

Design and Implementation of Real-Time Diesel Engine Operational Monitoring Devices Based on Microcontrollers

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Abstract: Monitoring of diesel engine operational performance on fishing vessels recorded in real time based on microcontrollers is still rarely used. Monitoring of diesel engine operations is important to ensure the engine is in optimal performance as well as a consideration for predictive maintenance actions. This study aims to design and implement a real-time monitoring device based on microcontrollers. This device can measure and record RPM, temperature, and pressure data on diesel engines with good accuracy. Hall effect sensors for RPM, DS18B20 for temperature, and piezoresistive sensors for pressure are used, to maintain the right time it is equipped with RTC, SD card module for data storage, and Wi-Fi module for data access via the web. The test results show that this device is able to measure with good accuracy on each parameter with an average error of below 2%. When the operational parameters exceed the predetermined threshold, the device successfully gives an alarm as a critical sign. This study makes a significant contribution to the management and maintenance of diesel engines with real-time data and wireless access that increases efficiency and minimizes downtime due to operational failures.

Keywords: Diesel engine; Monitoring real time; Hall effect; DS18B20; Piezoresistive

Introduction

In the industrial world, maintenance is one of the crucial aspects in ensuring that the operation of equipment or machines continues to run optimally. Without proper maintenance, machines tend to experience decreased performance, even damage that can disrupt productivity and safety (Kristianto et al., 2023). Based on the incident, in general there are two maintenance strategies that can be carried out, such as maintenance carried out after failure is detected and before failure is detected (Repdhi Febriyan & Bagus Dwi Cahyono, 2023). Maintenance carried out after a failure occurs is not appropriate if it is carried out on parts that have a high-risk profile. For components that have a high-risk profile, there are various types of maintenance that can be applied, predictive maintenance has become the main focus because of its ability to prevent damage by predicting when equipment will fail (Hu & Chen,

2020). Predictive maintenance involves data analysis and continuous monitoring to identify patterns and early signs of damage to machines or equipment. This approach allows companies to plan timely maintenance, reduce downtime, and optimize operational performance. However, the success of predictive maintenance is highly dependent on the availability of adequate data, so it often faces its own challenges in collecting data to support predictive maintenance (Davari et al., 2021).

Currently, many fishing vessels still rely on modified truck engines that are not equipped with sophisticated sensors or monitoring systems (Abrori et al., 2021). This results in a lack of access to the data needed to implement predictive maintenance effectively. One example of important data in fishing vessel maintenance is the operating temperature of the propulsion engine. High or unstable operating temperatures can be an early indicator of engine

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problems. However, without an adequate monitoring system, it is difficult to obtain information about this operating temperature accurately and timely. This article will explore how monitoring data acquisition devices are designed and built into accurate measurement instruments. It will also discuss potential solutions and technologies that can help overcome these obstacles, so that the fishing vessel industry can benefit from proper predictive maintenance.

Previous studies have shown various approaches to monitoring engine parameters, such as engine speed, temperature, pressure, and coolant level. For example, Kuncoro et al., (2023) successfully developed a rotational speed monitoring system using a magnetic sensor with an accuracy of 1.42%, although there is no time recording information. Fuadi, (2020) developed an IoT-based coolant temperature monitoring that can be accessed remotely, but focused only on temperature and water level. Alfitroh & Wardana, (2023) used the Blynk application to monitor steam temperature and RPM in real-time on mobile devices, with high accuracy but has limitations that depend on an internet connection.

Furthermore, Agustini et al., (2023) introduced a web-based system to monitor RPM and engine lubricant temperature using a DS18B20 sensor and optical encoder, but internet constraints still exist. Fikroh & Syahrurini, (2024) and Putra et al., (2024) showed the advantages of rapid integration of temperature and pressure sensors with automated spreadsheets, but the constraint was minimal recording due to internet limitations. Meanwhile, Surapati et al., (2023) succeeded in measuring the cooling water temperature accurately with a waterproof sensor, although they only focused on temperature without recording RPM and lubricant.

Several researchers have conducted research to create a monitoring device for rotational speed, pressure and temperature, but there are still shortcomings such as the lack of integrated sensors in one unit to measure the operational parameters of the ship's diesel engine, therefore this study aims to overcome the gap by designing and building an integrated diesel engine operational performance monitoring device that includes RPM, temperature, pressure, and engine operating time in real-time using a sophisticated microcontroller. The integration of various sensors such as hall effect, DS18B20, piezoresistive, and RTC is expected to provide more comprehensive and reliable results, accessed via a browser without depending on the internet at sea so that it can facilitate monitoring of engine operations and assist in making decisions on predictive maintenance actions. This research will provide effective operational recording effectiveness with accurate results for appropriate maintenance actions.

