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Boat-Mounted Debris Capture for Sustainable Rivers

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A B S T R A C T

Plastic and solid waste endanger rivers worldwide. Existing collection methods are labor-intensive. This paper proposes a novel boat-mounted system for collecting river debris. The research focuses on design, development, and evaluation. Key aspects include optimizing collection mechanisms (skimmers, intakes), evaluating efficient storage (mesh bags, bins), and developing secure boat attachment. Material selection will be justified. Following design, the paper details construction of a functional prototype, outlining relevant design tools and fabrication techniques. Testing and evaluation are critical. The methodology for assessing the prototype's functionality and effectiveness in collecting debris will be presented. Testing may occur in controlled environments or simulate real-world conditions. The analysis will focus on collection efficiency, impact on boat stability, and ease of deployment/retrieval. Based on findings, potential design improvements will be identified. This project offers a potentially cost-effective solution for plastic pollution in rivers. The system could benefit stakeholders in environmental remediation, preventative measures in tourism/recreation, and organizations focused on clean waterways.

Keywords: Debris; Skimmer; Sustainability; Environment.

1. Introduction

Rivers are an important part of human lives. But unfortunately, only few are aware of its importance. The proof of tons of trash in our rivers and creeks, making it look and smell like a dumpsite. The garbage in rivers is more than just an eyesore because it can possibly contaminate our drinking water and threaten nature, our lives, and that of our loved ones. Even a piece of litter thrown on the street may contribute to the piling garbage in our rivers and creeks. Rivers remain an important source of drinking water for many towns and cities. The water is purified first before it reaches our tap. However, if our rivers remain polluted, the water can't be purified to the extent that it won't be suitable for human consumption anymore. It is crucial to look after our river systems and protect them from pollution so we want them to keep on flowing to our taps. Rivers provide habitat to a wide range of animal and plant species. However, these species are already critically endangered due to the rapid deterioration of our rivers. These endemic species, which can only be found in the Philippines, may be saved if we clean up our rivers. Clean, healthy rivers reduce human health risk and improve quality of life. Less trash increases recreational activities along rivers clean and safe walk and run trails for the community. As recreational activities increase, tourists will be attracted. This affects both the economy and well- being of the community. We Could draw inspiration from Iloilo City. How they successfully revived their main river and built a beautiful Esplanade, the first of its kind in our country, with their key guiding principles of “unity, strategic planning, and political will”. It's all up to us to make it happen. As human and industrial waste and garbage add up to the river pollution, each of us can do small things to help clean up our river and that adds up to the pollution solution.

2. Methodology

As water is one of the most important factors for the survival of mankind on this planet it's our duty to keep the resources clean, which nowadays is becoming dirtier eventually and this was the problem identified in the identification stage. Then in the literature review stage, we reviewed research papers and online resources on existing boat-mounted waste collection systems, focusing on their collection mechanisms (skimmers, conveyor belts), waste storage methods (mesh bags, bins), and attachment systems (transom mounts, davit systems). Based on the problem identification and literature review the apparatus for the collection of the debris was designed. Then the calculations were made to select the required components. After the fabrication work of our apparatus with the proposed design the performance, efficiency, speed of the collection and also the load carrying capacity of the boat will be tested. The proposed design procedure includes assembling the apparatus over the hull of the boat. This is followed by the adjustment of the screw rods in order to have a proper fit over the hull. The main parts of the apparatus like the conveyor and the angle of the conveyors are operated electrically. Torque command is provided to the motor using potentiometer, electrically. In order to power the motor a suitable battery pack is placed in the boat. Battery is customized with the help of cells joined together in series. Motor and Battery are connected in series with a series of controllers.

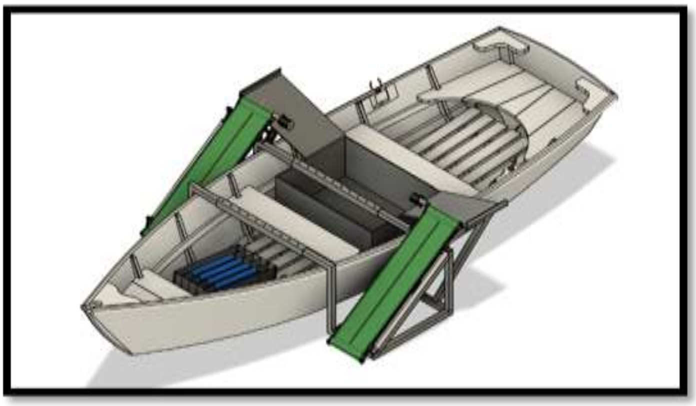

Fig. 1. *CAD Model of boat mounted debris capture mechanism*

Once CAD models are ready, they are assembled together to find out the best optimized positions for actual assembly of the kit. We have tried various configurations out of which the best one is in fig. no., where customers can enjoy larger boot space and the battery pack is also safe, and protected.

