Innovative Electric Pump Technology for Oil Leaks Prevention During Boat Maintenance and Engine Oil Replacement

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Abstract. Indonesia, with a maritime territory spanning approximately 5.8 million square kilometers, relies heavily on boats for fishing and transportation. However, traditional boat engine maintenance practices, particularly oil changes, often result in oil spills that contribute significantly to marine pollution and threaten ecosystem. This study aimed to address this issue by developing an innovative electric pump system for safer and more efficient oil replacement. Using a Research and Development (R&D) approach, the researchers applied Fishbone diagram analysis to identify five key contributing factors such as machine limitations, human error, inadequate methods, material conditions, and environmental constraints. The newly developed pump was field-tested and compared with three other oil change methods. Results showed that the new tool reduced the oil change duration to just 2.5 minutes per engine, substantially faster than conventional methods, which averaged up to 15 minutes. Moreover, the tool eliminated oil spillage, whereas traditional draining methods resulted in an average of 50ml of waste oil discharged per engine. Implementation and training sessions conducted with local fishing communities demonstrated high acceptance and ease of use. In conclusion, the integration of technological innovation with practical education offers an effective and low-cost solution to improve maritime maintenance while significantly reducing environmental impact.

Keywords: Boat, Efficient, Electric Oil Pump, Fishermen, Oil Leaks.

1 Introduction

Indonesia has a very large sea area, reaching 5.8 million square kilometers [1], which underscores its identity as a prominent maritime nation [2]. This condition makes the use of boats or ships one of the most frequently used modes of transportation [3-4]. Globally, the use of ships in maritime activities has shown a significant upward trend [5], especially in the sectors of cargo transport and fisheries. To operate effectively,

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boats or ships rely on engines that require regular maintenance, including periodic oil changes [6-7]. However, conducting oil replacements while boats are at sea poses considerable environmental risk. This process increases the likelihood of oil spills, which can result in serious marine pollution. Oil discharged into the marine environment can cause long-term ecological damage, adversely affecting marine biodiversity and ecosystem stability [8-9].

The impact of oil pollution on the marine environment is substantial and far-reaching [10–11]. Engine oil discharged from ships into the sea not only contaminates the water but also significantly disrupts the habitats of marine organisms [12–13]. Marine flora and fauna are particularly vulnerable to the toxic substances present in oil, which can lead to mass mortality events [15], genetic mutations [16], and a decline in biodiversity [14]. Furthermore, this type of pollution poses health risks to humans, particularly coastal communities that rely heavily on seafood as a primary food source [17–18]. Given the severity of these impacts, it is imperative to implement more effective preventive measures in the management and disposal of marine engine oil [19]. So, the development of advanced technologies to prevent oil leakage during maintenance operations is an urgent priority. While many countries have enacted stringent environmental regulations to mitigate marine pollution from shipping activities [20–21], conventional oil replacement methods remain prevalent and often lack sufficient control mechanisms to prevent spillage. Therefore, there is a pressing need for innovative solutions that enable safe and efficient oil replacement while minimizing environmental risks.

Based on these challenges, innovation in engine oil replacement practices is very important. This study presents the development and testing of a DC electric pump oil tool designed to facilitate safer and more efficient engine oil changes on boats. In addition to the technical development, the study also aims to promote awareness and proper practices related to marine engine oil maintenance. Many boat operators and crew members may lack adequate knowledge regarding the importance of using appropriate tools and adhering to correct procedures during oil changes. Therefore, this research not only focuses on technological advancement but also emphasizes educational outreach. An instructional guide tailored for fishermen has been developed as part of the study to ensure that all stakeholders understand the environmental consequences of improper oil disposal and are equipped with the knowledge to mitigate such impacts.

Unlike off-the-shelf oil extractors and mini-pumps that rely on manual suction or crude mechanical cams, our DC electric pump integrates a custom-designed 12 V, 120 W brush-type motor with an optimized ¾-inch quick-connect coupler and high-efficiency metal impeller. This configuration delivers up to 5 m suction lift and 10 m discharge head, all powered from a standard deep-cycle battery, allowing for truly portable, spill-free operation with affordable manufacturing costs. Bench testing of flow rates and power draw confirmed that these parameters maximize energy use while maintaining compatibility with common marine hoses, this feature not available in comparable commercial units.

