RiCE: Research in Chemical Engineering
Volume 4. No 2, 2025
Journal homepage: https://ejournal.ump.ac.id/index.php/rice

Innovation in catalytic converters for motorcycles in an effort to reduce air pollution from combustion

Silvia Rahmi Ekasari [1*], Eva Weddakarti[2], Ahsani Maulidina[3*]
[1,2,3] Department mechanical engineering, Polytechnic Negeri Malang, Kota Malang, Jawa Timur 65141.
**Corresponding author:* silviarahmi@polinema.ac.id

Article Info

Submit:
19 August 2025

Revision:
08 September 2025

Accepted:
08 September 2025

ABSTRACT

Air pollution remains one of the most challenging environmental issues. Motor vehicle exhaust gases contribute around 70%–80% of air pollution, while industrial activities contribute only 20%–30%. Exhaust emissions from incomplete combustion include carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and lead (Pb), which are harmful to health and the environment. One promising solution is the installation of catalytic converters. This study investigates the effectiveness of catalytic converters made of stainless steel coated with chromium and copper in reducing emissions from motorcycle exhaust systems. The experimental results show that the catalytic converter significantly reduced harmful gases: CO decreased by 44%, HC decreased by 63.65%, while CO_2 increased from 7.1% to 11.2%, indicating successful oxidation. These findings highlight the catalytic converter's role in reducing harmful emissions and its potential to mitigate air pollution from motorcycles.

Keywords: Catalytic converter, Copper, Chromium, Stainless steel, Exhaust emissions

1. INTRODUCTION

Indonesia is a developing nation with a significantly large population. According to the Central Statistics Agency (BPS), the country's population in mid-2024 reached 281.6 million. This demographic size places Indonesia among the top six contributors to global air pollution. Motorized vehicle exhaust accounts for approximately 70%–80% of total air pollution, while industrial activities contribute only about 20%–30% [1]. Emissions from motor vehicles are therefore one of the major causes of both air pollution and the greenhouse effect. The high number of vehicles leads to uncontrolled emissions, particularly since most Indonesians rely more on private transportation than on public transit [2].

Fossil fueled motor vehicles with the main elements of carbon (C) and hydrogen (H) in perfect conditions will produce CO_2 and H_2O. However, in reality, the perfect combustion reaction does not occur and what occurs is incomplete combustion with gases that still leave harmful emissions. Exhaust gases from the combustion of fossil fueled motor vehicles produce gas emissions containing Carbon monoxide (CO), Hydrocarbons (HC), Nitrogen oxides (NOx), and Lead (Pb) which can have a negative impact on the environment [3].

The negative impacts caused by exhaust emissions depend on the gas content in the air. Gases contaminated with CO, NOx, SOx, dust, and Pb can harm human health, especially the respiratory organs, blood vessels, and irritation to the eyes and skin [4]. Air pollution in serious conditions can cause chronic bronchitis, pulmonary emphysema, bronchial asthma, and lung cancer. In addition, high levels of lead in the air and water cause poisoning that can inhibit enzymes in the formation of red blood cells, thus causing other, more serious diseases such as anemia, kidney damage, and so on [5].

Motor vehicle exhaust emissions resulting from imperfect combustion have a dangerous negative impact on all living creatures and the environment, so steps are needed to control exhaust emissions. This control can be done using several methods such as modifying the vehicle's fuel system, modifying the engine and modifying the vehicle's exhaust gas duct [6].

Modifications to the exhaust gas ducts of motor vehicles are expected to reduce the concentration of exhaust gas emissions in the form of CO and HC compounds caused by imperfect combustion from motor vehicles, by adding *a Catalytic converter* to the exhaust gas duct placed close to the exhaust, it is hoped that the hot exhaust gas can reduce the concentration of harmful exhaust gas emissions more optimally [7].

Hazardous gases from motor vehicles such as hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NOx) are converted into safe compounds before being released into the atmosphere [8]. The process of converting hazardous gases into safe compounds is through the rate of chemical reactions in exhaust gases with the reaction results in the form of new compounds that are not dangerous when released into the environment so as not to cause air pollution. In the rate of chemical reactions, the influencing factors are cross-sectional area and temperature. A catalyst cross-section with a large area will further accelerate the rate of chemical reactions, this also applies to temperature. If the temperature received by the catalyst is high, the rate of chemical reactions will also be faster [9].

