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IoT-based Exhaust Gas Emission Detection System for Motorized Vehicles

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Abstract

The increase in the number of motorized vehicles results in air pollution by emission gases such as carbon dioxide (CO_2), carbon monoxide (CO), and hydrocarbons (HC). This causes air quality to decline and threatens public health. This research aims to monitor vehicle emissions using ESP32. The MQ-7, MQ-2, and MQ-135 sensors are used to detect exhaust emissions. The detected gas data are sent to the Blynk platform for real-time monitoring, printed using a thermal printer, and stored in Firebase for further analysis. The MQ-7 sensor detects CO, the MQ-2 detects HC, and the MQ-135 detects CO_2. The research results show that the developed tool is successful in monitoring and analyzing vehicle exhaust emissions. This hardware is capable of precisely detecting emissions, supported by the Blynk application for real-time monitoring and the Real-time Database for data storage. Variations in fuel type, such as 90 octane and 92 octane, significantly influence CO_2 emission levels. In an EFI engine, CO emissions range from 0.9% to 2.2% for 90 octane, while in a carburetor engine the range is from 1. 33% to 2. 87%. Variations in RPM also affect CO_2 emissions, with a 92 octane EFI engine showing a range of 1. 0% at low RPM to 2.63% at high RPM. In general, EFI engines show better performance with lower CO emissions compared to carburetor engines.

Keywords : Air Pollution, Emission Gasses, Real-time Database, EFI engines

1 Introduction

Human evolution has encompassed advances in transportation systems, with a significant number of vehicles today powered by fuel [1]. In recent years, air pollution levels have increased steadily worldwide [2]. Like other forms of pollution, air pollution has severe implications for human health, highlighting the importance of educating the public about the levels of pollution in our surroundings [3]. The rise in CO_2 levels is particularly concerning due to its predominantly irreversible nature, with impacts such as reduced rainfall and increased heat persisting even 1,000 years after emissions cease [4]. Climate conditions significantly affect the health and well-being of all living organisms [5]. Although the rapid growth of motor vehicles has provided undeniable mobility benefits, associated emissions, including carbon dioxide (CO_2), carbon monoxide (CO), and hydrocarbons (HC), pose serious threats to air quality and public health. As a result, research focusing on IoT-based ESP32 technology to detect vehicle exhaust gases is crucial to advancing environmentally friendly mobility and creating a healthier environment.

Several studies have explored IoT-based solutions for monitoring vehicle emissions. The research by [6] entitled "IoT-based Vehicle Monitoring System Using Bluetooth Technology" utilizes IoT and Bluetooth technology to monitor vehicle conditions. Another study by [7], "IoT-Based Smart System for Controlling CO_2 Emission," developed a system that employs IoT technology and Raspberry Pi to measure and control CO_2 emissions from public transport, industries and forest fires. This system continuously gathers CO_2 data in city locations and integrates them into a secure IoT platform, sending real-time notifications to mobile devices when CO_2levels exceed safe limits.

The research by [8], "Vehicle Pollution Monitoring System Using IoT," focused on an IoT-based system using MQ-7 gas sensors to detect carbon monoxide emissions. Connects to the Global System of Mobile Communications Network and the cloud to track vehicles that emit pollutants above a threshold, providing real-time alerts. This study addressed the limitations of infrequent emissions checks during fitness certification processes.

Another study by [9], "A Long-Range Internet of Things-Based Advanced Vehicle Pollution Monitoring System with Node Authentication and Blockchain," implemented a sensor node and gateway architecture using Long-Range communication to monitor real-time air quality index values. This system also proposed integrating blockchain for node authentication.

Lastly, the research by [9], "Motoring System of Motor Vehicle Feasibility Test Using Arduino Based on the Internet of Things," used Arduino and a simple linear regression method to correlate sensor ADC values with gas levels in parts per million (PPM).

