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(Research Article)

Smart oil change reminder system using viscosity sensor

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Abstract

This study aimed to design and develop a smart oil change reminder system using a basic viscosity sensor to monitor engine oil condition. Results from three trials showed that the 6-month oil obtained the highest mean (100.00) and was interpreted as dirty, while the 4-month oil (81.00) was also classified as dirty and the 5-month oil (61.33) as cloudy. In contrast, the 3-month (-6.33) and 2-month (6.00) oil samples were interpreted as clear, similar to the water control sample (-21.67). These increasing mean values indicate that oil condition deteriorates as storage time increases. The study therefore concludes that the smart oil change reminder system using a basic viscosity sensor can be successfully developed as a functional and reliable low-cost device capable of monitoring engine oil condition and providing timely maintenance reminders based on actual oil quality. This finding implies that affordable and locally developed sensor-based technologies can contribute to more efficient engine maintenance practices and can serve as practical instructional tools in automotive and technical-vocational education.

Keywords: Smart Oil Change Reminder; Viscosity Sensor; Automotive Maintenance; Design and Development; Tagum City

1 Introduction

Engine oil degradation continues to be a critical concern, as poor monitoring causes reduced efficiency, accelerated wear, and costly engine failures. Although changes in oil viscosity significantly influence engine performance, conventional maintenance methods rely on fixed intervals rather than the actual condition of the oil, often resulting in premature or delayed oil changes. The absence of accurate and real-time monitoring systems capable of assessing oil condition leaves engines at risk of damage, decreased lifespan, and unnecessary maintenance expenses [1].

Monitoring engine oil condition is challenging because traditional methods based on engine speed or temperature do not accurately reflect oil viscosity and degradation. This often causes inefficient maintenance, increased engine wear, and costly repairs. Microacoustic viscosity sensors provide reliable, real-time oil condition monitoring, helping optimize maintenance schedules, prevent engine damage, and improve vehicle reliability [2].

The social relevance of this study is supported by recent research emphasizing the role of smart vehicle maintenance technologies in improving road safety and sustainability. Sensor-based oil monitoring systems help drivers make data-driven maintenance decisions, reducing engine failure and unnecessary servicing [3]. A smart oil change reminder system using a basic viscosity sensor benefits society by lowering vehicle operating costs, minimizing environmental pollution from excessive oil disposal, and promoting safer driving conditions. Such innovations are especially valuable for communities with limited access to regular automotive services, as they encourage preventive maintenance and responsible vehicle use.

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Globally, studies conducted in Malaysia and China emphasize the use of sensor-based systems for condition-based oil monitoring. Viscosity sensors effectively detect engine oil degradation and support accurate oil change reminders [4]. Similarly, smart oil monitoring systems significantly improve engine efficiency and extend engine lifespan through real-time oil condition analysis [3].

In the Philippine setting, several studies focus on developing low-cost automotive monitoring systems applicable to local driving conditions. Microcontroller-based vehicle maintenance alert systems improve preventive maintenance practices among vehicle owners [5]. Integrating oil-related sensors such as viscosity sensors enhances existing engine monitoring systems used nationwide [6].

Locally, research conducted within the Davao Region explores the feasibility of smart vehicle maintenance systems. Low-cost, sensor-based reminder systems increase maintenance awareness among local drivers [7]. Implementing basic oil condition sensors proves to be practical and beneficial for extending engine life and reducing maintenance costs for local vehicle users [8].

A portable oil density scale device is developed as a practical and convenient tool for on-site measurement of oil density, addressing the problem of dependence on distant laboratories, which often results in testing delays, additional costs, and reduced efficiency in monitoring processes. Its compact design enables immediate testing and provides real-time results, enhancing the speed and accuracy of density evaluation. Additionally, the device contributes to environmental awareness by informing users about the potential risks associated with elevated oil density. Overall, the digital device demonstrates effectiveness in accurately performing density measurements and fulfilling its intended purpose [9].

A sensor is developed to measure engine oil viscosity using a metal-core piezoelectric fiber/aluminum composite, consisting of piezoelectric ceramic reinforced with a metal matrix capable of withstanding harsh engine conditions. An active measurement technique is employed, where self-generated vibrations evaluate viscosity changes in a glycerin solution as a model fluid. Viscosity is determined by analyzing damped vibration amplitude and shifts in resonance frequency, which enables measurement across a wide range of viscosities. Results show that vibrations are highly responsive to viscosity variations, confirming the composite's effectiveness as a viscosity sensor. This addresses the problem that conventional viscosity sensors often fail to operate reliably in extreme environments such as engine interiors, whereas this composite sensor offers durability, sensitivity, and suitability for real-time oil monitoring [10].

