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The Comparison of Exhaust Gas Emission Between Conventional and Electronic Fuel Injection System

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***Abstract*—The world's most discussed issues are energy and health. Concerns about environmental pollution and health motivated the automotive manufacturers to find solution to reduce the exhaust emission gas. One solution developed at this time is to replace the conventional into electronic fuel injection system. Emission comparison was tested between conventional fuel system and electronic fuel injection on a motorbike. In this study, the test was carried out using a 4-stroke motorcycle with a 110-cc capacity CVT transmission. Emission testing used a four-gas emission analyzer. The results of the test show the electronic fuel injection system produces a better quality of emission gas, with a decreasing in the composition of CO and HC, an increase in CO_2 and O_2 emissions occur above 2000 rpm. This is caused by combustion using a lean mixture.**

Keywords—emission, conventional, injection, lean

I. INTRODUCTION

One of the vehicles used by the public in transportationis motorbikes. The development of technology in the automotive field is currently very rapid. In general, gasoline engines are used as propulsion in transportation equipment. At this time the conventional system has been abandoned and replaced with an electronic fuel injection system. A carburetor is a device that mixes the air and fuel to be put into the engine based on the vacuum in the combustion chamber, with a vacuum of about 0.04Mpa-0.05 MPa [1]. While electronic fuel injection is a technology used to spray fuel into the intake manifold that works based on the Electronic Control Unit, with pressures reaching 0.25MPa- 0.45MPa. Based on these considerations, the author is interested in discussing "how much electronic fuel injection motorcycle can improve the quality of emissions compared to conventional/carbureted systems ".

Emission comparison testing between vehicles using a carburetor and electronic fuel injection has been done by [1]. By using a 125 cc four-stroke Honda motorcycle, with varying loading and rpm. By changing the conventional system to the electronic fuel injection system there was a decrease in emissions of 62.6%, 29.75%, and 11.33% for CO, HC, and CO_2 at 5 Nm loading.

Testing of conventional 125 cc motorcycles with a total capacity of 60 units in Teheran has been carried out by [2]. In the test, none of the motorcycles meet the Euro-3 standard, where the CO content was 7% higher than the standard set. About 40% of the fuel is burned incomplete. The combustion process tends to use a rich mixture.

Emission testing by driving vehicles in cities and villages has been carried out by [3]. Vehicle fuel consumption in urban areas is 30% higher than in rural areas. A two-stroke vehicle will produce higher HC emissions than a four-stroke vehicle. But NO_X emissions of two-stroke vehicles smaller than four-stroke vehicles. Other factors that affect emission levels are road characteristics, traffic volume, vehicle type, and driver behavior.

Conducting the fuel consumption and emissions testing by using different types of fuel between gasoline and ethanol [4]. The test has been carried out by analysis and using a dynamometer. [4] said that gasoline with a composition of C_8H_{15}. Small gasoline carburetor engines (between 50-350 cc) experience low operating efficiency, high fuel consumption, and produce high levels of hazardous emissions [5].

The fuel electronic fuel injection system has a relative advantage over the carburetor fuel system [6]. The main advantages that EFI has helped to reduce exhaust emissions gas also have the following advantages: Reducing wall wetting. Increased fuel atomization. In addition to reducing exhaust emissions, EFI has also introduced other benefits such as reducing fuel consumption.

A more advanced fuel system is the GDI (Gasoline Direct injection) combustion system reviewed by Archer, M. and Bell [7,8]. The purpose of the review is to motivate researchers to get deeper into this problem. His paper reviews the benefits of direct fuel injection in a gasoline engine in terms of fuel consumption and emissions, its feasibility, and its complexity.

Carbureted/conventional and electronic fuel injection System. The difference between the carburetor and the electronic fuel injection system is in the process of entering fuel into the combustion chamber. In the carburetor fuel system, the fuel intake process relies on the suction obtained from the movement of the piston in the cylinder. In the electronic fuel injection system using electronic devices such as injectors, whose function is to spray fuel into the combustion chamber.

