# A Solar-Powered Solution to Marine Plastic Pollution: Design and Implementation of an Automated Collection System

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**Abstract**

The rapid accumulation of plastic waste in oceans necessitates urgent and effective solutions for its remediation. This project focuses on the design and implementation of a solar-powered device aimed at collecting marine plastic pollution while minimizing labor and operational costs. Plastic pollution is increasingly recognized as a critical environmental challenge impacting coastal and marine ecosystems worldwide. The proposed device employs a thermal infrared camera to detect floating debris based on temperature differences. It is powered by solar energy, utilizing a battery, propeller, DC motor, thermal infrared camera, level sensor, and conveyor belt system. The conveyor belt transports floating plastics and waste into a square sieve collector, with collection levels monitored by the level sensor. The primary objective is to automate the ocean cleanup process, thereby enhancing efficiency in waste collection while protecting marine biodiversity. By employing automated detection and collection methods, this eco-friendly system aims to mitigate marine pollution and its detrimental effects on aquatic life.

**Key words:** Waste accumulation, Marine, Plastic Debris, Thermal Sensor, Conveyor, Plastic removal, Eco-friendly

## 1. Introduction

Water covers over two-thirds of the Earth's surface, with land comprising less than one-third. The benefits of plastic have led to a dramatic increase in its usage for health, safety, and energy applications. To date, over 7,800 million metric tons of plastic waste and fibers have been generated, with an estimated 150 million metric tons circulating in marine environments [1]. This project focuses on creating a portable aquatic device equipped with mechanisms to capture and store floating debris, enabling efficient disposal at shore or designated collection vessels. Common items found in waterways include empty bottles, plastic bags, and other debris. This project presents a functional, solar-powered prototype capable of autonomously collecting floating waste from the water's surface and depositing it into a floating bin. The device can be programmed for various sizes and operated remotely, ultimately reducing water pollution and minimizing harm to aquatic life [2]. The design emphasizes simplicity and cost-effectiveness, making it easy to maintain and operate under calm ocean conditions. Local sourcing of parts ensures accessibility for repairs, and the device can be powered by human effort or an electric motor powered by solar panels, providing a sustainable alternative to fuel-based models [3].

### 1.1.Ocean cleanup technologies

Numerous innovative technologies are emerging to combat plastic pollution in oceans. One notable example is Boyan Slat's Ocean Cleanup System, which utilizes passive methods to capture and remove plastic waste from marine environments. Seabin Technology deploys floating bins equipped with pumps to filter out debris, microplastics, and oils in marinas and ports. Similarly, the "Mr. Trash Wheel" technology targets plastic and debris in rivers, preventing them from reaching oceans. Drones and autonomous vehicles have revolutionized cleanup efforts by enhancing monitoring, identification, and collection capabilities [4]. Community-based initiatives actively engage local populations in addressing coastal plastic pollution. The Bubble Barrier technology captures and redirects plastic waste in rivers, preventing it from entering open seas. Additionally, FRED (Floating Robot for Eliminating Debris) is a solar-powered robotic collector designed for picking up debris ranging from 3 centimetres to 2 feet in size. Aquatic drones equipped with artificial intelligence represent a cutting-edge approach to identifying and removing plastic waste from marine environments.