This study differs from previous research by using ESP32 and a combination of MQ-7, MQ-2, and MQ-135 sensors to detect CO, HC, and CO_2 emissions at the individual vehicle level. The research integrates real-time monitoring through the Blynk platform and data storage using Firebase, offering an efficient and comprehensive approach. In addition, this study incorporates a thermal printer to provide immediate physical records of data for practical purposes.

2 Method

This research uses an experimental method to test the cause and effect relationship between three independent variables (variation of engine speed, type of fuel, and type of engine) with three dependent variables (CO_2 gas concentration, CO gas concentration, and HC gas concentration). The goal of this method is to explore and understand how changes in the independent variable affect the dependent variable.

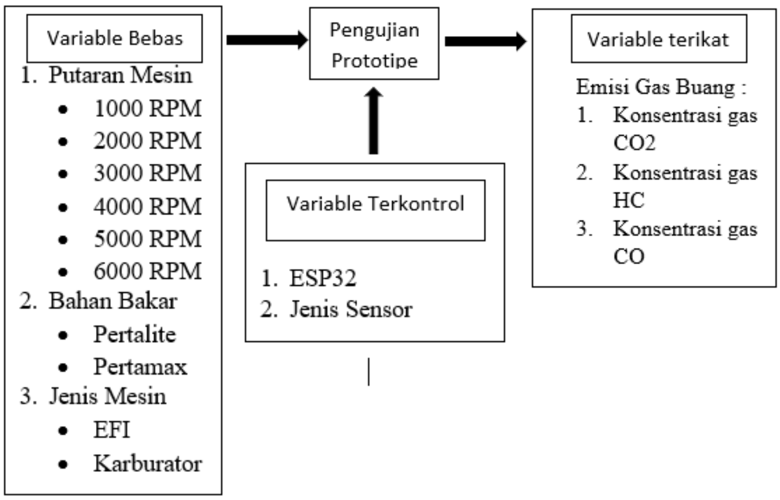

Figure 1: Research conceptual framework

The Research Flowchart explains the research process. First, it begins with problem identification through a literature review. Once the literature review is deemed sufficient, the research problem is formulated. The next step is the design and assembly of the equipment according to the initial design. After the equipment is assembled, the program is loaded onto the device, and experiments are conducted to ensure that it functions correctly. If the equipment does not work, the process returns to the design stage for evaluation. If the equipment works well, testing is conducted on exhaust gases from EFI and carburetor engines, followed by data collection and analysis. After analyzing the data, conclusions are drawn from the research and the research is completed.

- Tools used in research

    1. Laptop

2. Smartphone
3. Gas detection system
4. ESP 32
5. Usb to Usb mini
6. MQ-7
7. MQ-2
8. MQ-135
9. LM2596
10. Tachometer

- Materials used in research
    1. Octane 90
    2. Octane 92

2.1 Tool Design

In this study, the detection of exhaust gas emissions is performed using gas sensors connected to the exhaust system of the vehicle. This module requires a 5V power source from a 12V adapter, which is converted to 5V by a step-down converter. This voltage is used to power the ESP32 as the controller for the exhaust gas detection system. The input to the ESP32 comes from the gas sensors that detect the gases produced by the vehicle, as well as a push button that serves as a data collection trigger. Each time the button is pressed, a signal is sent to the microcontroller as a trigger, which then sends data to Firebase for storage in the database and commands the thermal printer to print the gas data results. In addition, every piece of data detected by the sensor will also be sent to the real-time Blynk database. The following is a schematic diagram for the IoT-based exhaust gas emission detection system for motor vehicles.