Method

This study uses an experimental method by designing and building to produce a diesel engine operational monitoring device, then the data is taken and analyzed to obtain research results. The stages of this experiment are carried out through several stages as carried out by Fauzi et al., (2024) as shown in Figure 1. This stage is carried out so that the implementation of the research is sequential, and no stages are missed so that it can produce the right device.

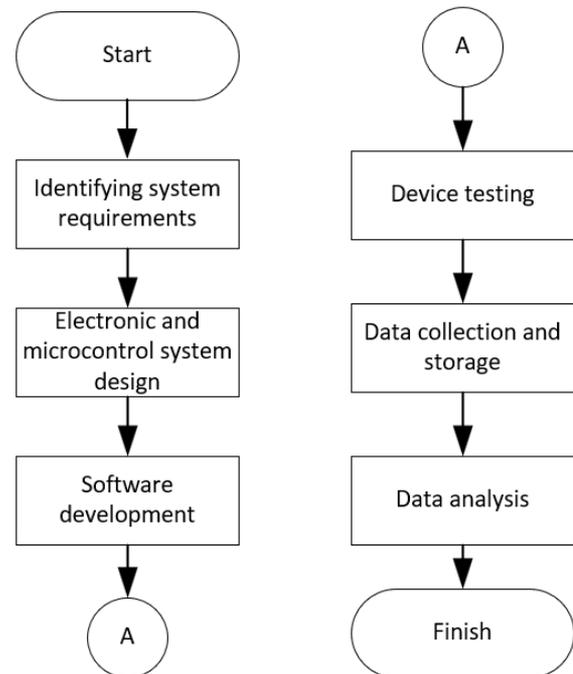


Figure 1. flow chart of design and construction research

The first stage in identifying the needs of this diesel engine monitoring system is to determine the main components used to measure engine operational parameters. These components are in the form of a Hall effect sensor because of its ability to measure RPM accurately (Girawan et al., 2022), a DS18B20 temperature sensor that can detect temperatures with a wide range with waterproof features (Reinanda et al., 2024), and a piezoresistive pressure sensor that can measure precise pressure (Yusup et al., 2020). Then the RTC module is selected to record the operational time or running hours (RH) of the engine so that each engine monitoring is more detailed and in accordance with the measurement time (Suryowinoto et al., 2022).

For ease of reading measurement results, an LCD monitor display is used because it is able to display measurement data directly (Bhakti & Bachri, 2024), and an SD card module is included which can store measurement data (Ardhi et al., 2024), this data can later be used as material for analysis of maintenance actions.

The system is also equipped with an alarm so that a relay is needed to provide voltage, the alarm can provide an automatic warning when the machine's operational parameters exceed the specified limits (Gragasin et al., 2024). Arduino Nano was chosen as the data processing center because of its compact size and ability to manage various inputs from connected sensors and a Wi-Fi module can be added to make this system a web server so that real-time data can be accessed via a local network (Aziz et al., 2024). To align the design, a block diagram was created as shown in Figure 2, showing the relationship of each sensor module and other devices to the microcontroller.

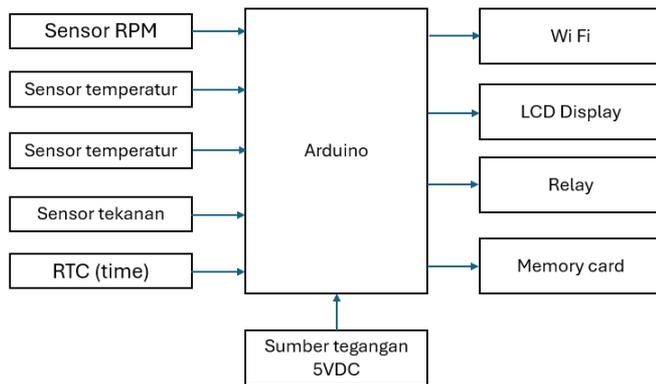


Figure 2. Diagram block for schematic

Schematic design is required for each module connected to the processor, in making this circuit schematic referring to the datasheet of each module and comparing it with previous research (Arnisti et al., n.d.). The design of this electronic system ensures the function of each voltage PIN used including input and output on the Module used according to its path and does not damage the module.

