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Emission Gas Detector (EGD) for Detecting Vehicle Exhaust Based on Combined Gas Sensors

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Abstract. In the modern era, combination of several sensor types to determine the vehicle exhaust content is needed. Dangerous and toxic vehicle exhaust, such as HC, CO, CO2 and NO, needs to be controlled to reduce air pollution level. The vehicle exhaust content level can be measured by applying a combination of several sensors. In this research, a tool to detect vehicle combustion system condition based on vehicle exhaust content level has been designed. The tool combines several sensors, they are: TGS22001 sensor, TGS2602 sensor and MG811 sensor. Bluetooth HC-05 technology is also used to support Android-based information system. The combination of these technologies makes all of gas detection result can be known in real time and updated via smartphone. Arduino UNO R3 module is used to control all systems (gas-sensor-ADC-interface-Bluetooth-display). The results of combustion level test conducted on 15 motorcycles are: 8 motorcycles are bad, 4 motorcycles are medium and 3 others are good.

Keywords: Exhaust emission, gas sensor, Arduino

1. Introduction

The increasing number of vehicles caused higher exhaust emissions. As a results pollution increase and can cause various respiratory diseases. Exhaust emissions are a serious problem because it contains various toxins such as nitrogen oxide (NOx), carbon monoxide (CO), carbon dioxide (CO2) and hydrocarbon (HC). This research is purposed for designing Emission Gas Detector (EGD). EGD is used for measuring level of HC, CO, CO2 in motorcycle exhaust. It performance was seen from its emission level [1].

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Previous research conducted by Bayu [2] designed a detector system for motor vehicle exhaust gas using a TGS-2201 sensor which results were displayed on PC. Moreover, the study about measuring tool for CO, CO2 and hydrocarbon HC in vehicle exhaust has been done by Kosegeran et al. and Korhonen et.al [3-4]. Furthermore, a research related to effect of exhaust emission from gasoline vehicles like NOx, CO, CO2 and HC on pollution level in the metropolitan city had been investigated [5-6].
This research attempted to create an instrument that its use is easy and does not take a long time and can show results in the form of parameters that can be understood by people. It used to measure the level of each gas contained in vehicle exhaust include of HC, CO, CO2, and O2 in the motor. Detection of element gases are using several sensors which HC and CO gasses by TGS-2201 sensor, CO2by MG-811 sensor, and O2by TGS-2602 sensor. Sensors will convert the amount of gas they received into voltage that will be sent to the ADC (Analog to Digital Converter) that already integrate with Arduino Uno microcontroller. Microcontroller process data from ADC and display the measurement result on display.

In this research, the MG-811 sensor is used to detect the presence of CO2 gas using the electrochemical reaction which produces an electromotive force as the output voltage of the sensor. Moreover, the TGS-2201 sensor is used to detect HC and CO gas [8]. This sensor has advantage of being able to detect diesel and gasoline gas. It also has a heater that is used to clean the sensor room from outside air contamination so that the sensor can work more effectively. The TGS 2201 sensor works with two supplies of heating voltage (Vh) and circuit voltage (Vc). Heating voltage is useful for activating heaters in the circuit [9].

TGS 2602 sensor has two main parts. First part is material sensor based on tin dioxide (SnO2) which is capable at high temperature and required a large energy source. The second part of the TGS sensor is a metal oxide semiconductor layer placed on the alumina substrate together with an integrated heater [10-11].

2. Research Method

The test is carried out idle by sucking the vehicle exhaust gas into the gas analyzer test then measured the content of the four elements that want to see the levels are HC, CO2, CO, and O2. ADC will convert an analog signal from sensor to digital which then processed displayed through PC by microcontroller. Moreover, the data from EGD and gas analyzer were compared. EGD accuracy can be seen by its error in percent. Figure 1 shows a schematic diagram of the EGD. Gas analyzer with Infrared-205 belonging of Environment Department of North Sumatera Province as shown in Figure 1a is used for testing EGD. Emission detector is inserted to the motorcycle exhaust as far as 30 cm. The end of the detector is attached directly to the exhaust tip as shown in Figure 1b. The measurement results of EGD are acquired by Arduino Uno modul and displayed on PC. The result is not only displayed on PC but also passed on through Bluetooth HC-05 so it can be seen by smartphone device.

