American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)

ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

Comparison of Three Way Catalytic Converter Exhaust Gas with Pertalite, Pertamax, and Pertamax Turbo Fuel in Gasoline Motor

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Abstract

Transportation emissions are the highest contributor to air pollution, which is around 85%. One technology that can be used to reduce exhaust emissions from transportation is by installing a catalytic converter in the exhaust emission exhaust system. This study discusses the use of catalytic converters to reduce carbon monoxide (CO) and hydrocarbons (HC) with variations in engine speed and fuel. The catalyst used is a three-way catalytic converter model. The engine speed used is idle, 1000 rpm, 1500 rpm, 2000 rpm, 2500 rpm, 3000 rpm, 3500 rpm. The variations in the fuel used are pertalite, pertamax and pertamax turbo. The use of catalytic converters can reduce the concentration of CO and HC with all three types of fuel. The biggest reduction in CO and HC concentrations reached 39.5% and 22.7%. From this study, it can be seen that the use of catalytic converters can reduce exhaust emissions. The greater the octane number of the fuel, the less CO and HC emissions contained in the exhaust gas. The use of catalytic converters can be a solution to overcome the problem of pollution caused by transportation equipment because of its ability to convert hazardous compounds to exhaust emissions into harmless gases.

Keywords: catalytic converter; carbon monoxide (CO); hydrocarbon (HC).

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1. Introduction

The use of motorized vehicles has increased rapidly as technology advances occur at this time. According to data reported by the Central Statistics Agency (BPS), in 2017 there were 138 million motorized vehicles in Indonesia with the highest number of motorcycles, nasmely 115 million [1]. This number will increase along with the times and increase in population. This certainly will have an impact on environmental health, because an increase in the use of motorized vehicles will increase air pollution. According to the International Energy Agency (IEA) since 2000 Indonesia experienced an increase in emissions of around 78%. Globally, transportation accounts for a quarter of total emissions in 2016 at around 8 GtCO2, 71% higher than in 1990 [2]. Land transportation has gradually become an important part of the transportation system in cities such as Indonesia. As a result, land transportation accounts for more than 90% of total oil use and is responsible for increasing the concentration of Greenhouse Gases (GHG) and other pollutants [3]. The use of public motorized vehicles is dominated by the highest number of microbus. Whereas use private motorized vehicles are dominated by motorbikes with 66% and 33% cars [4]. Transportation emissions are a contributor to the highest air pollution of around 85% [5]. Air pollution from transport includes carbon dioxide (CO_2), methane gas (CH_4), nitroxide (NO_2), carbon monoxide (CO), hydrocarbons (HC) and particulate matter (PM) [6]. In the city of Jakarta, motor vehicles account for around 71% of nitrogen oxide (NO_x) pollution, 15% of sulfur oxide (SO_x) pollution, and 70% of particulate pollution (PM_{10}) [7]. Hydrocarbons are simple organic compounds consisting of hydrogen and carbon. Hydrocarbons (HC) are a group of compounds that are widely found in nature as petroleum. Respiratory disorders can arise due to their hydrocarbon compounds, including laryngitis, pharynx, and bronchitis. The impact of photo-oxide formed is greater than the impact of hydrocarbons themselves. Hydrocarbons are also known as part of photochemical smog and are suspected of being a source of the odor [8]. Hydrocarbon emissions in fuel exhaust are caused by unburned fuel, incomplete combustion and the presence of engine lubricating oil in fuel or combustion chamber[9]. In addition to hydrocarbons, other dangerous compounds contained in exhaust emissions are carbon monoxide. In addition to hydrocarbons, other dangerous compounds contained in exhaust emissions are carbon monoxide. Carbon monoxide (CO) is a gas that is odorless and colorless. In terms of health, CO is dangerous because it has a strong affinity for joining blood hemoglobin. This causes the available hemoglobin to carry oxygen to the body. About 90% of men obtain carbon monoxide from cars [9]. CO is the result of incomplete combustion in the engine and is produced when the engine operates in a mixture of fuel-rich conditions or when an appropriate air-fuel mixture is not achieved [10]. CO and HC compounds found in vehicle exhaust have a negative impact on health, therefore it is necessary to control exhaust emissions to reduce the risk of contracting diseases caused by air pollution from vehicles. Controlling emissions from internal combustion engines can be done by designing fuel composition and treatment of combustion exhaust gases. Imperfect combustion increases with the age of the machine [11]. Various efforts are not enough to control emissions, therefore the catalytic system is utilized for this. This catalytic chemistry involves the activation of small pollutant molecules [12]. Engine exhaust emissions can be controlled with different catalytic converters [13]. Catalytic converters are device that use catalyst to convert hazardous compounds into vehicle exhaust gases into harmless compounds. In catalytic converter, there is a reduction process that reduces nitrogen emissions and oxidation processes which oxidize hydrocarbons and carbon monoxide that have not been burned [14]. There are several types of catalytic converters, one of which the three-way catalytic converter. The use of the Three Way Catalytic Converter (TWC) is developed based on precious metal catalysts (Platinum Group: Pt, Pd, and Rh) which can efficiently convert HC pollutants to CO_2 and water, CO to CO_2, and NO_x to nitrogen [15].