The software was developed in C++ to facilitate direct data processing from sensors used using Arduino Ide, this was chosen because of its ability to create software programs, ease of debugging and program repair (Arnisti et al., n.d.). The program was created by involving several steps, such as sensor initialization, periodic data reading, data processing, to data storage on SD cards and sending data via Wi-Fi to be displayed via a webserver. This process aims to make the device work automatically in monitoring machine operational parameters.

At this prototyping stage, the electronic system design that has been prepared previously begins to be implemented, each module used is placed on a breadboard and connected with copper wire. The next stage is the program that has been developed and then embedded in the microcontroller so that the system created can run. This process is carried out because it is

very helpful in testing the function of the entire system, facilitating component connection, and speeding up the repair process if necessary (Akbar & Chusyairi, 2021). If the results of the trial on the breadboard are successful, the next step is to place each module and microcontroller that has been programmed on the PCB hole board which is then permanently connected by soldering the connecting copper wire to the module pin.

Before this device is used, accuracy is crucial for the measuring instrument. In this study, accuracy is carried out by comparing the measurement results carried out by the sensor with the measurement results of other measuring instruments that are calibrated on the same object and time. Knowing the Mean Absolute Percentage Error (MAPE) value is chosen to measure the average percentage of absolute error between the measurement results of the trial instrument and the reference value shown in equation 1 (Ulfa et al., 2023). The smaller the MAPE value, the higher the level of accuracy of the test instrument.

$$MAPE = \frac{1}{n} \sum_{i=1}^n \left| \frac{y_i - x_i}{y_i} \right| \times 100\% \tag{1}$$

With the provision that y_i is the value obtained from the calibrated tool, while x_i is the value displayed on the prototype tool that was made, while n is the total number of measurements carried out.

Data collection is carried out on a diesel engine used as a ship's propulsion engine. The sensor is placed on the monitored system such as engine rotation, the RPM sensor is placed on the engine shaft, namely the flywheel, to determine the engine temperature, the temperature sensor is placed on the cooling and lubricating system, while to determine the lubricant pressure it is also placed on the lubricating system.

Result and Discussion

This research was conducted to achieve the goal of creating a machine monitoring device by implementing the stages that have been planned in the research method. Each stage is carried out to ensure that the research can be successful, and the results are presented in this section.

This monitoring device uses several sensor modules that are sensitive to changes in physical quantities and time. Changes in these quantities are received by the sensor and then converted into electronic signals so that they can be processed by the microcontroller. Some of the sensors used are shown in Table 1.

Table 1. RPM, temperature and pressure detection sensor specifications

Specification	Proximity Sensor (Magnet)	DS18B20 Sensor	Piezoresistive Pressure Sensor
Sensor Type	Hall Effect	Digital Temperature	Piezoresistive Pressure
Measured	RPM	Temperature	Pressure
Range	Based on magnetic field	-55°C to +125°C	0 to 1.2 MPa
Voltage	3.3V to 5V	3.0V to 5.5V	5V
Accuracy	±1 RPM	±0.5°C	±1.5%
Resolution	-	12-bit	0.1%
Output	Digital (pulse)	Digital (1-Wire)	Analog (voltage)
Response Time	Fast (milliseconds)	750 ms (12-bit)	1-5 ms
Operating Temperature	-40°C to +125°C	-55°C to +125°C	-40°C to +85°C
Additional Features	Anti-noise	Waterproof	Stable under temperature and moist

The three sensors can detect different parameters but are able to work with the same voltage 5VDC so that they can work with Arduino nano. by paying attention to the signals used, the proximity and temperature sensors DS18B20 are connected to the digital channel while the Piezoresistive sensor is connected to the analog channel. The electronic system is made based on the data sheet, by paying attention to the GPIO and being connected to each other as in Figure 3 below.

data on a micro-SD; 6). Displaying data on the LCD and web server.

