Journal of Machine Engineering, 2025, Vol. 25
ISSN 1895-7595 (Print) *ISSN 2391-8071 (Online)*

Received*: 15 February 2025* / Accepted: *02 April 2025* / Published online: *26 May 2025*

vehicle, health,
monitoring
sensors interfacing

Yogita DUBEY[1*], Khushal DAMAHE[1],
Usha AMBULE[1], Sanskruti ALONE[1],
Tanaya DESHPANDE[1], Roshan UMATE[2]

INTELLIGENT ENGINE HEALTH MONITORING SYSTEM FOR ENHANCED VEHICLE PERFORMANCE

In traditional vehicle maintenance, there's often no real-time data available, leaving drivers in the dark about important health and safety parameters. This gap can cause problems like low oil levels, poor oil quality, and overheating, which can put the vehicle and passengers at risk. This paper presents the intelligent engine health monitoring system for enhanced vehicle performance. The system uses ESP8266, ultrasonic sensor, light dependent resistor (LDR), and DS18B20 temperature sensors for continuous monitoring of the oil level, oil quality assessment, and engine temperature measurement in real-time. Oil quality assessment using RGB and white light transmission through a glass tube is proposed with improved accuracy in degradation detection. Blynk app interface in the proposed system produces the instant alert for exceeding threshold limit of sensor to ensures enhanced vehicle performance. Results demonstrate that blue light detects early-stage oil degradation, green light provides a balanced evaluation, and red light identifies severe degradation. A comparative analysis with optical color sensors and ultrasonic-based oil detection highlights the system's higher adaptability and real-time monitoring capabilities.

1. INTRODUCTION

Vehicle health monitoring (VHM) plays important role in vehicle maintenance and safety. Combustion engines in the vehicle are the backbone of industrial and automotive machinery and their durability and optimal functioning necessitates the need of engine oil monitoring. Engine oil plays the important role in any mechanical systems and need careful maintenance and monitoring for enhanced performance. It plays a crucial role in assessing engine conditions such as lubrication, heat dissipation, contamination control, and degradation monitoring. It acts as a lubricant which reduces friction between moving components and minimizes mechanical wear, factor to prevent premature engine failure [1].

[1] Department of Electronics and Telecommunication Engineering, Yeshwantaro Chavan College of Engineering, Nagpur, India
[2] Research and Innovation, Datta Meghe Institute of Higher Education and Research, India
[*] E-mail: yogeetakdubey@yahoo.co.in
https://doi.org/10.36897/jme/203660

Engine oil also serves as a thermal conductor, which absorbs and distribute excess thermal energy to prevent overheating, thereby ensuring optimal engine performance [2]. Statistical methods for oil classification using color histograms and pattern recognition is proposed in [3].

Engine oil also serves as a cleaning agent which captures and removes the contaminants such as metal particles, combustion by products, and dirt. This prevents sludge build-up and helps in maintaining the engine efficiency, in the contra ray, degraded oil leads to increased wear and compromised performance [4]. Oil degradation with respect to changes in viscosity, color, and contamination levels acts as a key diagnostic indicator for excessive wear, coolant leaks, or combustion inefficiencies [5].

Some research explored various approaches to enhance lubricant performance such as pollution and composition variations in engine oil issue in [6] for routine oil checks and condition-based modifications and LDR-based method to evaluate two-wheeler engine oil feasibility in [7]. Optical technologies are used for oil monitoring using optical color sensor in [8], RGB color sensor in [9] and optical equipment and color indices in [11]. Ultrasonic sensors used by [10, 12] for oil level measurement and carried out analysis under different thermal conditions and oil levels**.**

Several studies utilized IoT for real-time vehicle monitoring. IoT-based engine oil health monitoring using ultrasonic, LM35, and LDR sensors is proposed in [5, 13]. Sachin et al. [14] extended IoT capabilities for vehicle monitoring with improved travel safety and fuel efficiency. Pradhan et al. (2022) [8] developed an IoT-enabled engine oil condition monitoring system is proposed in [8] with comprehensive feedback and early alert. Recent research has highlighted the importance of deep learning for engine health monitoring such as soft computing approach for evaluating lubricant condition in [15] and convolutional neural network (CNN) based approach in [16]. Engine oil degradation analysis in optimizing fleet maintenance costs is carried out in [17]. Wu et al. [18] proposed the system for online lubricating oil state monitoring in critical applications.

