Detection and Analysis of CO, CO2 Exhaust Emissions in Two-Wheeled Motorized Vehicles

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Abstract **-- CO and CO2 are some of the exhaust gases resulting from the combustion of motor vehicles. The increase in the number of vehicles causes the concentrations of CO and CO2 exhaust gases in the air to increase. To be able to detect the amount of CO gas concentration using the MQ7 sensor and the CO2 sensor, the TGS4161 sensor is used. For the sensor to work properly, it needs a normalization process before it is applied to the testing stage. Based on the test results, the sensor normalization process requires 54 seconds with a maximum CO gas concentration of 4139.7 ppm, or 0.413%, and an output voltage of 4.39 volts. The CO2 exhaust gas test resulted in a maximum gas concentration of 5862.06 ppm, or 0.586%, with an output voltage of 0.51 volts. From several test results, the amount of exhaust gas concentration is dominantly determined by the type of vehicle and engine speed, while the type of fuel does not significantly affect the exhaust gas concentration, with an average percentage difference of 1.2%.**

Keywords: CO, CO_2 Gas Detector, Data Analysis

I. INTRODUCTION

The increase in the number of motorized vehicles is a threat to human air pollution [1]. The combustion products of these motorized vehicles produce exhaust gases that contain harmful toxins for the environment [13]. In general, the combustion process is the result of a chemical reaction or the reaction of compounds from fuel with oxygen and is influenced by sunlight and heat [14]. Carbon monoxide (CO) and carbon dioxide (CO2) gases are exhaust gases produced by the combustion of motorized vehicles [3]. One of the impacts caused by CO and CO2 gases is that they can cause various diseases, such as those of the respiratory system, nervous system, heart, headaches, and can even cause death [15], [16]. Another impact caused by this gas is that it can cause eye irritation and upper respiratory tract infection disorders (ARI), such as runny nose, sore throat, and bronchitis [7].

The main factor behind the increase in CO and CO2 exhaust emissions is the increasing number of motorized vehicle users. According to the latest data from the Indonesian Police Traffic Corps, the number of vehicles operating throughout Indonesia in 2013 reached 104.211 million units, an increase of 12% from 2012, namely as many as 94.299 million units, and also increased by 12% from 2011, namely as many as 84.193 million units. The dominant number of motorized vehicle developments is dominated by motorbikes [8], [11]. In Indonesia, the amount of air pollution caused by motorized vehicles reaches 70% to 80%. [4], [6], [12].

Based on data on the development of the number of motorized vehicles, especially two-wheeled vehicles, this research will realize a tool for detecting the amount of CO and CO2 gas content in two-wheeled motorized vehicles. By testing the concentration of CO and CO2 gases on these vehicles, it is possible to analyze the amount of CO and CO2 exhaust gas released into the air by two-wheeled motorized vehicles in line with the increase in the number of vehicles. Carbon monoxide (CO) gas is a colorless, odorless, and tasteless gas [5]. Carbon monoxide can cause poisoning of the central nervous system and heart. The concentration of CO gas in the air will not have an impact if the concentration of CO gas is below 10 ppm, whereas at a concentration of 10 ppm, this CO gas can cause disturbances in the central nervous system. The higher the concentration of CO levels, the more it can cause health problems in humans. At a concentration of 40 ppm, CO gas can affect heart function and can also cause headaches. At a concentration of 60 ppm, even at a concentration of 1000 ppm, CO gas can cause fainting and even death in humans [9].

II. BASIC OF THEORY

To detect CO gas, you can use a gas sensor. One of the gas sensors that has very high sensitivity, high stability, and a fast response to carbon monoxide gas is the MQ7 sensor [2]. The MQ7 sensor has a sensor resistance value (Rs) that can change when exposed to gas and also has a heater that is used as a sensor room cleaner from outside air contamination. This sensor has two voltage sources, namely the voltage for heating and the voltage for the circuit, each of which requires a DC voltage of 5 volts [10]. The voltage on the heater is used to heat the heater, which functions to activate the sensor element, which is sensitive to CO gas at an optimal temperature. The circuit voltage is used to measure the output voltage of the sensor. The MQ7 CO gas sensor can detect CO gas from 20 ppm to 10000 ppm. Figure 1 shows the characteristics of the MQ7 sensor, and Figure 2 shows the MQ7 sensor circuit.

