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DESIGN AND TESTING WIRELESS ENGINE MONITORING AND FAULT DETECTION THROUGH ON BOARD DIAGNOSTIC WITH MICROCONTROLLER

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ABSTRACT

Vehicle performance will always depend on maintenance by its users. Currently, vehicle monitoring technology is needed to optimize periodic vehicle maintenance. This research aims to Design and test wireless Engine Monitoring and Fault Detection through On board diagnostics with a Microcontroller. This research method uses research and development, which includes the stages of analysis, design, development, and evaluation. The parameters of the developed system include engine load, engine rpm, speed, engine temperature, throttle position, battery voltage, and error code checking on the vehicle injection system. The results show that the developed system can read all parameters used for monitoring and testing to see if damage has been detected to the injection system. In addition, the functionality test showed 100% results on the parameters set in the development process. In future research, further testing is needed on the battery power system so that the reliability of the wireless engine monitoring and fault detection through on board diagnostic with microcontroller system can be known.

Keywords: engine monitoring, fault detection, obd, microcontroller.

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1. INTRODUCTION

In the rapidly evolving field of automotive technology, the integration of wireless systems into vehicle diagnostics represents a significant advancement toward improving vehicle safety, efficiency, and longevity. The rising number of vehicles in Indonesia is attributed to the improving living levels of the populace [1, 2]. Vehicles are essential in the contemporary era of Industry 4.0, offering passengers superior mobility, comfort, and safety while bolstering both national and international economies [3,4]. This paper introduces the design and testing of a cutting-edge Wireless Engine Monitoring and Fault Detection (WEMFD), a tool poised to transform how vehicles are monitored and maintained. Utilizing advanced wireless communication technology, the WEFD system offers a real-time, comprehensive view of vehicle health, streamlining diagnostics and enhancing the precision of fault detection.

The WEMFD system is designed to be seamlessly integrated into the existing electronic architecture of vehicles, employing a network of sensors and actuators that communicate via a secure wireless protocol. Sensors are crucial for ensuring data accuracy.[5] In the rapidly evolving environment, it is virtually unfeasible to manually verify the details of every single vehicle [6]. These components work in unison to monitor various vehicle parameters such as engine temperature, fuel efficiency, and emission levels. Recent technology advancements that have impacted lifestyle changes include the Internet of Things (IoT) [7]. By transmitting data wirelessly, the system allows for continuous monitoring without the physical constraints imposed by traditional wired connections [7, 8]. This design facilitates ease of installation and maintenance and significantly reduces the system's vulnerability to wiring failures.

Central to the WEMFD system's innovation is its fault detection capability, which utilizes sophisticated algorithms to analyze the data collected. These algorithms are designed to identify anomalies that may indicate potential mechanical or electrical issues before they escalate into serious problems. By employing predictive analytics, the system can suggest proactive maintenance measures that can prevent costly repairs and extend the vehicle’s operational life. This predictive capability is particularly beneficial in fleet management, where it can ensure optimal performance across numerous vehicles.

To validate the effectiveness of the WEMFD system, a series of tests and pilot studies were conducted. These evaluations focused on various performance metrics, including the accuracy of fault detection, the response time of the system, and user interface accessibility. Numerical analyses are necessary to validate the experimental findings [10]. The results demonstrated not only the technical feasibility of the WEMFD system but also its practical benefits in real-world automotive settings. Feedback from these tests was instrumental in refining the system design to better meet the needs of end-users.

The development of the WEMFD marks a significant step forward in vehicle diagnostic technologies. With its robust design, real-time monitoring capabilities, and advanced fault detection, the WEMFD system stands to offer substantial improvements in vehicle maintenance and safety. As this technology advances, it holds the promise of becoming an integral part of modern automotive systems, driving further innovations in the industry and delivering enhanced value to consumers.

2. LITERATURE REVIEW

Recent advancements in automotive diagnostic technologies have increasingly focused on wireless systems, reflecting a broader industry trend toward Internet of Things (IoT) applications. The automobile industry is now working to improve remote vehicle connectivity, which raises the need for implementing a secure method of connecting cars and validating and safely storing their data [11]. New entrants, concepts, and technologies from the Information Technology (IT) sector emerge in the market, with software receiving significant emphasis [12]. Their research provides critical insights into the technical challenges and solutions associated with implementing wireless communication protocols in vehicles.