Traditional vehicle maintenance depends on scheduled servicing and manual inspections, which fails in real time monitoring of engine health. Due to this, vehicle owners are unaware of low oil levels, poor oil quality, or overheating of engines which leads to costly repairs, unexpected breakdowns, and safety risks with inefficient fuel consumption and increased emissions. Therefore, an integrated is required for continuous monitoring of key engine parameters for early detection of potential issues and timely corrective actions**.** This paper proposed an intelligent engine health monitoring system for enhanced vehicle performance with the following key contributions:

- IoT-based engine oil monitoring system using ESP8266 as the primary controller with ultrasonic sensor for oil level detection, a DS18B20 temperature sensor for engine heat measurement, and an LDR for oil quality assessment.
- Investigation of variations in transmittivity for oil degradation using experimental analysis of different monochromatic lights (Red, Green, Blue).
- Real-time visualization of oil quality, oil level, and engine temperature with user-friendly interface for enabling easy interpretation and decision-making.
- Alert system based on industry standards with early warning for deviations in oil level, temperature, and quality.

2. METHODOLOGY

This section describes the methodology adapted for intelligent engine health monitoring system. The proposed system comprises of ESP8266 Node MCU module, ultrasonic sensor, Light Dependent Resistor (LDR), and DS18B20 temperature sensors for real-time monitoring of engine parameters like oil level, oil quality, and engine temperature. The block diagram representation of the proposed system is shown in Fig. 1.