Research explores the relationship between oil viscosity and light transmission, showing that as oil ages, it becomes thicker and restricts light passage, demonstrating a clear correlation. The study indicates that simple tools are capable of assessing oil quality and providing timely signals for necessary oil changes. However, many maintenance practices still depend on fixed schedules rather than actual oil condition, which can lead to premature servicing or unexpected engine wear, underscoring the need for more accurate and responsive monitoring methods [11].

Researchers apply soft computing approaches such as artificial neural networks and support vector regression to predict lubricant viscosity, achieving highly accurate estimates based on simple engine parameters. Data-driven techniques show strong potential to enhance or complement sensor-based oil monitoring in a smart reminder system. Yet, conventional maintenance still relies heavily on fixed schedules, and the absence of integrated predictive tools limits timely detection of oil degradation, creating risks of unnecessary servicing or overlooked engine wear [12].

An analysis of fresh engine oils reveals that their electrical properties, particularly capacitance and impedance, show a strong correlation with viscosity and density. Findings indicate that electrical sensing can serve as an alternative or complement to viscosity sensors for monitoring oil condition. Yet, maintenance practices still rely on fixed schedules instead of real-time evaluation, leading to premature oil replacement or unnoticed degradation that threatens engine performance and longevity [13].

The innovation developed is the smart oil change reminder system using basic viscosity sensors to provide real-time insights into oil condition, ensuring maintenance is based on actual oil performance rather than arbitrary schedules, thereby enhancing engine longevity, maintaining optimal performance, and reducing costly repairs within the broader context of automotive maintenance research. Monitoring engine oil plays a vital role in preventing damage by continuously evaluating its condition, enabling maintenance based on actual quality rather than fixed schedules, which promotes timely action to extend engine life, optimize performance, and reduce repair costs.

Monitoring engine oil is crucial for preventing engine damage by continuously evaluating its quality, enabling maintenance based on real condition rather than fixed schedules, thereby ensuring timely intervention that prolongs engine life, optimizes performance, and reduces repair costs [16].

Engine oil can deteriorate more quickly than expected, potentially causing reduced engine efficiency, higher fuel consumption, and expensive repairs if not replaced promptly. Standard oil change schedules based on time or mileage do not accurately reflect the actual condition of the oil under different driving conditions. A smart oil change reminder system using real-time viscosity sensors alerts drivers immediately when the oil quality falls below safe levels, enabling timely maintenance and preventing serious engine damage. This proactive approach helps protect both the vehicle's performance and the driver's safety.

The increasing risk of engine failures from inadequate oil monitoring makes it urgent to develop a real-time smart oil change reminder system, which not only reduces maintenance costs but also enhances public safety and promotes environmentally responsible vehicle use. Neglecting to monitor engine oil viscosity can lead to severe engine damage, reduced efficiency, costly repairs, and increased environmental impact, making real-time alerts from the smart oil change reminder system essential for both vehicle reliability and community safety.

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1.1 Purpose and Description

This study aimed to design and develop a smart oil change reminder system using a basic viscosity sensor, integrating real-time monitoring technology to accurately determine the condition of engine oil. The system seeks to eliminate reliance on fixed mileage or time-based maintenance schedules by providing timely and data-driven reminders, thereby reducing unnecessary oil changes, preventing engine wear, and extending the overall life span of the engine.

1.2 Research Objectives

This study aimed to design and develop a smart oil change reminder system using basic viscosity sensors. Specifically, it sought to:

- Design and develop a smart oil change reminder system using basic viscosity sensors.
- Test the smart oil change reminder system using basic viscosity sensors.

2 Materials and Methods

2.1 Research Design

In this study, a design and development research design was used. A design and development research approach refers to a systematic method for studying new models, tools, and procedures to ensure their effectiveness and efficiency, generating findings that are context-specific yet adaptable to various educational and practical settings while contributing new principles that strengthen design, development, and evaluation practices [18].

The design and development research design refers to a process that is systematically organized to ensure efficiency and accuracy. It also involves comprehensive review, verification, and validation to guarantee that the product or service meets the required standards and fulfills its intended purpose [19]. This design is suitable for the study because it aims to create an innovative system using a viscosity sensor. It allows for systematic planning, construction, and testing of the system to ensure functionality and reliability, while ensuring that the final output meets required standards and addresses the limitations of traditional oil change methods.

2.2 Process Model

This section outlines the process model that was used in the study to innovate an oil change sensor. Figure 1 illustrates the project's process model, planning and designing system architecture (hardware and software), developing and integrating the prototype system, testing, evaluating, and refining the system based on performance and usability.