The processes of automobile diagnostics evolve alongside advancements in automotive technology, as the increasing number of embedded systems complicates the coordination of components for harmonic operation [13]. Turkson (2023) found that most structural linkages corroborated the hypothesis with strong positive associations [14]. The technology-facilitating condition emerged as the most significant predictor of the intention to utilize EVDT (Electronic Vehicle Diagnostic Technology).

Furthermore, the utilization of microcontrollers to automate the automotive industry is escalating with each successive decade. The growing utilization of microcontrollers has facilitated automation, simplified subsystem building, and diminished the reliance on wiring for interconnections, hence enhancing mobility [15]. On-board diagnostic systems are crucial for vehicle performance. Typically, diagnosing a car issue requires more time than resolving it [16,17]. Another characteristic of modern OBD systems is that they will erase the information of any created fault if the fault is absent after three driving cycles.

OBD II offers a standardized detection methodology for various automobile manufacturers and establishes a basis for the development of a universal automotive fault diagnosis system. OBD II offers a standardized data transmission framework, although it encompasses more than merely a communication protocol under its rules. Currently, OBD II employs the most prevalent communication protocols: SAE J1850 (PWM), SAE J1850 (PVM), ISO 14230 (KWP-2000), ISO 9141, and ISO 15765-4/SAE J2480 (CAN) [18,19].

Lastly, the practical implementation and operational testing of wireless diagnostic systems are discussed by Iskandar et al (2023). The study outputs an application designed for car diagnostics, utilizing a recommendation system that delivers notifications regarding vehicle health status and servicing time reminders to users [20]. The effectiveness of a fault diagnosis system is indicative of the level of process knowledge included in the representation approach employed for fault identification. Fault trees can represent a physical system failure as a conjunction of component failures with corresponding failure rates; nevertheless, their analysis may become computationally demanding [21].

Recent advancements in wireless communication and microcontroller technology have significantly impacted engine monitoring systems, particularly those involving On-Board Diagnostics (OBD). The ESP32 microcontroller, equipped with Wi-Fi and Bluetooth capabilities, has gained widespread attention for its use in real-time vehicle diagnostics. The efficiency of ESP32 in transmitting vehicle data to remote servers reduces the reliance on traditional wired connections [22]. Furthermore, these systems provide real-time fault detection and monitoring, which can potentially prevent engine failure. This shift towards wireless diagnostics enhances vehicle management and promotes more proactive maintenance strategies.

3. METHOD

This research is a Research and Development study with the stages of analysis, design, development, and evaluation. The analysis phase of the project focused on analyzing the requirements and limitations of current On-Board Diagnostic (OBD-II) systems in vehicles, particularly in monitoring critical parameters such as battery voltage, engine RPM, engine temperature, throttle position, and fault detection. This analysis included reviewing existing literature, and current market solutions, and conducting surveys with automotive maintenance professionals to understand common diagnostic challenges and performance metrics. The insights gained helped define precise functional and technical specifications for developing an enhanced wireless diagnostic system using ESP32 as the central development device.

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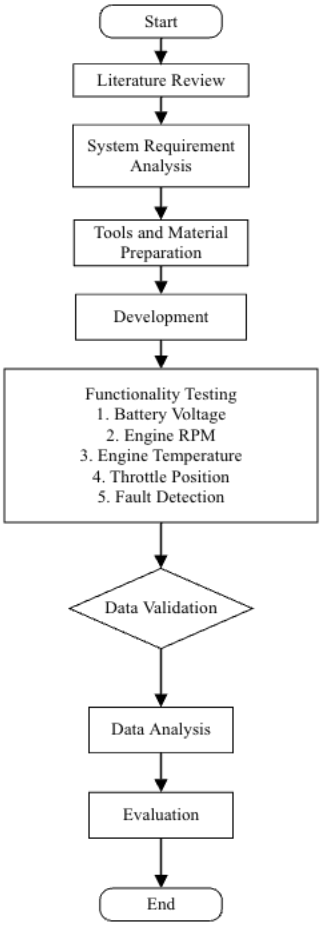

Figure-1. Research flow diagram.