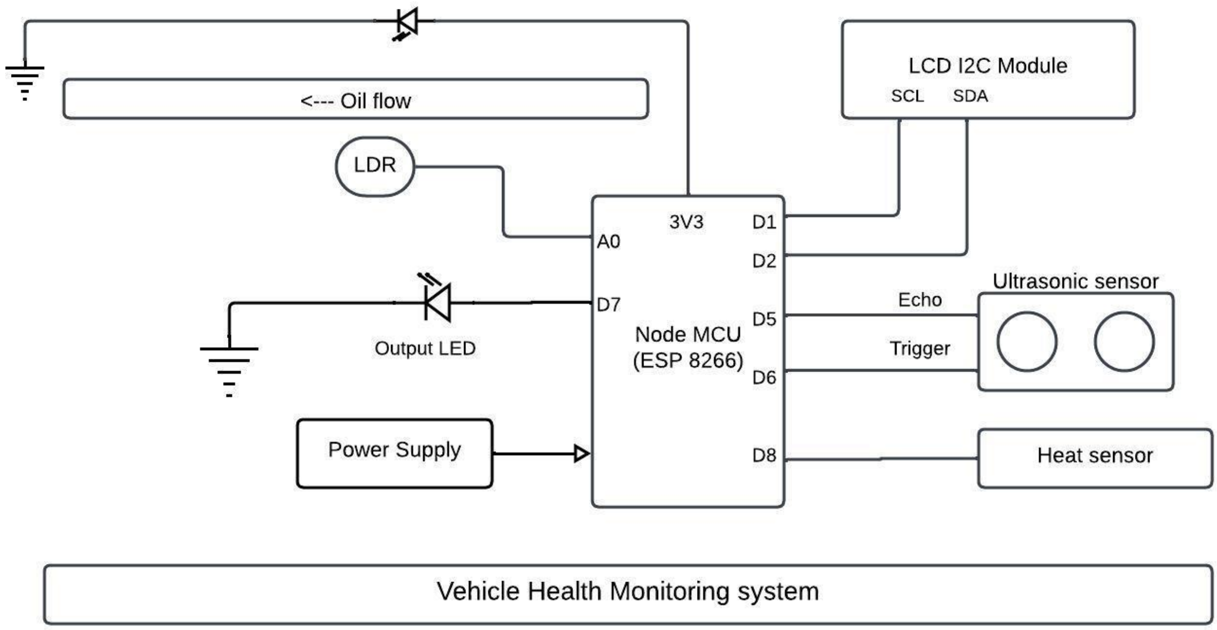

Fig. 1 Block Diagram of Proposed Intelligent Engine Health Monitoring System

The Node MCU (ESP8266) is a primary controller of the proposed system. The main function is to facilitates data collection and processing. It is widely used for IoT-based monitoring systems due to its wireless communication capabilities [6]. The LCD connected to pins D1 (SCL) and D2 (SDA) is used for real-time visual feedback on engine health. The ultrasonic sensor has demonstrated effectiveness in automotive applications [11]. It is used for oil level monitoring and connected to pins D5 (Echo) and D6 (Trigger). The DS18B20 digital temperature sensor is well known for its accuracy and reliability in real-time temperature monitoring [9]. It is connected to pin D8. The Light Dependent Resistor (LDR), is used for optical assessments using transmittivity [11]. It is connected to the analogue pin A0. The LED output, which provides visual alerts for degraded oil quality, is connected to pin D7. The supply voltage pin provides power to the Node MCU and all connected components. The entire system enables the real-time monitoring and analysis and provides the insights and alerts to the user via the Blynk app and the LCD display.

Figure 2 shows the complete flow of the intelligent engine health monitoring system. System design phase involves conceptualizing the architecture of the system with Node MCU as the primary microcontroller. Ultrasonic sensors for oil level measurement, DS18B20 sensors for engine temperature monitoring, and LDR sensors for assessing oil quality are integrated integration phase. The data then is collected from these sensor and preproceed using Node MCU in data acquisition and processing phase. User interface is designed using Blynk app interface which serves as the platform for visualizing real-time data and enabling user engagement. Code assembly, testing and validation includes integration of sensor algorithms into Node MCU for seamless operation. The components are physically deployed in the vehicle and seamlessly integrated into its infrastructure. Finally real time monitoring using Blink app interface ensures communication between Node MCU and user devices. It gives the visual representation of all engine parameters that are measured using sensors and notify users if the threshold exceeds the predefined threshold value.

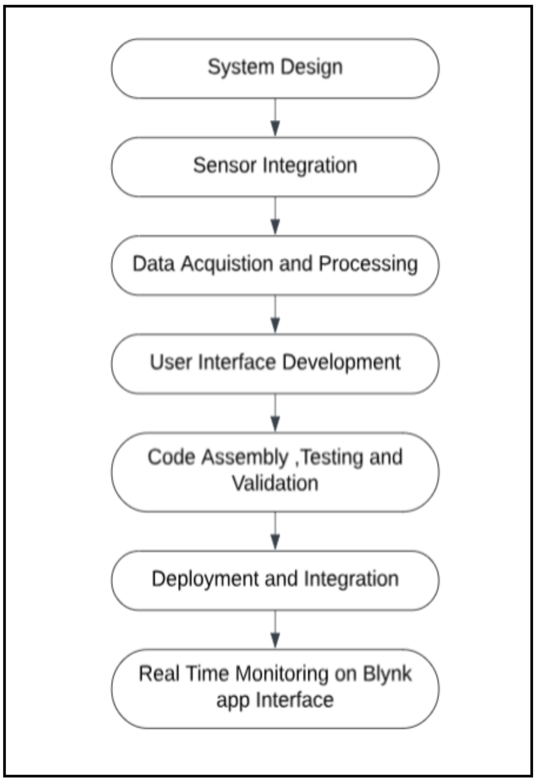

Fig. 2. Flow Diagram for Intelligent Engine Health Monitoring System

Experimentation were conducted to assess the engine oil condition under various vehicle conditions. The integration of an ultrasonic sensor, temperature sensor and LDR provides the enhanced performance for vehicle. A detailed overview of how these sensors works using threshold is discussed below:

