical structure was designed using CAD tools, and critical components were analyzed through ANSYS to ensure structural stability. A dynamic Simulink model was developed to simulate the torque-to-voltage process and predict battery charging behavior over time. Results confirmed that the system could deliver a constant voltage and effectively charge a battery using human effort.

Overall, this project demonstrates a practical approach to small-scale energy generation using mechanical input, offering potential applications in emergency kits, outdoor use, and developing regions.

2.Introduction

In today's world, access to electricity is often taken for granted. However, in emergency situations, outdoor environments, or underdeveloped regions, the lack of a stable power source can be a serious problem. For this reason, alternative charging systems that are independent of grid electricity have become increasingly important.

This project focuses on the design of a manual battery charging system that can generate electrical energy using human power. The idea is to create a simple, portable, and efficient device that can be used to charge small electronics like mobile phones or lights in off-grid conditions. The main goal is to convert mechanical energy, generated by pedaling, into electrical energy that can be stored in a battery.

In the early stages, various concept ideas were evaluated such as piezoelectric shoe systems and hybrid stationary chargers. After a comparison based on feasibility, efficiency, cost, and user-friendliness, the foot-pedal-based generator was selected. It was found to be the most suitable solution in terms of practicality and mechanical simplicity.

To build a reliable system, both mechanical and electrical aspects were considered. CAD software was used to model the mechanical parts such as the crank, gears, and generator housing. Structural analyses were performed using ANSYS to examine critical stress points and ensure the system could withstand repeated use. On the electrical side, MATLAB Simulink was used to simulate how the mechanical input would be translated into electrical output and how effectively the battery would be charged.

This report presents the design process, simulation results, material selection, and performance evaluation of the manual charging system. It includes a cost analysis, risk assessment, and a detailed look at each subsystem. The goal is to offer a working concept that demonstrates the potential of human-powered energy solutions for low-power applications in real-life scenarios.

3.Design Phases

3.1. Phase I

3.1.1. Statement of Need and Problem

Identifying the problems and needs is considered the most essential step in organizing the solution and defining the focus areas. Therefore, when the topic of a manual battery charger was considered, the list of problems and needs was divided into two main stages. First, the reasons why such a device is needed were identified. Then, observations were made regarding why the currently available manual chargers should be revised or redesigned completely.

The starting point was initiated by discussing a common daily issue that is faced by everyone: phone batteries running out. Based on the ideas that were gathered and as the perspective was broadened, it was realized that, especially in emergency situations, traditional charging methods and the dependency on wall sockets are considered a matter of life and death.

In the second stage, market research was conducted, previously used manual chargers were reviewed, and user experiences were taken as sources. Based on the data that was collected, it was noticed that this market has been turned into a junk market by Chinese manufacturers. The products were poorly designed and were considered unreliable in emergency situations.

As a result, the findings that were obtained were developed in two stages as follows:

Stage 1:

• **Environmental Issues**:

Traditional charging methods are not considered environmentally friendly. Very high carbon footprints are caused by the methods used to generate electricity. These methods, which cause irreversible long-term harm, are in urgent need to be replaced.

• **Dependency on Electrical Outlets**:

During outdoor activities such as hiking, camping, or long trips, where outlets cannot be found, essential devices cannot be charged. Serious problems, ranging from being unable to make a phone call to getting lost, can be encountered.

• **Emergency Situations**:

In emergencies, when the connection to electricity is lost, critical devices like phones, radios, and flashlights cannot be used. As an earthquake-prone country, this issue is known all too well by our citizens.

Stage 2:

• **Irregular Current**:

A common flaw of current manual chargers on the market is observed in that instead of energy being stored in a battery and then used to charge a device, unregulated current that is produced during the energy generation process is directly supplied to the device. This results in unstable charging, which is considered highly harmful to battery health.

• **Limited Storage**:

Devices with a storage feature usually are limited in capacity due to size restrictions. A single-use experience is provided at best, despite the affordable price. Furthermore, since the battery life is reduced quickly, no functional difference is left between these and manual chargers without storage, and irregular current begins to be delivered again.

• **Low User Satisfaction**:

Designs are made almost identically, and because of their small size, high effort is required for low output. These products, which are far from being considered ergonomic and comfortable, also fail to charge a device effectively leading to very low customer satisfaction.

• **Durability Issues**:

Due to the use of lightweight plastic materials, the probability of gear breakage in the internal mechanism is increased. It has been clearly observed that the reviewed or tested products are easily broken.

• **Short Usage Time**:

Because the devices are not designed ergonomically and appropriate gear ratios are not used, long-term operation cannot be achieved. Therefore, the devices, which are already inefficient, are unable to perform their intended function.

3.1.2. Scope

The scope of this project outlines the specific requirements, and limitations for the automatic electric generator.

- **Intended Use**: The generator is designed to provide low-power DC electricity in emergency or temporary conditions such as natural disasters, camping, or rural field operations. It is not intended for continuous use or for powering high-draw appliances.
- **Environmental Conditions**: The system is suitable for operation in ambient temperatures ranging from 0°C to 40°C, and should be stored between –10°C and 45°C. Relative humidity during operation or storage should remain between 10% and 80%, with condensation strictly avoided to ensure component reliability and safety.

- **Operating Duration Limit**: The device is intended for intermittent use with a maximum continuous operating time of two hours per session. A cooldown period of at least 20 minutes is required between sessions. The cooling system includes a passive heatsink, with an optional fan module available for extended use or higher loads.
- **Voltage Compatibility**: The generator is designed to operate with a maximum regulated DC output voltage of 12V. Under no circumstances should the system exceed this voltage limit to ensure compatibility with low-voltage electronic devices and prevent potential safety risks.

3.1.3. Objectives

The following objectives will be followed:

- Power Output: Achieve a regulated voltage of 12 V and continuous output power of 24 W to provide sufficient power for charging devices. These values will meet the needs of most modern electronic devices, ensuring faster charging capabilities than standard manual battery chargers in the market.

- USB-C Compatibility: The USB-C output supports Powers up to 6V/4A (24W) This will make the device compatible with a wide range of modern electronics, from flashlights to smartphones, improving its versatility and user accessibility.

- Stable Current Supply: Ensure that the system consistently delivers a steady DC current throughout the operation. System must have overcurrent protection. This stable current will prevent damage to sensitive devices, enhance battery lifespan, and ensure reliable performance during use.

- Weight Limitation: The total mass of the system will not exceed 10 kilograms. This ensures the design remains relatively easy to carry, offering convenience for users on the go without compromising on performance.

- Size Limitation: The system will be designed with a size range of 300x300x500 mm , making it relatively practical for a variety of storage and usage scenarios.

- Safety Standards: Ensure that the charger has protection against short circuits, overheating, and electrical surges. Ensure structural integrity of the device, focusing on durability and safety during use.

3.1.4. Design Partition

Design partition is a fundamental step in the engineering design process, involving the systematic decomposition of a complex system into smaller, more manageable, and functionally distinct subsystems or modules. This hierarchical breakdown simplifies the design task, allowing for parallel development, easier problem isolation, and more focused design efforts on specific components or functionalities. By breaking down the overall system into logical partitions, interdependencies can be identified, interfaces defined, and individual module designs can be optimized more effectively. This approach not only streamlines the development process but also enhances the clarity, maintainability, and reusability of the design.

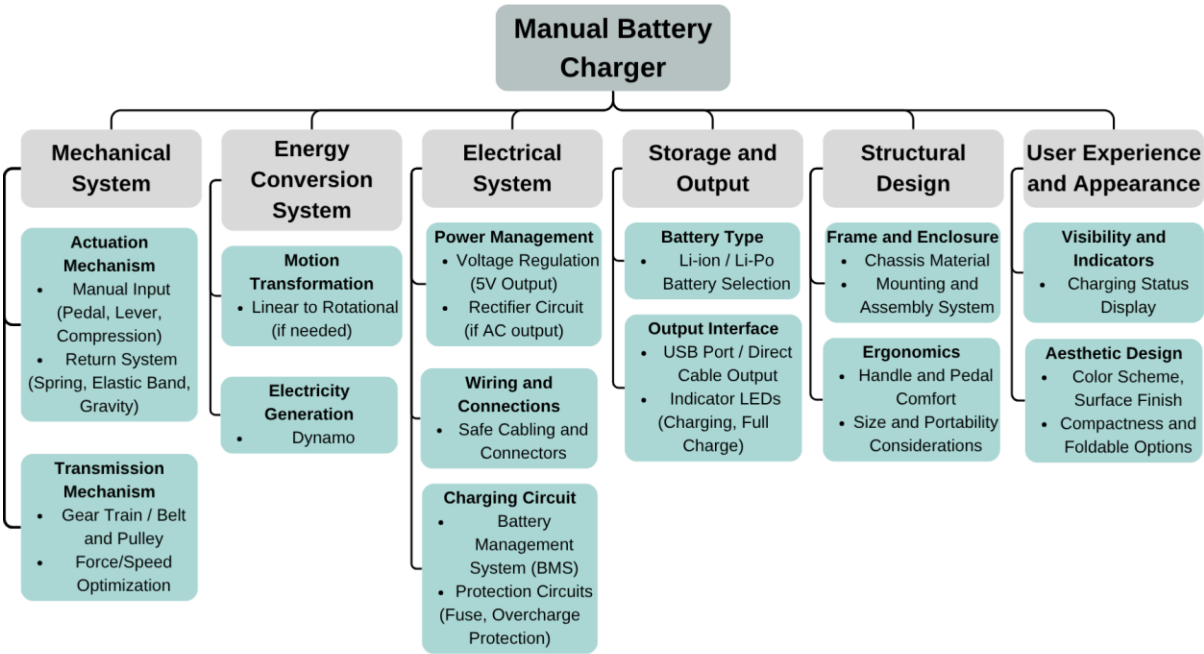


Figure 1 Design Partition Table

In the context of the manual battery charger project, the overall system was methodically partitioned into several key functional and physical subsystems, as illustrated in the figure. This modular decomposition facilitated a structured approach to design, analysis, and assembly, ensuring that each critical aspect of the charger was addressed systematically.

3.1.5. Project Timetable (GANTT Chart)

The timetable defines the planned schedule for the design and development of the manual battery charger. It reflects the sequential phases of the project, ensuring timely progress and effective task management. The timetable was structured around the academic calendar.