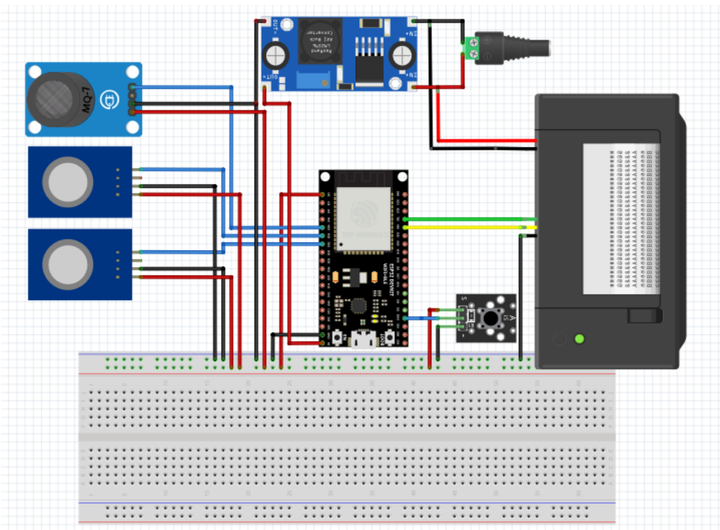

Figure 2: Circuit Schematic

2.2 System Block Diagram

The vehicle emissions monitoring system consists of two main aspects: software design and hardware design. The system block diagram is divided into three parts: input, process, and output. The implementation of the system involves integrating these components to collect data from each sensor and transmit the results using various types of output. Below are the stages of designing the vehicle emissions monitoring system and its block diagram.

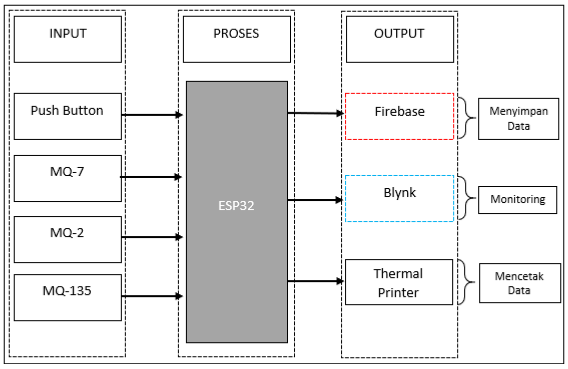

Figure 3: System Block Diagram

For its operation, the Internet of Things (IoT)-based vehicle emissions monitoring system uses the ESP32 microcontroller. It works by initializing the ESP32, establishing Wi-Fi connections, and using the MQ-7, MQ-2, and MQ-135 sensors to detect CO, HC and CO_2 gases. Sensor data is read and converted into digital data by the ESP32, which is then sent to the Blynk platform for real-time monitoring. The system continuously checks the push button, which, when pressed, triggers the printing of gas data via the thermal printer and the storage of data in Firebase. The system then returns to monitoring mode, ready to read and process new data. This system provides an effective solution for the real-time monitoring of vehicle exhaust emissions, with data accessible through Blynk and stored in Firebase for further analysis

2.3 Tool Work Flow Diagram

. The diagram begins with the ESP32 receiving power from the adapter. Following this, Wi-Fi initialization occurs; if the connection fails, it returns to reinitialize the ESP32. Once connected, the system proceeds with initializing the sensor program, Blynk, and Firebase. The calibrated sensors are then read, and data is sent to Blynk every second. If the push button is not pressed, the device continues to send data to Blynk. When the push button is pressed, the device sends data to the real-time database and the thermal printer for printing.

2.4 Tool Making

After making the circuit and designing the exhaust gas emission detection system, the next stage is to assemble each component according to the circuit that has been built as shown in the image below.

Figure 4: Tool Assembly Process

Then, when the components have been assembled, the next stage is to create a program using Arduino IDE software to create a program like the image below.

