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Design and Optimization of Disc Oil Skimmer

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Abstract: ***Oil Spills are a common phenomenon in the oceans and seas causing economic loss as well as loss of aquatic life. Oil skimmers are devices used to separate the oil from water and recover it to the maximum extent possible. This project focuses on material selection for oil skimmer discs, considering corrosion resistance, wear characteristics, cost-efficiency, and environmental impact. It explores common materials such as polyurethane, oleophilic materials, stainless steel, PVC, and aluminum, emphasizing their unique properties and environmental implications. By conducting a thorough literature review and establishing stringent material selection criteria, the project aims to inform a material choice that balances technical requirements with environmental responsibility. The exploration of advanced materials and optimization of material design are also discussed. The project anticipates enhancing oil skimmer efficiency, reducing maintenance needs, and promoting sustainable practices in environmental protection. The project further includes building a prototype of a single disc oil skimmer and find an ideal diameter for efficient oil skimming taking into consideration the mass of the disc as well as the overall oil skimmer.***

Keywords: Oil skimming, oleophilic, hydrophobic, oil spills

I. INTRODUCTION

Oil skimmers play a vital role in environmental protection and industrial settings by removing oil and contaminants from water surfaces. The material used for the skimmer disc is a critical factor that affects its performance, durability, and environmental impact. This project focuses on selecting the optimal material for oil skimmer discs, considering key factors like corrosion resistance, wear characteristics, cost-effectiveness, and environmental sustainability. It involves a comprehensive literature review of common materials, such as polyurethane, oleophilic substances, stainless steel, PVC, and aluminum, with an emphasis on their properties and environmental implications.

The project also establishes stringent material selection criteria to ensure the chosen material excels in corrosion resistance, durability, cost-effectiveness, and environmental responsibility. Furthermore, it explores advanced materials and material design optimization to enhance the efficiency and longevity of oil skimmer systems. By making informed material choices, this project aims to improve oil skimmer performance, reduce maintenance needs, and promote sustainable practices in environmental protection. It recognizes the evolving nature of the field and emphasizes the importance of ongoing research and adaptation to emerging materials and needs. Material selection is a critical component in mitigating the impact of oil spills and advancing environmental responsibility in industrial and environmental contexts.

II. LITERATURE REVIEW

In recent years, several studies have contributed to the improvement of oil spill cleanup methods. Yadav and Jolapara (2019) [1] aimed to enhance the efficiency of oil spill cleanup by replacing traditional oil skimmer materials with oleophilic discs, primarily focusing on mitigating the environmental impact and fire hazards associated with oil spills in the sea. Similarly, Dr. Gunale's work in 2022 [2] centered on the study of various belt materials used in oil skimmers, with the objective of enhancing system performance and efficiency to address the environmental consequences of oil accidents at sea.

Another study by Pawar and Kumar (2020) [3] focused on the design and evaluation of belt-type oil skimmers with different materials for separating mixed oil from water, aiming to improve the oil removal process in industrial applications by employing effective oil absorption techniques. In a laboratory-scale context, Widiaksana and Yudiana (2022) [4] conducted experiments on mechanical oil skimmers with disc plates, emphasizing the crucial factors of disc submersion depth and rotation speed in determining the skimmer's effectiveness in handling oil spill accidents. These research efforts collectively contribute to the advancement of oil spill cleanup technologies and environmental preservation.

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III. METHODOLOGY

The methodology for this project involves a systematic evaluation of materials for oil skimmer discs, guided by a set of carefully defined selection criteria or parameters. These criteria serve as the foundation for material assessment and comparison, ensuring that the chosen material excels in key aspects relevant to the efficiency and environmental responsibility of oil skimmer systems.

A primary parameter in the material selection process is the material's ability to resist corrosion, especially in marine environments. Materials will be evaluated based on their corrosion performance, with a preference for those exhibiting superior resistance to the corrosive effects of saltwater. The wear resistance of materials is a critical consideration, as oil skimmer discs are subjected to harsh operational conditions. Materials will be assessed for their ability to withstand wear and tear, helping to ensure the longevity of the skimmer system.

