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Development of Solar-Powered Automated Floating Type Oil Skimmer

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Abstract

Solar-powered automatic floating oil skimmer oil spills are one of the most pressing environmental issues because they cause significant damage to marine environments. The development of a solar-powered automated floating oil skimmer offers an efficient and sustainable solution for oil spill removal. Powered primarily by solar energy, the system operates continuously without reliance on external power sources, making it ideal for remote or offshore locations. Its automated design reduces the need for manual intervention, increasing efficiency and safety during cleanup operations. By utilizing renewable energy, the skimmer minimizes environmental impact while effectively addressing marine pollution. This innovation demonstrates the potential of combining automation and clean energy to create eco-friendly technologies for environmental protection, particularly in sensitive aquatic ecosystems affected by oil contamination. The skimmer floats on the water's surface and uses sensors and an inbuilt control system to automatically go to regions of oil contamination. It uses a rotating belt or drum mechanism to efficiently collect and separate oil from water. The collected oil is stored in an integrated tank that may be periodically emptied. This paper not only focuses on challenges faced in the actual hardware implementation but also discussion made based on the same.

Keywords: Polyurethane belt, oil-water separation, solar panel integration, floating mechanism, solar powered

INTRODUCTION

The increasing reliance on oil in various industries has led to frequent oil spills, which pose significant environmental and economic challenges. Oil spills pose a serious threat to water bodies, causing contamination, endangering marine life, and disrupting delicate aquatic ecosystems. They can lead to long-term ecological damage, impact biodiversity, and harm industries such as fishing and tourism. Therefore, efficient and timely removal of oil from water is essential to minimize these adverse effects. Traditional oil spill cleanup methods often rely on manual labor or stationary equipment, which can be labor-intensive, costly, and limited in effectiveness [1]. Environmental conditions such as rough waters, remote locations, or continuous oil leakage can further reduce the efficiency of these methods. Manual approaches also expose workers to hazardous conditions, while fixed systems lack the flexibility to adapt to changing spill dynamics. To overcome these challenges, the development of a solar-powered automated floating oil skimmer presents a sustainable and practical alternative [2]. Powered primarily by renewable solar energy, this

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system can operate continuously without the need for fuel or frequent human intervention, making it particularly suitable for remote or offshore locations. Its floating and mobile design allows it to navigate through affected areas, collecting and separating oil from the water surface efficiently [3]. Automation ensures precise operation, consistent performance, and reduced dependence on human labor, thereby enhancing safety and cost-effectiveness [4]. The integration of solar energy not only reduces operational costs but also minimizes the carbon footprint of cleanup operations. Furthermore, this approach supports global efforts toward renewable energy adoption and environmental conservation.

By combining clean energy with advanced automation, the solar-powered oil skimmer provides an eco-friendly, efficient, and scalable solution to oil spill remediation. It demonstrates how technological innovation can address pressing environmental issues while promoting sustainability. This system has the potential to become a vital tool in protecting marine ecosystems from oil pollution and ensuring cleaner, healthier water bodies for future generations [5]. This innovative device combines automation with renewable energy to efficiently remove oil from water surfaces while minimizing environmental impact. The key features of this system include its floating design, which allows it to adapt to varying water conditions, and an automated mechanism that ensures continuous oil recovery without human intervention.

LITERATURE REVIEW

A study demonstrated that oil is a valuable resource used in daily life, but its spills can cause significant harm to the environment. Accidents involving various oil-related infrastructure led to millions of gallons of oil spilling into water bodies each year. Cleaning up these spills is challenging and time-consuming, depending on factors like oil type and water temperature. To address this, industries employ oil removal methods such as disc-type oil skimmers, which utilize the principle of oil's affinity to certain materials to separate it from water [1].

Another study elaborated on the importance of oil skimmers, which are devices designed to remove floating oil from water. It works because oil is less dense than water and floats on top. Our goal is to create a belt-type oil skimmer, including components like belts, bearings, an engine, pulleys, a shaft, and a collection tank. We're focused on choosing the right dimensions for these parts and assembling them correctly. The skimmer runs over the water's surface with a small amount of water, removing oil and filtering out impurities. This method is cost-effective and simpler than alternatives like membrane filters or chemical treatments [2].