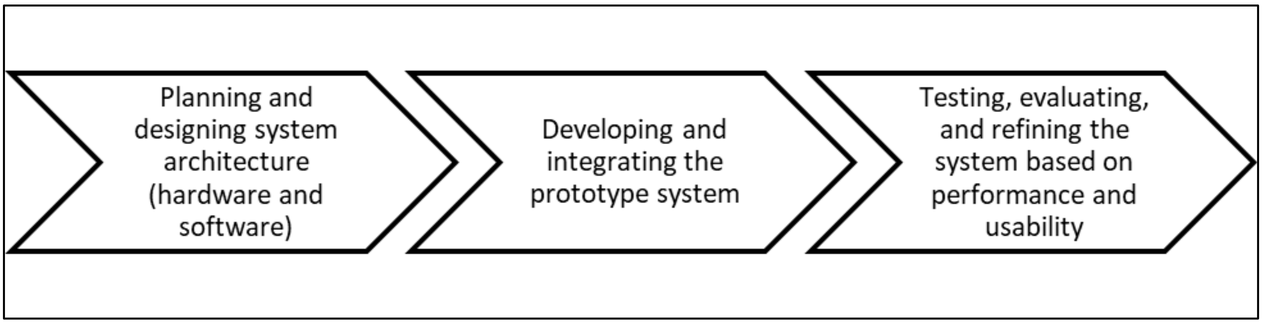

Figure 1 Process Model of the Study

Planning and Designing System Architecture (Hardware and Software). In planning and designing the system architecture, several materials and equipment were required. To support the control system, an Arduino circuit priced at ₱374.00 and an Arduino turbidity sensor costing ₱450.00 were used. Meanwhile, dupont wire worth ₱65.00 and a ¼ flyboard worth ₱150.00 served as the base for the prototype. Altogether, the total estimated cost of materials and equipment amounted to ₱1,039.00.

Figure 2 shows the connection between the motorcycle engine's turbidity sensor and the Arduino circuit. The turbidity sensor detected changes in oil quality by measuring its clarity, while the Arduino functioned as the processing unit that interpreted the sensor's data. The wiring connection included the VCC (power supply) and GND (ground) terminals to ensure proper operation. This design demonstrated how the system monitored engine oil condition in real time and alerted the user when an oil change was needed.

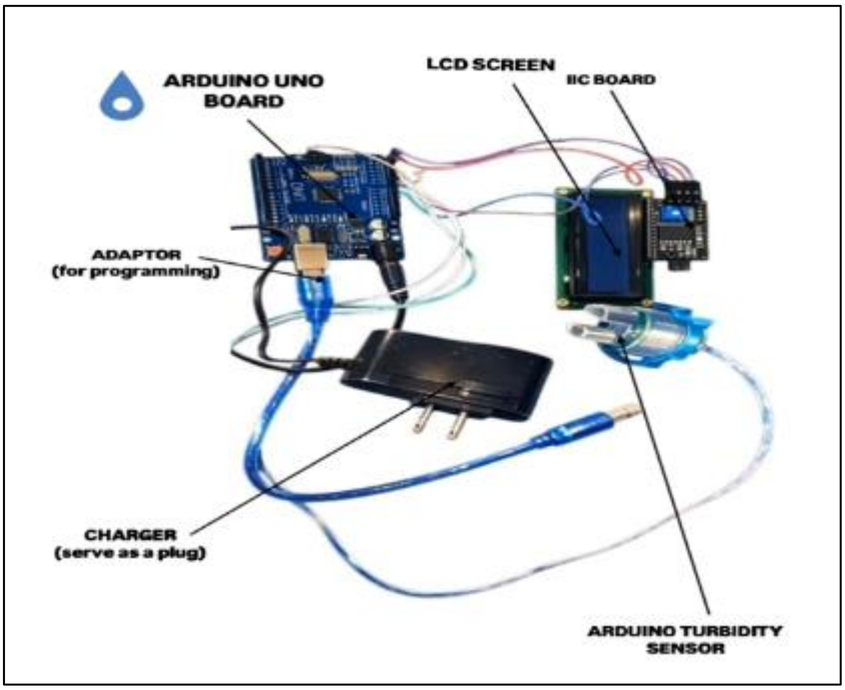

Figure 2 Design of the Smart Oil Change Reminder System

Table 1 lists the materials and equipment used to develop the smart oil change reminder system, including an Arduino Uno R3 board, an Arduino-compatible turbidity sensor, a Bosch power drill, safety gloves, and a full-face protective shield. The total cost of these materials and equipment amounted to ₱2,176.17.

Table 1 Materials and Equipment Used in the Study

Materials	**Specification**	**Quantity**	**Cost**
Arduino Board	Arduino Uno R3 (ATmega328P)	1	₱498
Turbidity Sensor Module	Arduino Compatible Turbidity Sensor (0-1000 NTU)	1	₱160
Equipment	**Specification**	**Quantity**	**Cost**
Power Drill	Bosch GSB 13 RE, 600W Electric Drill	1	₱999
Safety Gloves	RS pro white, Industrial Latex Gloves		₱139.17
Face Shield	TSP610 Full-Face Protective Shield	1	₱380
Total			₱2,176.17

Developing and Integrating the Prototype System. Once the design was finalized, the team proceeded to build the prototype system. The components were developed and connected, ensuring they functioned properly as one integrated system. This step also included initial testing to check that all modules were aligned with the intended design. For this development, the team made use of the following equipment: a motorcycle cap that was modified for sensor installation, a motorcycle engine which served as the testing platform, an Arduino circuit with a turbidity sensor to detect and monitor engine oil condition, and essential safety gear such as gloves and a face shield to ensure protection during assembly and testing.