Catalytic converters use oxidation catalysts and reduction catalysts to create chemical reactions. Oxidation catalysts that can be used are platinum, plutonium, nickel, manganese, and chromium. While metals that can be used as reduction catalysts are nickel, copper, iron, and their alloys. In addition, several other metals that are known to be effective as oxide and reduction catalysts ranging from large to small are Pt, Pd, Ru > Mn, Cu >> Ni > Fe > Cr > Zn and oxides of these metals, oxidation catalysts Pt (platinum), Pd (palladium), and Ru (ruthenium) all three are noble metals and are supported by an alumina area that provides increased heat resistance so that it is efficient when placed in exhaust ducts that have high temperatures [10].

This research aims to provide additional *catalytic converters* on motorbikes by using *stainless steel plate material* coated with *chrome* and copper, *stainless steel* is an alloy of Fe (*steel*) and coated with Cr (*chrome*) which has resistance to heat and corrosion, the Fe element (*steel*), Cr (*chrome*), and Cu (*copper*) are types of metals that are included in the oxidation catalyst group in *the Catalytic converter* so that they can be used to absorb CO and HC gases contained in motorcycle exhaust gases, *chrome plating* functions to increase the oxidation reaction that occurs in the *Catalytic converter catalyst* so that the absorption of CO and HC exhaust emissions is maximized, while copper has the same function but Cu is a single oxide catalyst as a variation, in this study using *chrome*- plated *stainless steel plates* and copper, each with three pieces arranged alternately. The exhaust gas coming out of the combustion will pass through the copper catalyst and *chrome*- plated *stainless steel* so that a chemical reaction will occur by oxidation and reduction due to the presence of oxygen from the combustion residue.

2. MATERIALS AND METHODS

2.1 Materials

This study uses a 2008 Yamaha Vega ZR 115 cc motorcycle as the main object. The main instrument used to detect motorcycle exhaust emissions is the gas analyzer, which functions to measure the carbon monoxide (CO) and hydrocarbon (HC) content in the exhaust of the motorcycle object of the research object. Then, the materials used to make catalytic converters are stainless steel plates and copper plates. The stainless steel plate is then coated with chrome using the electroplating method.

The creation of the catalytic converter is done by modifying the exhaust header section by adding an enlarged space as the housing/cover of the catalytic converter. Then for stainless steel and copper plates, they are made in the form of circles with a predetermined size, perforated with an irregular pattern, then arranged interchangeably (Figure 1 and Figure 2).

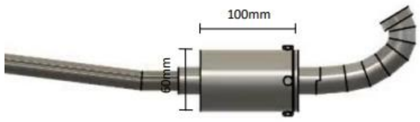

Figure 1. Exhaust modification design with casing / cover of catalytic converter

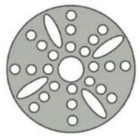

Figure 2. Design of chrome and copper plated stainless steel converter catalytic plate

2.2 Experimental procedure

This experimental procedure is carried out in three main stages: preparation, testing without catalytic converter, and testing with catalytic converter.

2.2.1 Preparation Stage

The preparation stage was conducted by several steps: (1) Tune up motorcycles; (2) Installation of modified exhaust without catalytic converter; (3) Heating the engine for 5 minutes; (4) Exhaust leak inspection; and (5) Gas analyzer tool calibration

2.2.2 Testing Without Catalytic Converter

The testing without catalytic converter was conducted by several steps: (1) The engine is run at 1500 RPM under working temperature conditions; (2) The sensor probe is inserted into the exhaust gas pipe; (3) CO and HC data are taken from the monitor or the results of the gas analyzer print-out; and (4) Recalibration is carried out after data collection is complete.

2.2.3 Testing with Catalytic Converters

The testing with catalytic converter was conducted by several steps: (1) The catalytic converter is inserted into the modified exhaust; (2) The engine was restarted and the test was carried out as before; and (3) CO and HC data are recorded from the results of the measurement of the tool.