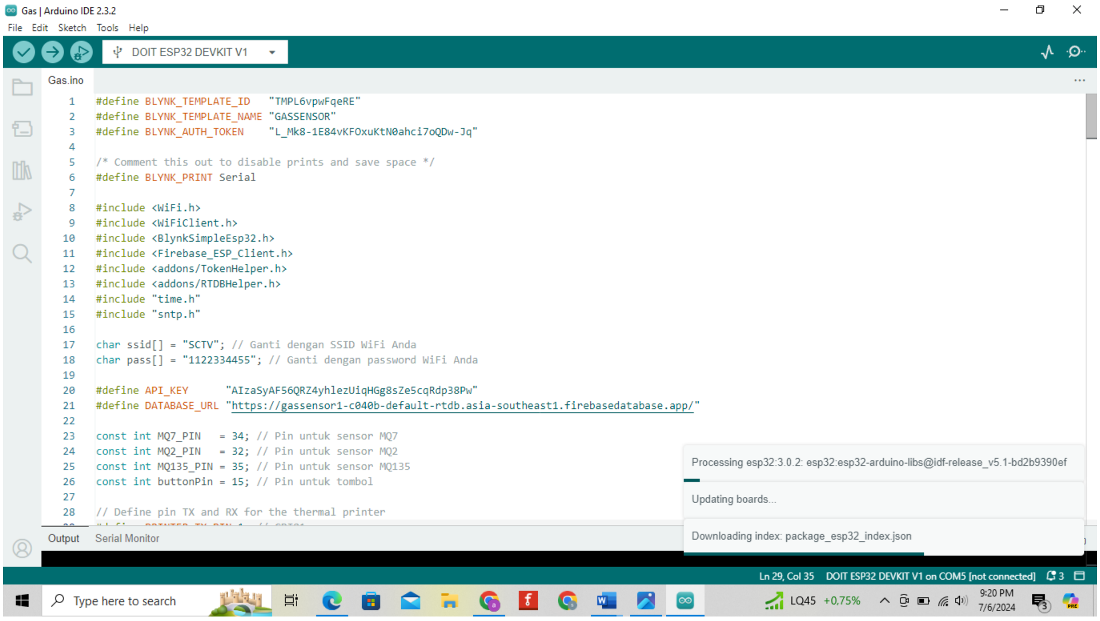

Figure 5: Program Creation Process

```
int rawValue_CO = analogRead(MQ7_PIN);
float resistance_CO = (float)(4095.0 - rawValue_CO) / (float)rawValue_CO;
float ratioMQ7_CO = resistance_CO / RatioMQ7CleanAir;
ppm_CO = A_CO * pow(ratioMQ7_CO, B_CO);
```

Figure 6: Tool Calibration Formula Program

The Formula Program begins with.

1. Read the analog value from sensor MQ-7
   int rawValue_CO = analogRead(MQ7_PIN);
   analogRead (MQ7_PIN)
   Retrieve the analog value from the pin connected to the MQ-7 sensor. This value will be in the range of 0 to 4095, depending on the voltage generated by the sensor.

2. Calculate Sensor Resistance
   float resistance_CO = (float)(4095.0 - rawValue_CO) / (float)rawValue_CO;
   Resistance is calculated using the formula shown below.

$$R = \frac{V_{ref} - V_{out}}{V_{out}} \tag{1}$$

3. Calculate RS/RO
   float ratioMQ7_CO = resistance_CO / RatioMQ7CleanAir; RatioMQ7_CO
   It is the ratio of the sensor's resistance when exposed to CO gas (RS) divided by the sensor's resistance in clean air (R0 or Rair). RatioMQ7CleanAir is the calibrated ratio value for clean air.

4. Calculate PPM
   ppm_CO = A_CO * pow(ratioMQ7_CO, B_CO);
   ppm_CO is calculated using the formula shown below.

$$ppm = Ax(\frac{R_{sensor}}{R_{cleanair}}) \tag{2}$$

In the PPM calculation formula, A and B are constants that have been pre-calibrated based on the datasheet.

After completing the programming and uploading it to the microcontroller, the next stage is to test the device as shown in the picture below.