Figure 3 illustrates how the motorcycle engine served as the system where the modified cap was installed. The motorcycle cap acted as the base component for sensor integration, while the power drill was used to create a hole in the cap for proper sensor placement. The sensor then was attached to measure vital parameters such as oil level, pressure, or temperature, and the final modified cap with the sensor was reinstalled into the engine to enable real-time monitoring. The modified cap functioned as a secure mount that ensured the sensor remained in direct contact with the engine oil without causing leaks. The sensor functioned as the data source, transmitting accurate readings to the Arduino circuit for analysis and user notification.

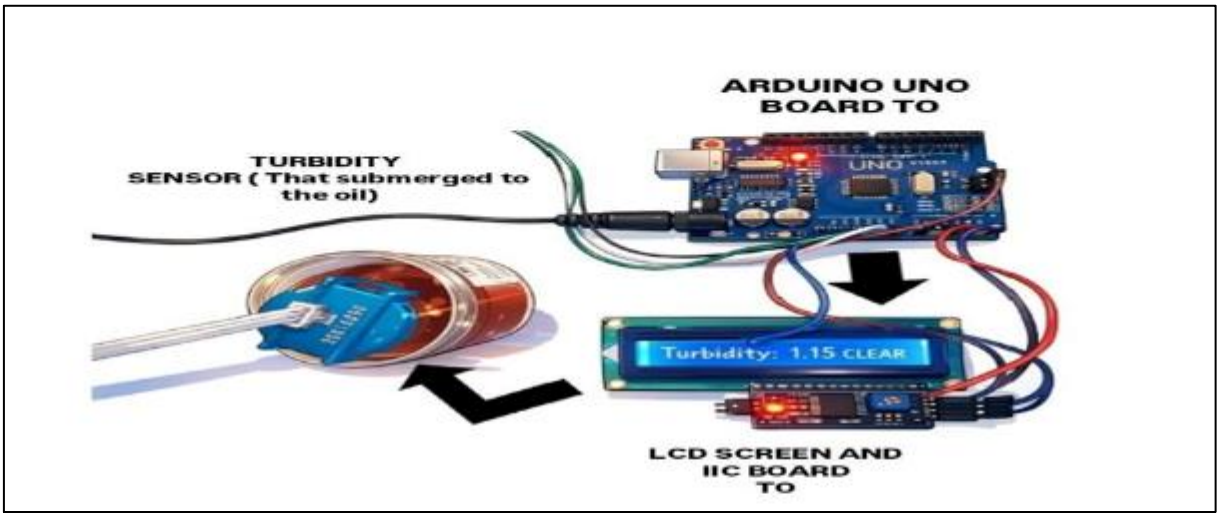

Figure 3 Sensor Integration Process in Motorcycle Engine Cap

The illustration shows modifying a motorcycle engine cap to integrate a sensor. The motorcycle's original cap was first removed, and a hole was created at the center using a power drill. This modification allowed the sensor to be properly installed in the middle of the cap. Once the sensor was attached, the cap was then reassembled onto the motorcycle engine. This procedure demonstrated the step-by-step development of a sensor-integrated motorcycle cap, which served as the foundation for monitoring engine parameters.

Developing and Integrating the Prototype System (Refinement Stage). In this stage, the prototype underwent modifications to resolve issues and implement necessary improvements. Through continuous adjustments and upgrades, the prototype evolved into a more stable and effective version, suitable for broader testing or deployment.

Testing, Evaluating, and Refining the System Based on Performance and Usability. This phase involved conducting a series of trials to determine whether the prototype functioned effectively under real operating conditions. Performance testing ensured that the sensor-equipped motorcycle cap accurately monitored vital engine parameters, while usability testing focused on the ease of installation, operation, and interpretation of data by the user.

Table 2 presents the range of means used to evaluate viscometer turbidity readings in determining engine oil condition. The readings classify oil as clear (<20), cloudy (>10), or dirty (>50), indicating increasing levels of contamination and viscosity that guide appropriate oil maintenance actions.