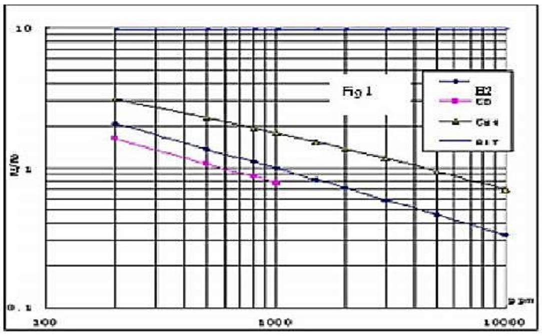

Figure 1. Characteristics of the MQ7 sensor

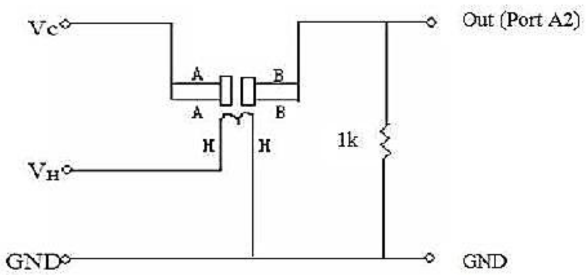

Figure 2. MQ7 sensor circuit

CO gas is odorless and colorless; it is toxic to the heart and can cause a decrease in contracting force. The volume of CO gas in the air, whose concentration reaches 3%, contains light narcotics that can cause an increase in blood pressure and pulse rate and a decrease in hearing ability. In addition, this gas has a concentration of up to 5% by volume in air and can cause stimulation of the respiratory center, difficulty breathing, dizziness, and confusion, followed by shortness of breath and headaches. In addition, in concentrations of up to 8%, it can cause headaches, reduced (blurred) vision, sweating, tremors, and loss of consciousness after five to ten minutes of exposure. Carbon dioxide, or carbonic acid, is a chemical compound consisting of two oxygen atoms covalently bonded to a carbon atom. It is a gas at standard temperature and pressure conditions and is present in the Earth's atmosphere. The average concentration of carbon dioxide in the Earth's atmosphere is approximately 387 parts per million by volume, although this amount can vary depending on location and time of day. Carbon dioxide is an important greenhouse gas because it absorbs infrared waves so strongly.

To detect CO2 gas, the TGS4161 sensor can be used. This sensor is very sensitive to CO2 gas. The sensor is composed of a solid electrolyte that forms between the two electrodes, together with a mold of a heating substrate (RuO2). Both of these electrodes can be used to detect changes in electromotive force (EMF), so these changes can be used to measure CO2 gas concentrations. The top of the sensor contains an adsorbent (zeolite), which aims to reduce the influence of gas disturbance.

The TGS4161 sensor requires an input voltage (VH) for the heater on the sensor. The heating voltage is applied in an integrated manner to maintain the sensing element at a certain temperature for optimization of the detection process. The solid electrolyte type of the sensor functions as a battery, so the EMF value itself will increase using the basic measurement circuit; for that, the EMF of the sensor must be measured using high impedance. The TGS 4161 sensor can detect CO2 gas from 350 ppm to 10000 ppm. Figure 3 shows the characteristics of the TGS4161 sensor.