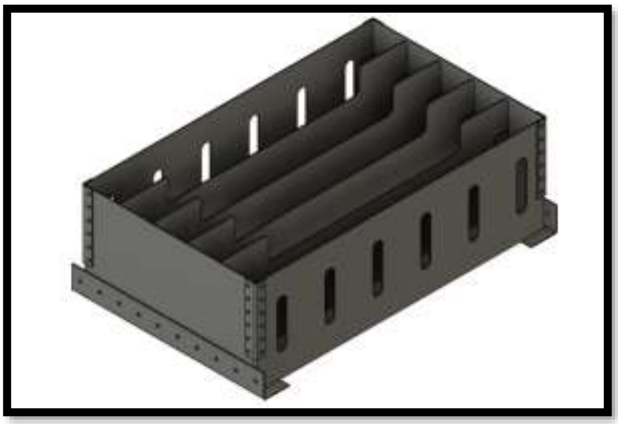

Fig. 2. *Design of battery pack case*

Fig. 3. *Conveyor design*

The popular battery technologies till date are lead-acid, nickel-cadmium, nickel metal hydride, and Lithium-ion (Li-ion) battery. Li-ion battery technology is considered superior to all other battery technologies because of their high operating cost. While different collection mechanisms can be employed (skimmers, subsurface intakes), a conveyor belt can be a vital component in a boat-mounted solid waste collection system for continuous collection, handling a variety of debris, improved sorting potential, efficient discharge into storage unit, and adaptability to different designs.

2.1 Analysis and Results:

The project will delve into recent research advancements that address some of the identified knowledge gaps. This includes studies on optimizing skimmer design through computational fluid dynamics simulations, life cycle assessments to evaluate environmental impact and economic feasibility, and the exciting potential of integrating artificial intelligence for real-time debris classification and route optimization.

<table>
<tr><td>Fixture name</td><td colspan="2">Fixture Image</td><td colspan="3">Fixture Details</td></tr>
<tr><td>Fixed-1</td><td colspan="2"></td><td colspan="3">Entities:6 face(s)
Type: Fixed Geometry</td></tr>
<tr><td colspan="6">Resultant Forces</td></tr>
<tr><td></td><td>Components</td><td>X</td><td>Y</td><td>Z</td><td>Resultant</td></tr>
</table>

	Reaction Force(N)	**-0.0718**	**444**	**1.83**	**444**
	Reaction Moment(Nm.)	**0**	**0**	**0**	**0**

Table 1: *Fixture details and resultant forces*

Name	**Type**	**Min**	**Max**
Stress1	VON: von Mises Stress	4.79e+06N/m^2	0.0 N/m^2

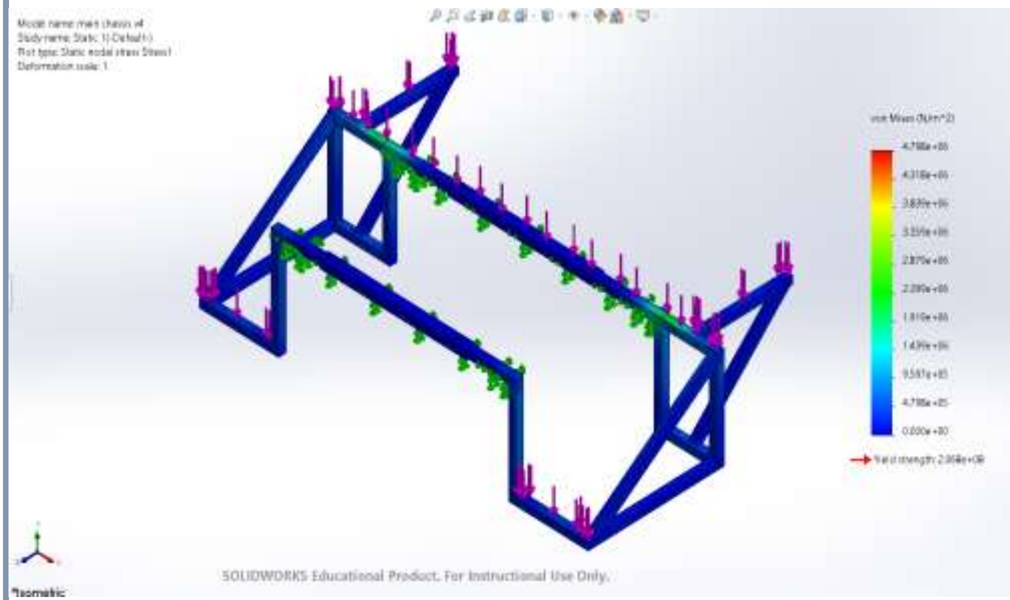

Fig. 3. *Static Analysis of Chassis*

Name	**Type**	**Min**	**Max**
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 15240	6.603e-01mm Node: 15492