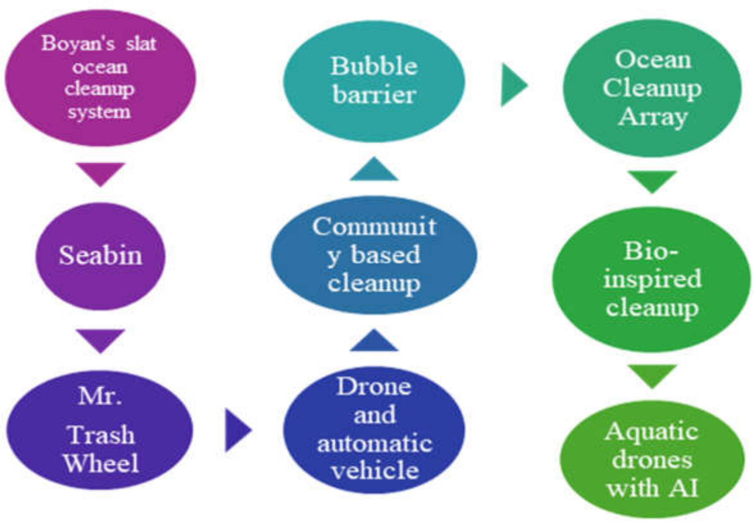



**Fig. 1: Shows on various Ocean Cleanup Technologies**

Plastic pollution poses a significant threat to our oceans, highlighting the urgent need for creative and effective cleanup solutions. A variety of advanced technologies have been developed to confront this pressing environmental issue. These range from autonomous robotic systems to community-based initiatives and biomimicry-inspired designs, each offering distinct advantages and capabilities in the fight against marine plastic waste. This paper provides a brief overview of these technologies, detailing their respective benefits and limitations [5,6]. Here Graphical representations (Fig.2) shows that ocean cleanup technologies used in various countries %.

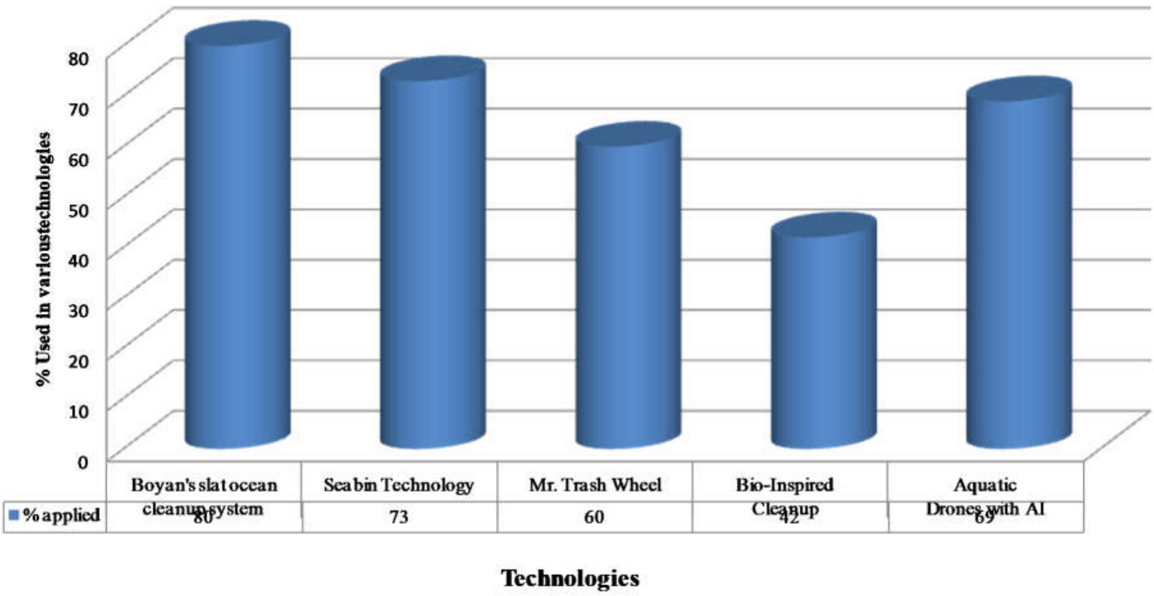



**Fig 2: Graphical representations shows that ocean cleanup technologies used in various countries %**

In this study, the following limitations are highlighted, drawing on reports from previous research that have explored various technologies applied to marine waste cleanup:

**Effectiveness in Harsh Ocean Conditions**

The device may exhibit reduced efficiency in turbulent or rough sea environments. Its performance could be hindered in areas with frequent storms, high waves, or strong currents, as the operational stability of the solar-powered system may be compromised.

**Reliance on Solar Energy**

Since the system is solar-powered, its energy supply may be insufficient during periods of prolonged cloud cover or in regions with low sunlight, leading to potential power shortages that affect the system's operational performance.