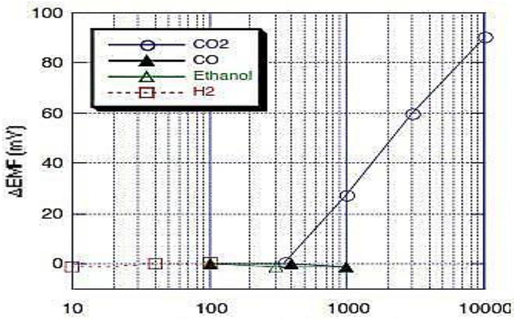

Figure 3. Characteristics of the TGS4161 Sensor

III. RESEARCH METHODS

This research method refers to the process stages in the data acquisition system for CO and CO2 exhaust gas concentrations in two-wheeled motorized vehicles, namely input, processing, and output. The amount of input in this study is in the form of CO and CO2 gas concentration data; the process is the processing of research materials; and the output is the output of the process. The stages of the research carried out followed the process shown in Figure 4..

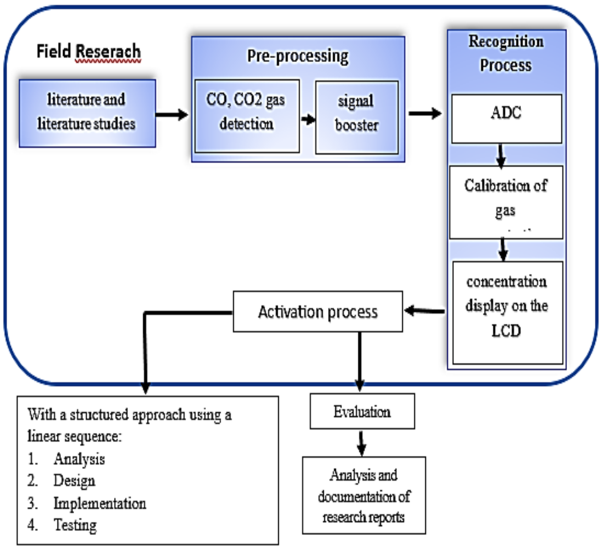

Figure 4. Stages of the Research Process

A. Tools and Materials

In this study the tools and materials used for the detection and analysis of CO and CO2 gases in two-wheeled vehicles are shown in Table 1.

Table 1. Tools and Materials

No.	Tools and materials	Function
1	MQ7 sensor and sensor suite, TGS4161	CO and CO2 gas detection
2	Sensor mechanics (sensor detection to motorized vehicles)	Motor vehicle exhaust gas detection test
3	Power Supply	The voltage source in the sensor circuit
4	LCD	Sensor output display (ppm gas concentration)
5	Microprocessor circuit (Arduino)	Processing units
6	PC	Integrated data processing with a microcontroller, record data, and data analysis

B. System Design

There are several circuits for CO and CO2 gas detection as shown in Figure 5. The workings of this system are that gas sensors are used to detect CO and CO2 exhaust gases. The output of this sensor is in the form of a large voltage (volts) where the output voltage of the sensor will change according to changes in the detected gas concentration. The greater the gas concentration detected, the greater the voltage.

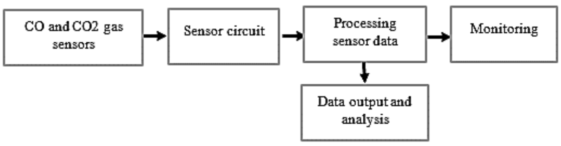

Figure 5. CO and CO2 gas detection system planning

The second circuit of the circuit shown in Figure 5 is the sensor circuit. This sensor circuit is used to adjust and calibrate changes in the magnitude of the sensor voltage to the exhaust gas concentration read by the sensor. Because the output of this sensor circuit is in the form of an analog signal, namely in the form of a large voltage (volts), the output signal of this sensor is converted first into a digital signal. To convert analog quantities to digital quantities, an ADC (analog-digital converter) is used.

The final stage of this system is the microcontroller circuit. The microcontroller is the main processing system. The process carried out on this microcontroller is the calibration process, displaying the detected gas concentration data on the display and the process of sending CO, CO2 gas concentration data detected to the computing system using a serial interface. The computational system used in this study is a database system that functions to make it easier to identify data on voltage changes, exhaust gas concentrations and data record times.