2 Literature Review

2.1 Replacement of Ship Engine Oil and Engine Maintenance

The maintenance and monitoring of oil pumps and lubrication systems on cruise ships are critical to ensuring operational safety and reliability [22]. The adoption of an appropriate maintenance strategy has been shown to reduce operational costs by up to 55.42% while enhancing the performance and output of ship engines [23]. Preventive maintenance plays a vital role in this context, encompassing condition monitoring, fault diagnosis, and strategic maintenance planning. These practices not only prevent potential failures but also extend engine lifespan, thereby improving the overall efficiency and performance of the system [24].

2.2 The Problem of Oil Spills at Sea

Having discussed the importance of maintenance and monitoring of lubrication systems on ships, it is important to recognize that failures in these systems can lead to severe environmental consequences, most notably oil spills. Marine oil spills represent a critical environmental hazard, capable of causing widespread mortality among marine organisms, destruction of natural habitats, and degradation of water quality [25]. The discharged oil often contains toxic compounds that disrupt marine ecosystems by altering the chemical composition of seawater and contaminating the surrounding environment [26]. Furthermore, such pollution can have cascading effects on broader ecological systems, ultimately posing health risks to both wildlife and human populations that rely on these marine resources [27].

2.3 Previous Research on Oil Spills

In the context of oil spill management, several studies have been conducted to explore effective mitigation strategies. One study introduced a hydrogel-based cup with hydrophobic and oleophilic properties, capable of rapidly collecting up to 92% of spilled oil. This innovation offers an environmentally friendly and cost-effective alternative to conventional oil recovery methods [28]. Another study demonstrated the effectiveness of a Bluetooth-controlled boat system in collecting oil spills both at sea and along shorelines, achieving an accuracy rate of up to 92%. This system minimizes the need for human intervention while enhancing cleanup efficiency, with the potential to remove up to 98% of oil, thus providing a sustainable approach to addressing marine oil pollution [29]. The third study emphasized the importance of using mechanical tools such as booms, skimmers, and absorbent materials in oil spill handling, where the selection of the right tool is very important depending on the type of oil and the conditions of the spill site [30].

However, existing research predominantly focuses on the remediation of oil spills after they have occurred, rather than on preventive measures to mitigate pollution at its source. In response to this gap, the present study introduces an innovative approach aimed at preventing marine pollution by developing a pump system designed to minimize oil leakage during the engine oil replacement process on boats.

2.4 Prevention-technologies

In recent years, prevention in marine engine oil management has shifted from purely spill cleanup to "smart" maintenance systems that avert leaks and unnecessary oil changes. Photonic in line sensors now sample oil through standard hydraulic fittings to measure degradation indicators, such as acid number and water content, without interrupting flow [35]. Likewise, integrated micro viscometers using capacitive micromachined ultrasonic transducers (CMUT) provide continuous, real time viscosity monitoring, detecting early oil breakdown with minimal intrusion into existing lubrication circuits [36]. Complementing these, the wear debris sensors based on inductive and optical detection identify metallic particles in circulating oil, offering an early warning of component wear before catastrophic failure [37]. When integrated into IoT enabled, condition-based maintenance platforms, these technologies optimize drain intervals, effectively preventing oil change spills and extending lubricant life—thereby reducing environmental impact and improving vessel reliability.

3 Research Method

This study employed the Research and Development (R&D) method to solve the problem of oil replacement in boat engines, with a particular focus on preventing oil spills. The R&D approach offered advantages in generating innovations, evaluating practical applications, and enhancing technology through a systematic and structured process [31–32].

At the problem analysis stage, the Fishbone diagram method was used to analyze the main causes contributing to the issue, which included five categories, such as Machine, Human, Method, Material, and Environment. The Fishbone diagram method had the advantage of systematically identifying and analyzing the root causes of problems [33–34]. By mapping the contributing factors, this method helped teams find appropriate solutions, enhanced collaboration, and facilitated more effective problem-solving across various contexts. The study aimed to design new tools that were both efficient and environmentally friendly, while also improving the technical skills of mechanics through proper training. With this systematic approach, it was expected that effective solutions could be developed to reduce negative environmental impacts and enhance operational efficiency in the marine oil change process.