![Figure 1](image)

**Figure 1.** Detector design of exhaust gas emissions by (a) gas analyzer standard, (b) design of emission gas detector

The block diagram of the EGD system can be seen in Figure 2. The advantages of EGD system can be known from the utilization of blended sensor based on TGS-2201, MG-811 and TGS-262. The EGD was calibrated by calibrator for exhaust gas emission detector which belong to environmental department of North Sumatera Province. The presence of three sensor simultaneously is a new innovation, which can directly measure four elements of exhaust gas vehicle.
3. Results and Discussion

There are three stages have done to examine EGD performance including of Arduino testing, Bluetooth testing, and gas sensor testing.

3.1. Arduino Testing

Arduino board module with Uno R3 type is used as microcontroller board in the detector project. This microcontroller is easily combined with modules such as GPS, Ethernet, SD card and other port [12]. Arduino testing is done by two condition and respond the condition as on for 4.3 V and off for 0.01 V.

| Circuit condition | Voltage  |
|-------------------|----------|
| Off               | 0.01 mV  |
| On                | 4.3 V    |

This shows that Arduino works well and can be used in this research. Then the tested using blinking program as simple coding is worked. In the testing, the setting of LED lamp duration had been done as shown in Figure 4.

```c
// the setup function runs once when you press reset or power the board
void setup() {
  // initialize digital pin LED_BUILDIN as an output.
  pinMode(LED_BUILDIN, OUTPUT);
}

// the loop function runs over and over again forever
void loop() {
  digitalWrite(LED_BUILDIN, HIGH); // turn the LED on (HIGH is the voltage level)
  delay(100);  // wait for a second
  digitalWrite(LED_BUILDIN, LOW); // turn the LED off by making the voltage LOW
  delay(100);  // wait for a second
}
```

Figure 3. Coding For Blinking Program Testing Sample in Setting LED Flash Duration

Figure 3 contains programming coding to adjust the duration of LEDs on the Arduino board. From the program listing can be set the time range when LED on and off. In the fourth and fifth row on the coding program also has been set quickly and slowly. Led blinks by creating categories "high" and "low". The display on the Arduino board based on the coding in Figure 3 had been shown in Figure 4 when LED is on state. While in Figure 5 is shown when the LED is off. Where in Figure 4 and Figure 5 can be seen an orange-lit LED right next to the 13th pin in the Arduino board.
3.2. Bluetooth HC-05 Testing
Bluetooth HC-05 is tested by measuring output voltage on VCC pin (5 V) and ground state (Gnd). Table 2 is shown voltage range for off and on circuit condition. The output voltage for off and on condition was obtained 0.01 mV and 4.4 V respectively.

| Circuit condition | Voltage   |
|-------------------|-----------|
| Off               | 0.01 mV   |
| On                | 4.4 V     |

3.3. Gas Sensor Testing
Three gas sensors examination is done by connecting A0 pin to the TGS-2201 sensor, connecting A1 pin to the TGS-2602 and connecting A2 pin to the MG-811 sensor. During examination the sensor is left in the free air and then the voltage output were measured. The big difference of this measurement value is caused by contaminated air around the sensor [13]. So if the element is detected by the sensor then its value will change.

| Room Condition | Temp. (°C) | Output voltage (Volt) |
|----------------|-----------|-----------------------|
| Indoor         | 27        |                      |
|                |           | TGS22001 | TGS2602 | MG811  |
| Outdoor        | 27        | 0.8284   | 0.189   | 1.313  |
| Outdoor with gas| 27        | 0.7331   | 0.246   | 1.573  |

Once the tested components are functioning properly then calibration is done. Calibration to analyze the data and calculate the percent error of the EGD. For comparison, the authors use Brand Assembled output gas emissions test kit with Infrared-205 "Pony" Gas Analyzer Type, with 3 pieces of the 4-stroke motorcycle with different gasoline variations i.e: Premium, Peralite and Pertamax.