**Scalability for Large-Scale Cleanup**

The current design might face limitations in addressing large-scale marine pollution due to its size and operational constraints. The device may struggle to handle the immense volume of plastic waste in highly polluted zones, reducing its efficiency in these regions.

**Maintenance Requirements**

Although the system is designed to minimize human intervention, it may still require regular maintenance due to wear and tear from exposure to seawater, salt, and debris. Critical components, such as the conveyor belt, motor, and sensors, may require upkeep over time.

**High Costs and Limited Scalability:**

Deploying multiple units of the system could be costly. The financial feasibility of scaling up the technology to cover large marine areas may be a significant barrier, especially for smaller communities or organizations with limited budgets.

**Environmental Impact of Construction Materials**

While the device is powered by solar energy, the materials used for its construction such as plastics, metals, and electronics could offset some of its environmental benefits if they are not sustainably sourced, raising concerns about the overall ecological footprint.

**Detection Limitations of Thermal Infrared Camera**

The thermal infrared camera employed to detect floating debris might have a limited range, possibly failing to detect smaller or submerged plastic particles. This could reduce the effectiveness of the device in certain marine environments where debris is less visible or submerged. To enhance the effectiveness of solar-powered marine waste collection devices, several research gaps need to be addressed. Improving energy efficiency through the exploration of alternative energy systems could help mitigate solar power limitations in areas with low sunlight. Optimizing the device for rough ocean conditions by enhancing its structural design, stabilization mechanisms, and durability is crucial for improving its performance in harsh environments. Additionally, scaling the system for large-scale operations, could address the challenges of highly polluted areas. Advancements in detection technology, such as AI-based image recognition or upgraded infrared sensors, could improve the device's ability to detect smaller or submerged plastics. Further studies on the long-term environmental impact are necessary to ensure the device does not negatively affect marine ecosystems. Exploring sustainable materials for construction would minimize the ecological footprint, while research into cost-effective designs and modular components could enhance economic viability and accessibility. Finally, developing fully automated systems with remote monitoring capabilities would improve operational efficiency by reducing human intervention and enabling real-time management. The objective of this research is to design and implement a solar-powered device for efficient marine plastic collection, focusing on minimizing labor and operational costs. The study aims to enhance environmental sustainability by automating the cleanup process and mitigating the harmful effects of plastic pollution on marine ecosystems.

## 2. Materials and Methodology

### 3.1 Materials

***Carbon Fiber***

Carbon fiber is renowned for its exceptional strength-to-weight ratio, making it an ideal choice for applications where lightweight materials are crucial. Its inherent corrosion resistance enhances longevity, particularly in harsh environments, while its fatigue resistance contributes to durability under repetitive stress. Additionally, carbon fiber exhibits low thermal expansion and high stiffness, making it suitable for applications that require dimensional stability under varying temperatures [7].

***Aluminum Alloy***

Aluminum alloys offer an improved strength-to-weight ratio compared to pure aluminum, making them a popular choice in aerospace and automotive industries. They possess increased corrosion resistance, which extends the material's lifespan when exposed to the elements. Enhanced durability and better weldability are significant advantages, allowing for versatile applications in construction and manufacturing. Furthermore, aluminum alloys demonstrate higher temperature resistance, ensuring structural integrity even in elevated thermal conditions.

***Titanium***

Titanium is characterized by a high strength-to-weight ratio, which is particularly advantageous in applications demanding robust materials without adding significant weight. Its excellent corrosion resistance, especially in seawater and chlorine-based acids, makes it a prime candidate for marine and chemical applications. With a low density (approximately 60% that of steel) and a high melting point (1668°C or 3034°F), titanium maintains its properties under extreme conditions. Additionally, its biocompatibility makes it suitable for medical implants, and its non-magnetic and non-toxic nature adds to its versatility in various fields.

***Acrylic Plastic***

Acrylic plastic is a transparent and impact-resistant material, valued for its lightweight and manageable nature. It offers excellent optical clarity and UV resistance, making it suitable for applications requiring transparency and light transmission. The material can be molded, extruded, or cast into various shapes, providing designers with considerable flexibility. Moreover, acrylic plastic exhibits resistance to chemicals and weathering, ensuring durability in outdoor applications.