In the carburetor fuel system, the distance between the gasoline nozzle and the cylinder is quite far, and the difference in density between fuel and air results in the volume of incoming air being unbalanced with the amount of fuel inhaled. In the electronic fuel injection system, it can balance the volume of fuel sprayed into the combustion chamber according to the needs of the engine, so that efficient combustion results are obtained. In the electronic fuel injection system, the volume of fuel spraying into the combustion chamber is always accurate because it is controlled by the ECU (Engine Control Unit) system. This has an impact on the mixture of air and fuel to always be accurately compared at all engine speed levels. This condition provides the advantage of reducing exhaust emissions and saving fuel consumption.

The pressure of fuel spraying will affect the homogeneity of the fuel mixture with air, the carburetor fuel system works at a pressure of 0.04MPa-0.05Mpa [1]. While the electronic fuel injection system works at a pressure of 0.25 MPa.

Air pollution is caused by the entry of certain gases or particles into the environment. This pollution results in decreased air quality. This will disrupt the quality of human life and other living things. Air pollution that occurs due to human activities generally occurs as a result of burning fuel for transportation and industrial facilities (factories another factor that causes air pollution is natural disasters, for example from volcanic eruptions and forest fires)

A. Carbon Dioxide (CO_2)

Vehicle emissions cause an increase in CO_2 concentrations in the atmosphere. Increased CO_2 occurs very drastically until late beyond the ability of plants and the sea to absorb it. In normal condition, the energy of sunlight which enters the earth will be reflected into the atmosphere in the form of infrared radiation. Due to the concentration of CO_2 is so huge in the atmosphere, that will radiate the reflection of infrared back to earth. The effect of this condition is an increase in global temperature that triggers the greenhouse effect which is now a major issue in the world called Global Warming. This happens because CO_2 concentrates by microorganisms, dust, and water points in clouds form. This concentration can be penetrated by sunlight but cannot release heat out of these clouds. The concentration of CO_2 in exhaust emissions is the ratio of the volume of carbon dioxide (CO_2) contained in the exhaust gas and expressed in percent (%)

B. Carbon Monoxide (CO)

CO gas is mostly the result of the incomplete combustion process of fossil fuels with air. The combustion of organic fuels aims to get heat used for a variety of purposes, such as transportation and industry. Vehicles are the main source of CO pollutants. Gasoline-powered vehicles produce more CO gas than diesel-fueled vehicles. CO emission occurs because the fuel does not burncompletely due to a lack of oxygen in the process, so it fails to become CO_2 as expected. Incomplete combustion due to incomplete atomized fuel in a fast process also results in the emergence of CO. CO concentration is the ratio of the volume of carbon monoxide (CO) contained in the flue gas expressed in percent (%).

C. Hydro Carbon (HC)

Is substances that are chemical bonds from carbon (C) and Hydrogen (H) only. HC occurs due to unburnt fuel and comes out into raw gas. This condition occurs around low-temperature combustion chamber walls where the temperature is incapable of combustion. The overlap is also a cause of the emergence of HC gas. This can occur in a cylinder wall far from the center of combustion. In the carburetor system, the tendency occurs the higher the combustion engine rotation has a shorter time so that more fuel is not burned completely.

D. Oxygen (O_2)

O_2 arises because of excess air in the combustion process. Unused air in the combustion process breaks down into O_2 and N2. The combustion process of the electronic fuel system tends to use a lean mixture. Lamba (λ) is the ratio of actual AFR to stoichiometric AFR. If the value of $\lambda = 1$ means a mixture of stoichiometry. Because the electronic fuel injection system uses a lean mixture, it means the value $\lambda > 1$. The concentration of O_2 in vehicle exhaust emissions is the ratio of the volume of oxygen (O_2) contained in the exhaust gases and expressed in percent (%).