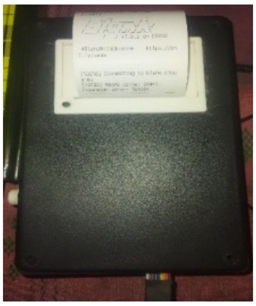

Figure 7: Tool Testing

- Data retrieval process
  1. Prepare the vehicle where the research will be carried out
  2. Prepare 90 and 92 octane fuel
  3. Put fuel in the vehicle to be tested
  4. Prepare a digital tachometer to measure engine speed
  5. Prepare the battery as a power supply for the digital tachometer
  6. Connect the digital tachometer +- cable to the battery and connect the cable to the high voltage on the vehicle
  7. Prepare the blower and aim it at the machine so it doesn't overheat when collecting data
  8. Prepare an IoT-based exhaust gas emission test tool and a gas analyzer
  9. Calibrate and warm up the sensor on the tool
  10. Adjust to a certain RPM when taking data on the tachometer
  11. Point the sensor probe at the vehicle exhaust and press the push button
  12. After taking the data, drain the tank on the vehicle and replace the fuel next
  13. Repeat the data capture process and save the physical data results.
- Data collection methods
  1. Testing of CO_2, CO, and HC emissions in an EFI engine using 92 octane fuel with an IoT detection system. The tests are performed at various vehicle RPMs (1000-6000 RPM), and the results are directly printed with a thermal printer for efficient documentation.
  2. Testing of CO_2, CO, and HC emissions in an EFI engine using 90 octane fuel with an IoT detection system. The tests are performed at various vehicle RPMs (1000-6000 RPM), and the results are directly printed with a thermal printer for efficient documentation.
- Data processing and analysis methods
  The data processing method used in this research involves the use of Excel to compare the results of CO_2, CO and HC exhaust emissions tests. This data was obtained through testing using an IoT-based exhaust gas detection tool. Data analysis was carried out by comparing the results of CO_2, CO and HC emissions based on fuel type, engine type, and engine speed variations (RPM).

3 Results and Discussion

Research results are the final result of a research process carried out to answer research questions, test hypotheses, or explore a phenomenon. The research results include data, information, findings, and analysis obtained during the investigation.

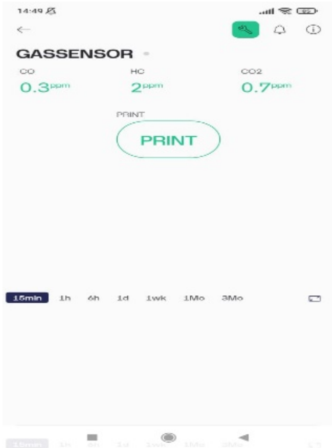

Figure 8: Monitoring Exhaust Emissions

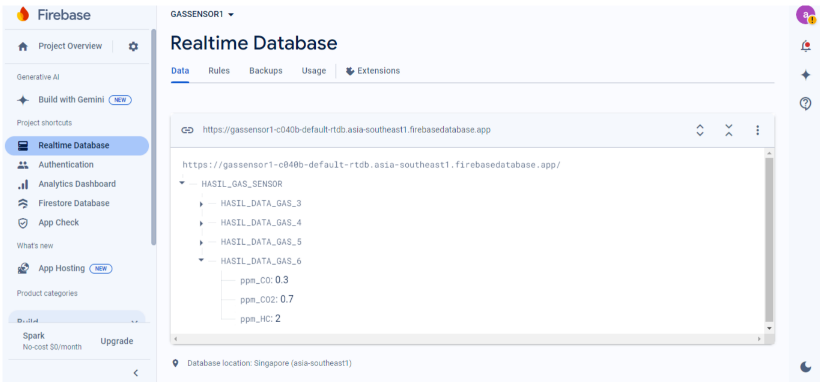

Figure 9: Realtime Database

Table 1: The average emission result is 92 octane for a carburetor engine

	RPM					
CO emissions Gas	1000	2000	3000	4000	5000	6000
Average	1	1.26667	1.6	2.16667	2.46667	3.06667
HC emissions Gas	1000	2000	3000	4000	5000	6000
Average	20.33333	25.66667	34	42.33333	51.33333	59
CO_2 emissions Gas	1000	2000	3000	4000	5000	6000
Average	1.66667	1.9	2.066667	2.3	2.933333	3.7