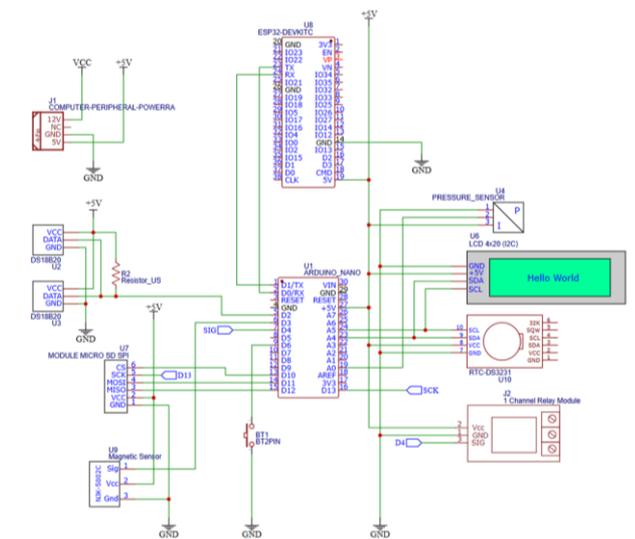


Figure 3. Electronic module circuit schematic.

The voltage source generated from the engine alternator is stored in the engine battery with a capacity of 12VDC, because this device is designed to only work with a voltage of no more than 5VDC, it requires a DC-to-DC step down module. This module functions to reduce the voltage from 12VDC to 5VDC as the voltage supply for each module.

Software development is carried out using the Arduino Ide application Figure 4, to facilitate software development, several detailed stages are made as in the following stages. 1). Embedding libraries; 2). Defining Pins and devices; 3). Initializing objects and error handling; 4) Retrieving and processing data; 5). Storing

```

ARDUINO_UNO_001.J.ESP32
1 #include <OneWire.h>
2 #include <DallasTemperature.h>
3 #include <Wire.h>
4 #include <LiquidCrystal_I2C.h>
5 #include <RTCLib.h>
6 #include <EEPROM.h>
7 #include <SD.h>
8 #include <SPI.h>
9
10 // Pin yang digunakan
11 #define ONE_WIRE_BUS 2 // pin untuk ds18b20
12 #define PROXIMITY_PIN 3 // pin untuk proximity
13 #define SD_CS_PIN 10 // pin untuk sd card
14 #define RELAY_PIN 4 // Pin untuk RELAY
15 #define PRESSURE_PIN A0 // pin untuk pressure se:
16 #define BUTTON_PIN 6 // pin untuk push button

```

Figure 4. Arduino Ide ver.1.8.19

Several libraries are used such as OneWire, DallasTemperature, and Wire for the DS18B20 sensor, LiquidCrystal_I2C for the LCD to work, RTCLib to communicate with the Real-Time Clock module, EEPROM to access and store data permanently in the Arduino EEPROM memory. In the code, this is used to store the "running hours" value that will not be lost when the Arduino is turned off. SD and SPI for communication to access and write data with the micro-SD card module.

Next, initialization is carried out for each component and sensor connected, such as the Hall effect sensor for RPM, DS18B20 for temperature, and piezoresistive sensor for pressure. After initialization, the software reads data periodically from the sensors. Each reading is done at a certain interval specified in the program. Data from the Hall effect sensor is converted into an RPM value, while data from the DS18B20 is taken in the form of temperature, and the pressure sensor provides the engine lubricant pressure value.

After the data is obtained, the reading results are stored on a micro-SD card in CSV format. This storage records time, RPM, temperature, pressure, and running hours (RH). Data obtained from the sensor is also displayed on the LCD screen so that operators can monitor engine conditions directly. In addition, a Wi-Fi module is connected so that Arduino can function as a web server. This development also includes a warning feature, if the temperature value exceeds the limit (80°C) and the pressure is below the threshold (> 0.2 MPa) which ensures the relay to activate the alarm, giving a warning sign of the critical condition of the engine that is operating.

Each time a program is given to the software embedded in the microcontroller, testing and debugging are first carried out at the program level (Arduino IDE) to ensure that each device used is as expected and to prevent the device from being used with inappropriate results. Results should be clear and concise. The discussion should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.



Figure 5. Prototype and integration of monitoring system

Some modules such as Arduino, Wi-Fi module, micro-SD card module, RTC and relay used are placed on the PCB board so that the modules can be arranged properly in the box, the modules that have been placed are then connected using connecting cables according to the electronic scheme shown in Figure 3. While the LCD is placed on the lid of the box to make it easier to access the reading information directly while the sensor is connected using three connector pins. The cables that have been connected are then soldered properly to prevent the cable connection from coming loose or being connected unstable as in Figure 5.