II. Experiment Setup and Procedure

AFR is the ratio of air mass to fuel mass [9]. The AFR value is obtained by calculating the equation of fuel reaction with air. In this study using gasoline fuel, which we consider that gasoline is isooctane fuel (C_8H_{15}) [4]. So the AFR can be calculated from gasoline fuel. The equation of the combustion reaction of stoichiometry from gasoline fuel with the amount of theoretical air is as below [10,11],

$$C_8H_{15}+11,75(O_2+3.76N_2)=8CO_2+7.5H_2O+44.8N_2 \quad (1)$$

$$AFR=11.75 * 4.76=55.93\ mol_{air}/mol_{gasolin} \quad (2)$$

$$AFR=55.93(28.84/111)=14.54\ gr_{air}/gr_{gasolin} \quad (3)$$

This study was conducted by observation with a 110 cc four-stroke motorcycle test equipment, CVT transmission, using gasolin fuel. The study was to test emissions gas using conventional fuel system motorcycle. Followed by testing the electronic fuel injection system motor cycle at 1300, 2000, 3000 and 4000 rpm. The exhaust emission composition was tested using a four-gas analyzer that was also used by [12-14]. The experimental setup in Figure 1.

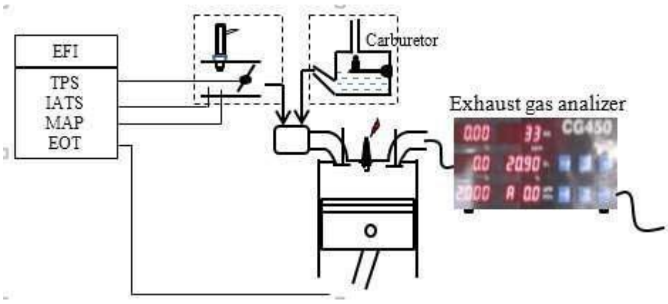

Fig. 1. Example Experimental setup.

III. RESULTS AND DISCUSSION

Vehicle emissions are generally produced by the incomplete combustion process, resulting in toxic gases or gases that damage the environment.

TABLE I. CARBURETOR EMISSIONS

Emission composition	RPM			
	1300	*2000*	*3000*	*4000*
CO (%)	1.06	2.17	3.06	5.34
HC (ppm)	85.00	69.00	37.67	82.67
CO_2 (%)	5.77	5.40	7.83	8.73
O_2 (%)	11.76	11.45	7.73	4.69
λ	1.94	1.85	1.46	1.05
AFR	28.21	26.89	21.23	15.27

TABLE II. ELECTRONIC FUEL INJECTION EMISSIONS

Emission composition	RPM			
	1300	*2000*	*3000*	*4000*
CO (%)	3.25	0.34	0.20	0.17
HC (ppm)	249.67	36.33	54.67	39.00
CO_2 (%)	4.30	7.27	8.27	10.07
O_2 (%)	11.95	10.63	9.05	6.58
λ	1.84	1.93	1.73	1.47
AFR	26.75	28.06	25.15	21.37

Based on the results of testing the exhaust emissions produced by conventional and electronic fuel injection motorcycle in Table 1 and 2.

A. CO Emissions

Based on research data that has been done the composition of CO emissions at several speeds in figure 2.

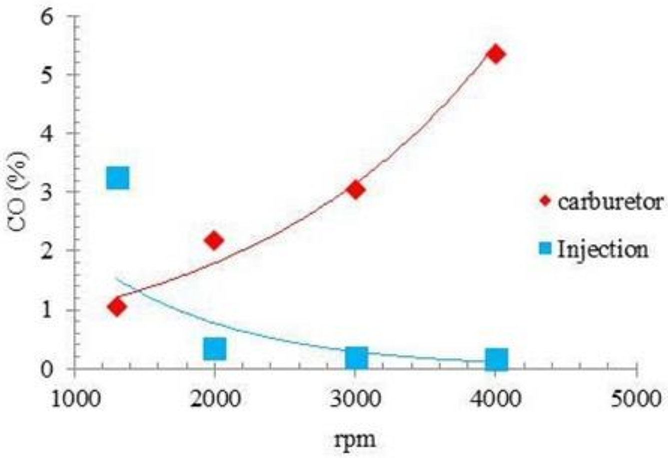

Fig. 2. CO emissions.