Table 2 Range of Means for Evaluating Viscometer Readings

Range of Means (Turbidity Reading)	Descriptive Equivalent	Interpretation
>50	Dirty	Oil is extremely thick and visibly dirty; indicates severe contamination such as soot buildup, polymer degradation, or sludge formation. This condition can restrict oil flow, increase friction, and cause engine stress. Immediate oil change is required.
>10	Cloudy	Oil appears dark and dirty; viscosity is higher than normal, suggesting contamination or thermal thickening. Lubrication efficiency may be reduced. Monitoring and early oil replacement are recommended.
<20	Clear	Oil is clear and within the normal viscosity range for many multigrade lubricants. Indicates good oil condition and acceptable lubrication performance if within tolerance of fresh oil.

The results from these tests are then evaluated to identify strengths and weaknesses of the system, and necessary refinements are applied to improve accuracy, durability, safety, and user-friendliness, ensuring that the final system is both reliable and practical for long-term application.

2.3 Data Analysis

Mean. The mean was used to identify the average viscosity readings of the smart oil change reminder system after three trials.

2.4 Safety Precautions

In this design and development project, various safety precautions were observed to protect the researchers and the environment. The study implemented measures such as wearing protective equipment, maintaining proper wiring, and keeping the workspace organized to prevent accidents and ensure reliable results.

During laboratory activities, the researchers handled motor oil samples, tested the smart oil change reminder system, and monitored sensor readings. They wore gloves and goggles to prevent exposure to oil spills and splashes, maintained a clean and dry workspace, and properly stored or disposed of motor oil samples to uphold safety and accuracy throughout the experiments.

Equipment and prototyping safety were strictly enforced throughout the project. The researchers conducted regular inspections of sensors and electronic components, secured wiring, and used insulated enclosures to prevent electrical hazards. The prototype was securely mounted, protective gear was worn during soldering and assembly, and the system was tested in controlled conditions to ensure safe, reliable, and effective operation.

3 Results and Discussion

3.1 Designing and Developing the Smart Oil Change Reminder System

The smart oil change reminder system is an innovative device designed to enhance vehicle maintenance by monitoring engine oil condition using a basic viscosity sensor. As illustrated in Figure 4**,** the system integrates a turbidity sensor installed in the modified motorcycle engine cap to detect changes in oil clarity and viscosity. The sensor transmits data to the Arduino microcontroller, which processes the readings and determines whether an oil change is necessary. When the oil quality falls below the acceptable level, the system activates a notification to alert the user, ensuring timely maintenance.

To ensure safety and reliability, the system incorporates proper wiring connections, insulated components, and secure sensor installation within the engine cap. The development process includes planning, assembling, testing, and refining the prototype to guarantee functionality, durability, and efficiency. As a smart oil monitoring device, the system effectively replaces traditional fixed oil change schedules with real-time, data-driven alerts, promoting engine longevity, reducing maintenance costs, and supporting sustainable vehicle operation.

Figure 4 shows the sensor integration process in the motorcycle engine cap, where the original cap is modified to accommodate the turbidity sensor. A hole is carefully drilled at the center of the cap to allow proper placement of the sensor. The sensor is then securely installed and sealed to prevent oil leakage and ensure accurate readings. After installation, the modified cap is reattached to the motorcycle engine. As a result, the system is able to monitor the oil condition in real time and transmit data to the Arduino microcontroller for processing and notification.

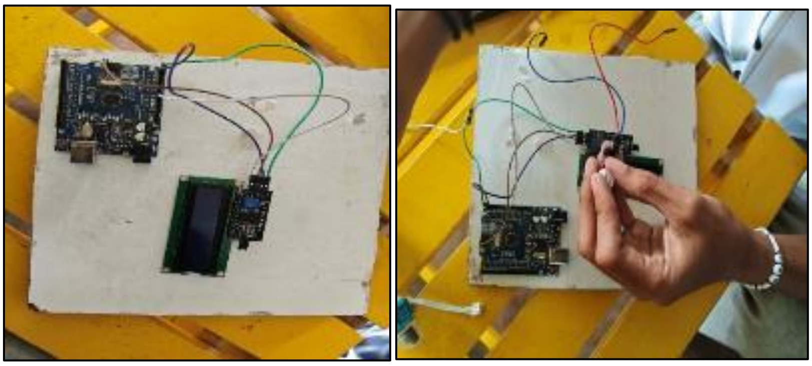

Figure 4 Installing the Components to the Board

Figure 5 shows the installation of the components onto the board, where the Arduino circuit and turbidity sensor are properly connected using jumper wires. This process ensures correct wiring alignment and stable electrical connections between the sensor and the microcontroller. As a result, the system is able to accurately receive, process, and transmit oil condition data, enabling reliable monitoring and timely oil change notifications.