The following Gantt chart presents the distribution of project activities across the semester:

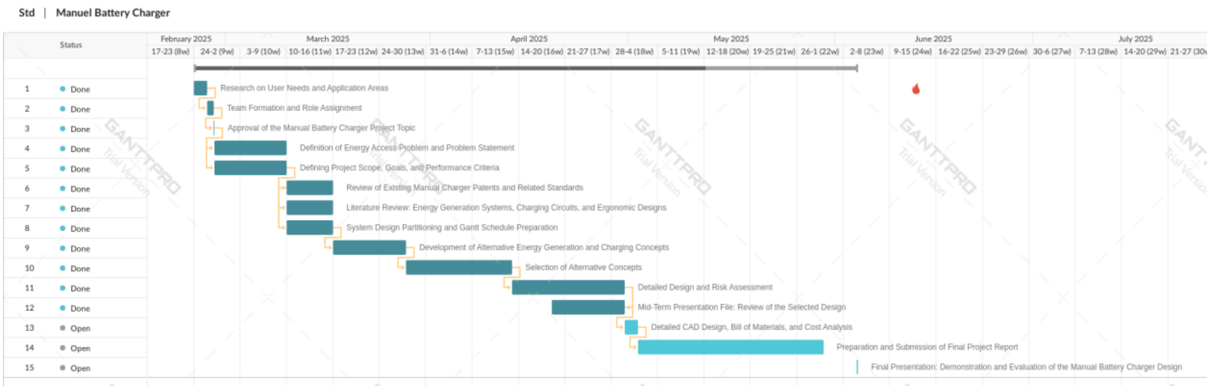


Figure 2 Project Timeline for Manual Battery Charger

3.1.6. Patents and Standards

Patent: Foot-Powered Energy Generator – Summary of U.S. Patent US 9,190,886 B2

This device is designed to generate electrical energy from human motion with waking. The system works by putting a step plate into footwear. When a person steps, the plate compresses and causes the carriage to move. With the help of a gear train, the linear motion is transferred into rotational energy.

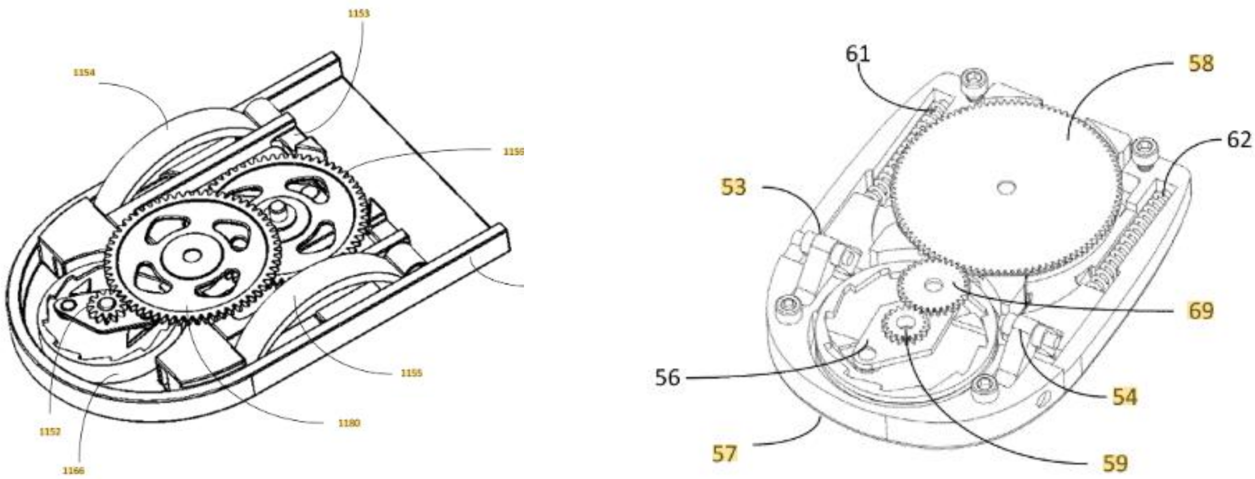


Figure 3 Technical Drawings of Foot-Powered Energy Generator

Patent: Bag/Pack Power Generation Device – Summary of U.S. Patent US20090243303A1

This invention focuses on harvesting kinetic energy from natural body movement while wearing a backpack or similar item with a special buckle. The system is integrated into the strap buckle of a bag or backpack and includes a rack and pinion mechanism connected to speed up gear shafts that increase the rotational speed of the system. These shafts are connected to a generator, which produces electrical power. This design is portable and can be used in everyday activities.

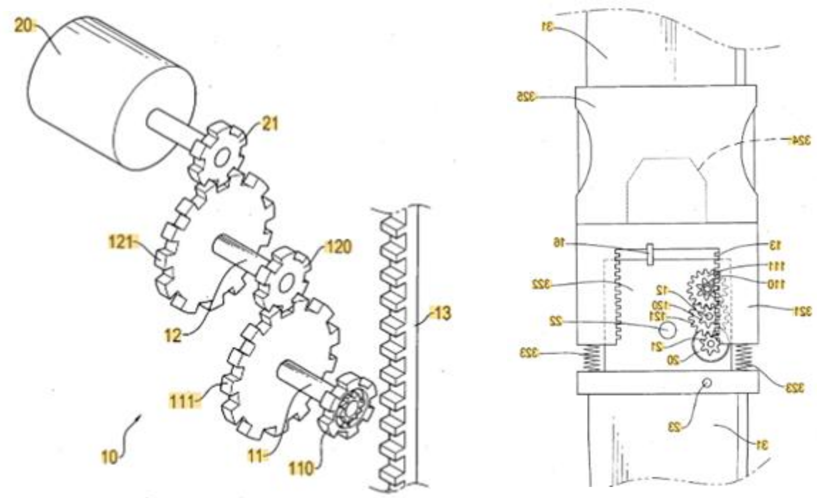


Figure 4 The Drawings of Bag/Pack Power Generation Device

3.1.7. Journals, brochures, and web pages

1-) Shock-Absorber Rotary Generator Energy Harvesting

Another solution is the Shock-Absorber Rotary Generator Energy Harvesting system. This device operates as a conventional damper system, absorbing mechanical vibrations acting on it. However, unlike traditional dampers, it features helical blades wound around the piston rod within its internal mechanism. These blades aim to convert the linear motion of the piston rod—moving through a fluid chamber—into rotational motion using aerodynamic principles.

(https://doi.org/10.3390/app10186599)

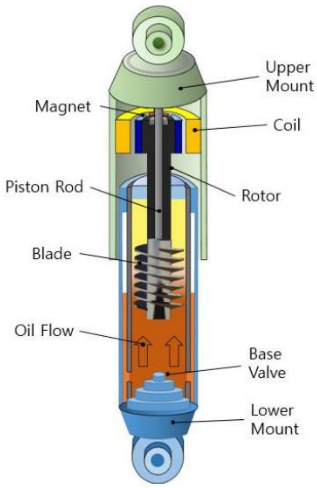


Figure 5 Shock-Absorber Rotary Generator

2-) Research on Power Generating Tiles

This mechanism, which is very similar to the damper system but much simpler, generates angular velocity through a pinion and rack gear system, thereby producing electricity. When a load is applied on the pressure plate, it moves downward to a certain extent. The electronic components responsible for limiting this motion and returning the pressure plate to its original position are the springs located at the connection points, as shown in the diagram.

(https://www.ijsr.net/archive/v13i5/SR24514192101.pdf)

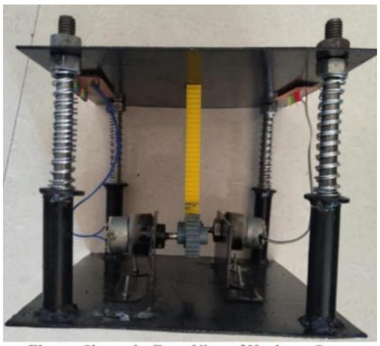


Figure: Shows the Front View of Hardware Setup

Figure 6 Power Generating Tiles

3-) Encore Player

This device generates electricity through both solar power and a hand crank. In addition to the detachable solar panel, electricity can also be generated by turning the crank on the back of the unit. This system, which combines multiple features in one, can function as a radio, flashlight, and charger.

(https://www.freeplayenergy.com/radios/encore-player)

Figure 7 Encore Player Generator

4-) Pedal Power Generator

This system, designed to produce electricity while exercising, has a simple operating mechanism. The rotation of the rear wheel of a bicycle is transferred directly to a shaft, which then generates electricity.

(https://www.pedalpowergenerator.com/)

Figure 8 Pedal Power Generator

Among the evaluated concepts, the Encore Player aligns most closely with the intended scope of Group 8's project. Its multi-functional design, which combines solar and manual crank energy generation with essential emergency features such as radio, flashlight, and device charging, demonstrates a user-centered and market-proven solution. Its availability at a global scale further supports its practical viability and relevance to emergency preparedness applications.

In contrast, the other three concepts, while innovative, fall short in addressing the core criteria of portability, usability by individuals, and effectiveness in emergency scenarios. The Shock-Absorber Rotary Generator, although technically sophisticated, is not intended for individual or portable use. Its primary applicability lies in industrial or automotive sectors, where mechanical vibrations are abundant and can be harnessed at scale—making it unsuitable for human-powered, off-grid charging.

The Pedal Power Generator, while capable of producing clean energy efficiently, is inherently dependent on access to a bicycle. This limits its practicality in spontaneous emergency situations. However, its integration in settings like gyms or off-grid locations could promote sustainable energy habits and contribute positively to eco-conscious infrastructure.

Similarly, the Power Generating Tile system, although promising in its low-cost, piezo-free electricity generation via mechanical pressure, is constrained by its immobility. Its potential lies in being embedded in urban infrastructure—such as sidewalks or building entrances—rather than in portable emergency solutions.

In summary, this comparative study has provided meaningful insights into diverse energy harvesting strategies. While each concept holds merit within its context, the findings underscore the importance of portability, user effort, and reliability in emergencies when developing a manual charging device. These insights will guide the design of a more refined and context-appropriate conceptual prototype.