3.1 Problem Definition

This study used the fishbone method to analyze problems related to oil changes in boat engines, particularly in the context of oil spill prevention. The method identified five categories of causes that contributed to the problem, including machine, man, method, material, and environment, as shown in Fig. 1.

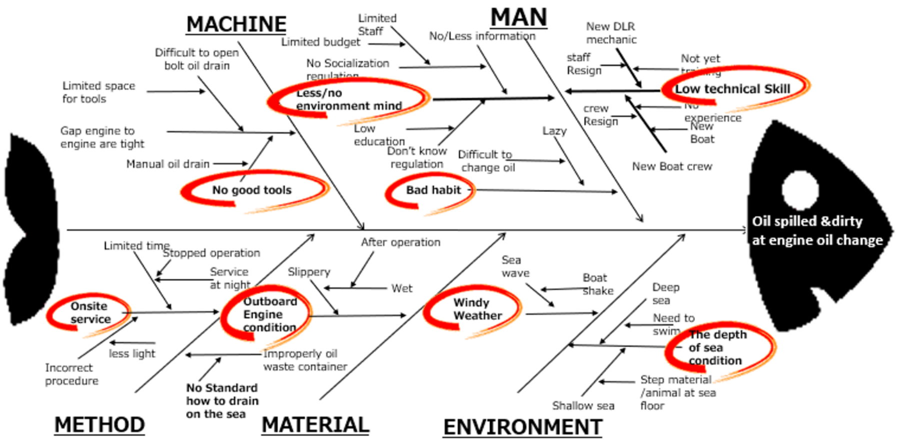

Fig. 1. Fishbone Diagram in this Study

The categories and sub-causes in Fig. 1 were populated through a structured brainstorming workshop with ten fishermen, the workshop guided by the researchers and supplemented by on-site observations during routine engine-oil changes, ensuring that all failure modes reflect real-world practices.

Based on the analysis using fishbone method, it revealed five primary aspects contributing to the challenges associated with oil changes in boat engines. The machine aspect encompassed technical difficulties, such as challenges in loosening oil bolts and the limited space between engine components, issues largely stemming from the absence of appropriate tools designed for efficient oil changes. The man aspect highlighted deficiencies in technical skills and low levels of environmental awareness, particularly among less experienced mechanics and boat crews. Furthermore, inadequate training contributed to procedural errors during oil changes, which in turn led to oil spills and potential engine damage.

The method aspect encompassed improper service procedures and limited time available for conducting on-site maintenance. Unclear procedures often led to confusion and operational errors, while time constraints placed additional pressure on crews to complete tasks hastily, frequently compromising quality and resulting in oil spills. The material aspect addressed the physical conditions of the engine that impacted the oil change process. For instance, wet and slippery external surfaces of the engine, combined with adverse weather conditions, exacerbated risks and increased the likelihood of accidents or procedural mistakes during oil changes. Lastly, the Environment aspect included external factors such as poor lighting during nighttime operations, which further hampered the effectiveness of the maintenance process. By systematically understanding each of these aspects, the study was able to identify root causes of the problem and develop more effective solutions aimed at improving the oil change procedures for marine engines.

3.2 Literature Review and Studies

The literature review included previous studies that highlighted the importance of waste oil management and its impact on the environment. These studies emphasized the need for improved procedures in oil changes to minimize spills. The findings also indicated that the use of appropriate tools and adequate training enhanced efficiency and reduced the risk of errors. By adopting the Fishbone method, this study aimed to provide a more structured and systematic solution to the existing problem.