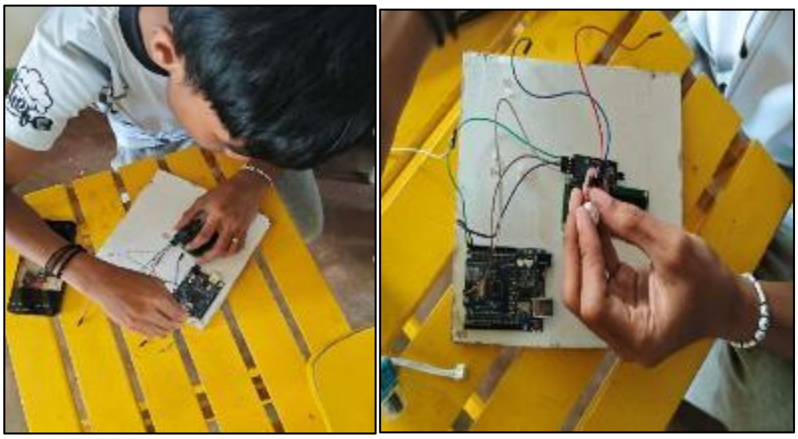

Figure 5 Wiring Connection of the Smart Oil Change Reminder System

Figure 6 shows the coding and programming process of the Arduino control board, where the developed source code is uploaded to the microcontroller using the Arduino Integrated Development Environment (IDE). The program is designed to read data from the turbidity sensor, analyze the oil condition based on preset threshold values, and trigger a notification when the oil quality falls below the acceptable level. This process ensures that the control board accurately interprets sensor readings and executes the appropriate response. As a result, the system operates automatically and provides real-time oil change reminders to the user.

```
//////////////////////////////////////////////////////////////////////
//              Arduino turbidity meter Project                     //
//                                                                  //
//              www.edisonsciencecorner.blogspot.com                //
//////////////////////////////////////////////////////////////////////

#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 2, 16);

int sensorPin = A0;
void setup()
{
  lcd.begin();
  pinMode(3,OUTPUT);
  pinMode(4, OUTPUT);
  pinMode(5, OUTPUT);

}

void loop() {
  int sensorValue = analogRead(sensorPin);
  int turbidity = map(sensorValue, 0,640, 100, 0);
  delay(100);
  lcd.setCursor(0, 0);
  lcd.print("turbidity:");
  lcd.print("   ");
  lcd.setCursor(10, 0);
  lcd.print(turbidity);
  delay(100);
  if (turbidity < 20) {
    digitalWrite(7, HIGH);
    digitalWrite(8, LOW);
    digitalWrite(9, LOW);
    lcd.setCursor(0, 1);
    lcd.print(" its CLEAR ");
  }
  if ((turbidity > 10) && (turbidity < 50)) {
    digitalWrite(7, LOW);
    digitalWrite(8, HIGH);
    digitalWrite(9, LOW);
    lcd.setCursor(0, 1);
    lcd.print(" its CLOUDY ");
  }
  if (turbidity > 50) {
    digitalWrite(7, LOW);
    digitalWrite(8, LOW);
    digitalWrite(9, HIGH);
    lcd.setCursor(0, 1);
    lcd.print(" its DIRTY ");
  }

}
```

Figure 6 Coding and Programming of the Arduino Control Board

Figure 7 shows the final assembly and finishing of the smart oil change reminder system, where all components are securely mounted and enclosed to ensure protection and durability. The wiring connections are properly arranged, insulated, and checked for stability, while the modified engine cap with the installed sensor is firmly reattached to the motorcycle engine. This finishing process ensures that the system is safe, organized, and ready for operation. As a result, the completed prototype functions efficiently and provides reliable real-time oil condition monitoring and timely maintenance alerts.