METHODOLOGY

The Arduino Mega and three DC motors in this skimmer are powered by a battery. The propeller is coupled to a single DC motor. The rudder is attached to a second DC motor. Additionally, a belt shaft that serves to draw in and separate the oil spill is attached to a third DC motor. A HC 05 Module is used to regulate the speed and direction of rotation of all three DC motors, which are connected to an Arduino Mega and motor driver [6]. PVC (polyvinyl chloride) pipe is used for the oil skimmer's float because it offers enough buoyant power to keep the entire module floating. In the proposed system, the belt material plays a crucial role in determining the efficiency and durability of oil recovery. Depending on operational requirements and environmental conditions, we may opt for either a polyurethane belt or a fiber belt. Polyurethane belts offer excellent resistance to oil absorption, high tensile strength, and longer service life, making them suitable for harsh conditions and continuous operation. Fiber belts, on the other hand, provide enhanced flexibility, lightweight handling, and are cost-effective, making them ideal for small to medium-scale applications where frequent maintenance or replacement is feasible.

During operation, the belt continuously moves through the oil-contaminated water, attracting and lifting the oil from the surface through its oleophilic properties. The collected oil is scraped from the belt and directed into the separator tank, specifically towards its right bank, where it is stored for later disposal or recycling. Meanwhile, the separated water undergoes a purification process to ensure that residual oil content is minimized. This treated water is then returned to the water body via a designated water output pipe, ensuring minimal environmental impact and compliance with water quality standards.

Additionally, Figure 1 illustrates the block diagram of the proposed system, highlighting the sequence of operations from oil collection to water purification. The diagram provides a clear representation of the interaction between various components, including the belt skimmer, scraper, separator tank, and water outlet system. This integrated design ensures efficient oil recovery, reduces manual intervention, and offers a sustainable approach to mitigating water pollution caused by oil spills.

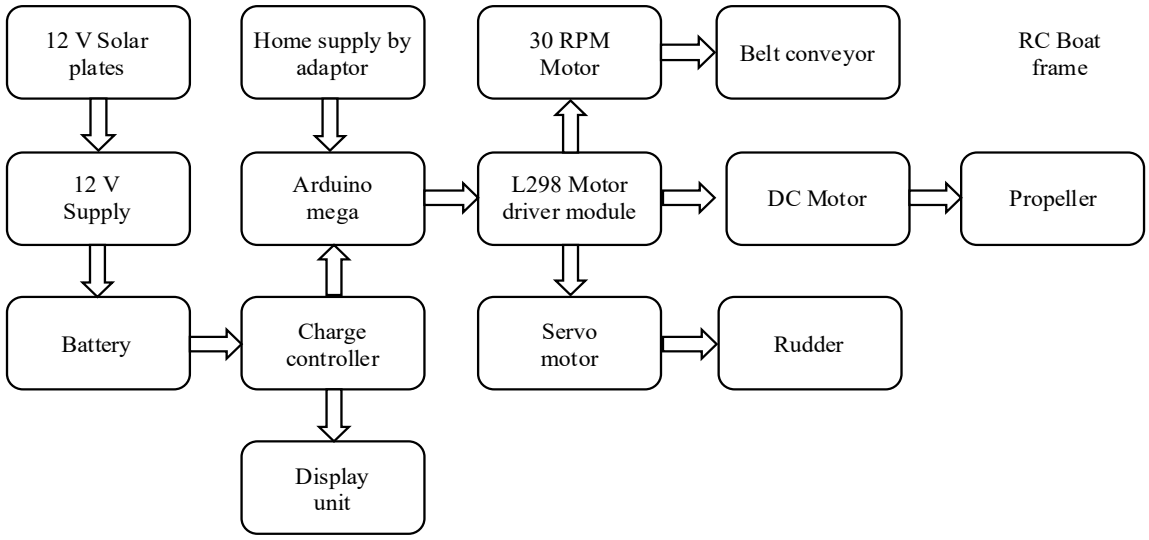

Figure 1. Block diagram of placement of electrical componentsof the proposed system.