The hydrocarbon stoichiometric combustion reaction should produce CO_2, H_2O and N_2. As a result of incomplete combustion to produce CO gas. CO emissions arise because the fuel does not burn completely due to a lack of oxygen. CO emissions occur because hydrocarbons fail to break down into CO_2. Incomplete combustion due to the fuel not being atomized into a homogeneous gas so that it does not burn completely in a fast process. This can occur in the cylinder walls that are far from the center of combustion. In the electronic fuel injection motorcycles, the tendency occurs, the higher rotation of the engine, the CO emission composition is getting reduces. This happens because of the high temperature of the combustion chamber at high speed so that the fuel is flammable. In contrast to conventional vehicles which tend to use a rich mixture and fuel atomization with a larger particle size so that the fuel does not burn out, thus increasing CO emission. These results are consistent with the results of research [1], in conventional fuel systems CO emissions increase at 2000-4000 rpm. But in testing the electronic fuel injection system at this time the graph has decreased slightly.

B. HC Emissions

Based on research data that has been carried out the composition of HC emissions at several speeds can be seen in Figure 3.

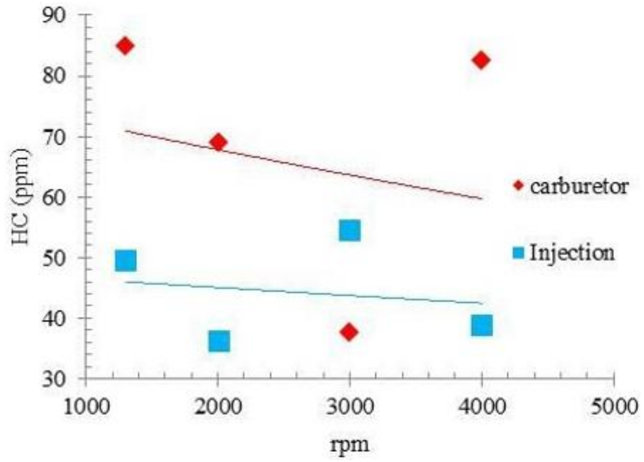

Fig. 3. HC emissions.

Hydrocarbon emissions are caused by unburned fuel particles in the combustion process. If the atomization diameter is large enough so that the fuel particles are difficult to burn during the combustion process, and they exit into the exhaust manifold more quickly, producing unburned hydrocarbons. This usually occurs in reactants that are far from the source of the ignition. In the atomization particle size is very small and mixes homogeneously with air resulting in a very fast combustion process which reduces the appearance of HC emissions. HC emissions decrease with increasing rpm occurring at 2000-4000 rpm. HC emissions have the same trendas test results [1].

C. CO_2 Emissions

CO_2 emissions in this test can be seen in Figure 4.

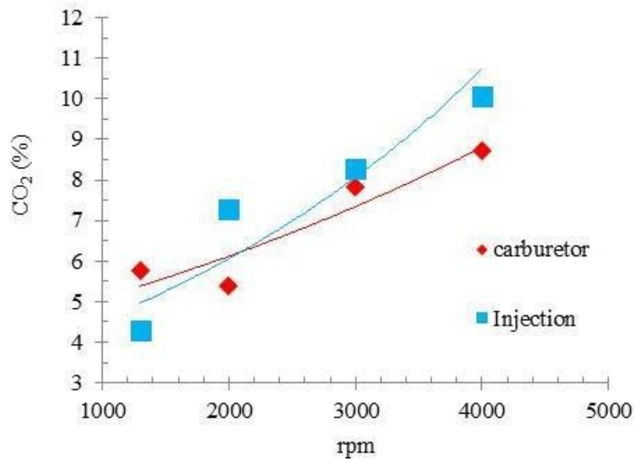

Fig. 4. Example of CO2 emissions.

The CO2 emissions of motorcycles using the electronic fuel injection system are greater than the CO_2 emissions of conventional motorcycles (figure 4). This shows that the combustion process of the electronic fuel injection system is better than the conventional fuel system combustion process. The complete combustion process will only produce CO_2, H_2O and N2.