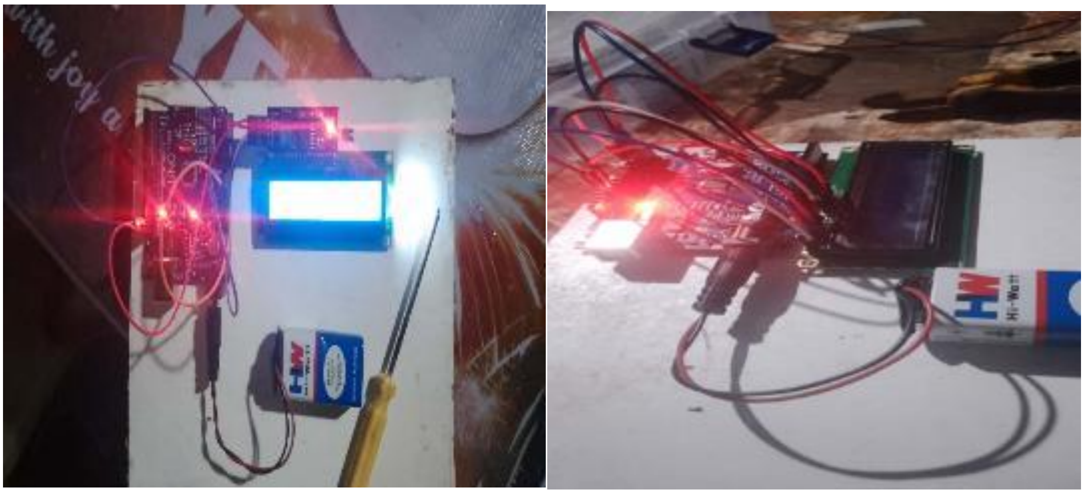

Figure 7 Final Assembly and Finishing of the Smart Oil Change Reminder System

Figure 8 shows the completed smart oil change reminder system prototype after all assembly, wiring, programming, and finishing processes were finalized. The turbidity sensor is securely installed in the modified engine cap, and the Arduino control board is properly mounted with organized and insulated connections. The system is fully operational and ready for testing under actual engine conditions. As a result, the finalized prototype demonstrates its capability to monitor oil quality in real time and provide accurate and timely oil change notifications.

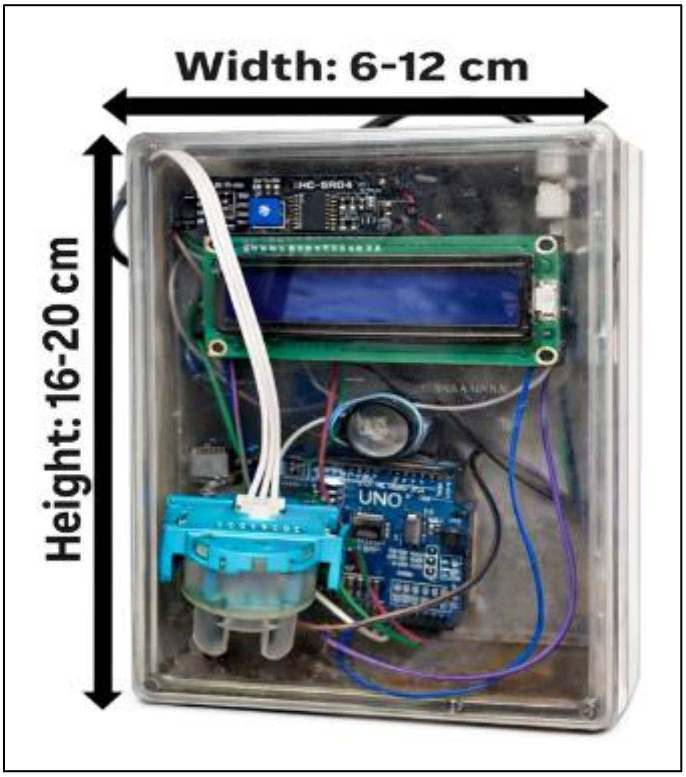

Figure 8 Completed Smart Oil Change Reminder System Prototype

3.2 Testing the Smart Oil Change Reminder System Using Basic Viscosity Sensors

Table 3 presents the performance evaluation of the smart oil change reminder system using a basic viscosity sensor. The system successfully detected varying oil conditions, classifying samples as clear, cloudy, or dirty, with clear readings indicating good oil, cloudy readings signaling moderate contamination, and dirty readings reflecting severe degradation requiring immediate change. The highest reading of 100.00 for the 6-month oil was classified as dirty, showing severe degradation that could reduce lubrication efficiency, while the 3-month oil had a low reading of -6.33, classified as clear, reflecting good oil condition. Consistent readings across multiple trials demonstrated stable performance and reliable data processing. These results show that the system can accurately differentiate between healthy and severely degraded oil, providing timely oil change reminders as a practical, low-cost solution for real-time monitoring.

Table 3 Viscosity Readings on the Different Samples of Oil

Indicators / oil sample tested	Trial 1	Trial 2	Trial 3	Mean	Interpretation
6 months oil	100.00	100.00	100.00	100.00	Dirty
5 months oil	61.00	62.00	61.00	61.33	Cloudy
4 months oil	80.00	81.00	82.00	81.00	Dirty
3 months oil	-5.00	-7.00	-7.00	-6.33	Clear
2 months oil	5.00	5.00	8.00	6.00	Clear
Water (control sample)	-20.00	-22.00	-23.00	-21.67	Clear

Online oil monitoring has advanced rapidly in recent decades due to its advantages in wear analysis and the increasing demand for condition-based maintenance (CBM) [17]. It is increasingly recognized as an independent state-monitoring technology capable of tracking a machine's performance in real time. Implementing simple viscosity-based sensors allows for timely detection of oil degradation, supporting predictive maintenance and reducing the risk of equipment failure [14]. Experimental studies confirm that acoustic wave and basic viscosity sensors provide accurate, real-time measurements that align with established rheological models [15]. These developments form the foundation for smart oil change reminder systems that improve maintenance efficiency and reliability.