3.3 Design

The design of the new oil change tool was developed by considering all the factors identified in the Fishbone analysis. The tool was intended to be user-friendly for mechanics of varying skill levels and capable of operating under diverse environmental conditions. Ergonomic considerations were also incorporated into the design to reduce operator fatigue. Furthermore, the tool was engineered to minimize oil spills through an efficient and environmentally friendly collection system. The initial design of this electric oil pump served as a prototype for a machine system that prioritized both operational efficiency and ease of use. To arrive at the 12 V, 120 W specification, we conducted preliminary performance calculations targeting a flow rate of 1 L/min against a 5 m lift, ensuring full battery operation from common motorcycle and marine deep-cycle batteries. The ¾-inch hose diameter was selected to balance flow capacity (minimizing pump run time) with the availability of lightweight, flexible couplers for field use. Iterative bench tests measuring pressure, current draw, and temperature under load confirmed that this motor–hose pairing delivered optimal energy efficiency (0.083 L/Wh) without exceeding safe operating currents for standard 12 V systems.

In addition, the pump was equipped with a coupler or suction hose, which functioned as a conduit for transferring oil from the engine into the pumping system, ensuring a smooth and leak-free distribution process. Internally, the pump featured a high-quality metal impeller, which played a crucial role in generating optimal suction power, enhancing fluid pressure, and accelerating oil flow. Fig. 2 below illustrates the design of the oil pump that was developed.

(a) (b)

Fig. 2. (a) DC Oil Pump Design, (b) Electrical Design of the Pump

3.4 Manufacturing

The manufacturing process of the tool involved the selection of durable and environmentally friendly materials. Early prototypes were tested to ensure that the tool functioned effectively under real-world conditions. During this phase, feedback from end users, specifically mechanics and boat crews, was essential for making necessary improvements. The process also included rigorous testing to verify that the tool met established safety and efficiency standards.

In our design, researchers employed a positive-displacement gear pump rather than peristaltic or diaphragm types. Gear pumps are self-priming, handling suction lifts up to 5 mWC without auxiliary priming, and deliver a steady, low-pulsation flow that ensures accurate oil transfer volumes. Their internal meshing gears maintain volumetric efficiencies above 85% across SAE 10W-30 viscosity, while marine-grade stainless steel construction resists corrosion, it is a critical advantage over polymer-based peristaltic hoses and elastomeric diaphragms, which suffer higher wear rates and pulsation at similar pressures.

The final result of the modified DC electric oil pump is shown in Fig. 3. The product was equipped with a 12V DC motor rated at 120W, capable of producing a current of 12A and operating at a speed of 3300 rpm. The pump demonstrated the ability to draw oil over a distance of up to 5 meters and push fluid as far as 10 meters. The system utilized a 3/4-inch caliber and consisted of a compact black motor connected to a metal pipe via a blue hose, with red and black power cables. The installation appeared orderly, with neatly arranged wiring throughout the system.

Fig. 3. Electric Oil Pump Result

In addition, the calculation of the cost when creating this DC electric oil pump tool. Based on Table 1. the cost incurred for making this product is IDR 1,000,0000, including the DC oil pump and modifications. This pump system is designed with quality components to move oil efficiently. The main pump operates at 12V with a battery clip for ease of use in the field. Equipped with a special hose coupler that is resistant to chemicals and heat. The deep cycle battery provides stable power for consistent operation. The portable design allows use in various locations with 12V DC electricity access, making it easier during ship oil change maintenance.

Table 1. Component Details and Prices For Manufacturing DC Electric Oil Pump

Component	Specification	Price (IDR)
DC Oil Pump	12V, portable, with battery clamp	450,000
Coupler Hose	Special design for oil transfer, heat and pressure resistant	175,000
Battery	12V, deep cycle, for pump operation	275,000
Impeller	Metal Material	100,000
Total Price		**1,000,000**

3.5 Testing

Testing was conducted to evaluate the effectiveness of the device in preventing oil spills during the engine oil replacement process. The testing methodology involved simulating real-world conditions in the field, where the device was assessed under various weather conditions and sea depths. The results demonstrated that the new device successfully reduced oil change duration and eliminated spillage, thereby offering significant benefits in terms of environmental protection and operational efficiency. By employing a Research and Development (R&D) approach and a systematic methodology, the study aimed to deliver a comprehensive solution to the challenges associated with oil changes in marine engines, with particular emphasis on sustainability and efficiency.