C. Planning of MQ7 CO Gas Sensor Circuit Module

The MQ7 gas sensor is capable of detecting exhaust gas from the combustion of 2 types of fuel, namely diesel fuel and gasoline. The remaining exhaust gas from diesel fuel consists of NO and NO_2 , while gasoline fuel can detect CO, CO2, H2, and HC gases. The conductivity of the sensor changes according to the concentration in the air. The circuit on this sensor converts changes in conductivity into an output signal (voltage).

The MQ7 sensor has two independent sensor elements. Each sensor element outputs a separate output, one output for diesel and a second output for gasoline.

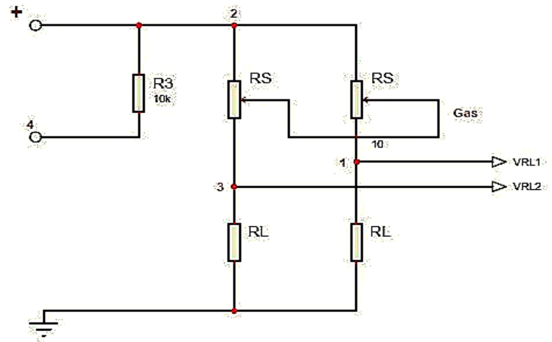

Figure 6. Basic MQ7 Sensor Circuit

The sensor element is made of a semiconductor metal oxide layer which is made of alumina base material that works together with the heating element. Figure 6. shows the MQ7 sensor circuit. The change in the magnitude of Rs is

$$Rs = \frac{Vc-VRL}{VRL} xRL \quad (1)$$

Based on Figure 6. element one on the VRL1 pin functions to detect the output signal from diesel and the VRL3 pin functions to detect the gasoline output signal. The MQ7 sensor requires two voltages, namely the voltage for heating (V_h) and the circuit voltage (V_c). The heater on the MQ7 sensor functions to optimize the measurement of the sensor elements and clean the sensor. The circuit voltage is useful for activating the basic circuit so that the output signals VRL1 and VRL2 can be measured through RL1 and RL2. The RL size used is 10kOhm with a voltage of 5Volt. The standard condition in free air is obtained by a VRL of 0.66 Volt so that the amount of Rs can be determined,

$$RS = \frac{5-0,66}{0,66} x10kOhm$$

$$RS = 65,78kOhm$$

The minimum VRL in the circuit is 0 Volt and the maximum VRL is 4.12 Volt. Changes in output voltage (V output) indicate changes in the amount of gas concentration in units of ppm using a scale of 1:50. The gas concentration is a minimum of 10 ppm and a maximum value of 10000 ppm.

D. TGS4161 CO2 Gas Sensor Module

The CO2 gas sensor used in this study is a type of solid electrolyte sensor manufactured by Figure Engineering Inc. namely TGS4161. The characteristics of this sensor are as follows:

1. CO2 gas targets.
2. The output of the sensor is the voltage (volts)
3. Typical detection Range 350 ppm – 10000 ppm.
4. Heater voltage 5 V DC.
5. Sensor sensitivity 44 – 72 mV.
6. Accuracy: 20% @ 1000ppm CO2

The TGS4161 sensor has a maximum deviation of 9650 ppm, and a detection range of 350 ppm to 10000 ppm. Figure 7. shows the basic circuit of the TGS4161. This sensor requires a voltage to turn on the heater (VH), this heater is already integrated with the sensor. The heater on the sensor functions to keep the sensing element in optimal condition. With the heater, the sensor will not be affected by temperature and humidity coming from outside.