Based on the requirements identified in the analysis phase, the design of the system was structured around the ESP32 microcontroller due to its robust processing capabilities, Wi-Fi and Bluetooth functionalities, and compatibility with OBD-II protocols. A schematic was developed to connect the ESP32 to the vehicle's ECU through the OBD-II port. This setup was designed to monitor the defined parameters and detect faults continuously. Each sensor's data was planned to be processed and relayed wirelessly, ensuring timely updates and alerts through a specifically designed user interface on a connected mobile or web application.

In the development stage, the ESP32 was programmed to interface with the vehicle's OBD-II system to retrieve data from the ECU directly. Software components included the development of firmware for the ESP32 to read data such as battery voltage, engine RPM, engine temperature, throttle position, and fault detection. Additionally, algorithms were implemented to analyze this data in real time and identify anomalies that could indicate potential faults. Special attention was given to creating a responsive and reliable data transmission system to handle real-time data feeds without latency or loss.

The evaluation of the system involved rigorous bench testing and field testing. Bench testing was conducted in a controlled environment to simulate various vehicle operating conditions to ensure accurate data collection and fault detection by the ESP32 system. Metrics for evaluation included the accuracy of data captured, the effectiveness of fault detection algorithms, and the stability of the wireless communication setup.

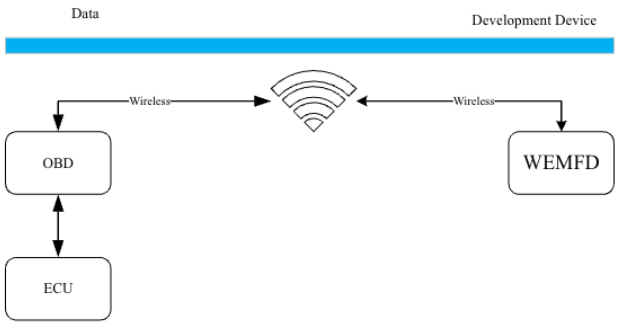

Figure-2. Schematic diagram of system.

4. EXPERIMENTAL RESULTS

This research is a Research and Development study with the stages of analysis, design, development, and evaluation. The analysis stage is carried out to determine the needs in the development process based on previous research. In the design stage, the system schematic diagram and flowchart were planned. Modeling is done systematically to get efficient system performance. The development stage is a system development process based on previous analysis and design. Furthermore, evaluation is to determine the performance of the system and whether it works well or not. In summary, the research flow is shown in the following diagram.

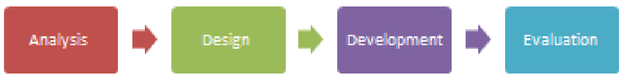

Figure-3. Research stages.

4.1 Analysis

At this stage, an analysis is carried out to obtain a design design according to the needs. The vehicle damage detection system refers to the Injection system on motorbike vehicles where the ECU (Electronic Control Unit) is the main system in receiving input from sensors. The results of initial observations show the needs of the system in damage detection through On Board Diagnostic Vehicles Using Wireless-Based Microcontroller, among others:

a) Engine Load Reading
b) Speed Reading
c) Engine RPM Readout
d) Throttle Position Reading
e) Engine temperature or temperature readings

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f) Battery voltage reading
g) Error code reading of the injection system

These indicators are the main indicators in early damage detection readings on vehicles. Each indicator has a role in analyzing vehicle damage that can be fatal if not handled immediately. Furthermore, the analysis of development device requirements refers to the results of the analysis of system requirements as a further step in the development of this system. The use of a microcontroller as the main device in the development of this vehicle damage detection system.

4.2 Design

System design is done after the needs and device analysis stage. The system design refers to the previous stage. The following are the results of the design of the Damage Detection System Through Vehicle On Board Diagnostic Using a Wireless-Based Microcontroller.