In testing, researchers conducted four independent trials per method (normal drain, extractor, mini pump, and DC pump) on identical 200 cc outboard engines. Trials were performed across two weather conditions (dry deck, rain-wet deck) and an oil viscosity grade that is usually used (SAE 10W-30). Each trial measured spill volume, total drain time, and operator effort, with all data logged by a single observer to eliminate inter-rater variability.

4 Research Method

4.1 DC Electric Oil Pump Working Scheme

The oil pump utilizes a 12V DC motor-based electrical system specifically designed for efficiency and portability. The motor is directly connected to a battery using red (positive) and black (negative) cables with clamps, enabling quick and convenient operation without the need for complex installation. The electrical current from the battery powers the motor, which in turn rotates a metal impeller to generate suction through the coupler system. The system is equipped with a non-return valve and a filter to ensure stable and unidirectional oil flow, thereby preventing backflow, contamination, and potential damage to internal components.

The schematic as shown in Fig. 4 illustrates a DC oil pump that works by utilizing the energy source from a 12 V battery connected via positive and negative cables to the battery terminals, then the pump is ready to be turned on. After receiving power, the rotor inside the pump will rotate rapidly so as to create negative suction at the inlet port, this suction draws used oil directly from the boat engine through the suction hose without spillage. The sucked oil is then forced out through the discharge port and into a closed oil container, ensuring that the oil change takes place cleanly and quickly. Thus, the manual oil drainage process which is usually time-consuming and risky to spill, becomes much more efficient and environmentally friendly.

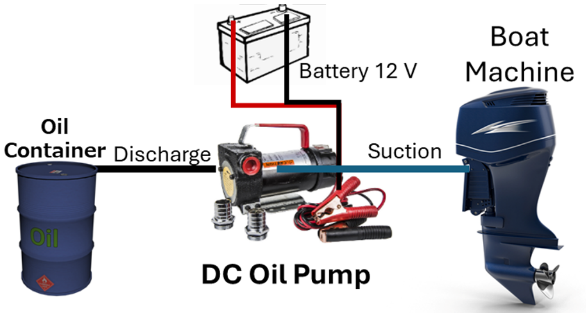

Fig. 4. DC Electric Oil Pump Working Scheme

4.2 Specification

Table 2. DC Electric Oil Pump Specification

No	Specification	Information
1	Volt	DC 12V
2	Rate Current	12A
3	Rate Torque	120W
4	Suction Distance	5 meters
5	Discharge Distance	10 meters
6	Speed	3300 rpm
7	Caliber	3/4

Table 2 provides the specifications for a DC Oil Pump designed for replacing or transferring oil. The DC Oil Pump is a compact, high-performance unit engineered for rapid and reliable oil transfer in mobile settings such as coastal area on the water. Powered by a standard DC 12 V source, it draws a steady 12 A current to deliver up to 120 W of mechanical output. At its core is a brush-type motor spinning at 3,300 rpm, which generates sufficient internal pressure to lift oil from depths of up to 5 meters and propel it through delivery lines as far as 10 meters. The 3/4-inch outlet caliber is compatible with common industrial hoses and fittings, ensuring a tight seal and minimal leakage during operation. Beyond its specifications, this pump is supplied with a set of reinforced hoses that have been pre-assembled with quick-connect brass fittings, allowing the user to switch between suction probes or distribution manifolds in seconds. This tool features a special hose package that includes several copper suction rods for sleek access to narrow reservoirs, as well as a braided discharge hose that can withstand the pressure generated at full load. Overall, this DC Oil Pump offers a versatile plug-and-play solution for boat engine maintenance.

4.3 Test Results and Comparison with Previous Tools

To test the feasibility of the tool, testing was conducted by comparing four types of oil changes that had been conducted. The first is normal drain, the second is oil extractor, the third is mini oil pump, and the last is DC electric oil pump. Comparative testing was conducted to evaluate the performance of each system, identify advantages and disadvantages, and determine the optimal solution for vehicle oil changes.