The EGD to be tested is shown in Figure 6, where in the funnel is placed three gas sensors are TGS-2201, TGS-2602, and MG-811. The function of laying the sensor inside the funnel is to bind the vehicle exhaust emissions when tested. The rounded pipe will make the air last longer in the tube space. This condition makes the gas element could be detected accurately by using three of sensors. Furthermore, Arduino Uno board had been connected to Bluetooth series with HC-05 type. This device is embedded and ready to connect to the Smartphone [14].
The calibration of EGD detector was carried by comparing a device that designed with the standard gas analyzer. After further calibration, 15 motorcycles with three variations of gasoline were proposed as sample testing. The vehicles offered in the three type based on kind of gasoline. The first vehicles are five motorcycles with pertamax fueled. The second vehicles are five motorcycles with pertalite fueled, and the third are motorcycles with Premium fueled. Testing and retrieval of data carried out in the car park of the State University of Medan (Unimed) and the parking of Physics Laboratory, State University of Medan.

The result of vehicle exhaust emission test on motorcycles fueled Pertamax 92 as shown in Table 5. From five motorcycles inspected, have been known four good quality of exhaust emission gas and the other is medium. The average age of all motorcycles inspected is 5 years old. It is reflected that all of the vehicle produced at the same time. Whereas the VR03 motorcycle is produce the maximum conduc HC emission 663 ppm. It is due to the journey distance of vehicles are maximum than other pertamax vehicle [15-16].

The EGD is successfully measured exhaust emission gas for HC, CO, CO$_2$ and also oxygen level of motorcycles. The data retrieval in these measurements are five repetition. The average data were listed in table 4-7. Data in table 5 to table 7 showa that the motorcycles with bad quality are the latest year's output of fewer than 2 years of service with a fairly regular service [17-18]. The third data shows the exhaust emission quality due to the motorcycle has been damaged. The result of gas emission test of vehicle exhaust on motorcycle fueled by Peralite 80% indicates poor quality of emissions. It is caused the kilometer journey of the motorcycle has been over than average of 5 years usage with irregular service and tune-up [19]. Table 6 shows the quality of motors are badly dominated and followed medium quality. Whereas for vehicles machine with Premium fueled were shows bad quality. The exhaust gas emission for four indicators, HC; CO; CO$_2$ and O$_2$ indicating that the motorcycle with premium fueled can be made the machine combustion system is pure. It is can be seen at Table 7, that from five motorcycles tested were obtained all of the machine bad for combustion system.

### Table 4. Comparison of Vehicle Exhaust Gas Emission Using Gas Analyzer and EGD

| Vehicles | Average of Gas Analyzer (Standard) | Average of Emission Gas Detector (EGD) measurements |
|----------|-----------------------------------|---------------------------------------------------|
|          | CO ($\%$vol) | CO$_2$ ($\%$vol) | HC (ppm) | O$_2$ ($\%$vol) | CO ($\%$vol) | CO$_2$ ($\%$vol) | HC (ppm) | O$_2$ ($\%$vol) |
| PTM      | 2.59         | 3.63          | 302      | 14.53        | 2.82         | 4.05          | 318      | 13.65        |
| PTL      | 3.42         | 4.74          | 494      | 14.40        | 3.75         | 5.36          | 528      | 12.86        |
| PRM      | 4.59         | 5.40          | 584      | 9.82         | 4.89         | 5.87          | 624      | 8.82         |