2. Materials and Methods

The study was conducted by setting up a measurement tool. Measurements were carried out in two conditions, namely measurement of exhaust emissions using catalytic converters and measurements without using a catalytic converter. From this study, it can be seen also the effect of engine speed and fuel on the efficiency of the use of catalytic converters.

2.1. Tool

The research was conducted by arranging several tools. The following are the tools used to measure exhaust emissions.

2.1.1. Testing machine

The test machine used is a Toyota 1500 CC 4 Cylinder, 4 Stroke engine installed in the engine stand. Figure 1 shows the test machine. The test machine used is set up as shown in Figures 2(a) and 2(b).

Figure 1: Testing machine

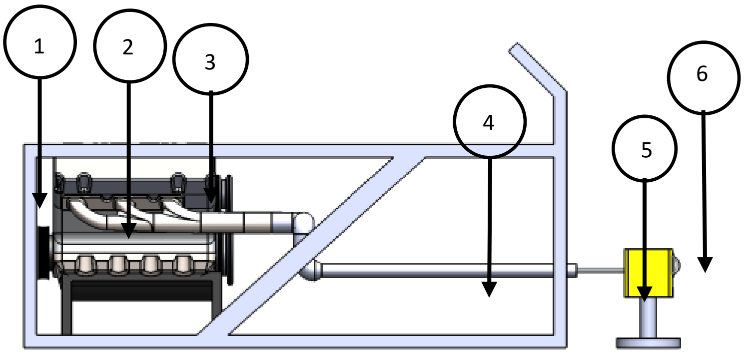


Figure 2 (a): Set up equipment withhout catalytic converter

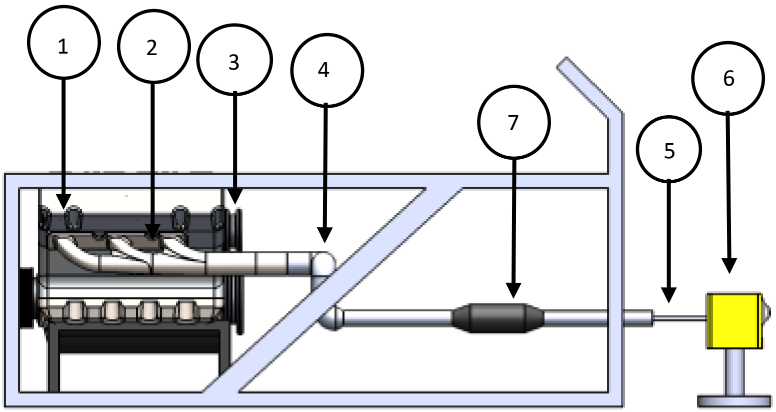


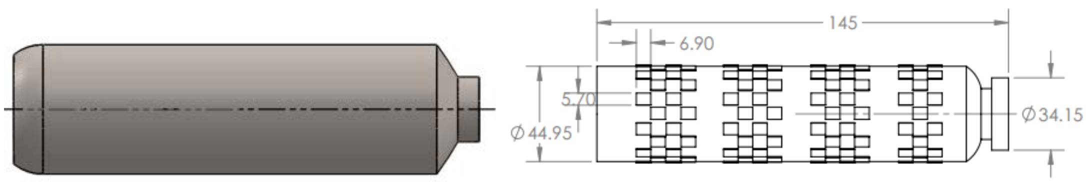
Figure 2 (b): Set up equipment with catalytic converters

Information:

1. Four Stroke Engine, Four Cylinder, 1500 CC
2. Exhaust Manifold
3. Pulley
4. Exhaust Pipe
5. Gas Analyzer Probe
6. Gas Analyzer
7. Catalytic Converter

2.1.2. Catalytic Converter

The catalytic converter used in this study is a Three Way Catalytic Converter type. TWC uses stainless steel material. TWC also consists of platinum and palladium which can reduce CO and HC. Figure 4 shows the catalytic converter.



a) b)

Figure 4: (a) casing of catalytic converter (b) dimension of catalytic converter core

2.1.3. Gas Analyzer

The tool used to test the exhaust emissions of carbon monoxide and hydrocarbons in this study is to use the AGS-688 type gas analyzer which is commonly used in car workshops. Figure 5 shows the gas analyzer.