D. O_2 emissions

The comparison of emissions produced by conventional fuel system and an electronic fuel injection system can be seen in Figure 5.

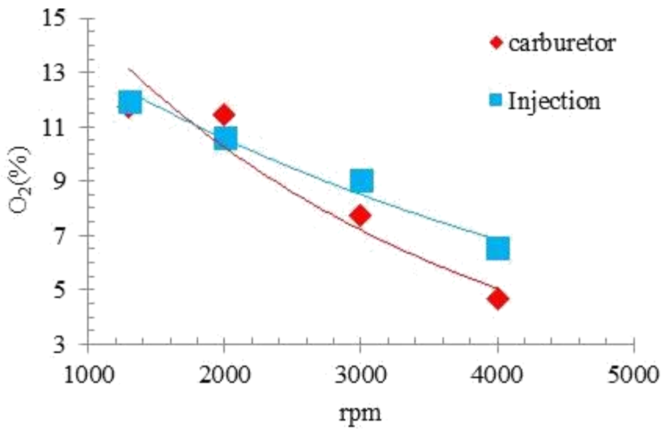

Fig. 5. O2 emissions.

In figure 5 O_2 emissions for electronic fuel injection systems are generally higher than for conventional fuel systems. This means that the electronic fuel injection system uses more air, so that more O_2 is produced without reacting with the fuel to produce CO_2. If viewed from CO and HC emissions, conventional fuel systems produce higher emissions. This indicates that the conventional fuel system tends to use a rich mixture.

E. AFR and Lamda (λ)

Air fuel ratio is the ratio the mixture of air and fuel. For gasoline fuel, AFR stoichiometry generally ranges from 14- 15 mass fractions. Lamda (λ) is a comparison of the actual AFR compared to the stoichiometric AFR. If $\lambda < 1$ indicates a rich mixture, $\lambda = 1$ is a stoichiometric mixture and if $\lambda > 1$ indicates a lean mixture. The current test results can be seen in Figure 6.

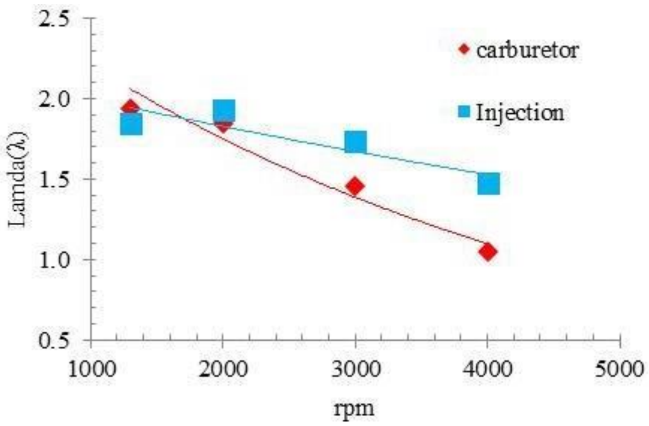

Fig. 6. Lamda.

Based on Figure 6, it can be seen that the electronic fuel injection system tends to use a lean mixture. Shown from a higher lamda value than conventional fuel systems. This canalso be seen from the exhaust gas emissions produced. O_2 emissions are higher, indicating the presence of O_2 does not burn or react with fuel to produce CO_2 gas. If combustion occurs stoichiometry O_2 should be bound by C atoms to form CO_2 molecules. From the CO emission, it can be seen that the percentage of CO emissions produced by the electronic fuel injection system is lower than the CO emission from the conventional fuel system. This means that there are fewer fuel atoms that do not react with the air

IV. CONCLUSION

The percentage of CO emission is lower in electronic fuel injection fuel systems than conventional fuel systems, and the percentage difference increases with increasing engine speed. The HC composition of the electronic fuel injection system is lower than the conventional fuel system, the difference in composition is almost the same at every rpm. The percentages of CO_2 and O_2 for injection fuel systems are higher than conventional fuel systems starting at 2000 rpm and the percentage difference increases with increasing rpm.

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