### 3.2 Methodology

**Step 1: Data Collections**

The initial phase of this project involved conducting a thorough review of scholarly articles and journals pertinent to the subject of ocean cleanup technologies. This literature review was instrumental in refining our project ideas and incorporating innovative concepts into our design approach. By critically analyzing existing research, we aimed to identify gaps in knowledge and explore potential improvements that could enhance the effectiveness of our ocean cleanup device.

**Step 2: Material Selection**

Following the journal collection, we meticulously selected materials based on the insights gained from our research. The chosen materials for our ocean cleanup device include carbon fiber, aluminum alloy, titanium, and acrylic plastic. Carbon fiber is recognized for its high strength-to-weight ratio, making it ideal for lightweight and durable applications. Aluminum alloy offers improved corrosion resistance and strength, while titanium is valued for its exceptional durability and resistance to harsh marine environments. Acrylic plastic contributes transparency and impact resistance, allowing for versatile design possibilities.

**Step 3: Components List**

The successful assembly of the ocean cleanup device requires various components that work synergistically to achieve efficient waste collection. Key components include an aluminum sheet, shaft, ball bearing, aluminum strip, DC motor, marine DC battery, thermal infrared camera (TIC), level sensor, conveyor belt, square-shaped sieve, propeller, and solar panel. Each component plays a crucial role in the overall functionality of the machine, ensuring seamless operation and effective debris collection from the water surface.

**Step 4: Design of the Ocean Cleaning Device**

In the design phase, we conceptualized a structure that integrates various components for optimal performance. The thermal infrared camera is strategically mounted at the front of the device, adjacent to the solar panel, to enhance visibility and functionality. The conveyor belt is positioned at the bottom front, facilitating the movement of collected debris into a square sieve designed to capture waste efficiently. Additionally, a DC motor and sensor panels are arranged to ensure smooth operation, with the level sensor set to the appropriate depth for effective waste collection. To enable mobility, two propellers are installed at the rear of the device, connected to the motors for propulsion.

**Step 5: Operation of the Ocean Cleaning Device**

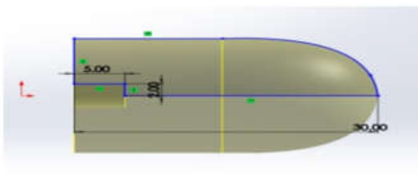
The operational mechanism of the ocean cleaning device relies on advanced technology to ensure efficient waste detection and collection. The thermal infrared camera is employed to identify floating debris by detecting variations in temperature. The entire system is powered by solar energy, with the battery, propellers, TIC, level sensor, and conveyor belt working in harmony through a DC motor. As the device navigates the water, the conveyor belt transports floating plastics and other waste into the square sieve collector, while the level sensor continuously monitors and regulates the collection process to optimize efficiency.

**Step 6: Advantages over Existing Devices**

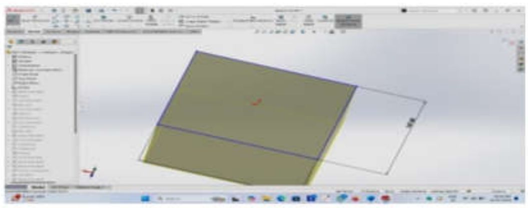
The proposed ocean cleanup device presents several distinct advantages compared to existing solutions in the market. One of the primary benefits is its automated cleaning and waste collection capabilities, which significantly decrease the labor needed for marine cleanup efforts. Furthermore, the device actively contributes to the protection of ocean ecosystems and biodiversity through effective plastic removal. The inclusion of a thermal infrared camera enhances the accuracy of debris detection, providing added convenience for users. Additionally, as an environmentally friendly system powered entirely by solar energy, this device offers a sustainable solution to mitigate marine pollution and its detrimental effects on aquatic life.