(a) (b) (c) (d)

Fig. 5. Comparison of (a) Normal drain, (b) Oil Extractor, (c) Mini Oil Pump, and (d) DC Electric Oil Pump

There were 4 machines tested for each method under identical machine, environmental and viscosity conditions. Based on the data presented in Fig. 5, the test results of four different boat engine oil change methods were further analyzed and evaluated through a comparative assessment focusing on oil spillage, cost, and the suction performance of the pump during the oil change process. The outcomes of this evaluation are summarized in Table 3. The assessment was conducted using three primary parameters, such as the effectiveness in preventing oil spills, the required investment cost, and the time efficiency per boat engine serviced.

Table 3. Evaluation Results of Oil Spill Prevention Ability, Investment Costs, and Time Efficiency Of Expenditure on Each Tool

Testing	Normal drain	Oil Extractor	Mini Oil Pump	DC Oil Pump
Ability to prevent oil spills	Oil spill 50ml	No oil spill	No oil spill	No oil spill
Investment costs	IDR 50,000	IDR 1,500,000	IDR 2,000,000	IDR 1,000,000
Time efficiency per machine	15 minutes / engine	60 minutes / engine	8 minutes / engine	2.5 minutes / engine

Based on the evaluation and analysis of the DC oil pump test results, the device demonstrated significant advantages over other alternatives. It achieved the fastest oil extraction time (2.5 minutes per engine), effectively prevented oil spills, and maintained a moderate investment cost of IDR 1,000,000. These factors collectively indicate that the DC oil pump offers optimal efficiency. Investing in this technology is expected to yield substantial time savings and enhance operational cleanliness during oil maintenance procedures.

4.4 DC Electric Oil Pump Implementation

The implementation of the tool was conducted within the fishing community, accompanied by training sessions designed to equip community members with technical competencies in the use and maintenance of oil pumps for effective boat maintenance. The implementation of DC electric oil pump is illustrated in Fig. 6. Through structured and intensive training sessions, participants were provided with a comprehensive understanding of the critical role of proper engine lubrication, the operational principles of various types of oil pumps, correct installation procedures, routine maintenance practices, and basic troubleshooting techniques. The primary objective of the training was not only to extend the operational lifespan of boat engines but also to enhance fuel efficiency and reduce the risk of mechanical failure at sea. By employing a practical, hands-on approach tailored to the specific needs and conditions of local fishing communities, the program aimed to foster technical self-reliance. Ultimately, this initiative sought to lower long-term operational costs and improve safety in daily fishing activities.

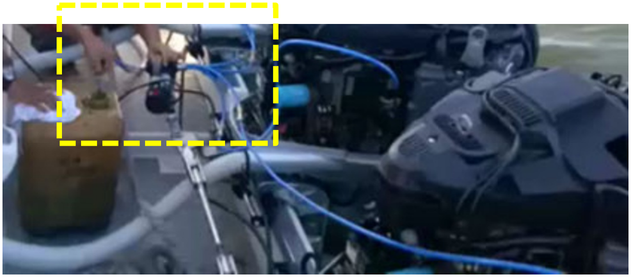

Fig. 6. DC Electric Oil Pump Tool Testing and Training for Fishermen

5 Conclusion

This study successfully developed and evaluated a DC electric oil pump designed to prevent oil leakage during boat engine maintenance. By applying a structured Research and Development (R&D) approach and employing root-cause analysis using the Fishbone diagram. The result of DC electric pump tool demonstrated superior performance in minimizing oil spills, reducing maintenance time to just 2.5 minutes per engine, and maintaining an affordable production cost. Field testing confirmed its operational reliability and environmental benefits, while community training initiatives ensured knowledge transfer and practical adoption by local fishing communities. Overall, the innovation offers a viable and sustainable solution to enhance maritime environmental protection and maintenance efficiency.

Moreover, this initiative contributes to broader environmental goals by reducing marine pollution caused by oil spills, an often-overlooked consequence of routine maintenance activities on the boat. By integrating technology development with user education and field implementation, the study bridges the gap between innovation and real-world application. The success of this tool not only supports environmental stewardship in the maritime sector but also empowers coastal communities through improved maintenance practices and operational self-reliance.

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