3.2. Phase II

3.2.1. Concept generation

Foot-Crank Generator:

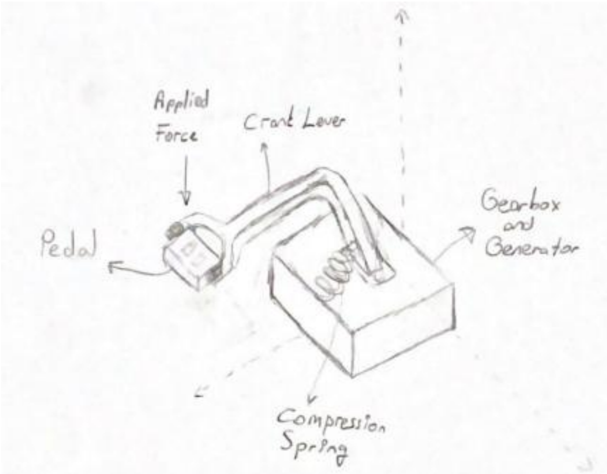


Figure 9 Foot-Crank Generator

This design, inspired by the kick-start mechanism of old motorcycles, stands out due to its practicality and feasibility. The basic structure of the mechanism consists of one pedal and two gear components. However, unlike traditional systems, the area where the pedal arm is connected to the large gear contains screw-like threads. As the pedal moves downward, these threads help rotate the shaft, responsible for generating electricity, in the correct direction. It's crucial that the shaft does not rotate in the opposite direction during the generation process. At this point, the screw threads provide assistance.

While the pedal returns to its starting position, the screw threads on the arm connected to the large gear allow it to move linearly along the arm, disengaging from the small gear. When the pedal is pressed again, it re-engages to initiate movement in the correct direction. This process repeats in cycles, enabling continuous energy generation.

Advantages

- Hands-Free operation
- Can be a form of light physical exercise.
- Portable enough to use under a desk.
- Educational value

Disadvantages

- Restoration force might be too high.
- Might slide or tip over if not on a flat surface.
- Wear or failure on moving parts.
- Might get squeaky over time.

Piezo Steps:

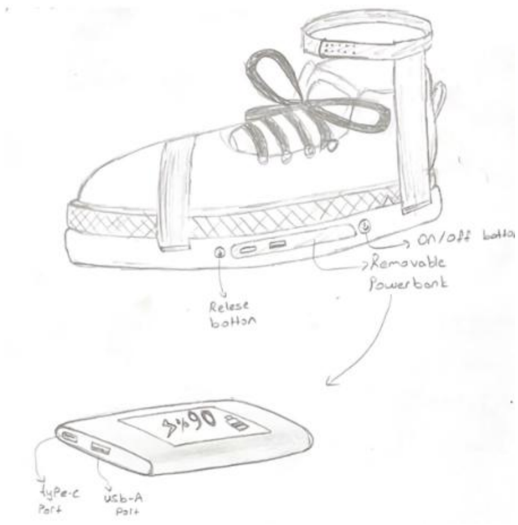


Figure 10 Piezo Steps

The Piezo Steps concept aims to generate electricity with minimal effort. Although slightly costly due to the circuit components involved, it offers a stylish solution. Designed in the form of an insole, this product is envisioned to be easily attachable to the underside of any shoe. It generates electricity through piezoelectric elements embedded in its sole.

The generated energy is stored in a built-in power bank, allowing for convenient use. However, since the device will come into direct contact with unwanted conditions such as rain and mud, safety must be a top priority in its design. With proper research and development, along with a well-planned budget, this concept has the potential to be revolutionary.

Advantages

- Ergonomic
- Light Mechanism
- Long time use

Disadvantages

- Cost
- Uncomfortable
- Does not look good

Dual Battery Charger:

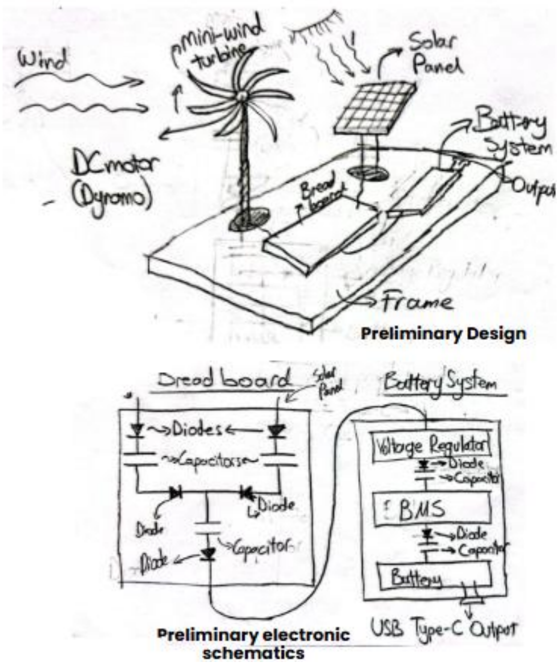


Figure 11 Dual Battery Charger

This system uses traditional clean energy generation methods and can be mounted on vehicles, caravans, or rooftops of houses. Aiming for effortless operation, this concept is not portable. Its standout feature is the simultaneous use of both a wind turbine and a solar panel, which is also where it gets its name.

Advantages

- No physical effort.
- Energy storage.
- Safe battery system.
- Effective in various weather conditions.

Disadvantages

- Dependent on weather conditions.
- Higher initial cost.
- Maintenance cost.
- Larger and sensitive components.
- Compatibility.

3.2.2. Selection of concepts

Concept selection is a critical phase where the findings obtained from all preliminary research are evaluated to guide the project toward a feasible design. In this process, the priorities defined in the *scope* and *objectives* sections have been taken as the main criteria.

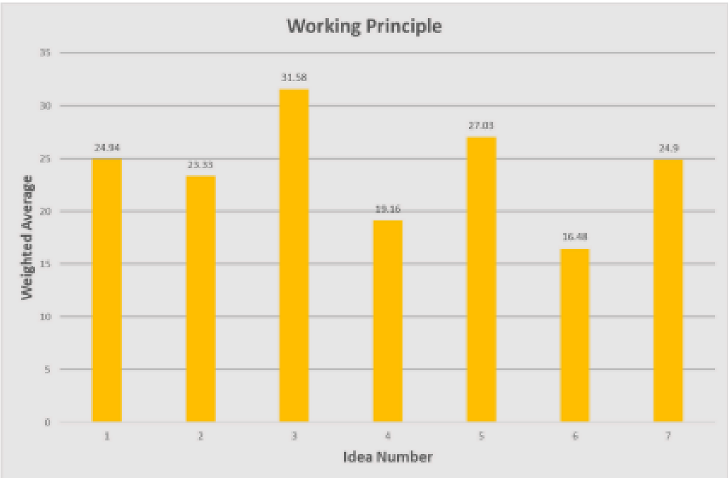
Concept Selection Criteria

The decision was made based on four main factors:

1. **Working Principle**
2. **Material Structure**
3. **Visual Design (Appearance)**
4. **Additional Features**

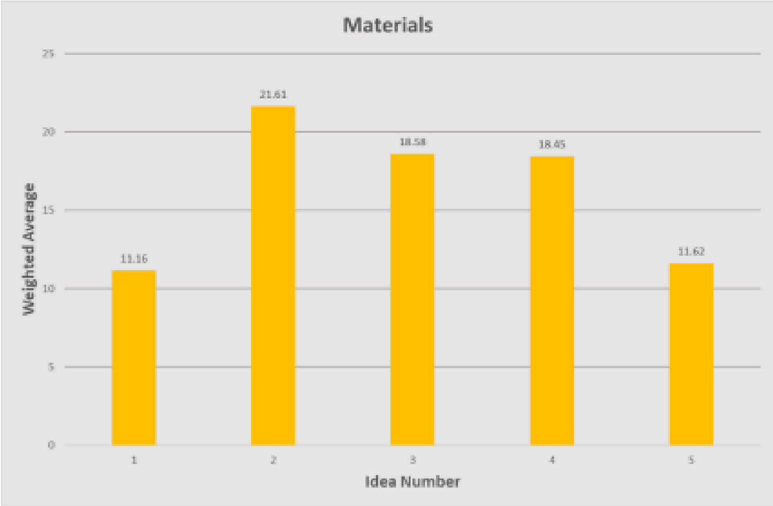
Each idea was evaluated in light of these criteria and voted on by the group members. The evaluation process also considered factors such as feasibility, durability, user-friendliness, and cost.

Below are the ideas and the scores they received under each category:



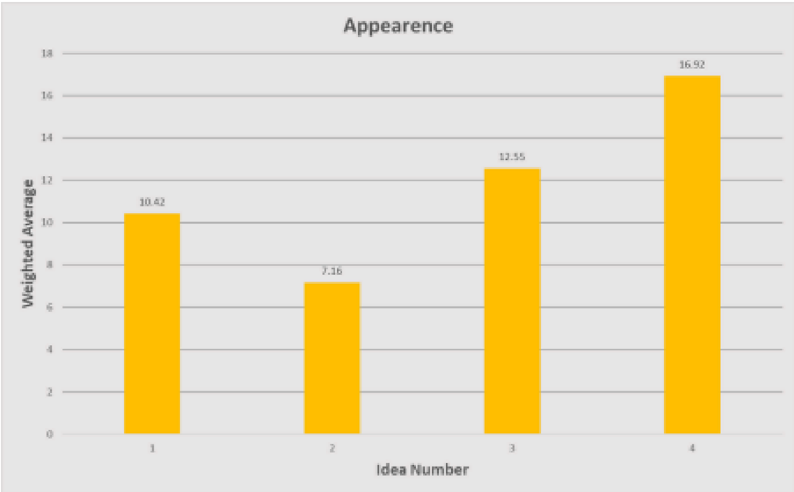
Working Principle	Ideas
Windbag-turbine energy generator	1
Piezoelectric energy generator	2
Footcrank energy generator	3
Backpack energy generator	4
Bike Seat Energy Generator	5
Jump rope generator	6
Human hamster wheel	7