### 3.3 Components Description

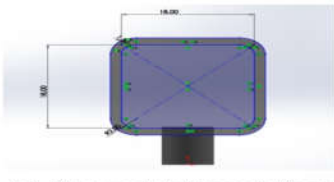
The ocean cleaning device is composed of several integral components that contribute to its functionality and effectiveness. The DC motor serves as the driving force behind the conveyor belt and propellers, facilitating both movement and waste collection. A DC battery stores the solar energy harnessed by the system, ensuring reliable operation throughout the cleaning process. The thermal infrared camera plays a vital role in detecting floating debris by leveraging temperature differentials. A level sensor is utilized to monitor the fill level within the sieve container, optimizing the efficiency of the collection process. The conveyor mechanism effectively transports collected debris into the designated storage area, while the propeller enables the device to navigate the water surface. Finally, the sieve container collects and retains the floating waste, and the solar panel provides the necessary energy to power the entire system, making it a self-sustaining solution for ocean cleanup.




**(a) DC Motor**



**(b) Marine Battery**



**(c) Thermal Infrared Camera**

**(d) Level Sensor**

**(e) Conveyor Mechanism**

**(f) Propeller & Solar panel**

**Fig. 3 : Shows (a) DC Motor, (b) Marine Battery, (c) Thermal Infrared Camera, (d) Level Sensor, (e) Conveyor Mechanism, (f) Propeller & Solar panel**

**DC Motor**

At the rear of the model, two 12-volt DC motors are installed to facilitate movement and operation of the device. DC motor have been designed by the required dimensions as shown in fig. 3 (a). These motors are essential for transmitting energy to the conveyor belt and propellers located at the back of the device. A waterproof DC motor have IP28 protection grade with 6000 W power. This DC motor can be made from titanium and plastic for underwater use.

**DC Battery**

A 12V (1.2 Amp) DC battery is incorporated to store energy for operational use. Positioned below the top surface of the model as shown in fig. 3 (b) & fig. 4, this maintenance-free sealed marine battery provides reliable energy storage, allowing the device to function efficiently during working periods. The battery is charged through solar energy or direct battery charging, ensuring a consistent power supply to the motor and other components.

**Thermal Infrared Camera**

The thermal infrared camera, also referred to as a thermal imager, is a critical component for detecting floating waste materials. It is designed to considering some features such as focuses of lens, sensors, housing and detector response as demonstrated in fig.3 (c). By measuring the infrared energy emitted by objects, the camera converts this data into electronic images that indicate the apparent surface temperature of detected items. This functionality enables the identification of various waste materials, such as plastic covers, empty bottles, and other debris, facilitating automated detection of floating waste in the water.

**Level Sensor**

The level sensor is designed to monitor the quantity of waste collected within the sieve container. When the container reaches its capacity, the sensor detects the waste level and triggers a notification. This sensor is equipped with a transmitter that operates wirelessly via Bluetooth, allowing users to view real-time data on waste levels and overall system status. It outputs a signal in the range of 4-20 mA and is capable of measuring waste levels up to 15 meters as shown in fig.3 (d).

**Conveyor Mechanism**

A conventional conveyor belt is employed to transport the collected plastic waste from the front of the device to the sieve container. This belt is supported by a series of rollers or idlers and is driven by a motorized pulley system. As the conveyor belt operates, it effectively facilitates the movement of debris, ensuring that waste is efficiently directed into the collecting sieve container.

As conveyor system become wider, faster, longer and designed by considering the space and distance required to cover as you can see in fig. 3 (e).

**Propeller**

The propellers of the device are essential for providing navigation and direction. The drive shaft, made of either rod or tube, transmits rotational energy from the gear motor to the propellers. Constructed using fiber with metal plates affixed externally, the propellers are designed for durability and efficiency. The direction of rotation, diameter, rotational speed and performance parameters propeller is outlined and refer Fig. 3 (f). Additionally, the impeller components are fabricated from metal sheets, shaped to the required dimensions, enhancing the device's ability to manoeuvre through water.