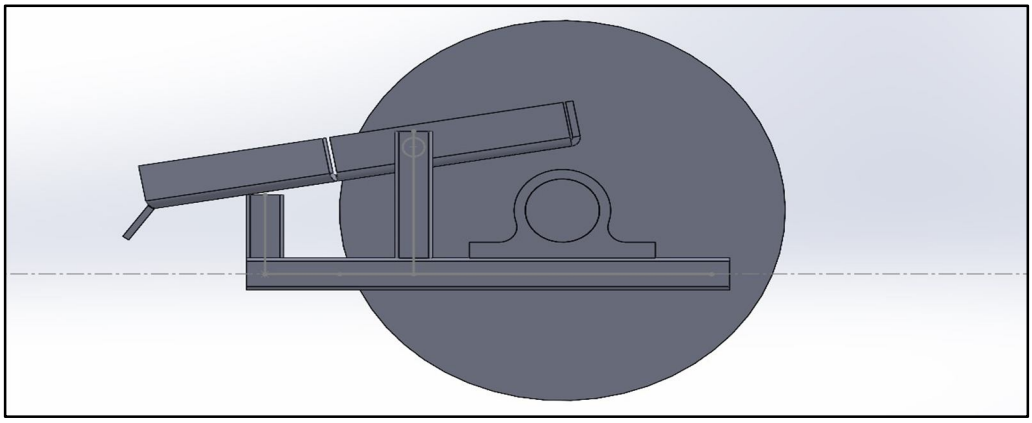


Fig 1. Single Disc Oil Skimmer Assembly

Economic considerations play a significant role in material selection. The cost-effectiveness of each material will be analyzed, taking into account factors such as material acquisition costs, fabrication expenses, and maintenance requirements. Environmental responsibility is a key component of material selection. Materials will be evaluated for their environmental impact throughout their lifecycle, including production, use, and disposal. This assessment encompasses factors such as recyclability and sustainability, contributing to the project's commitment to ecological responsibility. The methodology follows a structured approach in which materials are assessed and compared based on these parameters. This rigorous evaluation process ensures that the selected material not only meets the technical requirements for efficient oil recovery but also aligns with environmentally responsible practices. Through this method, the project aims to contribute to a sustainable and efficient approach to oil spill cleanup and environmental protection.

Table 1. Comparative assessment of materials for oil skimmer disc

Polyurethane	Stainless Steel	PVC	Aluminum	Oleophilic Material
highly oleophilic, hydrophobic to some extent	Not oleophilic, treated to make oleophilic	typically hydrophobic, can be oleophilic when treated	usually hydrophobic, can be oleophilic when treated	specifically designed to be highly oleophilic
Corrosion resistant	Corrosion resistant	Non corrosive	Corrosion resistant	Non corrosive
Durable	Durable	Limited heat resistance	Less durable unless treated	Variable durability
Moderate cost	Cost-effective	Low cost	Cost-effective	Application specific

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A. Selection of Stainless Steel

The selection of stainless steel as the optimal material for oil skimmer discs is underpinned by a series of compelling factors, which have been rigorously considered against the project's selection criteria. First and foremost, stainless steel excels in corrosion resistance, making it particularly well-suited for the demanding marine environment in which oil skimmers frequently operate. Its inherent resistance to corrosion is a direct result of its alloy composition, which includes a significant amount of chromium. This property ensures that stainless steel can endure prolonged contact with ocean water, remaining highly resistant to rust and corrosion, a critical characteristic for the longevity and reliability of oil skimmer systems.

Moreover, stainless steel showcases a remarkable capacity to withstand various chemical reactions. This chemical resilience significantly enhances its reliability and durability in diverse environmental conditions. The material's resistance to both chemical degradation and corrosion makes it an ideal choice for extended use in oil skimmer discs, ensuring the system's efficacy over time. Stainless steel's resistance to heat is another noteworthy attribute, setting it apart from other materials commonly considered for oil skimmer discs. This property ensures that the material remains structurally stable and functional even under elevated temperatures, further enhancing its suitability for the diverse conditions encountered in the field.