Figure 12 Selection of Working Principle



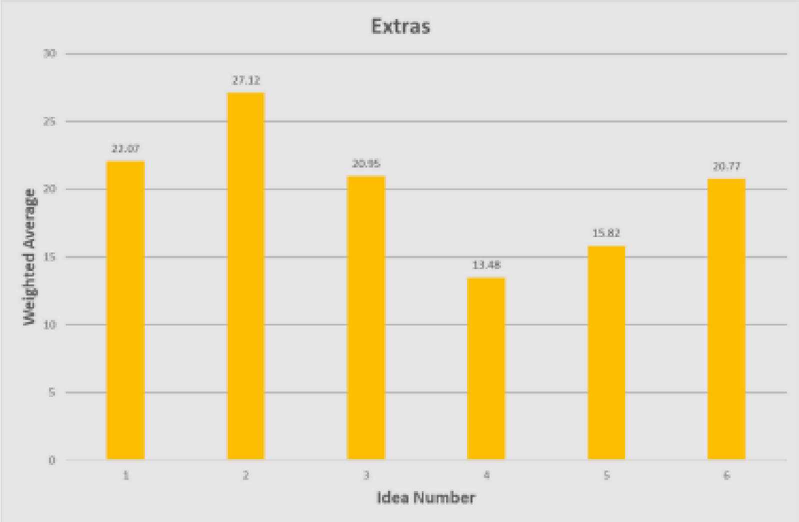
Idea	Materials
1	Cast Iron
2	Polymers
3	Composite Materials
4	Metal Alloys
5	Glass

Figure 13 Selection of Materials



Idea	Appearence
1	Smooth cornered oval design
2	See-through design
3	Personalized Design
4	LCD Ekran

Figure 14 Selection of Appearance



Idea	Extras
1	Multi-charging systems
2	Foldable Design
3	Spring restoring mechanism
4	Belt and pulley
5	Rack and pinion system
6	One-way clutch mechanism

Figure 15 Selection of Extras

Since portability is a fundamental requirement, the **Dual Battery Charger** concept was excluded from consideration. This system, which needs to be mounted on fixed surfaces, does not meet the portability criterion.

Although the **Piezo Steps** concept initially appeared to offer an innovative and elegant solution, it was deemed unreliable for emergency scenarios. In addition, the complex nature of the system and its high cost significantly reduced its feasibility, leading to the idea being shelved.

As a result of all evaluations, the **Foot-Crank Generator** was selected as the final design concept. The main reasons behind this decision include the simplicity of the mechanism, low cost, reliable structure, minimal maintenance requirements, and its potential to be produced in a small and lightweight form. The concept also offers significant advantages in terms of practicality and ease of manufacturing.

Initially based on a kick-start mechanism, the system was later revised and simplified. Following these improvements, the design reached its final version and became ready for implementation.

3.3. Phase III

3.3.1. CAD design & Assembly

Computer-Aided Design (CAD) is a vital tool in modern engineering, allowing designers and engineers to create, modify, analyze, and optimize designs in a virtual environment before physical production. CAD enhances precision, improves visualization, facilitates communication between teams, and reduces prototyping costs. For this project, all CAD modeling was performed using Onshape, a cloud-based CAD software known for its collaborative features and robust modeling capabilities.

In the context of our manual battery charger project, CAD played a critical role in the mechanical development of the system. The entire assembly was designed from the ground up, including precise modeling of each individual component and their integration into a functional mechanical unit. The design consists of the following key mechanical subsystems:

- Linear Slider with Step Plate: It is responsible for translating the user's manual input into a linear motion. This motion initiates the energy transfer process by moving the crank system.
- Crank Mechanism: The crank mechanism converts the reciprocating linear motion from the slider into rotational motion.
- Crankshaft: The crankshaft is the rotating shaft that transmits torque generated by the crank mechanism to the rest of the system.
- Flywheel: The flywheel stores kinetic energy from the rotating crankshaft and stabilizes the system's motion by reducing fluctuations in rotational speed.
- Gear Train: The gear train composed of drive and driven gears. The gear system increases the rotational speed delivered to the generator unit.
- Flexible Coupling: The coupling connects two shafts and transfer the motion between them.
- Generator Unit: The generator unit converts rotational motion into electrical energy.
- Electronics Enclosure: Electronics enclosure contains components such as BMS, battery, circuit board and voltage regulator. It receives generated electricity and prepares it for charging.

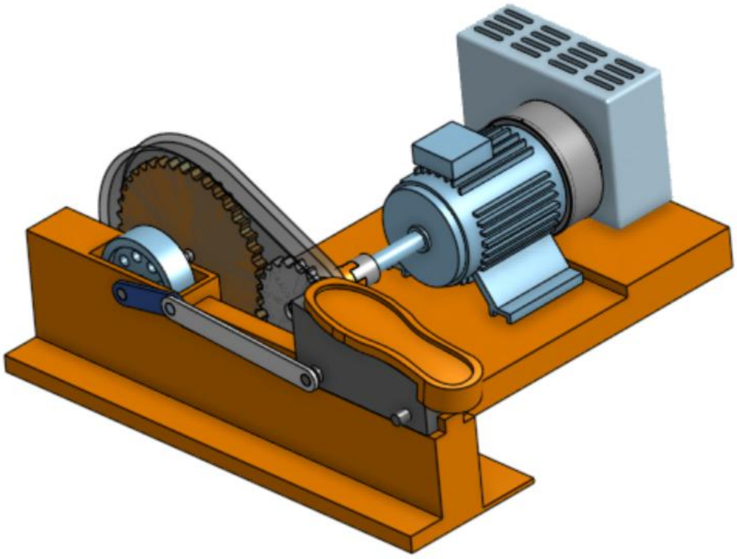


Figure 16 CAD Assembly

The rendered assembly view provides a full-color, realistic representation of the complete mechanical system. It visually demonstrates how all components interact and fit together, offering intuitive insight into part alignment, orientation, and physical integration. This view also reflects the expected final appearance of the assembled product (without casing), making it valuable for design reviews.

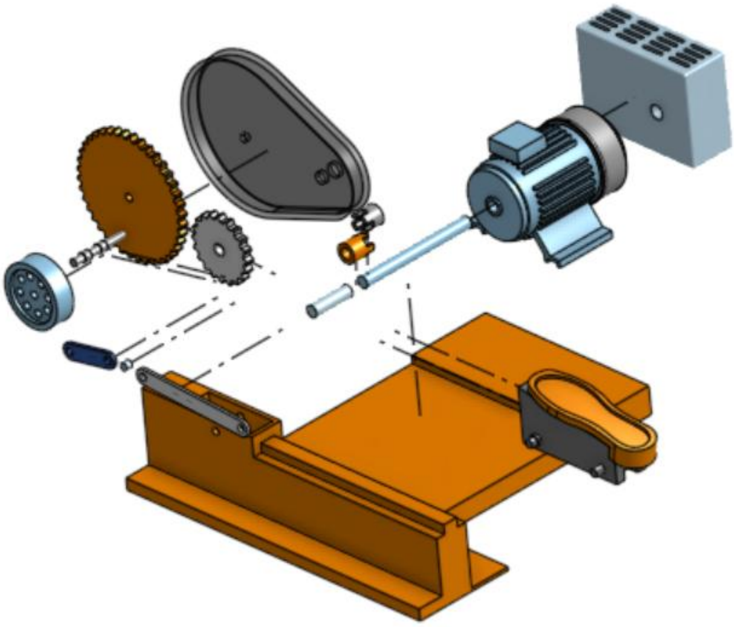


Figure 17 Exploded View of CAD Assembly

The exploded view displays all components separated along their assembly paths, clearly revealing their spatial relationships and order of assembly. This representation is crucial for understanding how parts are connected. It serves as a vital reference for both manufacturing processes and maintenance operations.

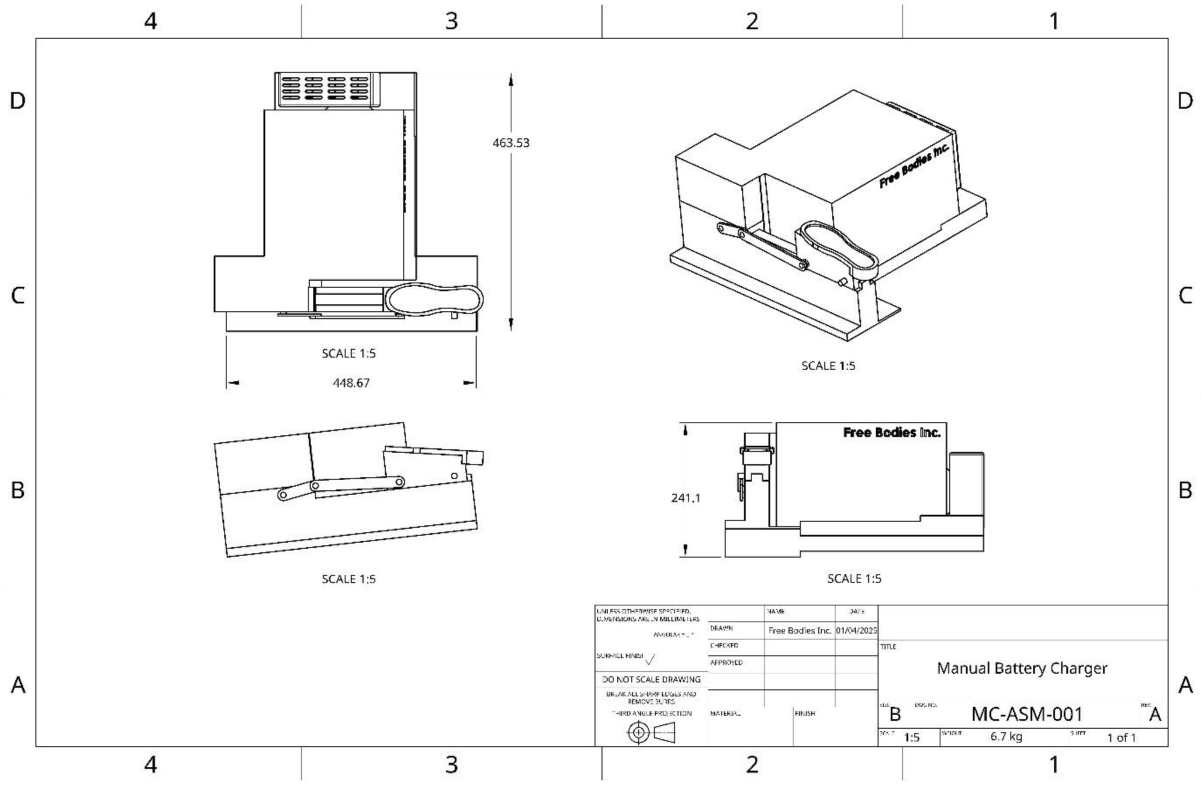


Figure 18 Technical Drawing

The technical drawing includes standard orthographic projections (top, front, and side views) with detailed dimensions and scales. After improving, it provides all necessary geometrical and dimensional data required for precise manufacturing of individual parts and accurate assembly of the entire system.