The results of the prototype and system integration run well, the LCD shows the expected information in the form of RPM, F/W temp, L/O temp and L/O press. When the green button is pressed, the LCD shows the second screen by conveying information on the name of

the day, date and hour (time), and at the bottom shows Running Hours which is the length of time the machine has been operating since it was first operated as shown in Figure 5.

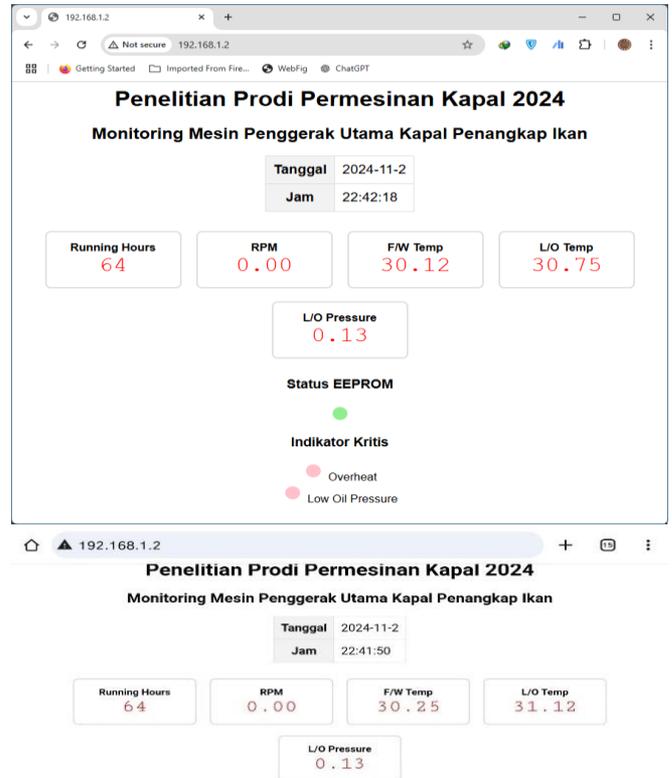


Figure 6. Display on monitor device via Wi-Fi

Information via the browser (Figure 6) is also successfully delivered clearly, although there is a one second delay when compared to the value on the LCD (Figure 5). Each sensor reading result is also successfully recorded and saved on a micro-SD in csv format which makes it easier to control and maintain the machine. For example, the overload sign will be active if it is set at a temperature of more than 30°C, so when the sensor gets a temperature condition exceeding the set point (30°C) at that time the critical overheat indicator is active and sounds an alarm, the LCD shows "OVERHEAT", on the browser on the monitor the critical overheat indicator sign lights up flashing red and the overheat event is also recorded in a csv file in real time as shown in Figure 7.

This design is very helpful in machine operation, it can prevent the machine from experiencing more severe damage due to the absence of early warning. The notes in the csv file will make it easier to diagnose the cause of the failure.

```
2024-8-8,00:12:09,1562,0.00,30.87,30.75,0.71,F/W OVER HEAT,L/O OVER HEAT
2024-8-8,00:12:11,1564,0.00,30.87,30.69,0.12,F/W OVER HEAT,L/O OVER HEAT
2024-8-8,00:12:12,1565,0.00,30.87,30.69,0.51,F/W OVER HEAT,L/O OVER HEAT
2024-8-8,00:12:14,1567,0.00,30.87,30.69,0.17,F/W OVER HEAT,L/O OVER HEAT
2024-8-8,00:12:16,1569,0.00,30.87,30.69,0.60,F/W OVER HEAT,L/O OVER HEAT
2024-8-8,00:12:17,1570,0.00,30.87,30.69,0.19,F/W OVER HEAT,L/O OVER HEAT
```

Figure 7. Sample data recorded on micro-SD

The measurement result test was carried out by comparing the measurement results made by the sensor with the measurement results of other measuring instruments that were calibrated on the same object and time. Calibration was carried out using a drill machine that could be adjusted for rotation, then the drill rotation was measured using a prototype measuring instrument and a calibrated tachometer, then the results were displayed in Table 2.