2.2.4 Final Stages

The final stage was conducted by: (1) The gas analyzer engine and tool are switched off; (2) Sensor Probe removable; and (3) Equipment cleaned and tidied

2.3 Methods of analysis

Data analysis was carried out using an experimental method, used to evaluate the effectiveness of the use of catalytic converters in reducing exhaust emissions from motor vehicles. Emission concentration measurements are focused on three main parameters, namely carbon monoxide (CO), hydrocarbons (HC), and carbon dioxide (CO_2). All data were taken using the Instrument Gas Analyzer and compared between the conditions before and after the installation of the catalytic converter. The stages of analysis are described in the following subchapter.

2.3.1 Experimental Process

The research begins with a literature review to understand the issue of air pollution caused by vehicle emissions as well as existing catalytic converter technologies. Based on this review, a catalytic converter design is developed, followed by the manufacture of the catalytic converter.

After the converter is fabricated, the next step is test preparation, where the motorcycle and instruments are set up. The testing is conducted under two conditions: with a catalytic converter and without a catalytic converter, in order to obtain comparative results.

The results from both tests produce emission test data. These data are analyzed to determine whether there is a reduction in CO and HC concentrations. If no reduction is observed, the catalytic converter design is re-evaluated. If a reduction is found, the research proceeds to the next stage.

The subsequent stage is data processing, followed by data analysis to evaluate the effectiveness of the catalytic converter. The findings are then discussed in the discussion section, and the research concludes with the final conclusion.

2.3.2 Analysis of Gas Emission

Emissions testing is performed before and after the installation of the catalytic converter in the vehicle's exhaust system using a Gas Analyzer to measure CO, HC, and CO_2 levels. The results showed a significant decrease in CO levels from 8.44% to 4.62% with a conversion efficiency of 44%, as well as a decrease in HC from 961 ppm to 386 ppm with a reduction efficiency of 63.65%. On the other hand, the CO_2 level increased from 7.1% to 11.2%, which indicates that the oxidation process in the catalytic converter successfully converts CO and HC into CO_2 and H_2O. This change proves the role of catalytic converters in suppressing harmful gas emissions and significantly reducing the potential for air pollution.

2.3.3 Data Processing

The data from the exhaust emission test obtained from the Gas Analyzer is then compiled in the form of tables and graphs to facilitate quantitative analysis. These values are compared between conditions without and with catalytic converters, and their efficiency is calculated for each type of gas. This processing process provides a clear picture of the direct effect of the use of catalytic converters on the quality of vehicle emissions.

3. RESULTS AND DISCUSSION

Table 1 shows the data resulting from the analysis of CO and HC gas testing in table form along with an explanation.

Table 1. Gas test results data table.

Information	Concentration		
	CO (%)	HC (pph)	CO_2 (%)
Without catalytic converter	8.44	961	7.1
With catalytic converter	4.62	386	11.2

Based on the results of the table and graph of the experiment above, it can be seen that adding a catalytic converter can reduce the concentration of CO and HC gases compared to exhaust without a catalytic converter. The decrease in CO concentration is caused by the oxidation reaction of CO by the catalyst, which converts CO to CO_2.

$$2CO + 4HC + 6O_2 \xrightarrow{(F_eC_r.C_r)} 4CO_2 + 2H_2O$$

The efficiency of the catalytic converter in reducing CO gas levels is 44% at a distance of 0 km. In addition, the catalytic converter also reduces the concentration of HC gas by 63.65% at a distance of 0 km. This decrease in HC concentration is caused by the catalytic converter reacting with oxygen at high temperatures. The high temperature of the exhaust gas will be absorbed and stored by the copper plate on the catalytic converter with a temperature of approximately 250-300˚C so that from the hot temperature it can and decompose the long HC chain into C, CO_2, H_2O and unreacted HC. The CO_2 gas compound contained in motor vehicle exhaust gas has increased by 63.39%. This is because the HC and CO gases that come out of the combustion engine undergo oxidation and reduction reactions to produce CO_2 gas. In this case, it can be said that the HC concentration will be small and the concentration of CO_2 released will be more as seen from the data in table 1. The results of this study are still not in accordance with predictions from the literature, this is due to the imperfect coating process.