In terms of its physical attributes, the overall systems weighs 6.7 kilograms, with dimensions of 241mm in height, 448mm in lengths, 463mm in width. Also, our design includes several key components and material that balance durability, weight and functionality:

- An ABS casing for lightweight and durable housing,
- Aluminum levers for strength to weight ratio and corrosion resistance,
- Steel coupling and shaft for reliable torque transfer.

3.3.2. Risk analysis

In the development and testing of the manual battery charger system, several risks were identified that could compromise safety, reliability, or user experience. These risks were evaluated using a **risk assessment matrix.**

			RISK ASSESSMENT MATRIX				
Likelyhood →	Almost Certain	5	Medium High	Medium High	High	High	High
	Likely	4	Low Medium	Medium High	Medium High	High	High
	Moderate	3	Low Medium	Low Medium	Medium High	Medium High	High
	Unlikely	2	Low	Low	Low Medium	Low Medium	Medium High
	Rare	1	Low	Low	Low	Low Medium	Medium High
			1	2	3	4	5
			Insignificant	Minor	Significant	Major	Severe
			Effect →				

Figure 19 Risk Assessment Matrix

1-4	Acceptable ,no action needed; maintain control measures.
5-9	Adequate, may be considered for further analysis.
10-16	Tolerable, review promptly to implement improvements.
17-25	Unacceptable, ease activities and take immediate action.

Figure 20 Range of Risk Points

The following table summarizes the evaluated risks rated by The Free Bodies. The risk analysis reveals several **tolerable** and **adequate** risks associated with mechanical safety, electrical protection, and long-term component reliability.

Risk	Likelihood (1-5)	Severity (1-5)	Risk Score
Limb/Cloth Getting Caught	4	5	20
Battery Overcharging/Overheating	3	5	15
Component Wear Over Time	5	3	15
Chain or Gear Failure	3	5	15
Battery Health Deterioration	5	3	15
Electrical Shock Risk	2	5	10
Environmental Vulnerability	3	3	9
Pedal Slippage	4	2	8
Frame Instability	3	2	6
Noise and Vibration Issues	3	2	6
Unstable Voltage Output	1	4	4
Excessive User Fatigue	2	1	2

Figure 21 Risk Scores of The Design

The most critical risks such as **limb/clothing entanglement** and **battery overcharging** necessitate **immediate mitigation** with design refinement, thermal cutoff mechanisms, and guarded enclosures. The last concern to tend is the optimization of the resistive forces that makes it harder for the end-user to actuate the system (User fatigue).

These risks above could be mitigated by fully enclosing the moving parts and ensure no exposed mechanisms; use rounded, smooth edges or by optimizing pedal resistance and use ergonomic crank design.

3.3.3. Cost analysis

A cost analysis is a fundamental aspect of engineering design, ensuring both economic feasibility and practical decision-making throughout the development process. This section outlines the cost evaluation methodology applied to the manual battery charger project**,** identifies the major cost drivers, and presents a complete breakdown of expenses.

To effectively focus on the primary contributors to total project cost, the **Pareto Principle (80/20 Rule)** was applied. This principle suggests that approximately 80% of the overall cost arises from 20% of the components or activities. By leveraging this approach, the team was able to:

- Identify high-impact components with the largest share of the project's cost.
- Prioritize cost-reduction strategies around these key items.
- Make informed decisions regarding material selection, sourcing, and manufacturability.

This targeted analysis enabled us to optimize the budget without compromising design quality or performance.

Based on the results of the Pareto analysis, a detailed cost breakdown of the essential components and associated labor was generated. These items represent the most financially significant aspects of the design.

COST ANALYSIS OF MANUAL BATTERY CHARGER (Pareto, 80-20 Principle)			
Quantity	Product	Cost Per Product	Total Cost Per Item
1,00	Compact Round-Face DC Motor	$ 124,17	$ 124,17
1,00	Bike Crank Arm, Bicycle Crank Arm	$ 16,24	$ 16,24
9 (Hours)	Labor Cost	$ 8,00	$ 72,00
1,00	Type C BMS for Lithium Battery	$ 12,99	$ 12,99
1,00	Overhead Cost (20% of total)	-	$ 45,08
	PARETO TOTAL (80% OF TOTAL COST)	$ 161,40	$ 270,48
		TOTAL COST	$ 338,09

Figure 22 Detailed Cost Analysis Table of The Design

To account for the remaining ~20% of project-related expenses (e.g., minor hardware, fasteners, packaging, contingency), the Pareto subtotal was multiplied by a factor of 1.25. This extrapolation yields a total project cost estimate of $338.09.

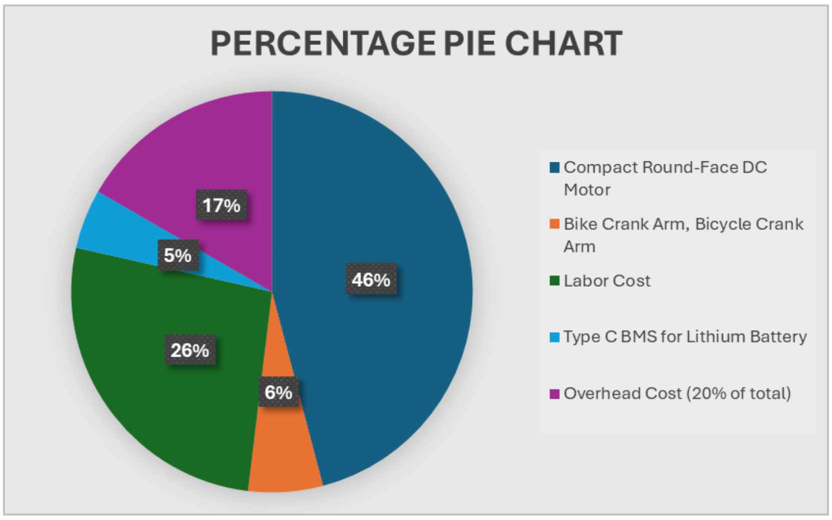


Figure 23 Percentage Pie Chart of Expenses

As illustrated in the figure, the pie chart offers a clear and concise visual representation of the overall cost distribution for the manual battery charger project. In alignment with the Pareto analysis methodology, the chart highlights the key components that dominate the total estimated cost.

The chart also includes an "Other" category, which represents approximately **20%** of the total cost. This segment encompasses minor, unitemized items such as fasteners, auxiliary wiring, packaging, and unexpected contingencies. Its inclusion reinforces the rationale behind the application of the Pareto Total in estimating the full financial scope of the project.

In conclusion, the application of Pareto analysis allowed for a focused and efficient estimation process, emphasizing the most critical cost elements. This approach supports better budget management and highlights areas for potential cost optimization in future iterations of the design.

3.3.4. ANSYS

Finite element analyses have been conducted for the two important parts of this project. The first one is the connecting rod (first lever) which provides connection between the slider and the second lever that converts linear motion into rotational motion thanks to cooperation with the connecting rod. The second part is coupling that aligns the axes of gearbox shaft and generator shaft.