Figure 5: Gas Analyzer

2.1.4. Tachometer

The tachometer is used to find out and see changes in the engine speed of the vehicle when the researcher variations the engine speed of the test vehicle. The working principle of the tachometer is by calculating the mileage of the rotor rotation multiplied by the rotor rotation. The output of the tachometer is in the form of engine speed.

Figure 6: Tachometer

2.2. Data Collecting

The initial preparation that needs to be done is to prepare the standard conditions of the machine by tune-up so that the engine is in a normal condition. At the stage of data retrieval, the machine is ready to operate so that the data taken can represent the actual engine condition. Measurements are carried out in 2 conditions. The first condition is the exhaust gas filtration condition with a three-way catalytic converter and muffler as shown in Figure 2 (a), while in the second condition filtering exhaust emissions uses only a muffler as shown in Figure 2 (b). Measurements were made by varying engine speed from idle conditions, 1000 rpm, 1500 rpm, 2000 rpm, 3000 rpm, and 3500 rpm as measured by a tachometer and measuring the concentration of exhaust emissions on the gas analyzer. This measurement aims to determine the concentration of exhaust emissions from the engine tested without additional tools. Measurements were made three times and each data obtained was recorded and the results were analyzed.

3. Results

Based on the research conducted, the measurement results show that the use of a three-way catalytic converter type can reduce the exhaust gas emissions of carbon monoxide and hydrocarbon emissions. The reduction of carbon monoxide and hydrocarbons varies according to variations in engine speed and variations in the fuel used.

3.1. Results

With the condition of equipment setup, several measurements of fuel emissions have been carried out with 3 types of fuels, namely pertalite, pertamax, and pertamax turbo. Measurements were made with variations in engine speed which were idle, 1000 rpm, 1500 rpm, 2000 rpm, 3000 rpm, and 3500 rpm. Measurements were made to determine CO and HC emissions in the vehicle exhaust gas with variations in engine speed and fuel type.