Figure 2. Disk skimmers.

TYPE OF SKIMMERS

Disc Skimmers

Discs (Figure 2) are unable to handle emulsified oil, and skimmers perform best with lighter oils (medium viscosity). On the other hand, disc skimmers are operated by crane operators and can be utilized for open water activities. Because of the size and quantity of revolving discs, the disc skimmers have a somewhat considerable volume and weight [7].

Skimmers for Rope Mop

Rope mop skimmers (Figure 3) collect oil by using ropes that float on the water's surface. Due to their size, rope mop skimmers must be launched from a ship or the shore using a crane for the duration of the operation. The ropes retrieve the oil, which is subsequently wrung out and released into a collection tank on the shore or aboard the ship [8]. Although this sort of skimmer is not wave-sensitive, it is often only utilized for single sweep operations. Because so little water is collected during recovery, vertical rope mop skimmers work best with lighter types of oil.

Drumming Skimmer

Because they are powered by hydraulics or air, drum skimmers (Figure 4) are frequently used in dangerous settings. Because of their versatility, drum skimmers can handle a wide range of oils, from lighter ones like diesel to larger ones like crude oil [9].

Skimmers for Brushes

From standalone units to modules installed on a barge (self-floating unit) or on a specifically built recovery vessel, brush skimmers (Figure 5) can be packaged in a variety of ways. Different types of oil can be retrieved depending on the comb shape and the density and stiffness of the bristles utilized. Generally speaking, heavier oils are better suited for stiffer, wider-space bristles, whereas lighter oils are best recovered by finer, softer bristles [10].

Figure 3. Rope mop skimmers.

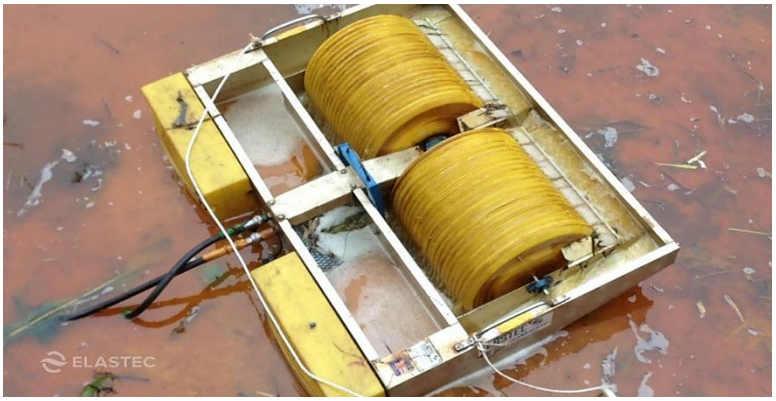

Figure 4. Drum skimmers.

Figure 5. Skimmers for brushes.

The Belt Skimmer

Due of their size, belt skimmers |(Figure 6) are frequently installed on barges or other particularly designed vessels. These skimmers have a high recovery efficiency and good recovery rate but are specialized products and can be complicated to operate, which requires heavy equipment and specially trained personnel [5]. However, a fixed position mounted belt skimmer requires an initial tuning but can then operate independently.

Suction Skimmers

According to operational theory, suction skimmers (Figure 7)—such as vacuum skimmers—represent the most basic skimmer design. Air suction systems retrieve oil straight from the water's surface. The most basic kind of vacuum skimmer is easily used in rivers or harbors and employs a hose that is linked directly to a vacuum truck. Vacuum skimmers are sometimes limited to use in harbors and calm waters due to their sensitivity to waves [7]. Furthermore, because vacuum systems are so widely available, suction skimmers are perfect for recovering oil on or near the coast. However, because of the suction device's lack of differentiation, large amounts of water may also be gathered.

Figure 6. The belt skimmer.

Figure 7. Suction skimmers.

Weir Skimmers

Weir skimmers (Figure 8) are skimming devices that remove oil from the water's surface by using gravity. Weir skimmers are floating units where the edge of the weir is positioned just below the upper slick surface or at the interface between the floating oil and water, hence allowing oil to flow over the weir edge into a collecting sump. The oil is then pumped to storage tanks. Moreover, Table 1 shows the flow chart of Skimming Technologies.