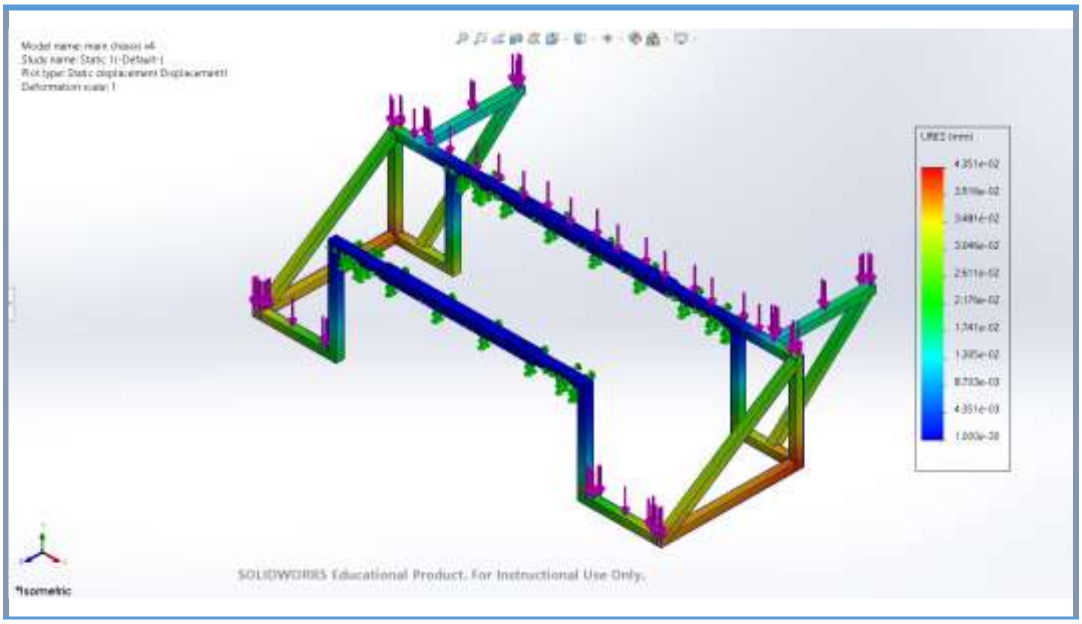

Fig. 4. *Displacement Analysis of Chassis*

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	4.792e-07 Element: 19284	8.596e-04 Element: 28344

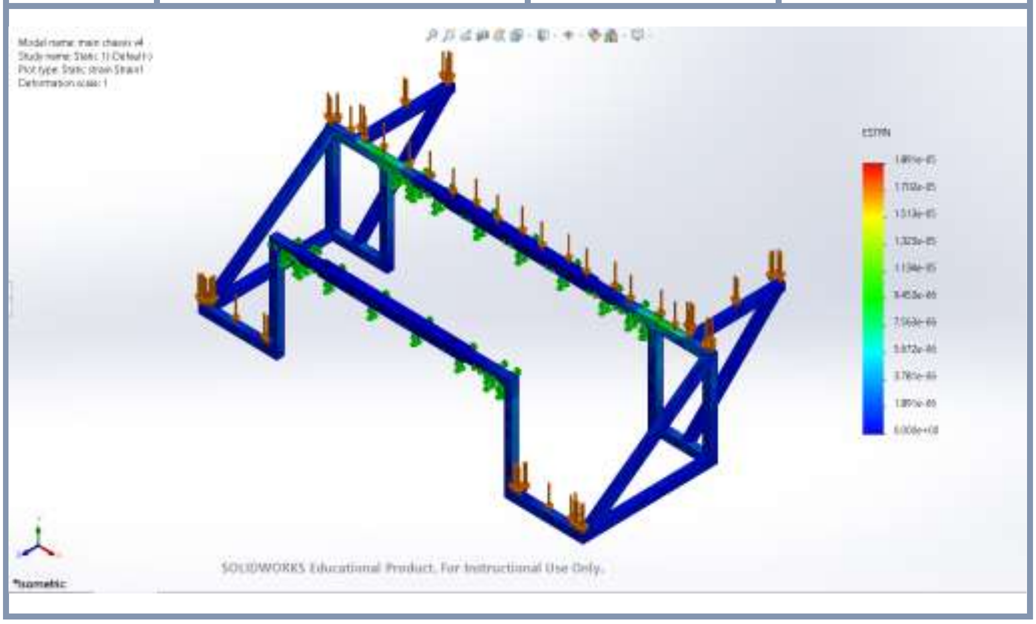

Fig. 5. *Strain Analysis of Chassis*

This project explored the design, development, and testing of a boat-mounted solid waste collection system for riverine environments. The focus was on a system utilizing a conveyor belt as a key component for continuous debris collection.