3.1.1. CO Concentration with Engine Speed Variations at Three Way Catalytic Converter

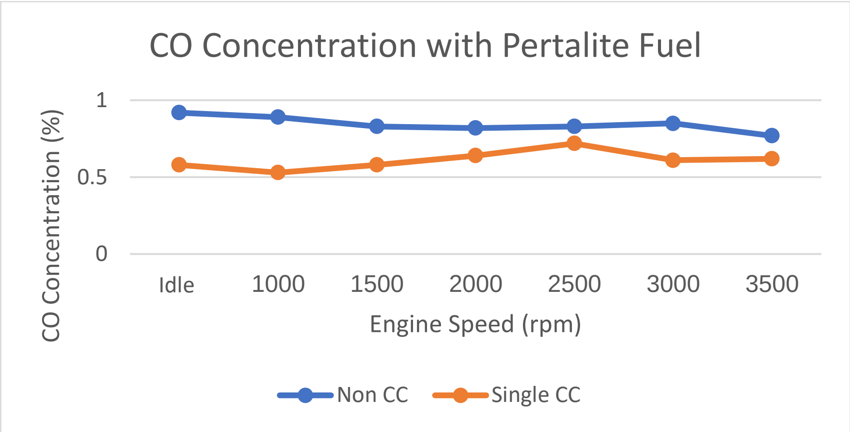


Figure 7: CO concentration in pertalite fuel with variations in engine speed

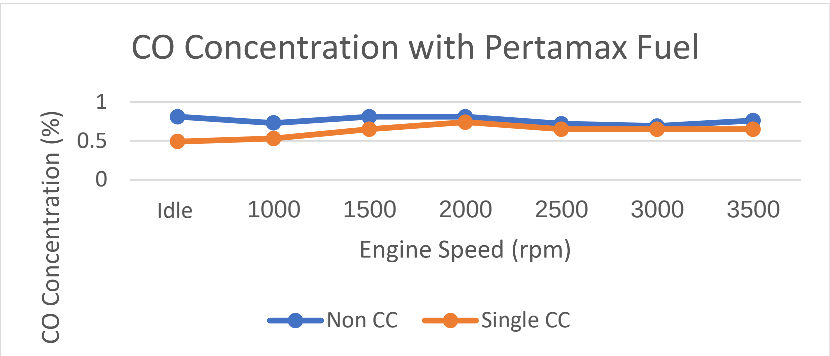


Figure 8: CO concentration on pertamax fuel with variations in engine speed

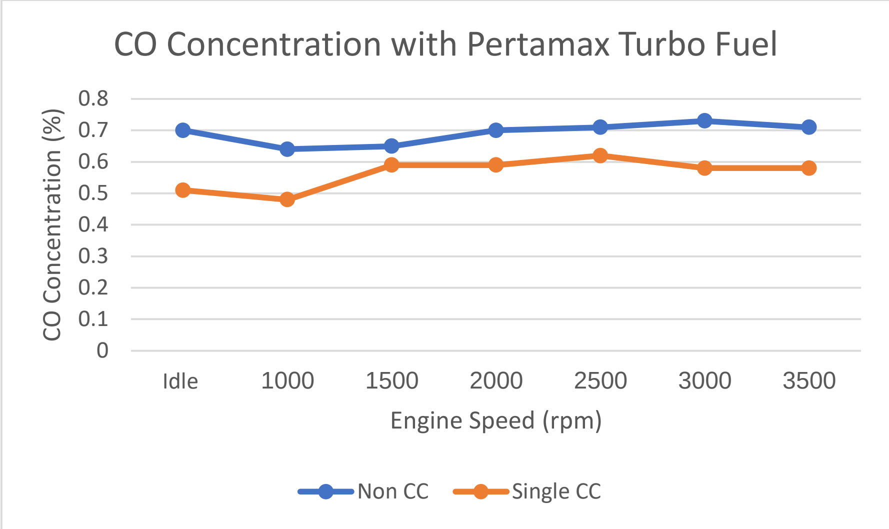


Figure 9: CO concentration in the pertamax turbo fuel with variations in engine speed

In the measurement results, CO concentration experienced a slight increase along with the increase in engine speed. Figure 7 to Figure 9 shows CO concentration in the exhaust gas with variations in fuel.

Figure 7 shows the comparison of CO concentration in the exhaust gas system with a catalytic converter and without a catalytic converter with pertalite fuel. The reduction that occurs in each variation of engine speed is 37%, 40.4%, 30.1%, 22%, 13.3%, 28.2%, and 19.5%. Figure 8 shows the comparison of CO concentration in the exhaust system with a catalytic converter and without a catalytic converter with pertamax fuel.

The reduction in each variation in engine speed was 39.5%, 27.4%, 19.8%, 8.6%, 9.7%, 5.8% and 14.5%. Figure 9 shows the comparison of CO concentration in the exhaust system with a catalytic converter and without a catalytic converter with pertamax turbo fuel. The reduction that occurs in each variation of engine speed is 27.1%, 25%, 9.2%. 15.7%, 12.7%, 20.5% and 18.3%.

TWC can reduce the CO content of exhaust gases in all variations of engine speed, but of the three fuels, the three-way catalytic converter is effectively used in pertalite fuel. Significant reduction in pertalite fuel occurs at idle conditions up to 2000 rpm with a reduction in CO concentration around 20% - 40%. In pertamax fuel, a significant decrease in CO concentration occurs at idle conditions up to 1500 rpm engine speed with the largest reduction percentage in idle conditions of 39.5%.

Whereas in turbo pertamax fuel, the biggest reduction occurs in idle conditions of 27.1%. CO reduction occurs because of the oxidation process in TWC which converts CO to CO_2 [15[.

