Application of catalytic converter copper catalyst with honeycomb surfaces to reduce emissions of flue gas in motorcycles

M A Siregar *, C A Siregar, Muharnif, A M Siregar and I Maulana
University of Muhammadiyah Sumatera Utara, Medan 20238, Indonesia

* Email: munawaralfansury@umsu.ac.id

Abstract. The application of a catalytic converter is believed to be able to accelerate the process of chemical reaction in vehicle exhaust gas. This will have an impact on reducing the high rate of air pollution from motorcycles exhaust gases. This study will compare the exhaust emission value of the standard exhaust muffler with the exhaust that has been installed catalytic converter. Catalytic converter which is made from copper with honeycomb surfaces. The motorcycle used with an engine capacity of 125 CC. Testing is done based on three different engine rotation that is 2000 rpm, 3000 rpm, and 4000 rpm. The result, at 4000 rpm engine speed decrease CO emission level of 1.76%, HC of 73 ppm and CO$_2$ of 1.7%.

1. Introduction

The high number of motorcycle growth in Indonesia in 2016 reached 5,931,285 units [1]. This amount is certainly affecting the air quality in Indonesia caused by the exhaust emissions of gas, which affects the level of air pollution such as Carbon Monoxide (CO), Hydro Carbon (HC), Nitrogen Dioxide (NOx) and Sulfur Dioxide (SO$_2$) which has a devastating effect on the health of the human body and erodes the ozone layer present in the atmosphere.

There are many technologies developed to reduce the number of air pollution sourced from vehicle exhaust gases. So far the use of Catalytic Converter is the best way to control vehicle exhaust emissions [2]. This allows the reduction of CO, HC, NOx and SO$_2$ levels. Catalytic converters are believed to be able to meet future emissions requirements and emissions regulations [3, 4].

Catalytic converter serves to accelerate the oxidation of HC and CO emissions, as well as reducing NOx. In addition, the installation of a catalytic converter may alter harmful pollutants such as CO, HC, and NOx into harmless gases, such as Carbon dioxide (CO$_2$), water vapor (H$_2$O) and nitrogen (N$_2$) by chemical reactions. The conversion of these harmful pollutants is reflected in the following reaction:

\[ \text{CO} \rightarrow \text{CO}_2 \] \hspace{1cm} (1)
\[ \text{HC} \rightarrow \text{H}_2\text{O} + \text{CO}_2 \] \hspace{1cm} (2)
\[ \text{NOx} \rightarrow \text{N}_2 + \text{O}_2 \] \hspace{1cm} (3)

At the equation of reaction 1 and 2 occurs oxidation reaction (addition of oxygen), while in reaction number 3 requires the release of oxygen (reduction). If the carbon in the fuel burns perfectly, there will be a reaction that produces:

\[ \text{C} + \text{O}_2 \rightarrow \text{CO}_2 \] \hspace{1cm} (4)
If the air oxygen element is inadequate, combustion is not perfect so that the carbon in the fuel burns by the process as follows:

\[
C + \frac{1}{2}O_2 \rightarrow CO
\]  

(5)

Materials used as catalytic converters are generally precious metals such as Palladium, Platinum, and Rhodium which are very expensive in the market. But the development of other types of materials has been done is copper coated with manganese. The result, capable of increasing the ability of carbon monoxide exhaust gas reduction [5]. In addition, Catalytic Converter made from aluminum oxide nanoparticles (Al₂O₃) as a catalyst has also been developed and found that the conversion efficiency of Al₂O₃-based catalytic converter is 99.5%, 92% for CO and HC emissions [6].

Purpose of Catalytic Converter made of a copper plate can also reduce CO₂ emissions of CO, HC, and CO₂ with a fairly good percentage of decrease [7]. Testing of catalytic converter made from copper oxide has also been done on diesel engines, resulting in the decay of HC value of 32%, NOx (61%) and CO by 21% [8].

The performance of the catalytic converter also depends heavily on the design and shape. This will affect the exhaust gas distribution. Simulation of conical pipe cone catalytic converter has been done. As a result, the incoming channel to the catalytic converter in the form of a cone pipe with a 300 angle is capable of significantly improving performance catalytic converter [9]. This paper will look at the performance of a copper-based catalytic converter with a honeycomb shape.

2. Experimental and Method

To conduct research, experimental equipment has been designed and developed to compare motorcycle exhaust emissions with the installation of catalytic converters made of copper with honeycomb form on vehicle exhaust and without catalytic converter (standard exhaust). The catalytic converter is installed in the exhaust and then connected to an SY-GA 401 gas analyzer to measure CO, HC, and CO₂ levels.

Experiments conducted using a motorcycle with a cylinder capacity of 125 CC assembly year 2015 with a 4-stroke engine, data retrieval will be done on 3 revolutions of different machines i.e. at 2000 rpm, 3000 rpm, and 4000 rpm. The fuel used is the type of fuel gas with octane content (RON) 88. Test method is done by connecting between the exhaust and gas analyzer by using probe cable. Then start the engine with 2000 rpm rotation, 3000 rpm and 4000 rpm each for 2 minutes. Then performed data recording on the gas analyzer. The test equipment is shown in Figure 1.