1. Light Dependent Resistor (LDR): LDR is used to evaluates engine oil quality. LDR combined with a white LED light and transparent glass pipes is used to measure the oil's transparency. This approach assesses oil quality by monitoring the light passing through the oil and how much reaches the LDR. The system is integrated with the Blynk app, to remotely monitor the oil quality in real-time and receive continuous updates on its status as as good, moderate, or degraded based on predefined thresholds [5] as given in Eq. 1.

$$\text{Oil Quality}=\begin{cases}\text{Good, if } Q > 800\\ \text{Moderate,if} 250 \leq Q \leq 800\\ \text{Degraded, if } Q < 250\end{cases} \tag{1}$$

The readings obtained using LDR sensor can be susceptible to fluctuations due to ambient light interference and sensor sensitivity. Hence transmittivity is used for engine oil quality assessment which is calculated using

$$\text{Transmittivity}=\frac{\text{Transmitted Light}}{\text{Incident Light}}\times 100 \tag{2}$$

where "Transmitted Light" is the intensity of light transmitted through the engine oil, and "Incident Light" is the intensity of the incident light. This ratio normalizes the fluctuations in LDR readings and gives more reliable conclusions regarding oil quality.

$$\text{Transmittivity}(\%) = \begin{cases}\text{Good, if R} > 80\\ \text{Moderate, if } 25 \leq R \leq 80\\ \text{Degraded, if R} < 25\end{cases} \tag{3}$$

LDR sensor is placed in a transparent glass tube connected to the oil flow system. This setup enables the passage of light through the oil sample, allowing the LDR to assess oil transmittivity and degradation based on light absorption.

2. Ultrasonic Sensor: An HC-SR04 ultrasonic sensor is used to accurately measure real-time oil levels. By establishing threshold values, we have categorized oil levels into low, medium, and high, enabling proactive monitoring and warning issuance before potential performance degradation. Integrated with the Blynk app, our system provides remote monitoring capabilities, indicating any oil level surpassing predefined thresholds. This ensures users are promptly alerted to elevated levels, facilitating proactive maintenance and optimal vehicle operation. Eq. 4 shows the Oil level threshold used in this project.

$$\text{Oil Level}(\%) = \begin{cases}\text{High, if L} > 80\\ \text{Medium, if } 40 \leq R \leq 80\\ \text{Low ,if R} < 40\end{cases} \tag{4}$$

These values were selected based on industry recommendations for minimum oil level requirements in automotive applications to prevent engine damage [12]. This sensor was installed above the oil reservoir to measure the distance between the sensor and the oil surface, allowing real-time detection of oil level variations.

3. DS18B20 (Temperature Sensor): The DS18B20 is a digital temperature sensor known for its high accuracy and reliability in temperature measurements. Temperature sensor is mounted externally on the oil reservoir or pipeline to measure temperature variations in the circulating oil. In this paper, threshold value of 70 degrees Celsius is used for engine temperature. This value was chosen based on manufacturer specifications and prior research indicating that prolonged exposure to temperatures above 70°C can cause oil degradation and reduce lubrication efficiency [8]. If the DS18B20 sensor detects engine temperature above this threshold, it triggers a warning signal. And the system can send out notifications via SMS and

email to the user about the overheating condition, ensuring timely intervention to prevent potential damage to the engine.

$$\text{Temperature}=\begin{cases}\text{Normal, if T<70}\\ \text{Overheating, if } T \geq 70\end{cases} \tag{5}$$

4. User Interface*:* The Blynk app provides a user-friendly interface for real-time data visualization and interaction. The Blynk app is integrated with the Node MCU microcontroller for real-time alerts and notifications when any parameter exceeds the predefined thresholds for oil quality, low oil levels, or overheating. These alerts help users address issues promptly to avoid potential damage to the engine or other vehicle components.

Figure 3 shows the android interface of the Blynk app. Notifications are directly received on the registered mobile where Blynk app is installed and are emailed to user.