**Solar Panel**

The energy system of the Potato Harvesting Device is powered by an 18V, 5-watt solar panel, which converts sunlight into electricity using photovoltaic (PV) cells. This solar panel generates a direct current (DC) output of 18V, which is then directed to DC regulators. These regulators manage the voltage supplied to the battery, ensuring that it charges effectively. The solar energy harnessed by the panel powers the sensors, motherboard, and motors, contributing to the sustainability and energy efficiency of the device. Calculation of usage kilowatt per hour, peak sun hours, and mounting structure a solar panel is designed as shown in fig. 3 (f). The solar panel utilizes crystalline silicon-type solar cells, which are among the most common and effective forms available.

## 3. Results and discussions

Framing plastic pollution as a resource problem is based on the idea that we are losing valuable materials when using plastics in short-lived products, such as packaging and single-use items. Such framing is closely connected to the waste problem as waste management is transforming into resources management [7]. The major objective of this work is designing the ocean cleaner, by considering various factors which will influence the performance of the machine. The model is designed and then the procedure is studied and optimization is done for effective automatic wireless controlled ocean cleaner. In this research work the major task of this equipment is to remove the trash from the surface of the ocean and discard them in the container. Here we are designing the ocean cleaning machine which is remote operated. The chain drives and collecting plates are rotating by the motor continuously. A collecting plate which is coupled between the two chains drives for collecting the materials which are waste from marine. The wastes which are collected are thrown on the collecting tray with the use of conveyer. Our work is having DC motor with propeller arrangement which is used to control the direction of the model. This work consists of a sensors which is operated by motor. It is having two Direct current Motor. The model is having two shafts. The Shafts are used for the purpose of hoisting and to balance the chain drive sprocket. The parts resting on the structure is the important feature of the model. Level sensor is used for determining the amount of waste collected in the collective container. The floating wastes like plastic covers, empty water bottles, garbage's and other waste materials are detected by the thermal infrared camera which senses automatically.

### 3.1. Experimental Analysis

The experimental analysis of the ocean cleaner focuses on its operational efficiency, primarily driven by the rotation of a chain belt conveyor. The system incorporates a low-speed, high-torque motor mounted on the upper shaft, which powers the conveyor mechanism. The design and assembly of the model have been meticulously crafted to facilitate an effective and automated ocean cleanup process that can be remotely controlled. The primary objective of this device is to efficiently remove debris from the ocean's surface and transfer it to a designated sieve container.

In this setup, the chain drives and collecting plates are continuously rotated by the motor, enabling seamless waste collection. The conveyor plate, strategically positioned between two chains, is responsible for gathering the floating waste materials prevalent in marine environments. Collected debris is subsequently directed into the collection container via the conveyor system. The design also features a DC motor equipped with a wheel arrangement, which provides the necessary control for manoeuvring the model. Additionally, the device is powered by two DC motors, one of which operates the propeller, allowing for enhanced mobility and functionality.

The specifications of the components contribute significantly to the overall performance of the ocean cleaner. The DC motor operates at a speed of 30 RPM and has a power output calculated using the formula $P=V\times IP = V$. With a voltage of 12V and a current of 7.6A, the power output is calculated as follows:

$$P=12\ V\times 7.6\ A=91.2$$

Similarly, the DC marine battery also provides essential power, rated at 12V and 7.5A, leading to a wattage of:

$W=12\ V\times 7.5\ A=90$ W/h. The belt conveyor, designed with a length of 600 mm and a width of 300 mm, supports a belt thickness of 100 mm. Its carrying capacity can be estimated using the formula:

$$M=\rho\times K(0.9B-0.05)2V$$

Here, $\rho$ represents the density of the belt material, which is approximately 1500 kg/m³. The shaft, crafted from titanium, has a diameter of 20 mm and a length of 300 mm, ensuring strength and durability during operation.

The propeller, which is critical for propulsion, has a radius of 7 cm, with six impeller blades each measuring 15 cm in length. The torque exerted by the propeller can be calculated using the formula:

$$T=F\times r$$

Finally, the solar panel utilized in the design is made from polycrystalline silicon, with a maximum output voltage of 7.2 volts and a power output of 3 watts. The dimensions of the solar panel are 230 mm by 140 mm, contributing to the energy sustainability of the device.

Overall, the analysis underscores the effectiveness of the designed ocean cleaner, highlighting its innovative features and operational parameters that collectively contribute to efficient marine waste management.