3.1.2. HC Concentration with Engine Speed Variations at the Three Way Catalytic Converter

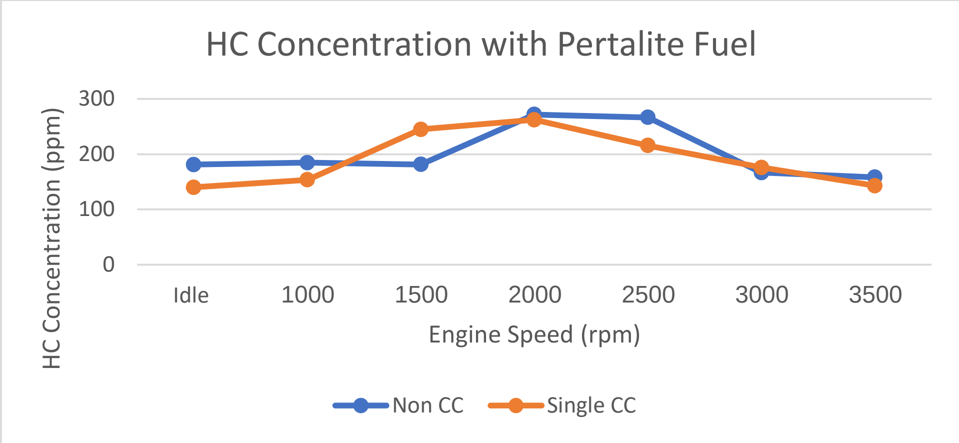


Figure 10: HC concentration in pertalite fuel with variations in engine speed

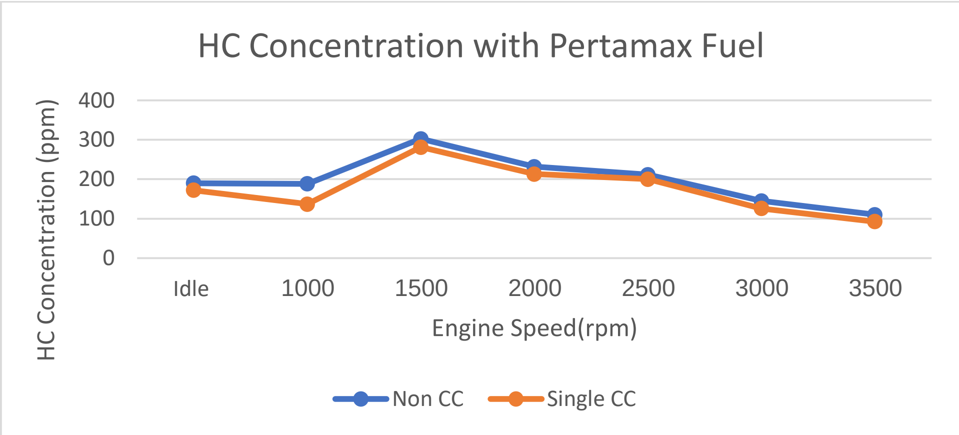


Figure 11: HC concentration in pertamax fuel with variations in engine speed

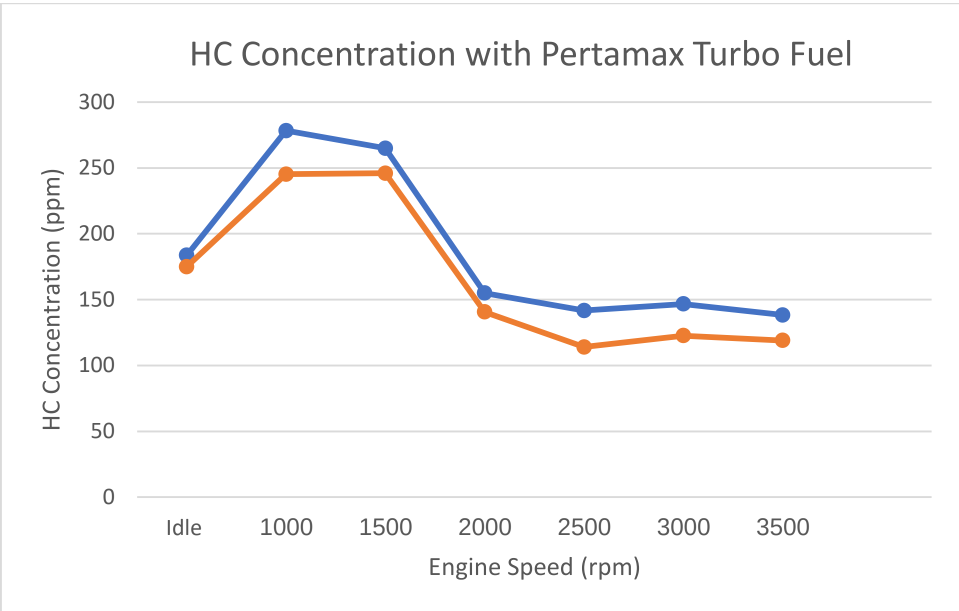


Figure 12: HC concentration in pertamax turbo fuel with variations in engine speed