Note: PTM= Pertamax; PTL= Peralite; PRM = Premium
Table 5. Exhaust gas emission data on Motorbikes with Fueled \textit{pertamax}

| Vehicle types | HC (ppm) | CO (% Vol) | CO2(% Vol) | O2 (% Vol) | Quality |
|---------------|----------|------------|------------|-----------|---------|
| VR01         | 540      | 3.7%       | 11.34%     | 8.55      | Good    |
| VR02         | 557      | 3.6%       | 11.46%     | 8.76      | Good    |
| VR03         | 663      | 6.5%       | 14.86%     | 7.24      | Medium  |
| VR04         | 545      | 3.6%       | 11.39%     | 08.60     | Good    |
| VR05         | 540      | 3.6%       | 11.34%     | 08.55     | Good    |

Table 6. Exhaust gas emission data on Motorbikes with Fueled \textit{peralite}

| Vehicle types | HC (ppm) | CO (% Vol) | CO2(% Vol) | O2(% Vol) | Quality |
|---------------|----------|------------|------------|-----------|---------|
| VR06         | 794      | 5.2        | 13.74      | 06.06     | Bad     |
| VR07         | 796      | 5.6        | 13.81      | 05.89     | Bad     |
| VR08         | 804      | 6.8        | 14.62      | 05.28     | Bad     |
| VR09         | 643      | 4.3        | 12.58      | 07.65     | Medium  |
| VR10         | 677      | 4.6        | 14.94      | 07.35     | Medium  |

Table 7. Exhaust gas emission data on Motorbikes with Fueled Premium

| Vehicle types | HC (ppm) | CO (% Vol) | CO2(% Vol) | O2(% Vol) | Quality |
|---------------|----------|------------|------------|-----------|---------|
| VR11         | 804      | 6.8        | 14.62      | 05.28     | Bad     |
| VR12         | 875      | 6.6        | 14.88      | 03.37     | Bad     |
| VR13         | 794      | 5.7        | 13.74      | 06.06     | Bad     |
| VR14         | 874      | 6.7        | 14.86      | 02.98     | Bad     |
| VR15         | 796      | 5.6        | 13.81      | 05.89     | Bad     |

The exhaust gas emission of vehicles with premium is highest for HC, CO, CO2 respectively. Besides due to the usage of premium, it is affected by assembly year (the age of the vehicles) and the number kilometers traveled \[20-21\]. Whereas for peralite, the highest emission obtained from HC gas for VR08 vehicle. Figure 8 is shows the comparison of vehicle exhaust emission based on CO whose measured by detector standard and EGD designed.

**Figure 8.** Comparison of vehicle exhaust for carbon monoxide (CO) by detector standard with EGD

**Figure 9.** Comparison of vehicle exhaust for carbon dioxide (CO$_2$) by detector standard with EGD
The comparison exhaust gas emission of carbon dioxide (CO2), Hydrocarbon (HC) and oxygen (O2) have been shown in Figure 9 to Figure 11. Figure 9 and Figure 10 shows that exhaust gas emission produced by pertamax (PTM) fuel are less than pertalite (PTL) and premium (PRM). The same trends are also observed for EGD detector, where the emission concentration is slightly higher for all three fuel type. Thus, different behaviour for oxygen measurement, where the higher concentration of exhaust is obtained from pertamax fuel as shown in Figure 11.

The percentage error of EGD when compared with standard detector device from environment department can be seen in Figure 12. The minimum error is obtained 5.2% when measure the hydrocarbon emission of vehicle pertamax. While, the maximum error is 13.08% had been produced by carbon dioxide (CO2) emission of vehicle pertalite.

4. Conclusion
Following conclusions is obtained based on the results. The EGD could be used to measure the levels of HC, CO and CO2 elements emission of exhaust gas from motor vehicle easily and in simple way. Moreover, the gasoline type used in each motorcycle can be affect the concentration of exhaust gas emission of vehicle. The motor which using gasoline pertamax produce exhaust gas emission were good. The motorcycle with gasoline pertalite have bad and medium quality. Whereas for motorcycle that use premium, it gas emission quality is bad.
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