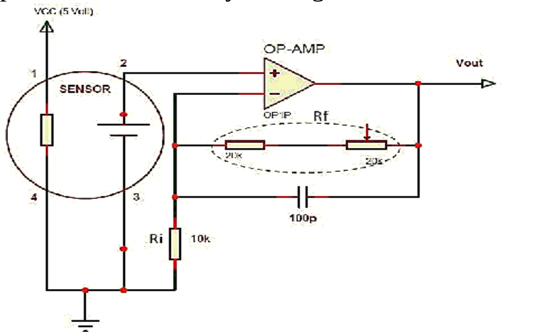

Figure 7. TGS4161 sensor circuit

IV. RESULTS AND DISCUSSION

A. Process Testing of CO and CO2 Gas Normalization

Before being used for testing, these sensors must warm up or activate the heater on each sensor. Based on the sensor data sheet, the heating process takes ± 60 seconds before the sensor is used. Based on the results of CO and CO2 gas normalization tests, it takes 54 seconds to heat up.

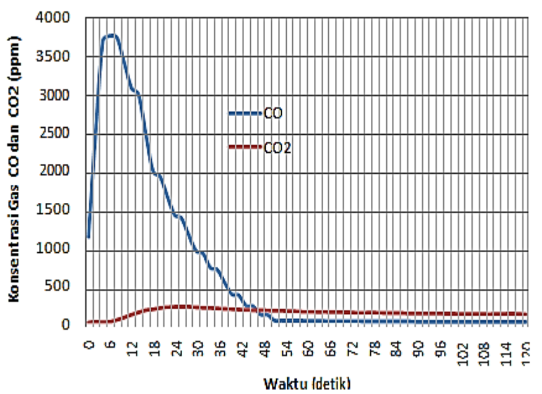

Figure 8. Graph of Change in Gas Concentration (ppm) against time in the normalization process

B. Testing of CO and CO2 Gas Sensors

The testing process is carried out by placing the sensor on the vehicle exhaust and observing changes in the exhaust gas sensor until it reaches its maximum value. The tests were carried out using several types of vehicles and several different types of fuel. Figure 9 shows the pattern of testing for CO and CO2 gas detection.

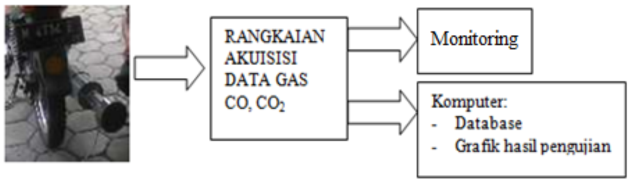

Figure 9. Block diagram of CO and CO2 gas concentration testing

1. CO Gas Concentration Test Results

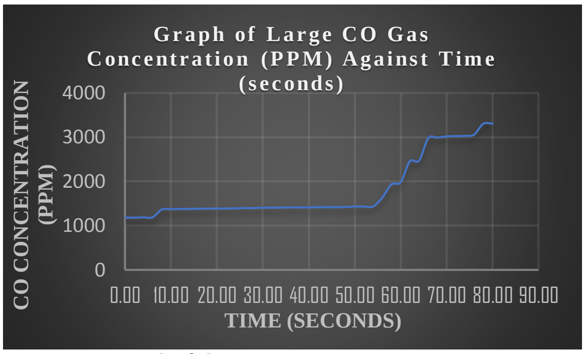

Figure 10. Graph of changes in CO gas concentration over time

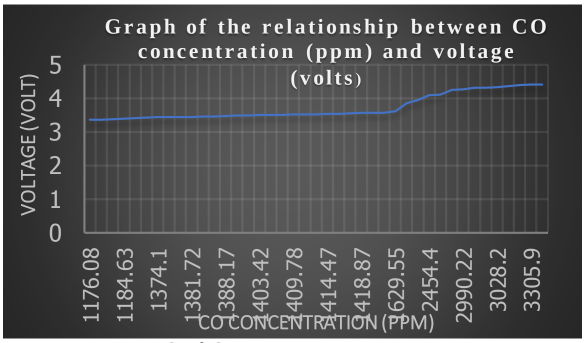

Figure 11. Graph of changes in CO gas concentration against voltage

Based on the test results, the maximum CO concentration is 3314.7 ppm which is carried out at maximum engine speed, with a detected voltage of 4.09 Volts.