Based on the measurement results, HC concentration decreases with increasing engine speed. Figure 10 to Figure 12 shows HC concentrations of variations in engine speed with 3 variations of fuel. Figure 10 shows the comparison of HC concentration in the exhaust gas system with a catalytic converter and without a catalytic converter with pertalite fuel. Reductions in all speed variations were 22.7%, 16.8%, -35.1%, 3.4%, 19.1%, -5.6%, and 9.7%. Negative values indicate no reduction, but an increase in HC concentration. Increased HC concentration in pertalite fuel occurs at engine speed 1500 rpm and 3000 rpm. Figure 11 shows the comparison of HC concentration in the exhaust gas system with a catalytic converter and without a catalytic converter with pertamax fuel. Reductions in each variation of engine speed were 9.5%, 27.4%, 6.9%, 7.9%, 5.4%, 13.1% and 15.8%. Figure 12 shows the comparison of CO concentration in the exhaust system with a catalytic converter and without catalytic converter with pertamax turbo fuel. Reductions in each variation of engine speed are 4.7%, 11.9%, 7.2%, 9.2%, 19.5%, 16.4% and 14%. By the 3 types of fuel used, the three-way catalytic converter is effectively used to reduce HC concentrations in pertamax and pertamax turbo fuels. In pertalite fuel, a decrease in HC concentration occurs in all variations of engine speed except at 1500 rpm and 3000 rpm. The biggest HC reduction in idle conditions is 22.7%. While for pertamax fuel, the decrease in HC concentration occurred in all variations of engine speed with the largest HC reduction at 1000 rpm engine speed of 27.4%. Reduction of HC concentration in turbo pertamax fuel occurs in all variations of engine speed with the greatest reduction in HC concentration of 19.5% at 2500 rpm engine speed. HC reduction occurs because of the oxidation process of the catalyst which causes HC to be converted into CO_2 and water [15].

3.1.3. Effect of Type of Fuel on CO Content on Exhaust Emissions

On the results of the measurement of CO content in exhaust emissions, the pertamax turbo has an average CO content of 0.79%, less than pertamax and pertalite, which is 0.69% and 0.62%. The greater the octane number of the fuel, the less CO is produced [9]. This is caused by more perfect combustion on the turbo pertamax fuel. Figure 13 shows CO concentration in exhaust emissions with 3 types of fuel.

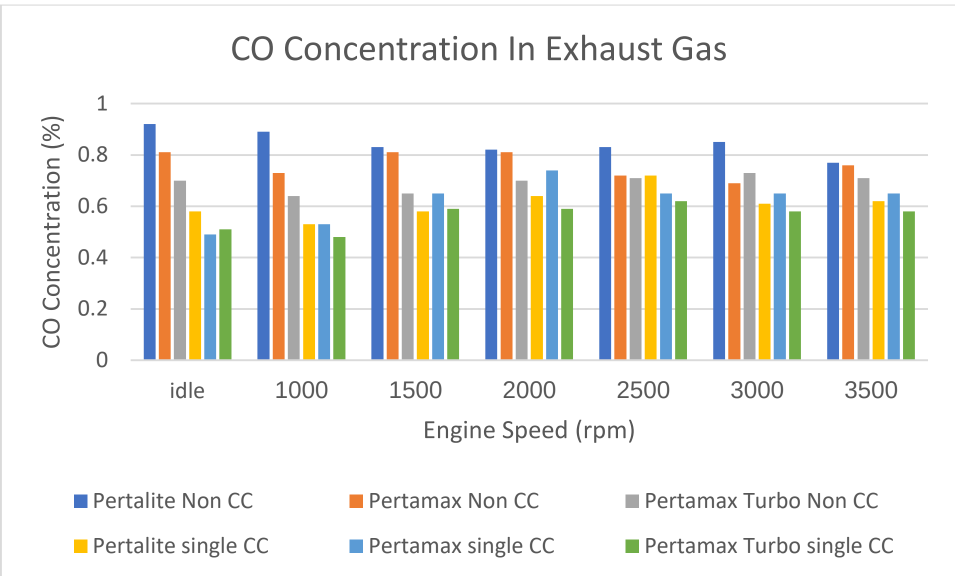


Figure 13: CO concentration in 3 types of fuel

3.1.4. Effect of Type of Fuel on HC Contents on Exhaust Gas Emissions

On the measurement results of HC content in exhaust emissions, the pertamax turbo has an average HC content of 196.14 ppm, less than pertamax and pertalite, which is 185.8 ppm and 176.5 ppm. HC gas emissions are produced from unburned fuel, incomplete combustion and the presence of engine lubricating oil in fuel or combustion [9]. From the results of the study, the greater the RON of fuel the less HC is produced. This is caused by, more complete combustion that occurs in fuels with higher octane numbers. The greater the octane number of the fuel, the greater the compression pressure that can be received by the fuel without experiencing detonation or premature knocking [9]. Figure 14 shows the concentration of HC in 3 types of fuel.