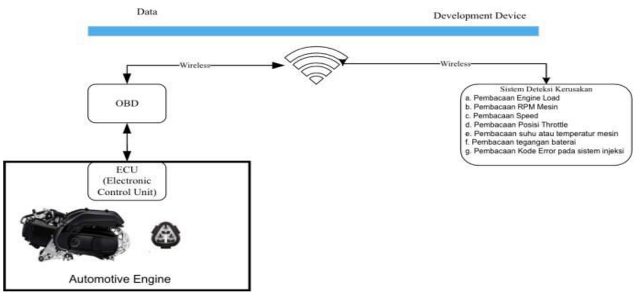


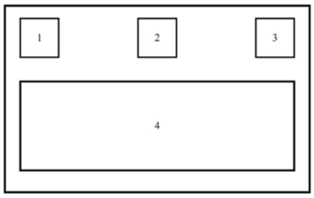
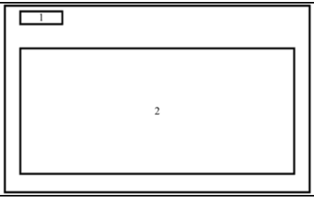
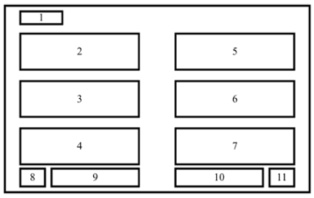
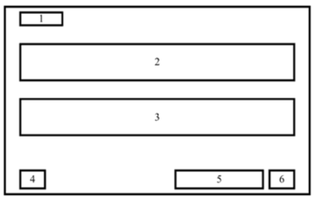
Figure-4. System design.

This research focuses on developing data stream monitoring and damage detection. Implementation and testing focus on motorized vehicles / 2 wheels that already have injection technology and OBD-II support. Testing is carried out on Engine Load, Speed, RPM, Temperature, TPS, Voltage data, and reading error codes on the system with a Microcontroller device. Testing is done by selecting a sample of vehicles that have been determined. Testing parameters are carried out to obtain product functionality data based on predetermined parameters.

4.3 Interface Design

Display design is done to get an informative and effective display design. The following is the system interface design.

Table-1. Design interface system.

Desain Interface Sistem	Description
	**Initial View** 1. Kemdikbud Logo 2. UNNES Logo 3. Merdeka Campus Logo 4. Title/System Name
	**Protocol View** 1. Percentage Device Battery 2. Option to select System Protocol
	**Monitoring System View** 1. Percentage Device Battery 2. Engine Load Readings 3. Engine RPM Readout 4. Engine Speed Readout 5. EngineTemperature Readout 6. Readings Throttle Opening 7. Readings Battery Voltage 8. Back button 9. Bluetooth Connection Status 10. Save 11. Data button 12. Next button
	**Injection System Error Code Detection Display** 1. Percentage Device Battery 2. Error Code 3. Error Info 4. Back button 5. Check button 6. Next button

4.4 Development

Hardware and software development was carried out in parallel. The ESP32 was chosen as the main microcontroller because it has wireless connectivity (Wi-Fi and Bluetooth) and the ability to process data in real-time. The ELM327 was used to read data from the vehicle's OBD port, and the Bluetooth module was used to transmit data to the ESP32. Application development is carried out to process and display data on user devices in an easy-to-

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understand interface. The following is a diagram of the system that has been developed.

4.5 Diagram of the Tamper Detection System

System development is carried out using ARDUINO IDE software in the system coding process. ARDUINO IDE is an open-source platform that can be used to connect to microcontroller devices.

Figure-5. Development Process with ARDUINO IDE the following are the results of system development.

Table-2. Implementation system.

Implementation of Development	Description
	Initial View
	Protocol View
	Monitoring System View
	Injection System Error Code Detection Display

4.6 Evaluation

At this stage, functional testing is carried out to ensure that the system runs by the design and specifications that have been set. Tests were conducted on several vehicles to evaluate the system's ability to read RPM data, throttle position, engine temperature, battery voltage, and error codes from the injection system. In addition, battery endurance trials were also conducted to see how long the system can operate without recharging.

The system developed using ESP32 as the main control centre successfully functioned as expected. ESP32 was chosen because apart from being a powerful microcontroller, this module also has excellent wireless connectivity capabilities, making it suitable for use in OBD-based vehicle fault detection systems. The ELM327 Bluetooth module was integrated with this system to read data from the vehicle's OBD port and transmit the data wirelessly to the ESP32.

The hardware used, such as the 2800 mAh battery, was able to provide sufficient power for the ESP32 and ELM327 modules during the test. The battery was able to provide up to 12 hours of operating time under continuous monitoring conditions. This shows that the system is very efficient in power consumption.

4.7 Vehicle Parameter Readings

In this system, tests were conducted to measure various relevant vehicle parameters, namely:

Figure-6. Engine condition readout/monitoring engine results.