2. Testing of CO2 Gas Concentration

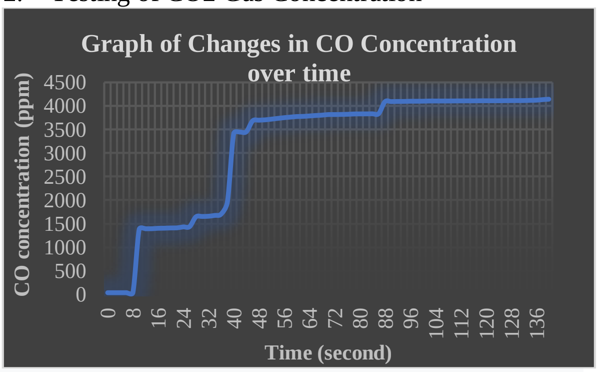

Figure 12. Graph of changes in CO2 concentration over time (seconds)

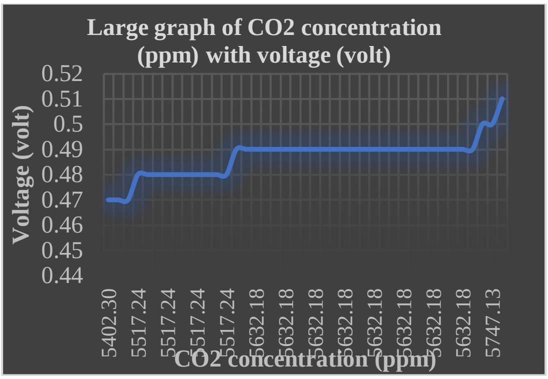

Figure 13. Graph of changes in CO2 gas concentration to changes in voltage

The test results resulted in the maximum concentration of CO2 gas being 5862.07 ppm using the maximum engine speed on the vehicle and the maximum voltage generated in this test was 0.51 volts.

C. 2010 Vario Vehicle, 125cc, and Pertamax Fuel Type

1. CO Gas Concentration Testing

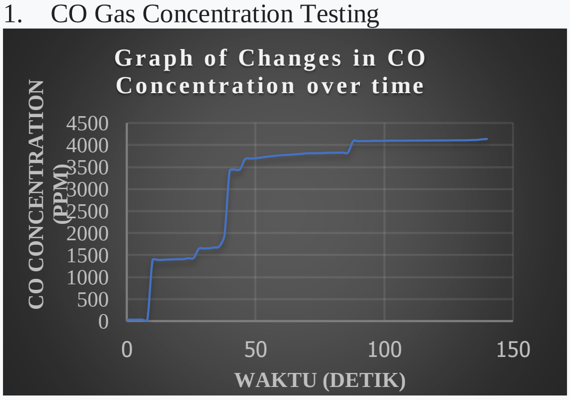

Figure 14. Graph of CO Gas Concentration Relationship with time

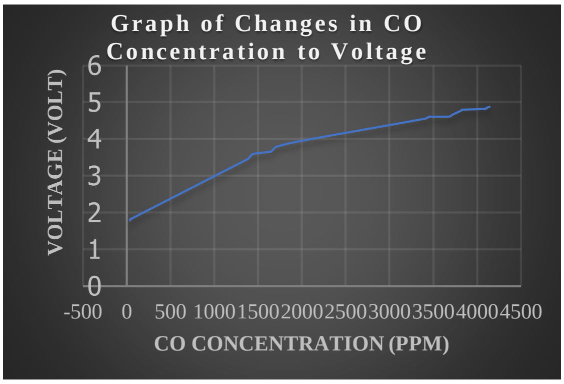

Figure 15. Graph of CO Gas Concentration Relationship to Voltage (Volts)

2. CO2 Gas Concentration Test Results

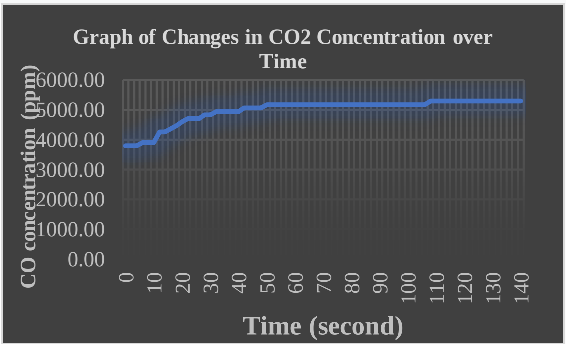

Figure 16. Graph of changes in CO2 concentration over time (seconds)