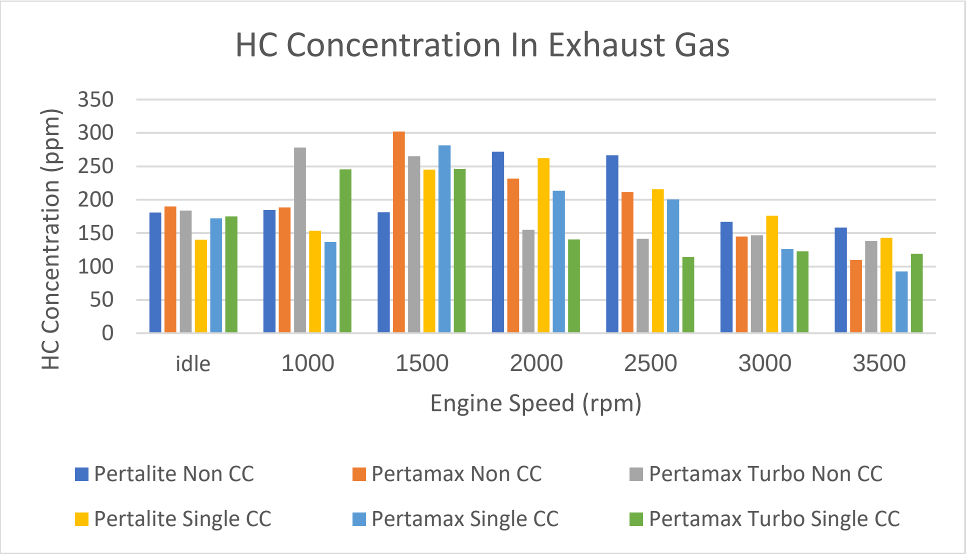


Figure 14: HC concentration in 3 types of fuel

3.2. Discussion

Three-way catalytic converters can reduce CO and HC emissions in all three types of fuel as shown in figure 7 to figure 9. The use of three-way catalytic converters is developed based on precious metal catalysts (Platinum group: Pt, Pd, and Rh). That's because the catalyst can efficiently convert HC pollutants to CO2 and water, CO to CO_2 and NOx to nitrogen [11].The reduction of CO and HC occurs due to the oxidation catalyst process. This process reduces unburnt hydrocarbons and CO by burning (oxidizing) through platinum and palladium catalysts. This catalyst helps the reaction of CO and HC with oxygen in the exhaust gas [16]. The catalyst provides a faster route to becoming the desired product. With the presence of a catalyst, the energy needed to produce the product becomes lower and energy activation decreases. But the total energy between reactants and their products has not changed [17]. The fuel aspect also influences the effectiveness of catalytic converters. CO emission reduction is best for pertalite fuels, which are fuels with the lowest octane number (RON 90). Whereas HC reduction is best done on pertamax fuel, which is fuel with RON 92 octane number. However, on the average, the pertamax turbo produces the lowest CO and HC emissions as shown in figure 13 and figure 14. Because fuel with RON is more high yields fewer CO and HC emissions. The greater the octane number, the fuel can withstand higher compression without experiencing detonation or knocking prematurely [9]. Changes in the concentration of exhaust emissions also occur due to aspects of engine speed. The higher the engine speed, the CO concentration experienced a slight increase. But the opposite occurs at the concentration of HC. Increased engine speed can reduce HC concentration. CO and HC are the main pollutants of internal combustion engines due to incomplete combustion of hydrocarbons during the combustion process. The main emission level depends on the octane number of gasoline and engine operating conditions such as ignition time, load, speed and air-fuel ratio Volumetric efficiency increases with increasing engine speed. Increasing volumetric efficiency encourages a more homogeneous mixture in combustion space, therefore it can be observed that HC emissions are reduced for all types of fuel [9]. Catalytic converters can work optimally if the vehicle operates under normal conditions. However, in some conditions, catalytic converters can fail due to several things, such as improper engine operating conditions, fuel entering the exhaust system, damaged spark plugs and spark plug wires, oxygen sensors not operating properly, and flow path damage gas in catalytic converters [14].