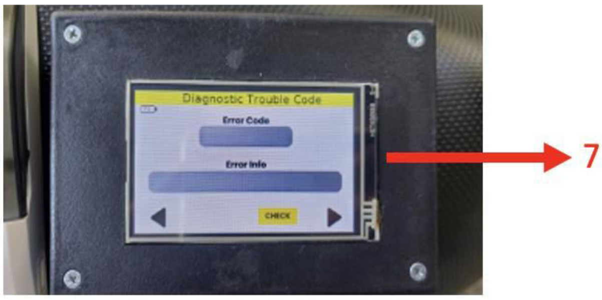

Figure-7. DTC/Error code reading display.

a) Load engine

Load Engine shows the engine workload when the engine is running, this reading is a real-time reading.

b) Engine RPM

RPM (Revolutions per Minute): The RPM parameter was successfully read accurately through this system. Tests were conducted at several different engine speeds, and the data obtained through the ESP32 matched the data displayed on the vehicle instrument panel.

c) Speed

Speed is a reading of the speed of the vehicle when the vehicle is working by reading the speed sensor on the vehicle.

d) Engine temperature

Engine Temperature: Engine temperature testing is also conducted to ensure the system can accurately detect changes in engine temperature. The system can provide early warning if the engine temperature approaches dangerous limits, which is important to avoid further damage to the engine.

e) Throttle position

Throttle Position: The throttle position, which indicates how far the accelerator pedal is depressed, is also successfully read by the system. The throttle position value shows a linear relationship with vehicle acceleration, and the data obtained can be used to monitor engine performance.

f) Battery voltage

Battery Voltage: Battery voltage readings are taken to monitor the electrical condition of the vehicle. Abnormal battery voltage can indicate problems in the vehicle's electrical system, and the system is able to detect such discrepancies in real-time.

g) Error codes:

One of the main functions of the system is to read and display error codes generated by the vehicle's injection system. When an error code is detected, the system provides clear information to the user regarding the problem, allowing immediate repairs to be made.

OBD II readers are designed to measure speed and mass airflow, from which distance and fuel consumption are also calculated [1, 2]. Current findings regarding real-time monitoring of driver behaviour, driving safety, and driver categorisation suggest smart phone-based devices with good detection and quality[3], or using vehicle inertial sensors via CAN Bus[4,5].

4.8 Wireless Connection Implementation

The implementation of wireless connection in this system using ESP32 and ELM327 Bluetooth modules proved to be effective. Data from the vehicle can be transmitted quickly to the user's device via Bluetooth, with very low latency. In addition, the stable connectivity allowed the system to work continuously without interruption during the test. All components of a car vehicle can communicate with each other with CAN-Bus. For example, the position value is sent to the Electronic Control Unit (ECU) after the human driver presses the accelerator pedal, and the ECU adjusts the air/fuel injection according to the position value. Therefore, we can read this position message transmitted through the CAN bus from the OBD port [6]. ELM-327 is one such adapter where the data read from the OBD2 port is transmitted via Bluetooth after pairing [7]. Lastly, there is the iSaddle OBD-II Wi-Fi/Bluetooth Scanner which connects also by Bluetooth or Wi-Fi [8]. The application developed for the user provides an easy-to-understand interface, where all data obtained from the vehicle is displayed in real-time. In addition, the user can also view the data history and get notifications if any errors require attention.

4.9 Functionality Testing Results

The following are the results of engine parameter readings during idle conditions and the results of damage detection functionality tests through On Board Diagnostic Vehicles Using Wireless-Based Microcontroller.

Table-3. Reading results and functionality testing.

Data Stream Parameters	Reading Result	Functionality Test Results
Engine Load	28,2 %	Successful
RPM	1572 rpm	Successful
Speed	2 km/h	Successful
TPS	9%	Successful
Engine Temperature	62 °C	Successful
Battery Voltage	14.5 V	Successful
Error Code Reading	No Error	Successful

5. CONCLUSIONS

The system is compatible with various vehicle models that support OBD2, making it quite universal in its application. In addition, the development of a Bluetooth-based application allows users to access data from the device easily, making vehicle condition monitoring more practical and easy to do.

, some challenges remain, such as battery limitations. In a real-world implementation, this system may require integration with the vehicle's electrical power source for long-term use, especially for users who wish to use the system continuously. Also, while the system works well on most vehicles, further testing needs to be done on vehicles with special configurations or the latest technology.

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