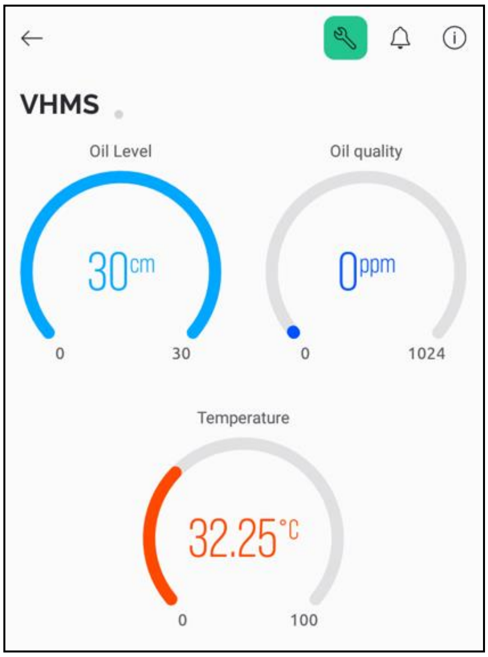

Fig. 3. Android Interface of Blynk App

3. RESULTS AND DISCUSSION

The experimentation was performed Spark Ignition 10W-30 engine oil of Wagon-R travelled regularly. The data collected from different sensors for the distance travelled from 0 km to 3000 km are shown in Table 1. It is observed from Table 1, there is gradual decreased in engine oil levels with increasing distance travelled due to oil consumption during the combustion process, leaks because of aging of engine components and evaporation. This suggests the requirement of regular maintenance and accurate measurement techniques for ensuring optimal engine performance and longitivity. It is observed from Table 1 that, the temperature readings are remained relatively constant in the range of 28°C to 33°C. However, the major changes are observed in oil quality readings. Up to 500 km, it is classified as “Good”. the oil quality gradually declines at 2700 km transitioning to "Moderate" and eventually to “Degraded” at 3000 km. This reflect the system's sensitivity to changes in oil quality for more distance travelled. These observation indicates that oil quality is a reliable indicator for preventive maintenance interventions and overall engine performance enhancement.

Table 1. The results of the proposed system tested for Spark Ignition 10 W-30 Engine Oil

Sr. No.	Distance (Km)	Oil quality (ohms)	Temperature (°C)	Oil Level (%)	Status of Oil
1.	0	1024	28	95	Good
2.	100	985	31	92	Good
3.	500	942	29	88	Good
4.	1000	876	28	83	Moderate
5.	1400	774	33	79	Moderate
6.	1800	674	32	76	Moderate
7.	2100	543	33	72	Moderate
8.	2500	448	31	69	Moderate
9.	2700	320	29	65	Moderate
10.	3000	156	32	63	Degraded

Experimentation is carried out for analysing the readings obtained under monochromatic lights, Red, Blue, and Green LEDs. Blue light has a higher energy level and shorter wavelength (450–495 nm), making it more sensitive to detecting fine particulate contamination and early oxidation products in oil. Its high scattering tendency allows it to reveal small molecular-level changes in oil transparency. Green light with medium wavelength (495–570 nm) provides an intermediate analysis as it interacts with both small and larger contaminants, offering a balanced representation of oil degradation over time. Red light has a longer wavelength (620–750 nm), which makes it less affected by small contaminants but more effective at detecting significant degradation, such as carbon build up, sludge formation, and heavy oxidation residues.

In Table 2, the results correspond to the LDR sensor readings, which are expressed in ohms (Ω), representing the resistance change based on the amount of light transmitted through the oil sample. This resistance is used to assess oil degradation, with higher resistance indicating better oil quality and lower resistance suggesting contamination or degradation. The transmittivity trends given in Table 3 show that blue light readings decline faster at shorter mileage, indicating early contamination detection. Green light readings decrease more gradually, suggesting it tracks oil degradation across a wider range of operational mileage.

Red light readings remain stable initially but drop significantly in later stages, highlighting its ability to detect heavily degraded oil conditions.

