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Design and Development of Oil Skimmer

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Abstract

Oil contamination in water bodies poses significant environmental and operational challenges. To address this, an efficient oil skimmer device was designed and developed. The presented model employs a rotating belt mechanism to selectively remove oil from the surface of contaminated water.This project proposes a good oil-water separation system that utilizes a PVC conveyor belt that is powered using a Johnson Motor. The system depends on using the principle that although oil floats on water due to its lower density, and also forms oil slicks and films of time due to its relatively higher surface tension along with its inherent adhesive properties, as such when separation is possible, it is economically viable. The experimental rig consisted of an acrylic tank containing oil/water mix, a belt moving continuously to attract the oil forming adhesion to the belt, a scraping mechanism to remove the oil from the belt, and a collection tank that had an internal baffle separating oil from residual water. This paper discusses the systematic approach undertaken for design, material selection, fabrication, and testing of the oil skimmer. Experimental results demonstrate the device's efficiency, cost-effectiveness, and potential for broader industrial applications.

Keywords: Oil Skimmer, Oil Spill Clean-up, Oil-Water Separation, Belt-Type Skimmer, Environmental Pollution Control, Adhesive Oil Recovery, Johnson Motor Mechanism, Wastewater Treatment, Mechanical Oil Removal.

1 Introduction

Industrial activities and accidental oil spills have long been recognized as a major threat to aquatic ecosystems, marine life, and human health. Studies indicate that vessels contribute nearly 15 percent of the oil entering the world's oceans each year, amounting to over six billion tonnes since 1970. Rapid and efficient removal of surface oil is therefore critical to minimizing long-term environmental damage. Conventional remediation methods—such as booms, sorbents, skimmer ships, and chemical dispersants—often require specialized vessels and heavy machinery that may not arrive on scene in time or pose additional fire and safety risks in oil-contaminated waters. Moreover, these approaches can be prohibitively expensive for small-scale operations or developing regions. This study focuses on the design and development of a belt-type oil skimmer, intended for low-cost, reliable, and efficient operation in small-scale applications.

2 Problem Statement

The need for a simple, cost-effective, and low-maintenance device to efficiently separate oil from water has driven the development of the oil skimmer. Current technologies either incur high operational costs or are unsuitable for small-scale industries.

3 Objectives

The primary objectives of this project were:

- To design a compact oil skimmer suitable for industrial effluents.
- To fabricate a prototype using readily available materials.
- To test the efficiency of the skimmer under different operating conditions.

4 Methodology

The project followed a structured approach comprising:

- **Design:** A belt-type mechanism was selected for continuous oil removal. Key components include a motor, pulley system, and a belt made of oil-attractive material.
- **System Setup:**The experimental setup consists of an acrylic tank containing a mixture of oil and water. A PVC conveyor belt is positioned in such a way that it moves from the lower portion of the tank to the upper portion. The movement of the belt is powered by a John- son motor, ensuring continuous operation.
- **Oil Attraction Mechanism:** The oil, being less dense than water, floats on the surface. As the conveyor belt moves through the mixture, oil adheres to the belt due to surface tension, viscosity, and adhesive properties of the belt material. The upward movement of the belt carries the attached oil away from the mixture.
- **Oil Collection and Separation:**At the upper end of the conveyor system, a scraping mechanism removes the oil from the belt, directing it into a collection tank. The col- lection tank has an internal boundary wall that separates

the collected oil from any remaining water or mixture, ensuring effective separation.

• **Fabrication:** Materials were selected based on corro- sion resistance and durability. Assembly was completed with a focus on compactness and ease of maintenance.

• **Working Principle:** The rotating belt captures floating oil, which is then scraped off and collected into a sepa- rate container, achieving effective oil-water separation.

5 Literature Review:

1. **X. Wang et al:** This review explores recent ad- vancements in oil-water separation techniques, empha- sizing innovative materials and methodologies. It dis- cusses membrane technol- ogy, surface modifications, and adsorption-based solutions for enhanced separation efficiency. The authors highlight the importance of envi- ronmental sustainability and energy efficiency in design- ing separation systems. The paper provides a foundation for understanding the state-of-the-art technologies in oil spill recovery, serving as a guide for researchers and en- gineers to develop improved skimming mechanisms. Its insights are pivotal for addressing hydrodynamic chal- lenges and achieving high recovery rates in realworld applications.

2. **M. Singh and A. Patel:** This paper examines the role of IoT in enhancing environmental monitoring during oil spill cleanup operations. The authors propose a framework integrating sensors, cloud computing, and real-time analytics to improve decision-making and ef- ficiency. Case studies demonstrate the effectiveness of IoT systems in tracking oil spill dynamics and optimiz- ing resource deployment. The paper underscores the benefits of automation and connectivity in minimizing environmental impact and operational costs. Its findings are instrumental for developing smart oil skimmer boats equipped with real-time monitoring and control capabil- ities.