3.3 Summary of Findings

This study employed a design and development quantitative research method, involving prototype construction and system evaluation to develop a smart oil change reminder system using a basic viscosity sensor. The system was evaluated for functionality and efficiency, with sensor readings used to classify oil condition as clear, cloudy, or dirty. The findings guided improvements in system design, sensor integration, and programming to ensure reliable real-time monitoring of engine oil. The researchers successfully developed a functional prototype consisting of a turbidity-based viscosity sensor, Arduino microcontroller, modified motorcycle engine cap, and supporting electronic components, which were systematically assembled, calibrated, and tested.

The system effectively detected varying oil conditions, accurately classifying samples as clear, cloudy, or dirty, and provided timely oil change reminders based on actual oil quality rather than fixed schedules. Consistent sensor readings across multiple trials demonstrated stable performance and reliable data processing, while repeated testing confirmed that the system functioned effectively under continuous use. The highest readings, 100.00 for 6-month oil and 81.33 for 4-month oil, were classified as dirty, indicating severe degradation, while the 5-month oil showed a cloudy reading of 61.33. The lowest readings, -21.67 for the water control and -6.33 to 6.00 for 3- and 2-month oils, were classified as clear, reflecting good condition. These results indicate that the smart oil change reminder system provides accurate, real-time assessments of oil quality, supporting timely maintenance as a practical, low-cost solution.

4 Conclusion

The study concluded that the smart oil change reminder system using a basic viscosity sensor was successfully designed and developed as a low-cost oil monitoring device through systematic planning, sensor integration, programming, and testing. The positive performance of the final prototype was attributed to proper sensor placement, accurate Arduino-based data processing, and effective classification of oil conditions as clear, cloudy, or dirty. However, the system had limitations in sensor sensitivity and environmental adaptability, indicating the need for further refinement to ensure consistent accuracy under varying engine conditions.

Regarding acceptability, the system was rated highly in terms of functionality and efficiency for monitoring engine oil condition. This demonstrates that low-cost, locally developed electronic monitoring systems can serve as effective alternatives to conventional mileage-based oil change practices when properly designed. Despite this positive outcome, the study was limited to a specific testing setup and short-term evaluation, which may affect the generalizability of the findings.

The evaluation of the prototype revealed that improvements in system design, sensor integration, and programming enhanced its performance and reliability. The system accurately classified oil samples as clear, cloudy, or dirty, providing dependable readings for timely maintenance. These results confirm that systematic development and performance testing are essential for improving the quality of sensor-based automotive monitoring devices. However, long-term engine use, exposure to extreme temperatures, and integration with different vehicle models were not assessed, highlighting areas for future research and improvement.

Recommendations

Based on the findings of the study, it is recommended that the final prototype design of the smart oil change reminder system using a basic viscosity sensor be adopted or replicated, as it demonstrated high levels of acceptability in functionality, efficiency, and durability. The positive evaluations indicate that the system's sensor integration, data processing, and oil condition classification effectively met user needs. Therefore, the developed version is considered the most suitable and recommendable model for basic engine oil monitoring in small automotive workshops and educational settings.

To address the limitations of the study, further improvements in system design and calibration are recommended, particularly in enhancing sensor sensitivity, improving protection against heat and oil contamination, and stabilizing electronic components. These refinements will help improve accuracy, reliability, and user confidence during prolonged use. The integration of additional protective housings or improved sensor materials may also be explored to increase durability and resistance to harsh engine environments.

Technical-vocational and automotive schools may adopt the project as an instructional model to help students develop skills in electronics, sensor integration, and automotive maintenance technology. Future researchers are encouraged to conduct long-term field testing, explore integration with additional engine parameters such as temperature and pressure, and compare the system's performance with commercial oil monitoring devices to further validate its effectiveness and practical value. For future research, it is also recommended that kilometer-based monitoring be used as the primary basis for evaluating oil condition instead of relying on monthly duration. Using accumulated mileage as a reference provides a more practical and realistic measurement of engine oil usage, as oil degradation is directly affected by vehicle operation and driving distance. Integrating a kilometer tracking system alongside the viscosity sensor may improve the accuracy of maintenance reminders and better align the system with real-world automotive practices.

Compliance with ethical standards

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Disclosure of Conflict of interest

We, Jhuniel Jay L. Lambongog*, Justine Kyle C. Ancero, Philip John T. Tumaroy, Chrisvera Gwyneth S. Aloro, Blessie T. Aquino, and Cromwell F. Gopo, declare that we have no conflicts of interest or competing interests to disclose regarding the publication of this manuscript or any institution, product, or entity mentioned therein. Furthermore, we have no affiliations or financial interests in any products or organizations that could influence the study outcomes presented or compete with those discussed in the manuscript.

Statement of ethical approval

All ethical standards were strictly followed in the conduct of this study. All sources and authors referenced in the manuscript were properly cited in accordance with academic and ethical guidelines.

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