Table 2 Results of proposed system for Monochromatic Light

Sr. No.	Distance (km)	White	Red	Green	Blue
1.	0	1024	1024	1024	898
2.	100	985	990	965	818
3.	500	942	968	884	711
4.	1000	876	931	764	593
5.	1400	774	883	652	249
6.	1800	674	812	520	86
7.	2100	543	686	412	67
8.	2500	448	519	304	58
9.	2700	320	367	210	52
10.	3000	158	176	124	37

Figure 4 provides a visual representation of how engine oil condition varies when exposed to different wavelengths of light. This graphical depiction illustrates the degradation of engine oil over increasing distances travelled using light transmittivity analysis under different monochromatic light sources (Red, Green, Blue, and White). The conditions presented in the figure correspond to oil samples taken at various mileage intervals, as shown in Table 2. The oil degradation process is analysed by measuring how different wavelengths of light pass through the oil. At lower mileage (e.g., 0–500 km), oil exhibits higher transmittivity, indicating minimal contamination and degradation. As mileage increases (e.g., 1000–2500 km), oil gradually darkens, reducing light transmittivity and increasing LDR resistance and at higher mileage (e.g., 2700–3000 km), oil shows significant contamination, with low transmittivity values, indicating oxidation, soot accumulation, and potential viscosity breakdown. Each colour wavelength interacts differently with the oil, helping to distinguish various degradation stages. Blue light, due to its shorter wavelength, is more sensitive to detecting early-stage degradation, while red light, with its longer wavelength, better captures advanced oil contamination.

The proposed system has demonstrated its effectiveness in real-time engine health assessment by analysing data from ultrasonic sensors, DS18B20 temperature sensors, and LDRs under various LED lights. It accurately detects changes in oil condition and temperature, highlighting a 35% decrease in oil quality over 3000 km. Incorporating White, Red, Blue, and Green LEDs enhances precision, allowing for a comprehensive examination of oil properties.

The system's sensitivity to subtle variations in oil quality makes it a valuable tool for proactive maintenance, aiding in informed decision-making for engine performance optimization. Its role in ensuring engine longevity and functionality positions it as a key player in future automotive maintenance practices. The comparative analysis with existing methods is shown in Table 4.

Table 3. Results for monochromatic light using transmittivity

Sr. No	Distance (Km)	Transmittivity (%)			
		White	Red	Green	Blue
1.	0	100	100	100	87.69
2.	100	96.19	96.67	94.23	79.88
3.	500	91.99	94.53	86.32	69.43
4.	1000	85.54	90.91	74.60	57.91
5.	1400	75.58	86.23	63.67	24.31
6.	1800	65.82	79.29	50.78	8.39
7.	2100	53.02	66.99	40.23	6.54
8.	2500	43.75	50.68	29.68	5.66
9.	2700	31.25	35.83	20.50	5.07
10.	3000	15.42	17.18	12.10	3.61