1. Connecting Rod:

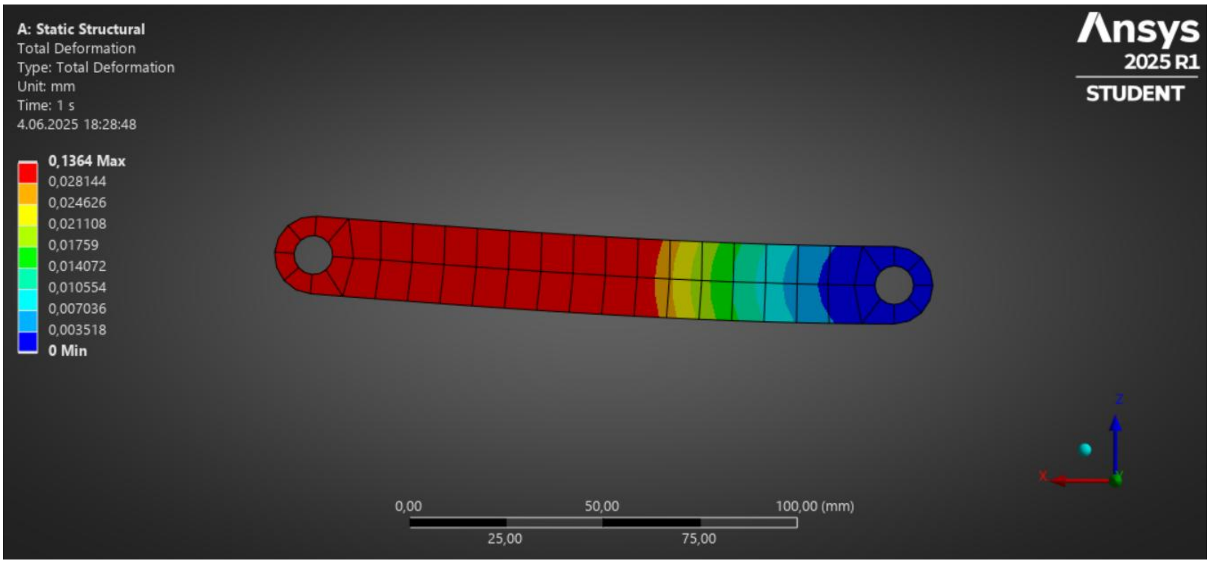


Figure 24 Total Deformation Analysis

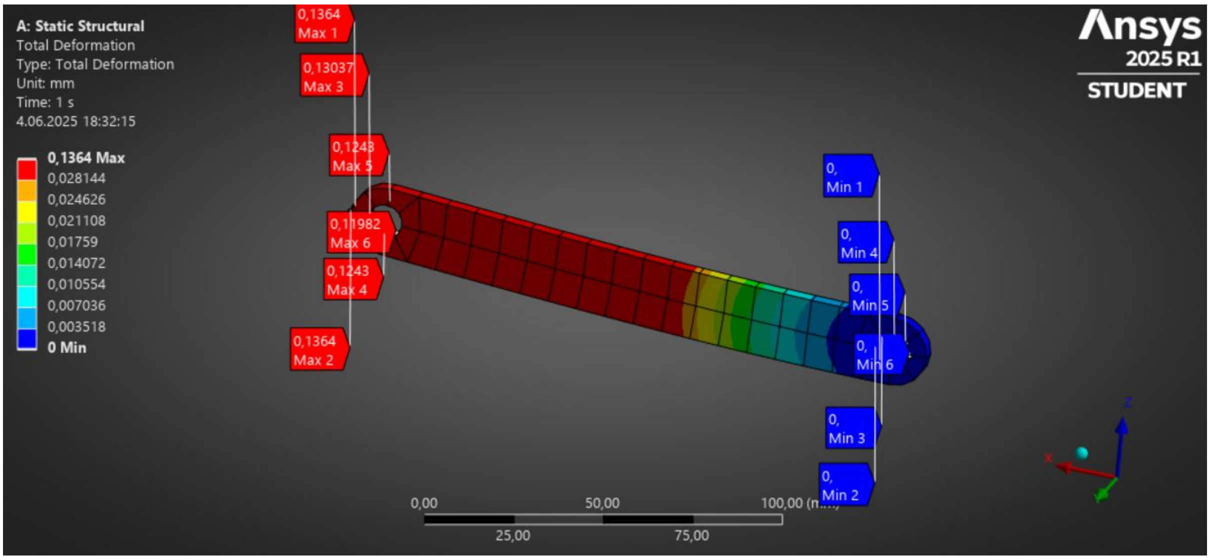


Figure 25 Local Min and Local Max Deformations

In Figure 1 and Figure 2, the right pinhole bounded as fixed support and 20 N*m moment is applied in clockwise direction from the center of the right pinhole. Ultimately, maximum deformation can be observed nearby of the left pinhole which is approximately equal to 0.1364 mm.

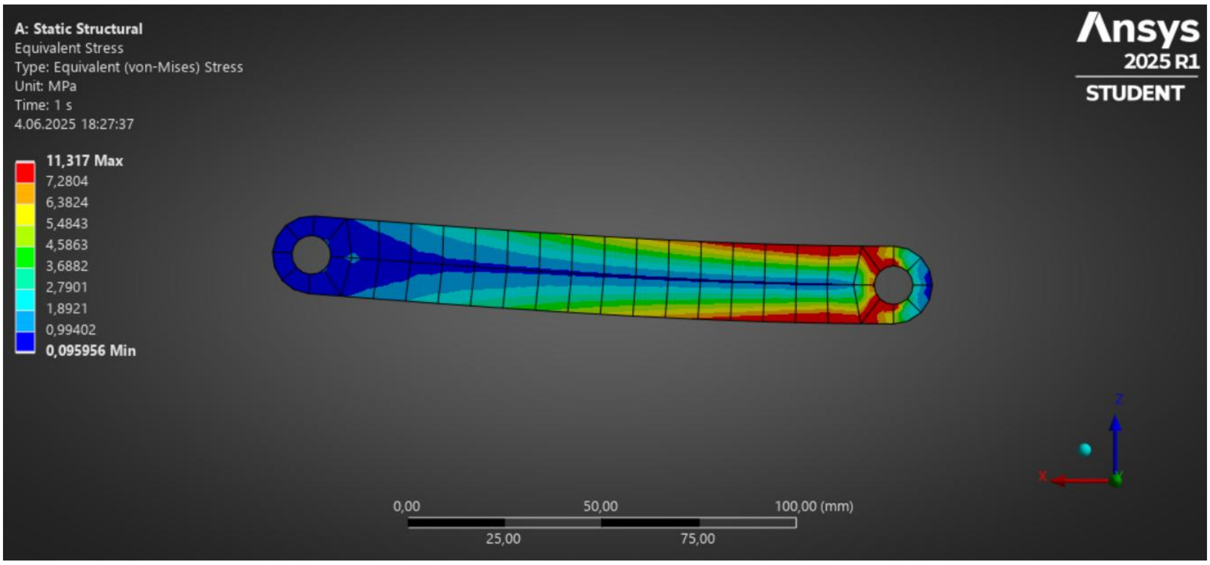


Figure 26 Von-Mises Stress Distribution of Connecting Rod

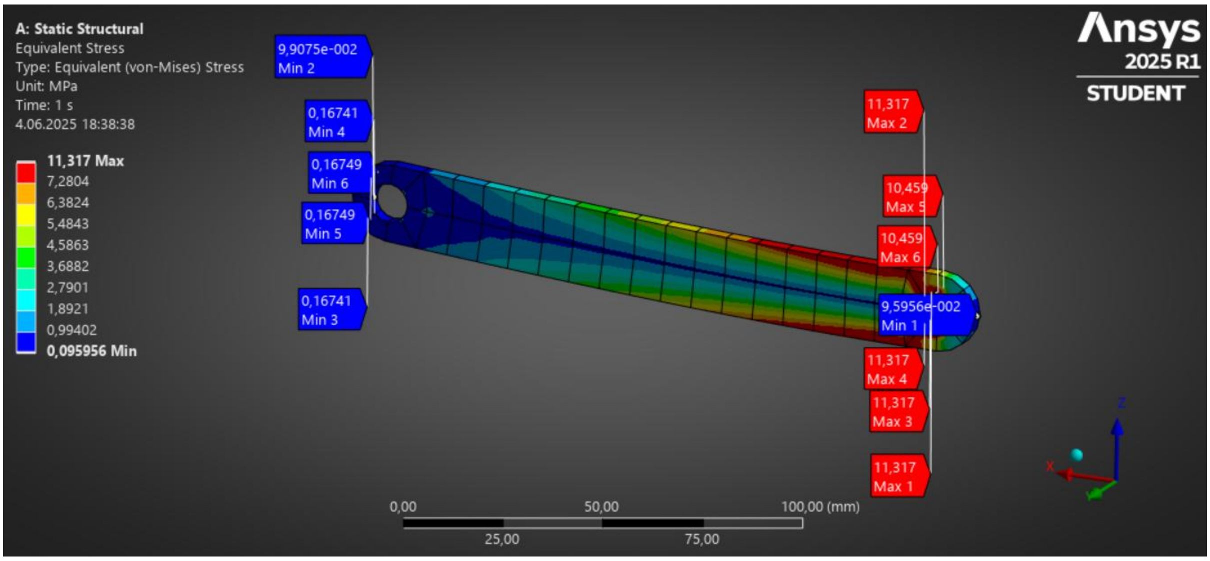


Figure 27 Local Max and Local Min Values of Von-Mises Stresses

In Figure 3 and Figure 4, the same moment is applied as it was described in the previous figures. Therefore, the following results were observed: the maximum von-Mises stress values were nearby of right pinhole and their values are approximately equal to 11.317 MPa.

Especially from Figure 4, local max and local min von-Mises stress values can be observed.