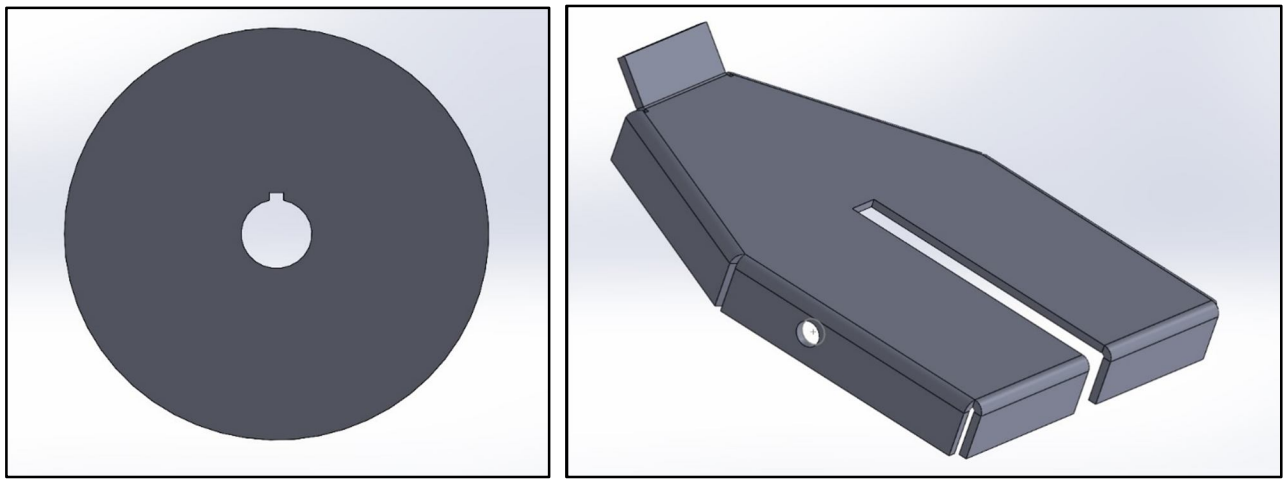


Fig 2. a) Oil Skimmer Disc b) Oil Skimmer Wiper Blade

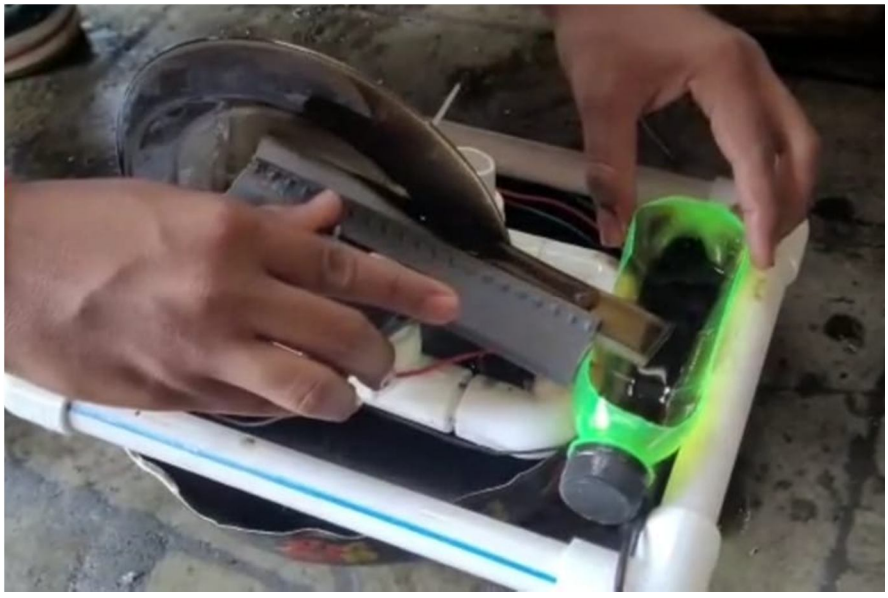


Fig 3. Testing the Oil Skimmer

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Furthermore, stainless steel proves to be cost-effective, considering the advantages it offers in terms of durability and longevity. While it may have a slightly higher initial acquisition cost compared to some alternatives, the reduced maintenance requirements and longer lifespan make it an economically viable choice in the long run. The environmental impact of stainless steel is relatively low when viewed holistically. Its durability and long lifespan contribute to lower material waste, and its recyclability is notably high. With a recyclability rate approaching 1:1, stainless steel ranks as one of the most sustainable options for oil skimmer discs. This aligns with the project's commitment to minimizing environmental impact throughout the lifecycle of the chosen material.

In summary, the selection of stainless steel for oil skimmer discs is a judicious choice, primarily driven by its exceptional corrosion resistance, resistance to chemical reactions, capacity to withstand heat, cost-effectiveness, and low environmental impact. These attributes collectively position stainless steel as a material that excels in both technical and ecological aspects, thereby contributing to the enhanced efficiency and environmental responsibility of oil skimmer systems.

IV. RESULTS AND DISCUSSION

The comprehensive evaluation of materials for oil skimmer discs revealed that stainless steel emerged as the optimal choice. Its exceptional corrosion resistance, resistance to chemical reactions, and durability make it well-suited for the challenging marine environment in which oil skimmers operate. The material's ability to withstand elevated temperatures further enhances its suitability. In terms of cost-effectiveness, stainless steel proved advantageous, as its initial acquisition cost was offset by reduced maintenance requirements and a longer lifespan. This aligns with the project's goal of minimizing expenses while maintaining operational efficiency. Environmental considerations also favor stainless steel. Its