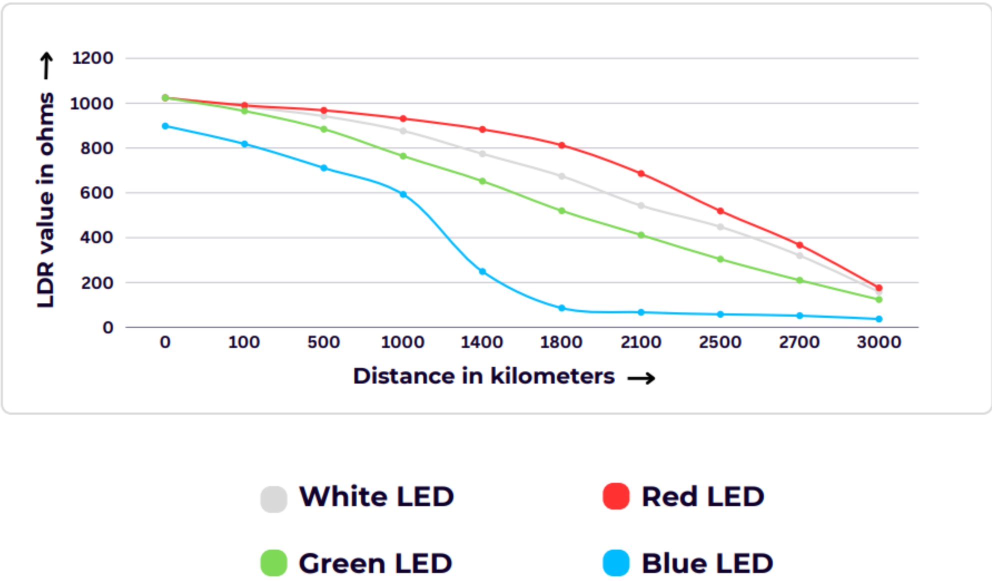

Fig. 4. Oil quality Analysis of SAE 10 W 30 Engine Oil using proposed system

Table 4. Comparative analysis with existing methods

Sr. No.	Feature	Jha et al., 2020 [5]	Hercik et al., 2023) [12]	Proposed Method
1.	Monitoring Parameters	Oil color and degradation	Oil viscosity and contamination	Oil quality, oil level, and temperature
2.	Real-Time Monitoring	No	Limited	Yes, IoT-enabled
3.	Sensor Technology	Optical color sensor	Ultrasonic sensor	LDR, ultrasonic, DS18B20
4.	Oil Type Dependency	Requires calibration different oil types	Requires calibration for viscosity changes	Adaptive to multiple oil conditions
5.	Sensitivity to Degradation	Moderate, depends on external lighting conditions	High, but mainly for viscosity changes	High, detects transmittivity and contamination trends
6.	Data Transmission & Alerts	No IoT-based data sharing	No real-time data sharing	IoT-based alerts via Blynk app

Table 4 demonstrates that proposed system integrates multi-sensor technology, real-time IoT monitoring, and enhanced oil quality assessment compared to existing methods. Unlike optical colour-based detection, our system analyses light transmittivity using different wavelengths, providing a more detailed assessment of oil degradation. Compared to ultrasonic-based detection, our system offers real-time monitoring and multi-parameter analysis, making it more comprehensive and practical for vehicle health monitoring.

4. CONCLUSION

Intelligent engine health monitoring system revolutionizes automotive maintenance practices by providing proactive insights into engine health, enabling timely interventions to extend engine lifespan. Integrated with advanced sensor technologies and IoT connectivity, it offers actionable intelligence to enhance operational efficiency. Ultrasonic sensor provides more accuracy as it is more suited for dynamic and turbulent environments and is a non-contact sensor. Digital temperature sensor provide more accurate readings than analogue sensors and is integrated into the system. Oil quality analysis demonstrated blue light with least wavelengths works best with early phase of oil deterioration whereas, red light with highest wavelength works best with later part of oil deterioration and green light with medieval wavelength provides a balance in the central part of oil quality life cycle. A combined effect of these three provides a comprehensive analysis about oil quality. A real time monitoring is exhibited with all sensors integrated together using NodeMCU to measure the readings of sensors with the results displayed on the LCD display and the Blynk app. The alert signals are provided to the user via buzzer/led light and email/text message on the Blynk app.

REFERENCES

[1] KUMAR S., MUKHERJEE P.S., MISHRA N.M., 2005, *Online Condition Monitoring of Engine Oil*, Ind. Lubr. Tribol., 57/6, 260–267, https://doi.org/10.1108/00368790510622362.

[2] IDROS K.M.F.M., ALI S., ISLAM M.S., 2012, *Quantitative Analysis of Spectroscopy's Study for Engine Oil Degradation Monitoring Due to Temperature Effect*, Proc. 3rd Int. Conf. Intell. Syst. Model. Simul., Kota Kinabalu, Malaysia, 278–282, https://doi.org/10.1109/ISMS.2012.56.

[3] AHMADI S., MANI-VARNOSFADERANI A., HABIBI B., 2018, *Motor Oil Classification Using Color Histograms and Pattern Recognition Techniques*, J. AOAC Int., https://doi.org/10.5740/jaoacint.17-0308.

[4] KUMARESAN N., MANIKANDAN S., SANTHOSH M., SUSHARSAN V., 2019, *Engine Oil Color Monitoring System*, Int. Res. J. Eng. Technol., 6/3, 7750–7753.

[5] JHA K.K., ARORA R., PABLA B.S., 2020, *Condition Monitoring of Lubricating Oil Using Iot*, Int. J. Mech. Prod. Eng. Res. Dev., 10/3, 9877–9888.