Overall, the project successfully developed a proof-of-concept for a boat-mounted solid waste collection system. The results offer promising potential for further development and real-world application.

3. Calculations

Motor Selection

Considering,

Arm weight = 0.5 kg

Conveyor belt weight = 0.5 kg

Material passing through the belt = 3 kg

Total weight = 0.5 + 0.5 + 3 = 4 kg

The required rpm at the upper part is about 100 to 120 rpm. Let the torque on one side of the arm = Tb Nm

Tb = g * MI

M = W * d

Where, W = Weight of the conveyor belt and debris.

d = Distance between the centre of mass of the conveyor belt and debris and the

vertical axis of the arm.

Tb = 9.81 * 3 * 1.7 * 10^2 * 10^{-3} = 5.003 kg-cm

Torque,T=2*Tb=4*5.003=20.1kg-cm
With a FOS(1.3) the required motor torque = 26.13 kg-cm

Therefore, we are using a Nema-23 stepper motor of 28 kg-cm torque for the conveyor.

Battery Pack Selection

We'll calculate the total drag force acting on the conveyor belts due to water and debris, and then the friction force due to belt movement. The motor needs to overcome these forces to move the belts.

Water density = 1000 kg/m^3

Debris density = (900 kg/m^3 + 1000 kg/^{3}) / 2

= 950 kg/m^3

Average water flow rate = 570.55 * 10^6 m^3 / day

= 570.55 * 10^6 m^3 / (24 hours * 3600 seconds/hour)

= 2.15 m^3/s

Assuming a simplified approach where drag acts on the entire belt width,

Drag force = 0.5 * water density * belt speed^2 * belt width * (1 + debris density/water density)

= 0.5 * 1000 kg/m^3 * (3 m/s)^2 * 0.29 m * (1 + 950 kg/m^3 / 1000 kg/m^3)

= 4024.75 N

We'll use a friction coefficient of 0.2 (typical for PVC on a wet surface) and gravitational acceleration (9.81 m/s^2),

Friction force = friction coefficient * debris mass flow rate * gravity

Friction force = 0.2 * 593.07 kg/s * 9.81 m/s^2 = 1163.61 N

To calculate the mass flow rate of debris, we assume it covers the entire belt width,

Mass flow rate = water flow rate * belt width * debris density

= 2.15 m^3/s * 0.29 m * 950 kg/m^3

= 593.07 kg/s

Total required motor force is the sum of the drag force and friction force,

Total force = Drag force + Friction force

= 4024.75 N + 1163.61 N

= 5188.36 N

We'll consider a typical motor efficiency of 80% to calculate the motor power,

Motor power = Total force * belt speed / motor efficiency

= 5188.36 Ns * 3 m/s / 0.8

= 19051 W

Battery Calculations, Battery voltage (assuming a nominal voltage of Li-ion cells) = 3.7 V

Desired battery life = 8 hours

Battery capacity (Ah) = Motor power (W) * Runtime (hours) / Voltage (V)

= 19051 W * 8 hours / 3.7 V

= $4.19 * 10^5$ Ah

= 1,550.3 kWh

Considering losses and low volt systems battery pack required is: **2.01 kWh** (FOS 1.3) **Li-ion 18650 cell** of C rating 1.5C is being used with output as 72V and 43.33A. 18 cells in 1 series gives 75V at full charge and 17 such series gives 56.1 A at 1.5C rating, hence resulting output of 2.01 kWh of energy, counting 306, 18650 Li-ion cells connected 18S17.

4. Conclusion

Boat-mounted solid waste collection systems, as explored in existing research, offer a promising approach to combating river pollution. Studies by Abdullah et al., Walker, and Ahirrao establish the feasibility of these systems using skimmers or potentially alternative collection mechanisms. Future research should focus on scalability, automation, data collection capabilities, and the development of standardized performance metrics. By addressing these knowledge gaps, boat-mounted systems can become more efficient, cost-effective, and widely applicable tools for promoting cleaner riverine environments.

The reviewed literature underscores the importance of innovative materials, efficient mechanical systems, and smart technologies in developing effective aquatic debris collection systems. For your boat-mounted debris collection kit, leveraging insights from these studies can guide the design process, ensuring a robust, efficient, and environmentally sustainable solution.

Incorporating findings such as the optimal design of conveyor belts, the use of durable materials, and the integration of smart technologies will enhance the functionality and adaptability of your device across various river boat types and environmental conditions.

Acknowledgements

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