recyclability and lower environmental impact position it as a sustainable choice. This complements the project's commitment to ecological responsibility throughout the material's lifecycle. The selection of stainless steel reflects a balanced approach, addressing both technical and environmental considerations. It promises to significantly enhance the efficiency and longevity of oil skimmer systems, contributing to more effective oil spill response and environmental protection. The results underscore the importance of selecting materials with a holistic view of their performance and ecological impact.

Table 2. Oil Skimming Capacity for different Diameters of Disc

Diameter of Disc	10 cm	12 cm	20 cm	30 cm
Surface Area of Disc	78.55 cm^2	113.112 cm^2	706.95 cm^2	1963.75 cm^2
Volume of oil skimmed (area x 2mm thickness)	15.710 cm^3	22.62 cm^3	141.39 cm^3	392.75 cm^3
Mass of Disc (Volume x 7.9 g/cm^3 density)	124.109 g 0.124 kg	178.71 g 0.178 kg	111,6.981 g 1.117 kg	3102.725 g 3.103 kg

From the above Table 2., we can observe that as the diameter of the disc is increased there is an obvious increase in the amount of oil being separated. However greater diameter means greater volume and thus greater mass eventually affecting the overall performance of the oil skimmer. Also, more oil can be separated by increasing the velocity of the disc. However, as the velocity is increased centrifugal forces will lead to oil being spilled back in the water. Through experimentation, it was found that a disc of diameter 20 cm was ideal for our prototype being able to skim enough oil and not be very heavy to float in the water.

V. CONCLUSION

The systematic evaluation of materials for oil skimmer discs has led to the informed selection of stainless steel as the optimal material. Its exceptional corrosion resistance, resistance to chemical reactions, durability, and capacity to withstand heat make it an ideal choice for oil skimmer systems, particularly in challenging marine environments. Stainless steel's cost-effectiveness, with initial acquisition costs balanced by reduced maintenance and extended lifespan, enhances its appeal. This economic advantage aligns with the project's goal of maintaining efficiency while managing expenses.