2. Coupling:

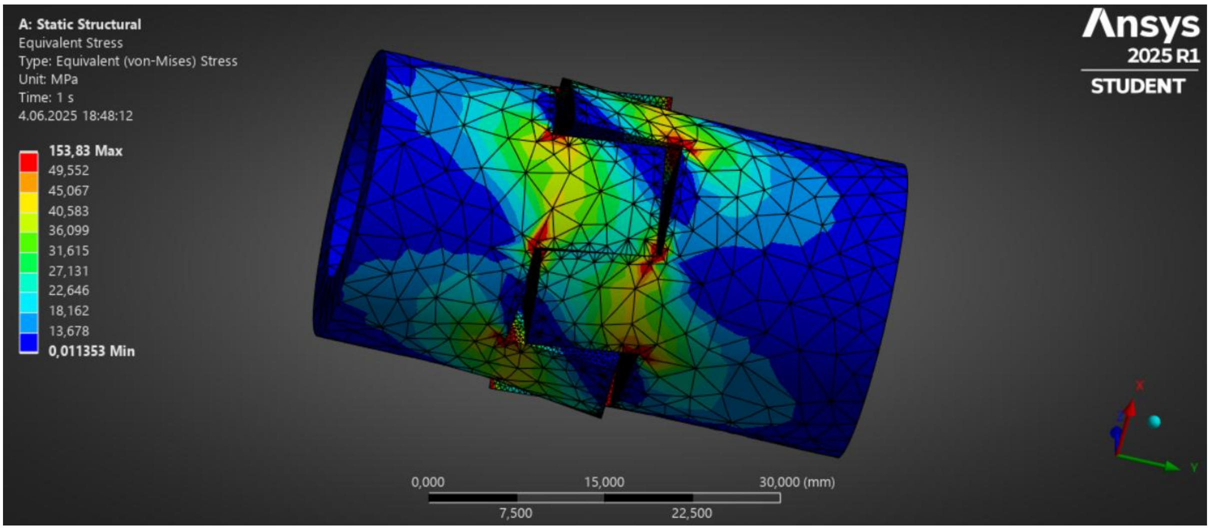


Figure 28 Von-Mises Stress Distribution of Coupling

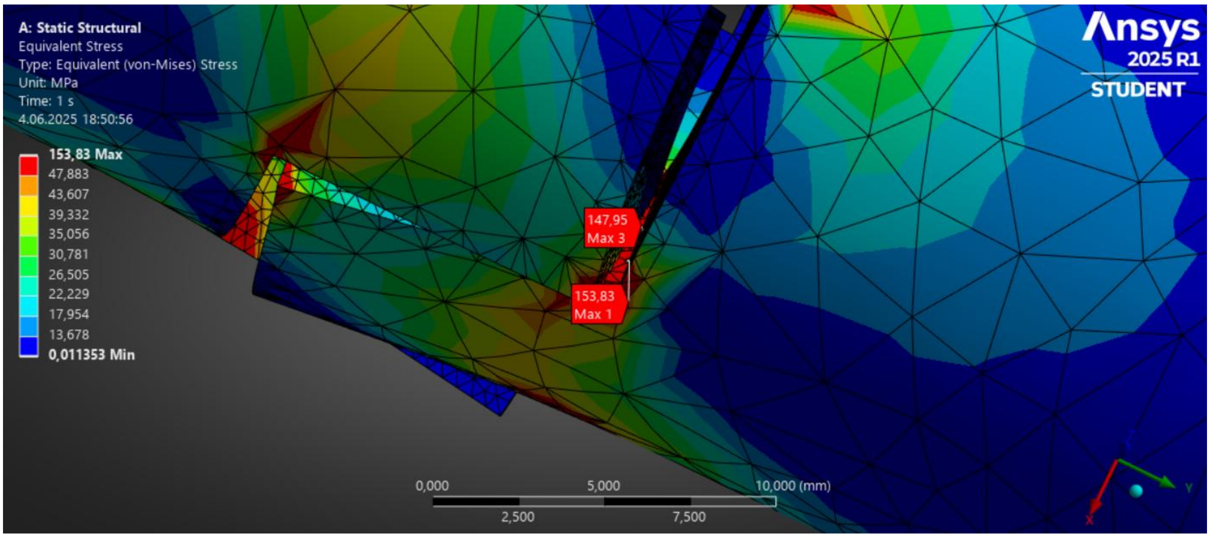


Figure 29 Local Max Points of Von-Mises Stresses of Coupling

Von-Mises stress distribution was shown in Figure 5. The maximum von-Mises stress values were observed on the roots of the teeth, as expected. In Figure 6, local max values of von-Mises stresses which were located on the roots can be observed.

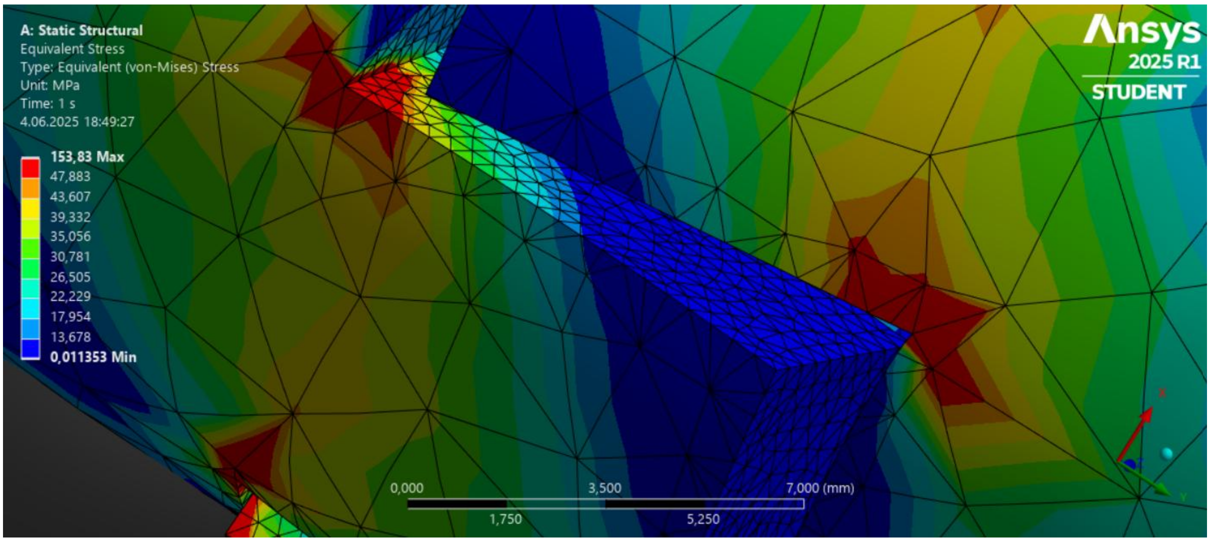


Figure 30 Specialized Mesh of Critical Points

In Figure 7, specialized mesh for the critical sections is created with lots of effort and they can be observed in the same figure.

3.3.5. Simulink

To better understand the dynamic behavior of the conversion of mechanical energy into electrical energy, a simulation in MATLAB/Simulink was conducted. The system was modeled from a sinusoidal mechanical force input down to the electrical output stored in the battery. The analysis assumes an ideal system with no resistive, frictional, and inductive losses. It focuses solely on energy conversion efficiency and fundamental physics.

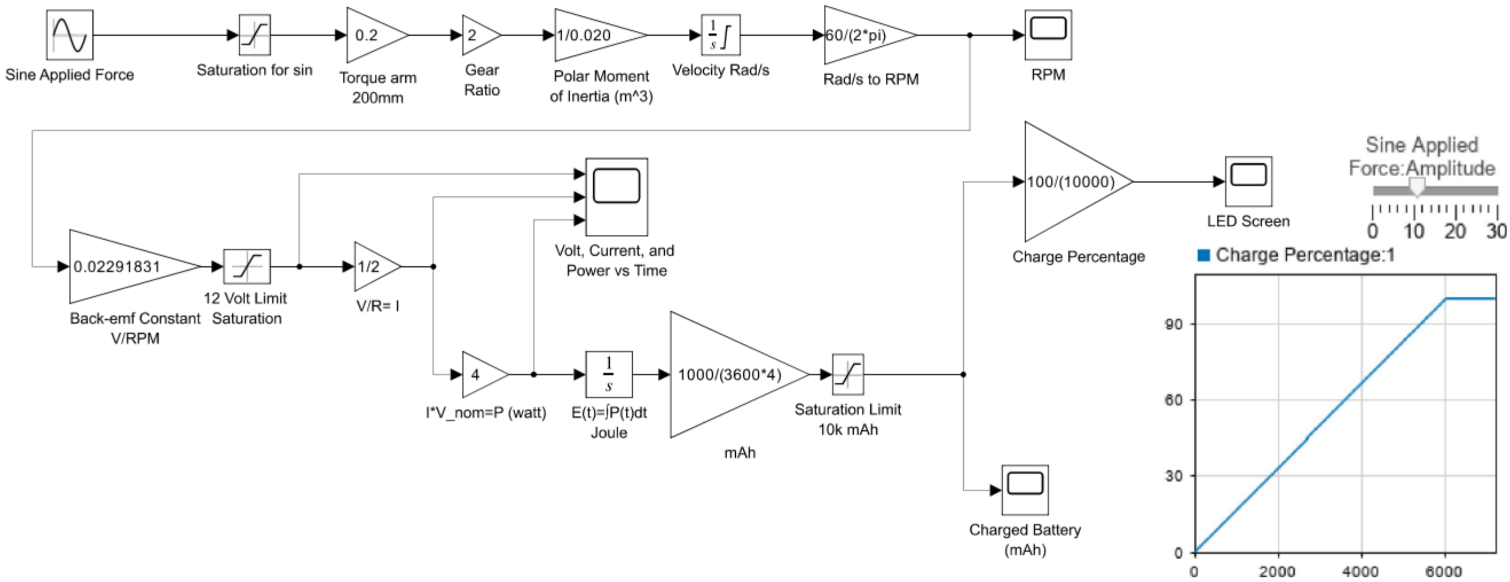


Figure 31 Simulink Model of The Design

The simulation begins with a user applied foot force which is converted into torque (τ = N.m) by using the moment arm (r = 200 mm) relation and F = 20 N where F is foot force and can be adjustable.

$$\tau = F \cdot r$$

This torque and the moment of inertia (J) are used to calculate angular acceleration using:

$$\alpha = \frac{\tau}{J}$$

After that, integration of the angular acceleration yields angular velocity:

$$\omega(t) = \int \alpha(t)\, dt$$

The angular velocity was converted to RPM to be used with the back-emf constant.

$$RPM = \omega \cdot \frac{60}{2\pi}$$

A gear ratio is applied to speed up the rotation of shaft which is connected to the generator. The resulting RPM is then used to calculate the induced voltage (Back-emf) with:

$$V = K_{\mathrm{e}} \cdot RPM_{gen}$$

Here, *Ke* is the back-emf constant of the generator in Volt/RPM, which was derived from the voltage and the maximum RPM of the generator. The voltage is capped using a **saturation block** to represent the maximum voltage allowable by the battery (12 V). The current is assumed to be linearly proportional to the voltage, and power is calculated using:

$$P = V \cdot I$$

This power is integrated over time to calculate the total **energy delivered to the battery**:

$$E(t) = \int P(t)\, dt$$

After converting the resultant value to mAh, a saturation limit of 10000 mAh was applied to simulate the capacity of the chosen battery. The energy stored and the charge percentage (%) was shown in a graph.

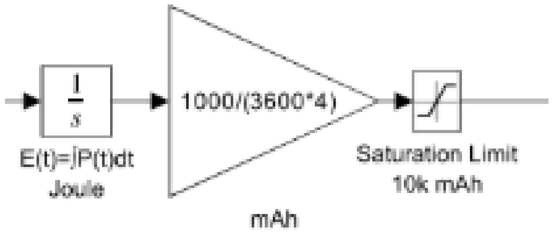


Figure 32 Stored Energy Blocks

After connecting the blocks of the formulae, the relevant values were put on scope blocks, enabling the visualization of the key variables such as RPM, voltage, power, stored energy, and battery percentage.

In the figure below, the generator's RPM has a stepped increase over time, which suggests that the input is applied in variable intervals. Eventually, the RPM stabilizes, showcasing the maximum RPM limit of the generator. The energy is supplied in bursts rather than as a continuous stream.