Table 2: The average emission result is 90 octane for a carburetor engine

	RPM					
CO emissions Gas	1000	2000	3000	4000	5000	6000
Average	0.7	10.93333	1.23333	1.533333	1.8	2.16667
HC emissions Gas	1000	2000	3000	4000	5000	6000
Average	10.33333	13	17.3333	23.66667	29	37.66667
CO_2 emissions Gas	1000	2000	3000	4000	5000	6000
Average	1.333333	1.566667	1.866667	2.133333	2.466667	2.866667

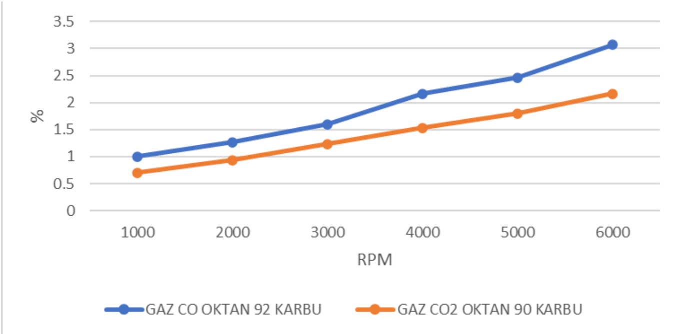

Figure 10: Graph of CO exhaust emissions from 90 and 92 octane carburetor engines

In the graph above, CO (carbon monoxide) gas emissions for 90 octane range from 0.7% at 1000 RPM to 2.17% at 6000 RPM, while for 92 octane it ranges from 1.0% at 1000 RPM to 3.07% at 6000 RPM. In conclusion, 90 octane produces lower CO emissions compared to 92 octane at all levels of RPM.

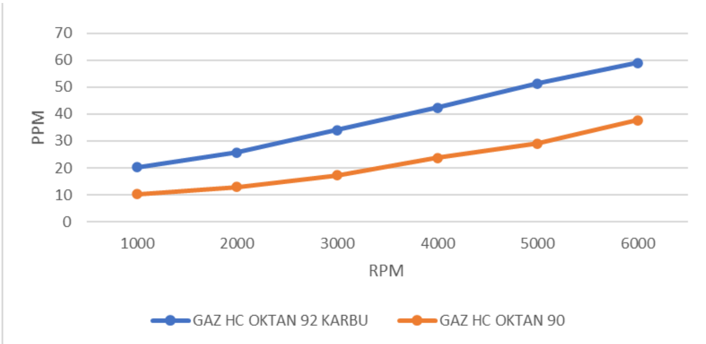

Figure 11: Graph of HC exhaust gas emissions for 90 and 92 octane carburetor engines

In the graph above, HC (hydrocarbon) gas emissions for 90 octane range from 10.33 ppm at 1000 RPM to 37.67 ppm at 6000 RPM, while for 92 octane it ranges from 20.33 ppm at 1000 RPM to 59 ppm at 6000 RPM. In conclusion, 90 octane produces lower HC emissions compared to 92 octane at all RPM levels.

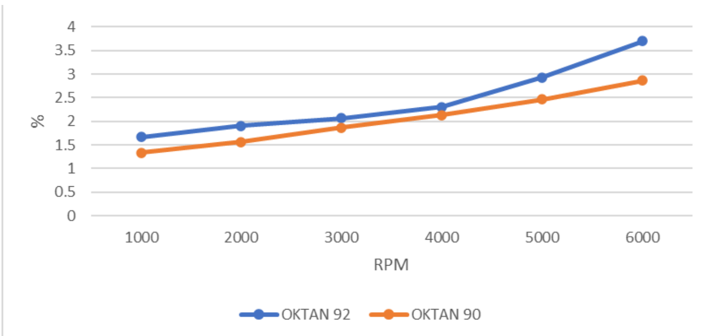

Figure 12: Graph of CO_2 exhaust emissions from 90 and 92 octane carburetor engines

In the graph above, CO gas emissions$_2$ (carbon dioxide) for 90 octane range from 1.33% at 1000 RPM to 2.87% at 6000 RPM, while for 92 octane they range from 1. 67% at 1000 RPM to 3.7% at 6000 RPM. In conclusion, 90 octane produces lower CO_2 emissions compared to 92 octane at all RPM levels.