Table 2. RPM sensor test results

n	RPM		
	x	y	APE
1	200	198	1.01%
2	228	222	2.70%
3	376	372	1.08%
4	447	441	1.36%
5	704	695	1.29%
6	894	887	0.79%
7	998	992	0.60%
8	1058	1045	1.24%
9	1148	1134	1.23%
10	1368	1354	1.03%
MAPE			1.24%

In the first measurement, the design device showed a result of 200 RPM, while the calibrated device showed 198 RPM, resulting in an APE of 1.01%. Higher results occurred in the second and fourth measurements, where the APE values were 2.7% and 1.36%, respectively. In other measurements, the error rate was smaller, even in the third measurement the APE value was 0.6%, the MAPE value of 1.24% showed results that were close to the same between the device and the calibrated device, and this produced a value that was not much different from Harsoyo et al., (2019), measurement results with errors that were still within the tolerance limit. The trial to determine the temperature was also carried out by measuring the heat using an electric heater, the heater was operated until it reached a temperature of 82°C, then the heater was stopped and then measured using the device that was made and the calibrated device, the measurement results are shown in Table 3 as follows.

The prototype successfully reads the temperature with a value close to the calibration tool as evidenced by the large percentage of absolute errors that vary at each measurement point. In addition, in consecutive F/W temp measurements, the absolute error percentage was obtained as much as 0.23% to 2.49% and the MAPE was 1.23%. At the same time, in consecutive L/O temp measurements, the absolute error percentage was obtained as much as 1.49% to 2.49% and the MAPE was 2.08% and was similar to the measurement results with

the DS18B20 sensor carried out by Putra et al., (2024). This value shows that the prototype that has been designed is able to show the same level of accuracy. However, there are still differences in the level of accuracy of the two sensors.

Table 3. Temperature sensor test results

n	F/W Temp (°C)			L/O Temp (°C)		
	x	y	APE	x	y	APE
1	81.22	80	1.53%	81.96	80	2.45%
2	75.71	75	0.95%	76.12	75	1.49%
3	71.12	70	1.60%	71.74	70	2.49%
4	66.62	65	2.49%	66.17	65	1.80%
5	60.92	60	1.53%	61.23	60	2.05%
6	55.64	55	1.16%	56.34	55	2.44%
7	45.48	45	1.07%	46.12	45	2.49%
8	40.09	40	0.23%	40.85	40	2.13%
9	35.31	35	0.89%	35.56	35	1.60%
10	30.27	30	0.90%	30.55	30	1.83%
MAPE			1.23%			2.08%

Pressure testing is also done using a pressure vessel. The sensor is connected to the vessel and then pressure is applied gradually, and the observation results are recorded to determine the sensor reading capability. The measurement results are displayed in theTable 4.

Table 4. Temperature sensor test results

n	L/O Pressure		
	x	y	APE
1	0.39	0.40	2.50%
2	0.78	0.80	2.50%
3	1.17	1.20	2.50%
4	13.55	1.60	1.25%
5	1.98	2.00	1.00%
6	2.37	2.40	1.25%
7	2.76	2.80	1.43%
8	3.24	3.20	1.25%
9	3.68	3.60	2.22%
10	4.1	4.00	2.50%
MAPE			1.72%

Lubricant pressure testing (L/O pressure) produces data where the accuracy level of the prototype tool can be said to be quite good when compared to the calibrated tool. The pressure range tested is between 0.4 to 4.0 kg/cm², and the absolute percentage error of each measurement varies between 1.00% and 2.50%. The highest error rate is 2.50%, and at the measurement point of 3.20 kg/cm². The average absolute percentage error of this measurement is 1.72%, which shows a fairly good level of accuracy and reliable results regarding the measurement of lubricant pressure.

Table 5. Results of measuring the operational parameters of diesel engines

Time	RPM			F/W Temp			L/O Temp			L/O Press		
	x	y	APE	x	y	APE	x	y	APE	x	y	APE
15.05.47	670	676	0.89%	30.12	52	42.08%	67.54	66.1	2.18%	4.28	4.05	5.68%
15.15.56	684	692	1.16%	33.44	64	47.75%	75.66	74.2	1.97%	4.18	3.8	10.00%
15.21.03	718	730	1.64%	50.81	70	27.41%	75.66	74.3	1.83%	4.08	3.7	10.27%
15.39.16	730	750	2.67%	62.54	70	10.66%	75.66	74.3	1.83%	3.98	3.6	10.56%
15.50.08	774	782	1.02%	62.54	70	10.66%	75.66	74.3	1.83%	3.98	3.6	10.56%
15.51.25	780	794	1.76%	62.54	70	10.66%	75.66	74.3	1.83%	3.98	3.6	10.56%
15.52.37	840	836	0.48%	62.54	70	10.66%	75.66	74.3	1.83%	3.98	3.6	10.56%
15.54.18	866	862	0.46%	62.54	70	10.66%	75.66	74.3	1.83%	3.98	3.6	10.56%
15.55.54	894	878	1.82%	62.54	70	10.66%	75.66	74.3	1.83%	3.98	3.6	10.56%
15.57.18	912	898	1.56%	62.54	70	10.66%	75.66	74.3	1.83%	3.98	3.6	10.56%
MAPE			1.35%	MAPE		19.18%	MAPE		1.88%	MAPE		9.98%