3. **J. Tanaka et al:** This study focuses on optimizing skimmer designs to improve oil recovery efficiency. The authors analyze various skimmer configurations and their performance under different conditions, consider- ing factors like hydrodynamics and oil viscosity. The findings highlight the significance of design parame- ters, such as drum material, rotation speed, and surface modifications, in maximizing recovery rates. This re- search offers practical insights for developing efficient skimming mechanisms tailored to specific spill scenar- ios. It serves as a valuable reference for designing next- generation oil recovery systems with improved environ- mental and economic outcomes.

4. **P. K. Roy:** This review addresses the hydrodynamic challenges encountered in oil spill recovery operations. The authors discuss the impact of turbulent water condi- tions, oil properties, and equipment design on recovery efficiency. Strategies to mitigate these challenges, in- cluding advanced modeling and adaptive technologies, are explored. The paper em- phasizes the need for robust skimmer designs capable of withstanding adverse ma- rine environments. Its insights are crucial for engineers and researchers aiming to enhance the performance and reliability of oil spill cleanup systems in dynamic con- ditions.

5. **K. E. Brown :** Proposed that This paper focuses on the design and development of portable oil skim- mers for small-scale spill operations. The authors evaluate var- ious skimmer types, in- cluding disc, drum, and belt mechanisms, highlighting their advantages and limita- tions. Design parameters such as portability, power requirements, and recovery efficiency are analyzed. The study provides practical insights for developing lightweight and cost-effective skimmers suitable for lo- calized spill scenarios. Its findings contribute to the ad- vancement of skimming technologies, particularly for industries and regions requir- ing flexible and easily de- ployable recovery solutions.

6. **T. Wilson and S. Hall:** This study investigates the development and application of hydrophobic and oleophilic coatings for oil recovery systems. The au- thors discuss the synthesis and characteri- zation of ad- vanced materials with selective oil absorption capabil- ities. Experimental results demonstrate the effective- ness of these coatings in enhancing the performance of skimming and separation devices. Its findings provide a foundation for advancing mate- rial science in oil spill cleanup technologies.

6 Design Analysis

Several structural design considerations should be taken into account for economical and efficient manufacturing. Many of these apply to other joining methods, and all apply to both subassemblies and the complete structure. The device should be suitable for local manufacturing capabilities. The attach- ment should employ low-cost materials and manufacturing methods.

1. It should be accessible and affordable by low-income groups, and should fulfill their basic need for mechani- cal power

2. It should be simple to manufacture, operate, maintain and repair.

3. It should be as multi-purpose as possible, providing power for various agricultural implements and for small machines used in rural industry.

4. It should employ locally available materials and skills. Standard steel pieces such as steel plates, iron rods, an- gle iron, and flat stock that are locally available should be used. Standard tools used in machine shops such as hacksaw, files, punches,

5. taps, dies; medium duty welder; drill press; small lathe and milling machine should be adequate to fabricate the parts needed for the dual-purpose bicycle.

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7 Components & Specification

1. **Tank:**This is the main container where the oil-water mixture is held. The skimming mechanism operates within this tank.

Figure 1: Tank

2. **Oil Scrubber:**The scrubber collects and removes the floating oil from the tank surface. It plays a key role in separating oil from water.

Figure 2: Oil scrubber

3. **Shafts :** These are cylindrical metal rods that act as rotating elements to carry the rollers. They transmit torque and help in skimming the oil from the surface.

Figure 3: Shafts

4. **Roller shafts:**The shafts are mounted with rollers and connected to the support structures, ensuring proper alignment for smooth rotation.

Figure 4: Roller Plates Integrated with Shaft

5. **Belt:**The belt mechanism, made from PVC material, plays a crucial role in attracting and lifting oil from the water surface. Its continuous motion ensures efficient oil adhesion and transfer to the scraper for separation.

Figure 5: Belt Installation for Continuous Oil Recovery in Skimming System.

8 Calculation

Tank Dimension Oil Skimming Depth

Parameter	Value (mm)
Length (L)	518
Width (W)	292
Height (H)	200

$$d = 194 \text{ mm} \tag{1}$$

Roller Speed

$$\text{RPM} = 55 \tag{2}$$

Belt Speed Calculatic calculated using the formula:

$$v = \pi D_r \frac{\text{RPM}}{60} \tag{3}$$

Substituting values:

$$v = 3.1416 \times 28 \times \frac{55}{60} \tag{4}$$

$$v \approx 80.6 \text{ mm/s} \tag{5}$$

Oil Removal Rate Calculation Oil removal rate (Q) is given by:

$$Q = W_b \times d \times v \times E \tag{6}$$

where, $E = 0.7$ (Skimming Efficiency).

$$Q = 200 \times 194 \times 80.6 \times 0.7 \tag{7}$$

$$Q \approx 7.87 \text{ L/hr} \tag{8}$$

Torque Calculation Torque (T) is given by:

$$T = F \times \frac{D_r}{2} \tag{9}$$

where,

$$F = \mu \times W_b \times d \times \rho \times g \tag{10}$$

Assumptions:

- $\mu = 0.4$ (Friction Coefficient)
- $\rho = 850$ kg/m^3 (Oil Density)
- $g = 9.81$ m/s^2 (Gravity)

$$F \approx 12.96 \text{ N} \tag{11}$$

$$T \approx 0.1814 \text{ N·m} \tag{12}$$

Motor Power Calculation Motor power (P) is calculated using:

$$P = \frac{2\pi T \times \text{RPM}}{60} \tag{13}$$

Substituting values:

$$P = \frac{2 \times 3.1416 \times 0.1814 \times 55}{60} \tag{14}$$

$$P \approx 1.05 \text{ W} \tag{15}$$

Recommended Motor Power: Considering efficiency losses, a motor between 5W - 10W is recommended for smooth operation.

Belt Speed Calculation To calculate the belt speed, we use:

$$\text{Belt Speed} = \frac{\pi D N}{60}$$

where

- $D = 65$ mm $= 0.065$ m
- $N = 60$ RPM

$$\text{Belt Speed} = \frac{\pi \times 0.065 \times 60}{60} = \pi \times 0.065 \approx 0.2042 \text{ m/s}$$

Belt Travel in One Minute

$$\text{Belt Travel} = \text{Belt Speed} \times 60 \approx 0.2042 \times 60 = 12.25 \text{ m}$$

Oil Extraction Rate

Oil Extracted in 1 Min = 150 ml

Recovery Efficiency

$$\text{Efficiency} = \frac{\text{Oil Collected}}{\text{Total Oil Present}} \times 100$$

For 500 ml test: $\frac{80}{100} \times 100 = 80\%$

Time Estimation

$$\text{Time for 500 ml} = \frac{500}{150} \approx 3.33 \text{ min},$$

Parameter	Value
Belt Speed	0.2042 m/s
Belt Travel in 1 Minute	12.25 m
Oil Extracted per Minute	150 ml
Recovery Efficiency (500 ml Test)	80%
Time to Extract 500 ml Oil	3.33 minutes
Time to Extract 1 L Oil	6.67 minutes

Table 1: Efficiency Test Results of Oil Skimmer

9 Cad Model

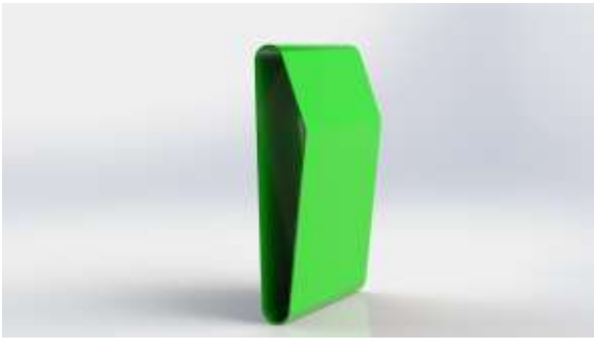

Figure 6: PVC conveor belt

Figure 7: Upper roller shaft

Figure 8: Lower roller shaft

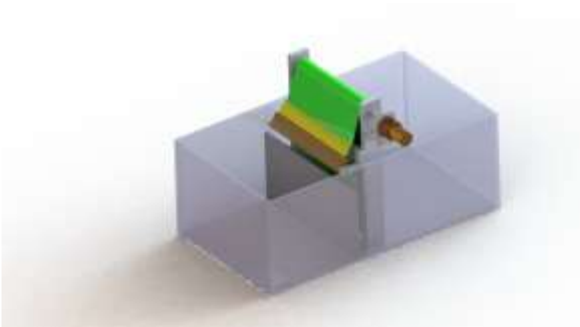

Figure 9: Assembly of Oil Skimmer

10 Results and Discussion

Upon testing, the oil skimmer demonstrated consistent performance in separating oil from water surfaces. The device achieved a separation efficiency of approximately 80–90%, depending on the type of oil and water conditions. The low energy consumption and simple operation make it suitable for small and medium-sized industries.

- The oil adhesion rate on the belt was higher when the belt was submerged deeper into the mixture, optimizing oil pickup.

- The scraping mechanism efficiently removed most of the oil from the belt, minimizing wastage and improv- ing separation efficiency.

- The collection tank with an internal boundary effectively separated the oil from any residual water, ensuring a higher purity of collected oil.

- The system performed best at moderate belt speeds; excessively high speeds reduced oil adhesion, while very low speeds led to excessive buildup on the belt.

11 Conclusion

The developed oil skimmer provides a reliable and cost-effective solution for oil-water separation. Its simple design ensures ease of manufacturing and maintenance, while the test results affirm its potential application in real-world industrial setups. Future work may involve scaling up the design and automating oil collection mechanisms.

Figure 10: Assembly of Oil Skimmer

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