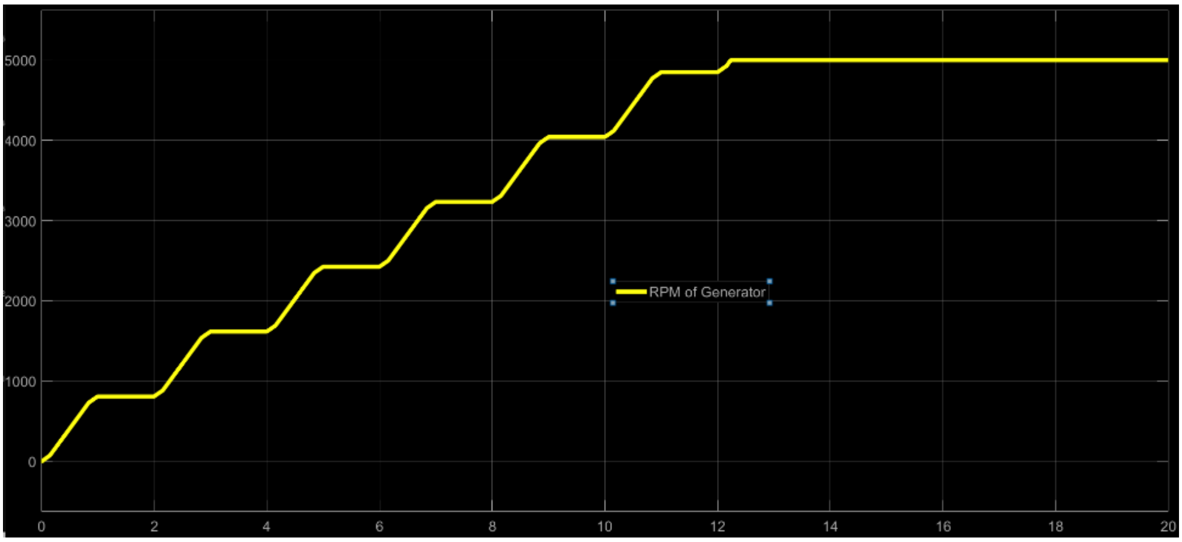


Figure 33 Time History Graph of Motor RPM

In the plot below, we see how the system reaches electrical steady-state conditions In the plot below, we see how the system reaches electrical steady-state conditions quite rapidly. Voltage is capped at a limit of 12 V. It represents a boundary for safe battery charging from the generator.

The current and power lines follow accordingly. The power curve reflects the product of the other two. This stabilization shows that the system quickly adapts to input changes and maintains safe, consistent delivery.

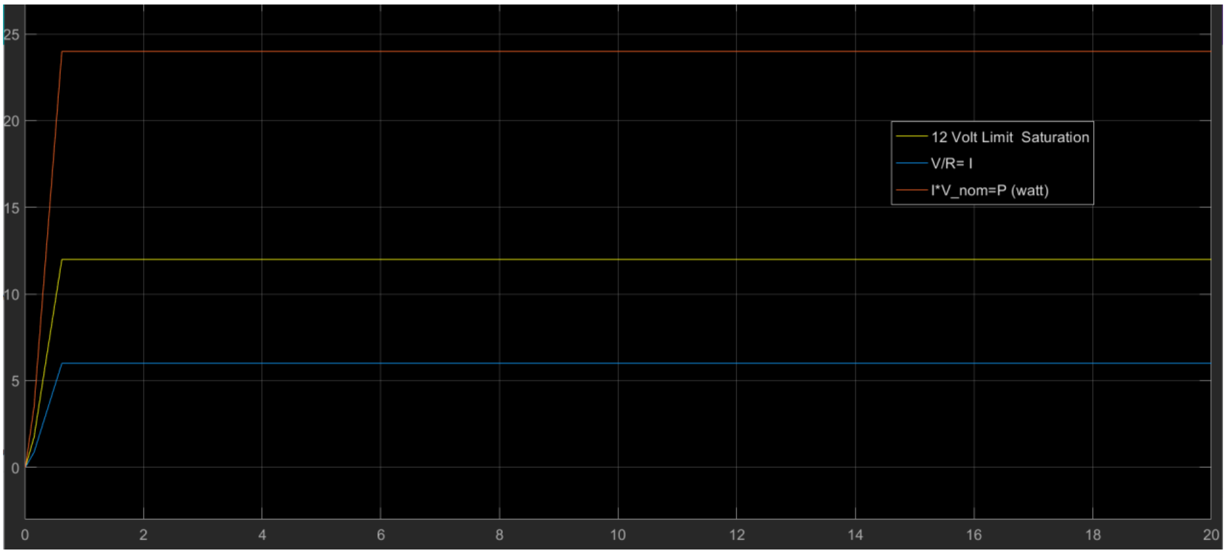


Figure 34 Time History Voltage, Current and Power

The time history of the charge percentage has a smooth and linear progression up to a saturation point. This implies that the electrical power output from the generator is relatively constant over time, despite the non-uniform RPM input seen before.

The steady increase reflects efficient energy conversion in an environment where there is no losses. The increasing trend ends at the full capacity. It indicates that the battery reaches full charge in 1 hour 40 minutes.

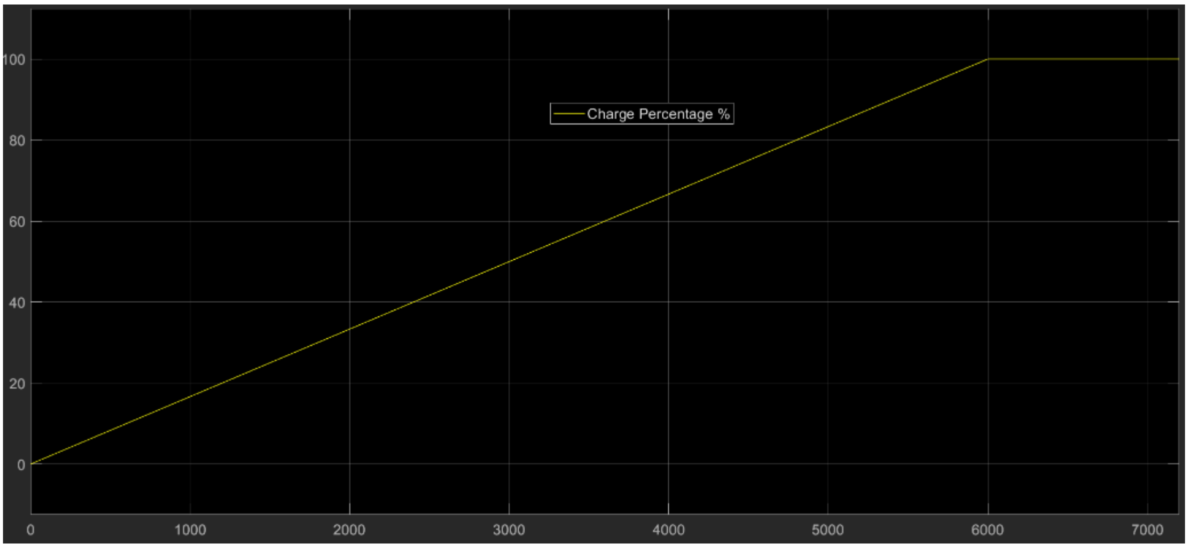


Figure 35 Time History Graph of Charge Percentage

The simulation mimics the dynamic behavior of a generator powered battery charging system. Despite non uniform input torque resulting in stepped RPM increases, the system reaches electrical steady-state conditions quickly. Overall, the results highlight the properties of the system while delivering reliable energy delivery.

4.Conclusion

The development of the manual battery charger throughout this project successfully addressed a critical need for emergency and portable energy generation. The project began by identifying specific problems related to current manual chargers on the market such as irregular current delivery, poor design quality, and lack of durability; and systematically worked toward overcoming them through well-defined design phases and practical engineering solutions.

The findings from patent reviews, market analysis, and external case studies such as the Encore Player helped validate the relevance of the chosen design. The selected design stands out because it balances simplicity with functionality. It does not rely on complex materials or require specialized environments. This makes it ideal for mass production and for use in real emergency kits.

The selected concept, the foot-crank generator, was chosen due to its simplicity, reliability, and user-centered features. Compared to other designs explored, such as piezoelectric insoles or dual-source stationary chargers, the foot-crank mechanism offered the best balance between portability, usability, and power generation capability. It also satisfied key constraints including weight, size, and voltage regulation, which were outlined in the early scope and objectives.

Mechanically, the design integrates several interdependent subsystems: a slider, crank mechanism, gear train, flywheel, coupling, and generator unit. These components were carefully modeled in Onshape, and technical drawings were produced for manufacturing readiness. The system was not only structurally feasible but also intuitive and ergonomic for human use. The detailed CAD and exploded views highlighted how the entire mechanical system is assembled, and how each part contributes to the intended motion and energy conversion.

Finite element analysis (FEA) was used to evaluate the structural integrity of two critical components: the connecting rod and the coupling. ANSYS simulations showed that both components were operating well within the material strength limits. Stress concentrations were observed near right pinholes and teeth roots of coupling, expected locations due to applied moment and load. These did not exceed failure criteria, confirming the reliability of the design under typical loading conditions.

The use of a flexible coupling between the gearbox and generator shafts further enhanced mechanical integrity and alignment accuracy. The detailed meshing and local stress examination supported the structural consistency of the design under expected loading conditions.

On the electrical side, MATLAB Simulink was used to simulate the energy conversion and battery charging process. From a user-applied sliding foot force, the simulation modeled the transformation from torque to angular velocity, then to RPM, voltage, current, and ultimately stored the energy in the battery. The simulation revealed how energy is delivered in steps, mirroring the physical act of sliding. Importantly, it confirmed that the voltage never exceeded the safe 12V upper limit, the current was steady, and the battery charge progressed in a smooth and predictable manner.

Battery charging was observed to reach full capacity in around 1 hour and 40 minutes, under ideal conditions. This timeframe is practical for real-world emergencies or camping scenarios. Moreover, the power output of 24W and USB-C compatibility makes the device suitable for modern electronics, including phones, radios, and flashlights.

Throughout the project, key engineering disciplines; including mechanical design, simulation and, electrical modeling were integrated effectively. Each phase built upon the last in a logical progression, from concept to virtual testing. Risks were considered in terms of structural failure, user safety, and energy delivery. Cost analysis ensured that the design remained within a reasonable budget while meeting performance criteria.

In conclusion, the foot-slider-crank manual battery charger developed in this project is a viable, functional, and necessary solution to current gaps in emergency power devices. Its durability, ease of use, and reliable electrical output offer real benefits for users in off-grid or urgent situations. Moreover, the development process serves as an example of how engineering design, when executed systematically, can provide meaningful solutions to real-world problems.

Future work can involve physical prototyping, incorporating regenerative braking or more efficient power electronics, and conducting user testing to further refine ergonomics and performance. However, as a final deliverable, this project demonstrates that manual energy generation is not only possible but can be made practical and effective through thoughtful design.

5.References

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