In general, 90 octane fuel in carburetor engines produces lower CO, HC, and CO emissions$_2$ at all RPM levels compared to 92 octane fuel.

- CO gas emissions: 90 octane is lower at all RPMs.
- HC gas emissions: 90 octane is lower at all RPMs.
- CO_2 gas emissions: 90 octane is lower at all RPMs.

Thus, 90 octane fuel in carburetor engines is more efficient in reducing CO, HC and CO_2 exhaust emissions compared to 92 octane fuel at all engine speed levels.

Table 3: The average emission result is 92 octane for a EFI engine

	RPM					
CO emissions Gas	1000	2000	3000	4000	5000	6000
Average	0.5	0.63333	0.93333	1.2	1.4	1.76667
HC emissions Gas	1000	2000	3000	4000	5000	6000
Average	3.33333	6.33333	11.666667	14	18.666667	27
CO_2 emissions Gas	1000	2000	3000	4000	5000	6000
Average	1	1.53333	1.7	2.133333	2.333333	2.633333

Table 4: The average emission result is 90 octane for a EFI engine

	RPM					
CO emissions Gas	1000	2000	3000	4000	5000	6000
Average	0.4	0.566667	0.8	1.033333	1.266667	1.53333
HC emissions Gas	1000	2000	3000	4000	5000	6000
Average	1.66667	3.666667	5	11	13.33333	16
CO_2 emissions Gas	1000	2000	3000	4000	5000	6000
Average	0.9	1.166667	1.4	1.66667	1.9	2.2

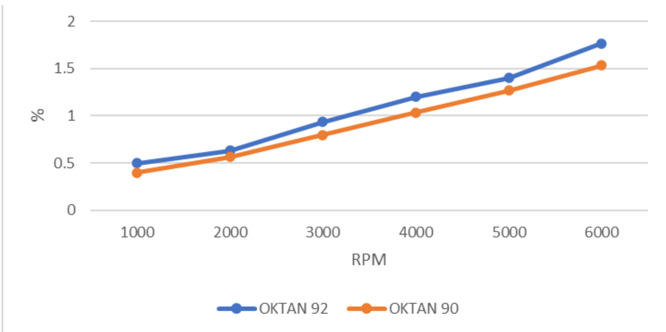

Figure 13: Graph of CO exhaust gas emissions from 90 and 92 octane EFI engines

In the graph above, CO (carbon monoxide) gas emissions for 90 octane range from 0.4% at 1000 RPM to 1,533% at 6000 RPM, while for 92 octane it ranges from 0.50% at 1000 RPM to 1.77% at 6000 RPM. In conclusion, 90 octane produces lower CO emissions compared to 92 octane at all levels of RPM.

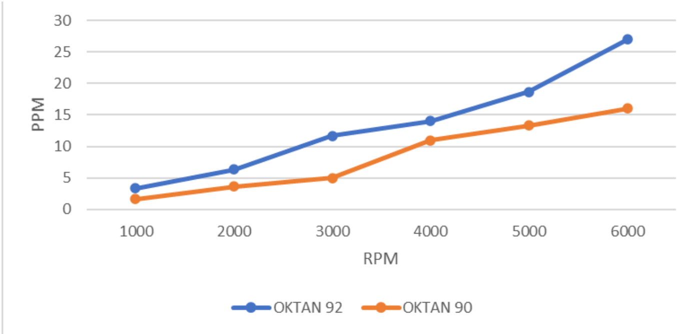

Figure 14: Graph of CO_2 exhaust emissions from 90 and 92 octane EFI engines

In the graph above, HC (hydrocarbon) gas emissions for 90 octane range from 1,667 ppm at 1000 RPM to 16 ppm at 6000 RPM, while for 92 octane it ranges from 3.33 ppm at 1000 RPM to 27.00 ppm at 6000 RPM. In conclusion, 90 octane produces lower HC emissions compared to 92 octane at all RPM levels.