![Figure 1. Experimental Apparatus](image)

Catalytic converter diameter outer circle 8 cm with a diameter of each hole 5mm and distance between hole 3 mm. Figure 2 shows the surface shape of the catalytic converter to be used in the test.
3. Result and Discussions

Based on the results of testing at 2000 rpm engine rotation, 3000 rpm and 4000 rpm has been done, exhaust emission levels produced by the exhaust using catalytic converter is lower than the standard exhaust (without catalytic converter). At 2000 rpm engine speed there is a decrease in CO content of 0.18%, 3000 rpm engine speed of 1.19% and at 4000 rpm engine son of 1.76%. For the value of HC at 2000 rpm rotation, no impairment occurs, at 3000 rpm engine speed and 4000 rpm HC content has decrease respectively 4 ppm and 73 ppm. CO2 levels on exhaust emissions also decreased, at 2000 rpm engine speed decreased by 3.3%, decrease in CO2 levels also occurred at engine speed 3000 rpm and 4000 rpm with a value of 1.6% and 1.7% respectively. This proves that the application of copper material catalytic converter can accelerate chemical reactions that occur in vehicle exhaust so as to reduce exhaust emission levels. The test results are shown in Table 1.

| Engine Speed (rpm) | Value CO (%) | Value HC (ppm) | Value CO2 (%) |
|--------------------|--------------|----------------|---------------|
|                    | Catalytic Converter | Standard | Catalytic Converter | Standard | Catalytic Converter | Standard |
| 2000               | 3.59         | 3.77         | 165           | 165       | 5.1            | 8.4     |
| 3000               | 4.49         | 5.67         | 237           | 241       | 5.4            | 7.0     |
| 4000               | 4.01         | 5.77         | 187           | 260       | 4.6            | 6.3     |

Figure 3 shows that the overall CO value decreased in each round variation. the largest CO decrease occurred in 2000 rpm rotation, the presence of CO in the exhaust gas caused by the burning that occurred in the combustion chamber is not perfect, caused by the lack of amount of air in that mixture get into the combustion chamber or lack of time available for finish the burning time. The comparison graph of HC values is shown in Figure 4.

![Figure 3. The CO of value comparison graph uses a catalytic converter and standard exhaust](image-url)
Figure 4. The HC of value comparison graph uses the catalytic converter and standard exhaust

From figure 4 above, the use of copper material as a catalyst can reduce the value of HC released from the exhaust. The test results show that overall HC emissions decrease in concentration in every variation of rotation. The presence of HC is caused by unburned fuel and exit into raw gas so that the fuel is split because the heat reaction turns into another HC cluster that comes out with the exhaust gas. The comparison graph of H\textsubscript{2}O values is shown in Figure 5.

Figure 5. CO\textsubscript{2} of value comparison graph uses the catalytic converter and standard exhaust

Figure 5 shows that the influence of the Catalytic converter on CO2 emissions can oxidize well; this is due to copper increase the surface area of the catalyst. The results of the study showed a reduction in exhaust emission levels on the value of CO, HC, and CO2. The reduction of the value is caused by the installation of catalytic converter of copper material with the form of a honeycomb as a catalyst. Copper catalysts can increase the rate of reaction without permanently altering the chemical elements, and may work to form intermediates or adsorb the reacted substances.

4. Conclusion
Application of copper catalytic converter with honeycomb surface shape is able to reduce exhaust gas emission levels on motorcycles. The highest decrease in CO value was at 4000 rpm with a difference of 1.76%, for the highest decrease in HC value occurred at 4000 rpm with 73 ppm. While the decline for the highest CO2 value occurred at 2000 rpm engine speed of 3.3%. The decline in the value of the exhaust gases will help and reduce air pollution from motorcycle exhaust gases.
References

[1] https://www.bps.go.id/statictable/2017/11/23/1981/produksi-kenderaan-bermotor-dalam-negeri-unit-2000-2016.html accessed on May 24, 2018

[2] Pardiwala Julie M., Femina P., Sanjay P 2011 Review paper on Catalytic Converter for Automotive Exhaust Emission (Ahmedabad : Institute Of Technology, Nirma University)

[3] R. Zhang., A. Villanueva., H. Alamdari., and S. Kaliaguine 2006 Reduction of NO by CO over nanoscale LaCo1−xCuxO3 and LaMn1−xCuxO3 perovskites, (Journal of Molecular Catalysis A: Chemical), vol. 258, pp. 22–34

[4] H. Iwakuni, Y. Shinmyou, H. Yano, H. Matsumoto, and T. Ishihara 2007 Direct decomposition of NO into N2 and O2 on BaMnO3 – based perovskites oxides (Applied Catalysis B: Environmental) vol. 74

[5] Irawan Bagus R.M., Purwanto P., and Hadiyanto H 2015 Optimum Design of Manganese-Coated Copper Catalytic Converter to Reduce Carbon Monoxide Emissions on Gasoline Motor (Elsevier) 23 p 86-92.

[6] Aalam C Syed., Saravanan Dr. C.G., and Samath C Mohamed 2015 Reduction of Diesel Engine Emissions Using Catalytic Converter with Nano Aluminium Oxide Catalyst (International Journal For Research In Emerging Science And Technology) Vol 2

[7] Maulana Imam 2018 Analisis Catalytic Converter Dengan Bahan Tembaga Terhadap Emisi Gas Buang Pada Sepeda Motor 125cc (Medan: University of Muhammadiyah Sumatera Utara)

[8] Venkatesan S.P., Udai Desai Shubham., and Heman Borana Karan., Goud Kagita Rajarshi Kushwanth., Kumar G Lakshmana., Kumar K Pavan 2017 IOP Conference Series: Material Science and Engineering 197 012026

[9] Zainal Nurul Amina., Azmi Ezzatul Farhain., and Samad Mohd Arifin 2018 IOP Conference Series: Material Science and Engineering 328 012029