The prototype that has been made is then used for operational observation of the ship's propulsion engine by placing the sensor in a place that allows for engine parameter measurements (Figure 8). The permanent magnet as a trigger sensor is placed on the flywheel while the magnetic sensor is placed in such a way that its position is close to the permanent magnet, this is done to obtain engine rotation data (RPM). While the temperature sensor is placed on the engine coolant reservoir tank, this placement is because there is no special place that can be used on the engine to place the coolant sensor. While the pressure sensor is placed on the oil channel cover bolt on the engine block and the oil temperature sensor is placed on the crankcase, this is also because there is no special place for the DS18B20 temperature sensor on the engine block and the measurement results are displayed in table 5.



Figure 8. Implementation of measuring instruments on ship propulsion engines

From the results of these measurements, there are differences between the values produced by the prototype (x) and the calibrated tool (y) on several parameters, namely RPM, water temperature (F/W Temp), and oil pressure at two measurement points (L/O Press). Each measurement shows the percentage of absolute error (APE) to compare the accuracy between the prototype and the calibration tool.

The RPM parameter, the MAPE value of 1.35% indicates that the prototype can record RPM quite accurately compared to the calibrated tool. While for the water temperature (F/W Temp) the MAPE value is

19.18%. This value is very different from the results during the tool test with a MAPE of 1.23%. This deviation is caused by the position of the existing temperature sensor installed on the engine before the thermostat, while the position of the prototype sensor is placed on the engine coolant in the heat exchanger, this is done because there is no place near the engine thermostat to place the prototype sensor. However, from these results it can be found that the engine coolant thermostat only opens to flow coolant to the heat exchanger when the engine temperature is 64°C and the thermostat opens at a stable position at a temperature of 70°C. This is indicated when the engine temperature is 64°C, then the water temperature in the heat exchanger begins to increase drastically from 30°C to 62°C.

Based on the data from the oil pressure measurement results (L/O Press) compared between the prototype test results with the oil pressure on the engine, there is a significant difference. The MAPE value on the test prototype is 1.72%, while the one placed on the engine is 9.98%. This shows a fairly large difference in oil pressure measurements. This condition is due to the placement of the prototype sensor which is not the same because the lubricant path is in the engine which is not visible. It is estimated that the pressure sensor on the prototype is installed before the lubricant filter and oil pressure control which can cause a pressure difference due to the difference in flow paths. This position allows for a decrease in pressure after passing through the lubricant filter and oil pressure control, resulting in a different value from the main sensor in the engine.

Conclusion

The operational monitoring system of diesel engines on fishing vessels aims to help facilitate decision making in predictive maintenance actions by analyzing the results of engine rotation speed measurements, engine coolant temperature and lubricant temperature as well as circulating lubricant pressure. This device uses a magnetic proximity sensor with a half effect principle

to measure RPM, SD18B20 to detect temperature changes and piezoresistive which can detect pressure magnitude with good accuracy and a compact Arduino Nano is used as a microcontroller. The results of this design produce a measurement prototype with a low error of between 1.23% to 2.08%, this shows that the tool works precisely so that it can be trusted as a reference material for making the right decisions. The significance of the real-time recording feature that provides operational data continuously, in addition, the embedded alarm feature will provide a warning if the engine operational parameters exceed the set threshold, so that damage prevention measures can be taken immediately. This device can also be accessed via a Wi-Fi network which makes it easy to monitor engine operational conditions without having to be directly on site. Adjustment of the sensors used is recommended according to the physical specifications available on the engine so that the sensors used can be positioned in the available space on the engine so that this device can be truly implemented on the ship's propulsion engine.

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Author Contributions

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Conflicts of Interest

The authors declare that there are no conflicts of interest, financial, personal, or professional, that could have influenced the objectivity or results of this study. The funders were not involved in the design of the study, collection, analysis, or interpretation of the data, writing the manuscript, or the decision to publish the results of this study.

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