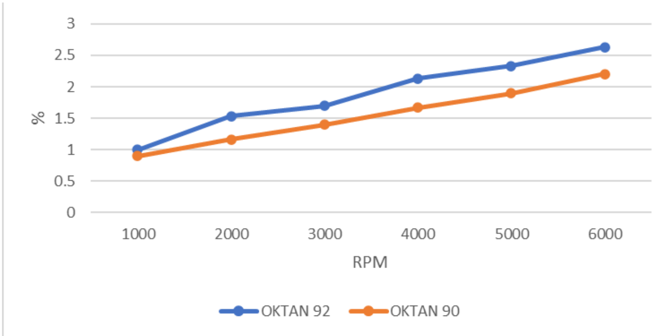

Figure 15: Graph of CO exhaust gas emissions from 90 and 92 octane EFI engines

In the graph above, CO_2 (Carbon Dioxide) gas emissions show that for 90-octane fuel, the average CO_2 emissions range from 0.9% at 1000 RPM to 2.2% at 6000 RPM. Meanwhile, 92 octane fuel has average CO_2 emissions ranging from 1.00% at 1000 RPM to 2.63% at 6000 RPM. In conclusion, 90 octane produces lower CO_2 emissions compared to 92 octane at all levels of RPM.

Overall, 90 octane fuel in an EFI engine produces lower emissions for CO, HC, and CO_2 at all RPM levels compared to 92 octane fuel.

- CO gas emissions: 90 octane is lower at all RPMs.
- HC gas emissions: 90 octane is lower at all RPMs.
- CO_2 gas emissions: 90 octane is lower at all RPMs.

Thus, 90 octane fuel in an EFI engine is more efficient at reducing CO, HC, and CO_2 exhaust emissions compared to 92 octane fuel at all engine speed levels.

4 Conclusion

This study shows that engine RPM variation significantly affects exhaust gas emission levels. For example, on an EFI engine with octane 92 fuel, CO_2 emissions range from 1.0% at low RPM to 2.63% at high RPM. This indicates that a higher engine RPM tends to increase CO, HC and CO_2 emissions because a higher RPM results in more intense fuel combustion, producing more combustion by-products. Fuel type also significantly influences exhaust gas emissions. In this study, an EFI engine with octane 90 fuel shows CO_2 emissions ranging from 0.9% to 2.2%, while octane 92 shows CO_2 emissions from 1.00% to 2.63%. This suggests that higher-octane fuel (octane 92) tends to produce higher emissions compared to lower-octane fuel (octane 90) when used in engines with a compression ratio not suited for higher octane. For instance, the Supra Carburetor and Supra EFI 125 cc motorcycles with a compression ratio of 9.3:1 are better suited for lower-octane fuel, while octane 92 is more appropriate for engines with a compression ratio of 10:1. EFI engines generally produce lower CO_2 emissions compared to carburetor engines for both types of fuel (octane 90 and 92) because EFI engines have more precise control over the air-fuel mixture, leading to more efficient combustion and lower exhaust emissions. For example, an EFI engine with 90 octane fuel shows a lower range of CO_2 emission (0. 9% to 2. 2%) compared to a carburetor engine (1.33% to 2.87%).

In general, this study confirms that RPM variations, fuel type, and engine type have significant effects on motor vehicle exhaust gas emissions. The IoT technology developed with sensors like MQ-7, MQ-2, and MQ-135, as well as platforms like Blynk and Firebase, has proven effective in monitoring and analyzing exhaust gas emissions in real time and accurately.

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