4. Conclusion

Using the three-way catalytic converter can be one solution to overcome the problem of air pollution caused by vehicle exhaust gas. Catalytic converters can reduce CO and HC concentration in exhaust emission and convert these exhaust emission into safer and environmentally friendly compounds. The use of fuel with higher octane numbers result in lower exhaust emissions.

References

[1] Suhariyanto. “Perkembangan Kendaraan Bermotor Menurut Jenis”. Badan Pusat Statistik: Indonesia. 2018.

[2] International Energy Agency. CO_2 Emission Statistics. Dapat diakses di: https://www.iea.org/statistics/co2emissions/ [Accessed 22 Mei 2019]

[3] I. Sukarno, H. Matsumoto, L. Susanti. “Transportation Energy Consumption and Emission: A View From the City of Indonesia”. Future Cities and Environment 2:6. 2016.

[4] I. Sukarno, H. Matsumoto, L. Susanti. R. Kimura. “Urban Energy Consumption of A City In Indonesia: General Overview”. International of Journal Energy Economics and Policy. vol 5 no. 1, pp. 360-373. 2015.

[5] Ismiyati., Devi. M., dan Saidah, Deslida. (2014). Pencemaran Udara Akibat Emisi Gas Buang Kendaraan Bermotor. Jurnal Manajemen Transportasi & Teknologi Vol. 1 No. 03

[6] A. Azhaginiyal, G. Umadevi. “System Dynamics Simulation of Modelling Transport, Energy and Emission Interaction”. Civil Engineering and Architecture 2(4): 149-165, 2014.

[7] Anonym. “Zat – Zat Pencemar Udara”. Badan Pengelolaan Lingkungan Hidup Jakarta. Indonesia. 2013.

[8] T. Subramani. “Study of Air Pollution Due To Vehicle Emission In the tourism Centre” International of Journal Engineering Research and Applications, vol 2. issue 3. pp. 1753-1763. 2012.

[9] Y.H. Teoh, H.G. How, K. H.Yu, H.G. Chuah, W. L. Yin. “ Influence of Octane Number Rating On Performance, Emission, and Combustion Characteristics In Spark Ignition Engine”. Journal of Advanced Research in Fluid Mechanism and Thermal Sciences vol 45. Issues 1 22-34. 2018.

[10] Mohamad. T. I., Geok. H. H., Abdullah. S., Ali. Y., Shamsudeen. A. (2010). Comparison of Performance, Combustion, Characteristics, and Emissions of A Spark Ignition Engine Fuelled By Gasoline and Compressed Natural Gas. Journal of Technology Today Vol II Issues II

[11] A. Ghofur, Soemarno, A. Hadi, M.D. Putra. “Potential Fly Ash Waste As Catalytic Converter For Reduction of HC And Co Emission”. Sustainable Environment Research 28 pp. 357-362, 2018.

[12] R. Ganji, V.N. Yenugula. “Emission Reduction In Automobile Engine Exhaust Using Bio Catalytic Converter: An Experimental Study”. IOSR Journal Of Mechanical and Civil Engineering, vol. 14 issue 6, pp. 24-28, 2017.

[13] M. M. Abdelaal, A. H. Hegab. “Combustion And Emission Characteristics Of A Natural Gas Fueled Diesel Engine With EGR”. Energy Convers. Manag, vol. 64, pp. 301-312, 2012.

[14] S. Banna,O. N. Deen.“Diesel Catalytic Converters As Emission Control Devices”. TESCE, vol. 30 no. 2, pp. 1143 – 1161, 2004.

[15] Santos. H., Costa. M., (2008). Evaluation Of The Conversion Of Ceramic And Metallic Three Way Catalytic Converters. Energy Convers Manag Vol 49 Pp. 291-300

[16] Ellyanie. “Pengaruh Penggunaan three way catalytic converter terhadap emisi gas buang pada kendaraan Toyota kijang inova”. Prosiding Seminar Nasional AVoER 3rd, Palembang. 2011.

[17] W. Baslyman. “Microwave-assisted Dehydration of Fructose Into 5-Hydroxymethylfurfural (5-HMF) Over Acidic Porous Catalysts”. University of Ottawa: Ottawa, Ontario. 2015.