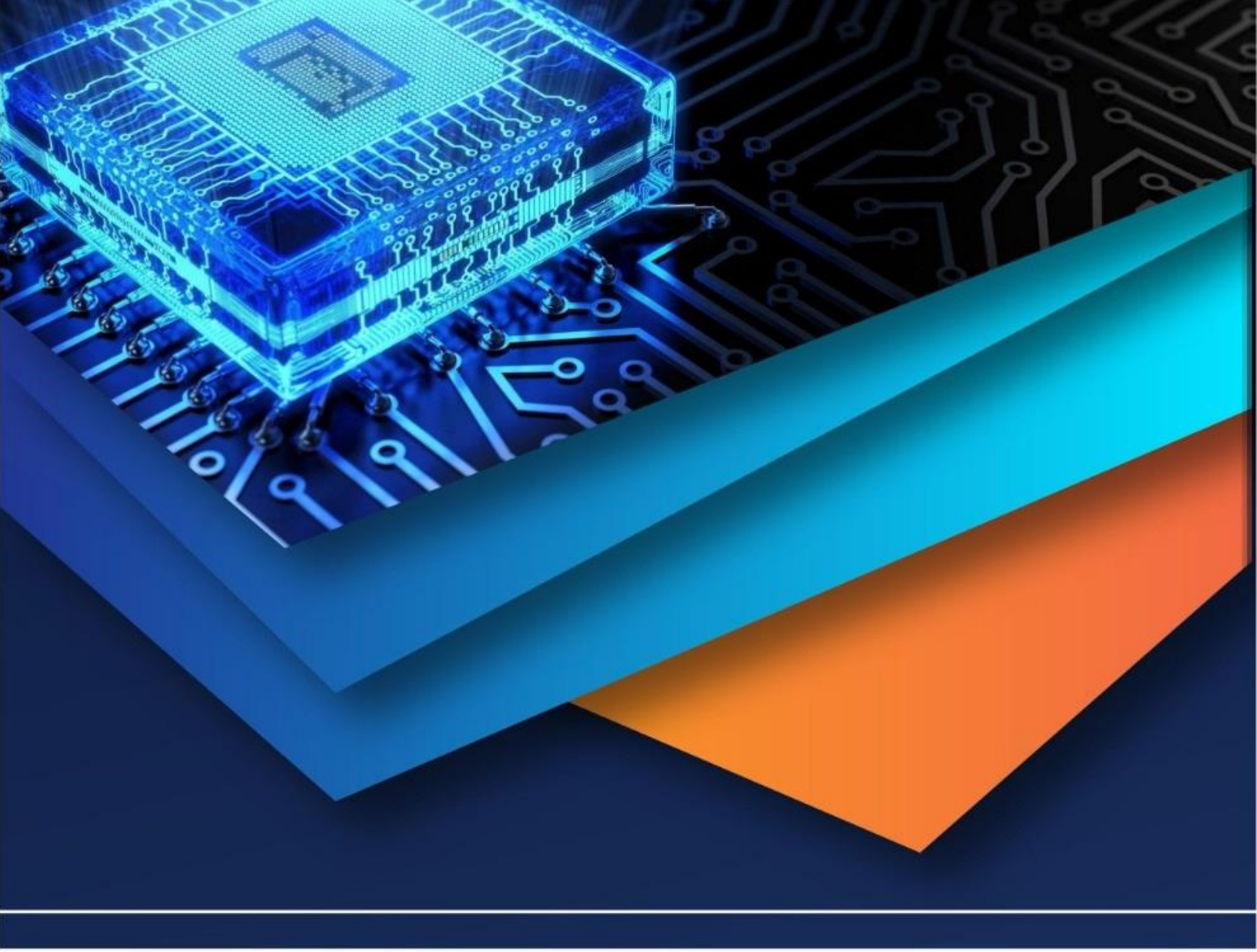
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Environmental responsibility remains a core consideration, and stainless steel's recyclability and relatively low environmental impact reflect a commitment to sustainability throughout its lifecycle. The selection of stainless steel represents a balanced approach, addressing technical and environmental criteria. It is poised to significantly improve the efficiency and longevity of oil skimmer systems, contributing to more effective oil spill response and a responsible approach to environmental protection. The project's success emphasizes the importance of holistic material selection in industrial and environmental contexts

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