[6] MORICOVA K., PAPUCOVÁ I., ĎURISOVA S., JANIK R., 2020, *Determination of Engine Oil Characteristics*, IOP Conf. Ser.: Mater. Sci. Eng., 776/1, https://doi.org/10.1088/1757-899X/776/1/012099.

[7] WULANDARI I.Y., ASRI Y.N., 2020, *Analysis of Feasibility Indicators of Two Wheel Engine Oil Using Light Sensor (LDR)*, Journal of Applied Science and Advanced Technology, 3/2, https://doi.org/10.24853/jasat.3.2.51-56.

[8] PRADHAN P., SRIDHAR N., 2022, *Iot Based IC Engine Temperature and Lubricating Oil Condition Monitoring System*, 9/4, 367–375, https://doi.org/10.32628/IJSRST.

[9] OLIVEIRA G.C., MACHADO C.C.S., INACIO D.K., SILVEIRA PETRUCI J.F., SILVA S.G., 2022, *RGB Color Sensor for Colorimetric Determinations: Evaluation and Quantitative Analysis of Coloured Liquid Samples*, Talanta, 241, 123244, https://doi.org/10.1016/j.talanta.2022.123244 .

[10] CARRERES-PRIETO D., GARCIA J.T., CERDAN-CARTAGENA F., SUARDIAZ-MURO J., 2020, *Performing Calibration of Transmittance by Single RGB-LED within the Visible Spectrum*, Sensors, 20/12, 3492. https://doi.org/10.3390/s20123492.

[11] IVANOVA-VASILEVA A., ZLATEV Z., GEORGIEVA T., DASKALOV P., 2023, *Determination of the Parameter Color of Fresh Engine Oils by Color Indices and Predictive Models*, MATEC Web of Conferences, 387/04001, https://doi.org/10.1051/matecconf/202338704001.

[12] HERCIK R. MACHACEK Z., BYRTUS R., KOZIOREK, J., 2023, *Identification of the Physical Dependencies of Accurate Oil Level Measurement for Automotive Applications*, Appl. Sci., 13, 7707, https://doi.org/ 10.3390/app13137707.

[13] JHA K.K., PABLA B.S., 2020, *A Real-Time Engine Oil Monitoring System for Diagnosis of Lubricant Using Iot Network*, Int. J. Innov. Technol. Explor. Eng., 9/8, https://doi.org/10.35940/ijitee.H6524.069820.

[14] SACHIN. M.N., SURESH R., 2020, *IOT Based Vehicle Surveillance*, International Journal for Research in Applied Science & Engineering Technology (IJRASET), 8/V, http://doi.org/10.22214/ijraset.2020.5295.

[15] POURRAMEZAN M.R., ROHANI A., KERAMAT SIAVASH N., ZAREIN M., 2022, *Evaluation of Lubricant Condition and Engine Health Based on Soft Computing Methods*, Neural Comput. Appl., 1–13, https://doi.org/ 10.1007/s00521-022-06756-4.

[16] RAHIM M.A., ET AL., 2024, *Deep Learning-Based Vehicular Engine Health Monitoring System Utilising a Hybrid Convolutional Neural Network/Bidirectional Gated Recurrent Unit*, Expert Syst. Appl., 257, 125080, https://doi.org/10.1016/j.eswa.2023.125080.

[17] GOLEBIOWSKI W., WOLAK A., ZAJAC G., 2024, *Evaluation of Engine Oil Degradation: Enhancing Cost-Efficiency in Vehicle Fleet Maintenance*, in Proc. Int. Symp. Farm Mach. Process. Manag. Sustain. Agric., 165–178, https://doi.org/10.1007/978-3-031-23401-4_14.

[18] WU L., WANG K.C., HAU G., LEI Q., YANG C.H., 2024, *Online Monitoring and Prediction Methodology of Lubricating Oil State in Gearbox of a Nuclear Power Plant Based on Measurement with Sensors*, Sensors Mater., 36, https://doi.org/10.18494/SAM4436.