D. Data Analysis

By using the same process, the tests were carried out on different types of vehicles and the same type of fuel. The result was that the concentration of CO and CO2 exhaust gases was influenced by the type of vehicle and affected by the vehicle's engine speed. Meanwhile, from the results of several tests to detect CO and CO2 exhaust gas concentrations based on the type of fuel, namely Premium, Petalite, and Pertamax types, the average type of fuel does not have a dominant effect on the CO and CO2 exhaust gas concentrations. Of the three types of fuel, the Pertamax fuel type can produce a 1.2% reduction compared to the petalite and premium fuel types. To be able to use CO and CO2 exhaust gas detection devices using the MQ7 and TGS4161 sensors, the normalization process must be carried out on the sensors first, namely by activating heating on each sensor. Based on the datasheet book, CO and CO2 sensor heating takes 58 to 62 seconds so that the sensor can be optimally used to detect CO and CO2 exhaust gas levels. Meanwhile, based on the test results, the sensor heating process takes 54 seconds. Based on these two sets of data, there is a difference of approximately 2 seconds between the test results and sheet book data. Testing of CO and CO2 gas concentrations in several tests is shown in Table 2.

Table 1. Test Results for Detection of Exhaust Gas Concentration

N0	Vehicle Type (year)	Fuel	Detection Max limit gas concentration (ppm)		Duration (second
			CO	CO_2	
1	SupraX 125CC (2006)	Premium	3314,7	5862,07	78
2	SupraX 125CC (2005)	Premium	3073,7	5172,41	126
3	Supra 100CC (2001)	Premium	2468	4022,99	54
4	Beat 125CC (2010)	Pertalite	2954,13	5287,26	46
5	Vario 125CC (2010)	Pertalite	4189,8	5296,47	132
6	Vario125CC (2010)	Pertamax	4139,7	5287,36	136

Based on Table 2, The test was carried out to determine the amount of CO and CO2 exhaust gas concentrations produced against the detection time until it reaches the maximum exhaust gas concentration. To find out the effect of the amount of CO and CO2 exhaust gas concentrations, during the test, several variations or patterns of the testing stages were also carried out, either by changing the engine rotation speed or by using a different type of vehicle with the same type of fuel. Table 3 shows the results of the comparison of the average exhaust gas concentration between testing tools and standard tools. The test is carried out based on the year of the vehicle, the type of vehicle, and the type of fuel used.

Table 3. Comparison of test results with standard equipment results for

Fuel type	Average detection			
	Test Results with a Comparison Tool		Tool Testing Results	
	CO	CO2	CO	CO2
premium	0,3%	0,5%	0,2952%	0,5019%
Pertalite	0,35%	0,53%	0,3672%	0,5292%
pertamax	0,4%	0,53%	0,414%	0,5287%

From the tool test, the quantity measured is in units of ppm, while the standard tool used is in the form of % so the ppm amount must be converted to the form of %.

V. CONCLUSION

From the test results, it can be concluded that the normalization process for CO and CO2 sensors takes 54 seconds; this process is categorized as very good by comparison based on sensor sheet book data, with the time needed being 60 seconds. To test the concentration of CO and CO2 gases, the maximum exhaust gas concentration of CO2 is 4139.7 ppm, or 0.413%, with an output voltage of 4.39 volts, while the maximum exhaust gas concentration of CO2 is 5862.07 ppm, or 0.586%, with a voltage of 0.51 volts. The measurement results show that the variable engine speed and vehicle type have a significant effect on the amount of exhaust gas concentration, while the type of fuel has no significant effect, with an average percentage difference of 1.2%.

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