4. CONCLUSION

The use of chopper and chrome-plated stainless steel catalytic converters in motorcycle exhaust manifolds can reduce carbon monoxide and hydrocarbon levels. CO levels decreased by 45.26%, from 8.44% to 4.62%. Hydrocarbon levels also decreased by 59.83%, from 961 ppm to 386 ppm. The resulting reaction increased CO2 levels from

7.1% to 11.2%. Reducing the amount of CO and HC released into the atmosphere will reduce air pollution.

ACKNOWLEDGMENT

-

CONFLICT OF INTEREST

No potential conflict of interest was reported by the author(s).

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work, including its accuracy and integrity

REFERENCES

[1] W. N. W. Waskitho, A. F. Afif, A. C. Wijaya, M. A. Nurdiansyach, P. R. Hidayatullah, and F. D. Arianto, “Literature study: potential of additional technology on conventional motorcycles on reducing the impact of exhaust gas emissions on the environment Wiji,” *J. Mech. Eng. Learn.*, vol. 13, no. 2, pp. 31–36, 2024, [Online]. Available: http://jurnal.untidar.ac.id/index.php/mechanical/index

[2] S. R. Ariyanto, A. S. Nugraha, W. R. Cahyadi, Y. Dianastiti, and M. Y. Pratama, “Analyzing Transition Metal Catalytic Converter Impact on Four-Stroke Motorcycle Fuel Consumption,” *J. Mech. Eng. Sci. Technol.*, vol. 7, no. 2, pp. 119–128, 2023, doi: 10.17977/um016v7i22023p119.

[3] S. Anwar, A. Aziz, and P. Fajar, “ANALYSIS OF EXHAUST GAS EMISSIONS ON A 125 CC FI 4 STROKE ENGINE USING VARIATIONS OF BIOFUEL AND PERTAMAX FUEL MIXTURES ON THE ENVIRONMENT,” *J. Baut dan Manufaktur*, vol. 6, no. 1, pp. 45–54, 2024.

[4] Ismiyati, D. Marlita, and D. Saidah, “Pencemaran Udara Akibat Emisi Gas Buang Kendaraan Bermotor,” *J. Manaj. Transp. Logistik*, vol. 01, no. 03, pp. 241–247, 2014.

[5] Haruna, Lahming, F. Amir, and A. R. Asrib, “Pencemaran Udara Akibat Gas Buang Kendaraan Bermotor Dan Dampaknya Terhadap Kesehatan,” *UNM Environ. Journals Vol.*, vol. 2, no. 2, pp. 57–61, 2022, doi: 10.26858/uej.v2i2.10092.

[6] B. C. Yoga and A. H. Firdaus, “ANALYSIS OF THE EFFECT OF THE NUMBER AND THICKNESS OF PLATES BRASS ON CATALYTIC CONVERTER ON EXHAUST GAS EMISSIONS 100 CC GASOLINE MOTORCYCLE,” *J. Mech. Eng.*, vol. 3, no. 1, pp. 293–297, 2024.

[7] M. A. Siregar, C. A. Siregar, Muharnif, A. M. Siregar, and I. Maulana, “Application of catalytic converter copper catalyst with honeycomb surfaces to reduce emissions of flue gas in motorcycles,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 674, no. 1, pp. 1–5, 2019, doi: 10.1088/1757-899X/674/1/012060.

[8] K. Hou, B. Deng, Y. Chen, J. Ran, and J. Fu, “For cleaner exhaust of a high performance motorcycle: A macroscopic comparative study of catalytic converters under world-wide motorcycle test cycle,” *J. Clean. Prod.*, vol. 284, no. 1, pp. 1–11, 2021, doi: 10.1016/j.jclepro.2020.124730.

[9] A. Mokhtar and T. Wibowo, “Catalityc Converter Jenis Katalis Stainless Steel Berbentuk Sarang Laba-Laba Untuk Mengurangi Emisi Kendaraan Bermotor,” *Semin. Teknol. dan Rekayasa*, vol. 2, p. 2015, 2015.

[10] R. B. Irawan, “Modifikasi Catalitic Converter Menggunakan Tembaga Berlapis Mangan Untuk Mereduksi Emisi Gas Carbon Monoksida Motor Bensin-(2012),” *Pros. Semin. Nas. Pengelolaan Sumberd. Alam dan Lingkung.*, pp. 65–74, 2012.