RESULT

An IOT-based, solar-powered, sophisticated oil skimmer thatwe have successfully built produces exceptional outcomes in oil spill cleanup operations. The excellent effectiveness of our skimmer is demonstrated by its remarkable oil removal rate of 87.5 ml/min at 30 rpm. It has quick and efficient cleanup capabilities, separating 0.5 L of oil in 5 minutes and 33 seconds. In some situations, such skimming 200 milliliters of gear oil in 60 seconds, this skimmer gets an outstanding 96.65% efficiency rating. All things considered, our skimmer keeps an amazing 96.5% efficiency level, guaranteeing complete cleanliness with the least possible negative influence on the environment. These results show how the skimmer may transform oil spill response activities by providing a sustainable solution that respects environmental laws and safeguards aquatic ecosystems.

DISCUSSION

The solar-powered automatic floating oil skimmer is designed to provide an eco-friendly solution for oil spill remediation. It integrates solar panels for sustainable energy, a floating mechanism for stability, and an automated skimming system for efficient oil recovery. The system offers continuous functioning under a variety of situations, minimizes environmental effect, and lessens dependency on fossil fuels. Optimizing solar energy use, guaranteeing durability in challenging conditions, and adjusting to various oil viscosities are some of the main obstacles. This innovative approach demonstrates potential for scalable, cost-effective solutions to mitigate oil spill damage.

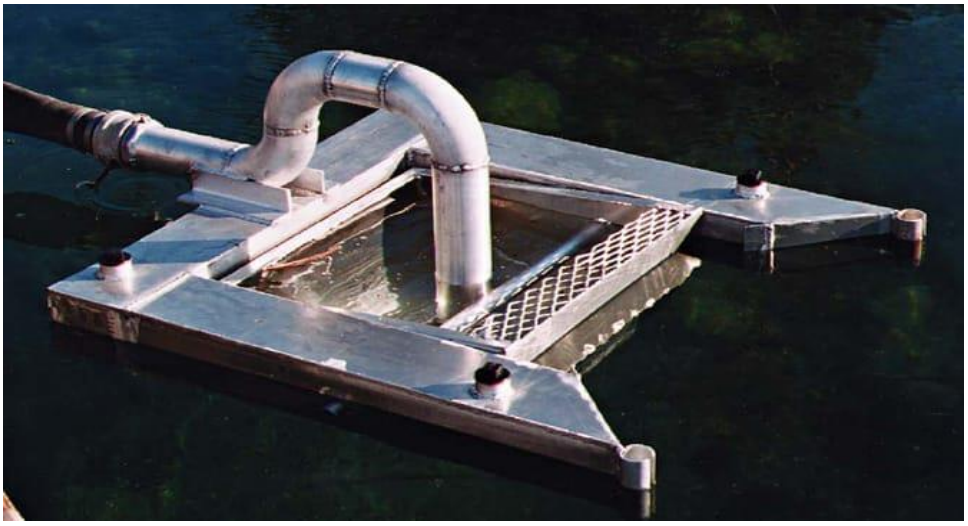

Figure 8. Weir skimmers.

Table 1. Flow chart of skimming technologies.

S.N.	Oleophilic Skimmers	Non-Oleophilic Skimmers
1	Disc Skimmers	Suction Skimmers
2	Rope Mop Skimmers	Weir Skimmers
3	Drum Skimmers	
4	Brush Skimmers	
5	Belt Skimmers	

CONCLUSION

The solar-powered automatic floating type oil skimmer is an innovative and sustainable solution for effective oil spill management. The system runs independently by using renewable solar energy, which makes it appropriate for off-grid and rural areas. Its floating design and automation ensure efficient oil recovery with minimal water contamination while adapting to varying water conditions. This eco-friendly approach reduces environmental pollution and promotes sustainable practices. Although challenges like low sunlight performance and debris handling exist, future improvements can enhance its reliability and efficiency. All things considered, this technology presents a viable solution to combat water pollution and save aquatic environments.

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