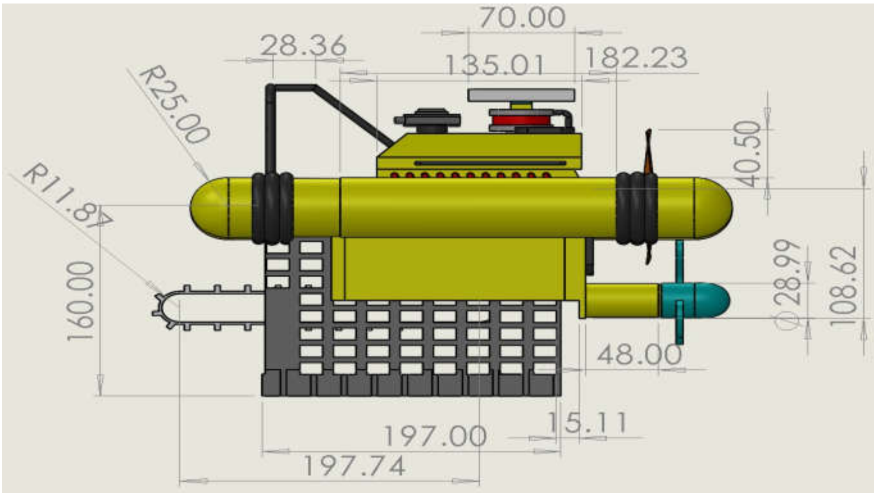



**Fig no 4: Shows the finalized Design chain-type drive mechanism**

The ocean cleanup model employs a chain-type drive mechanism, equipped with a collector sieve container designed to efficiently gather floating debris. The model consists of two shafts, which play a crucial role in hoisting the device and ensuring the stability of the chain drive sprocket. This structural design enhances the overall functionality and reliability of the system, allowing it to operate effectively in challenging marine environments. The integration of these shafts not only supports the weight of the device but also facilitates smooth operation, making it an essential feature of the model.

The operational analysis reveals that the ocean cleanup device successfully minimizes manual labor while maximizing efficiency in waste collection. This innovative approach significantly reduces the physical strain typically associated with marine cleanup efforts. The system is designed to operate autonomously, demonstrating reliability in stabilizing itself within the ocean while effectively removing waste materials. The successful implementation of this project aligns with environmental sustainability goals, showcasing its potential to make a positive impact on local ecosystems.

The device is capable of collecting trash from various water bodies, including lakes, rivers, and ponds, effectively addressing the problem of aquatic pollution. It incorporates a wireless remote control system, allowing for convenient operation without the need for direct human intervention. This feature not only streamlines the waste collection process but also reduces the risk associated with manual labor in potentially hazardous environments.

Utilizing solar power as its energy source presents significant advantages, enabling the device to harness renewable energy and operate in an environmentally friendly manner. This aspect of the design reinforces the project's commitment to sustainability, as it minimizes reliance on fossil fuels and decreases the carbon footprint associated with waste collection operations.

Additionally, the automatic functionality of the system ensures a reduction in operational time compared to traditional methods. The emphasis on using locally sourced materials further enhances the project's sustainability and encourages local production practices, which can stimulate economic growth within the community.

## 4. Conclusion

In conclusion, the ocean cleanup device represents an innovative solution for minimizing manual labor while effectively addressing marine pollution. The project's successful execution demonstrates its reliability and effectiveness in stabilizing waste collection efforts in aquatic environments. By providing a means to collect trash with minimal human intervention, the device not only enhances operational efficiency but also promotes environmental sustainability. The implementation of solar power further underscores its eco-friendly design, contributing to the protection of marine life from the adverse effects of pollution.

This system significantly reduces the need for human labor in waste collection, minimizing direct contact with hazardous materials and enhancing safety for workers. Its automated operation also leads to quicker and more efficient cleanup processes compared to conventional methods. Ultimately, the project aligns with broader environmental goals, contributing to cleaner oceans and healthier ecosystems while emphasizing the importance of using local materials and promoting sustainable production practices.

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