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THE IMPACT OF CHROME PLATED COPPER CATALYTIC CONVERTERS ON ENGINE PERFORMANCE WAS EVALUATED BY CHASSIS DYNAMOMETER EXPERIMENT

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ABSTRAK

Emisi yang dihasilkan oleh kendaraan bermotor sangat berkontribusi besar terhadap berbagai masalah lingkungan dan kesehatan. Salah satu teknologi yang saat ini banyak dikembangkan untuk menekan jumlah emisi yang ada di lingkungan adalah catalytic converter. Teknologi ini terbukti mampu menurunkan emisi gas buang dengan baik, namun seberapa besar dampaknya terhadap performa mesin (torsi dan daya) masih diperlukan penelitian lebih lanjut. Tujuan utama dari penelitian ini adalah untuk mengetahui dampak penggunaan *catalytic converter* berbahan dasar tembaga berlapis *chrome* (CuCr) terhadap performa mesin. Kendaraan yang digunakan dalam pengujian adalah Yamaha Vixion Lightning 150 CC. Performa mesin (torsi dan daya) ukur menggunakan alat uji *Inertia Chassis Dynamometer* dengan standar SAE J1349. Temuan penelitian ini menunjukkan bahwa penggunaan knalpot eksperimen mengakibatkan penurunan terhadap torsi dan daya kendaraan. Ini tentunya menjadi faktor kompromi yang harus diterima, mengingat memasang katalis sama halnya dengan menambah penghalang aliran gas buang. Penurunan torsi dan daya masih masuk dalam kategori yang dapat diterima, mengingat rata-rata penurunan hanya terjadi sekitar 5% untuk torsi dan 7% untuk daya. Semua argumen ini menunjukkan bahwa karena tujuan utama penggunaan katalitik konverter untuk menurunkan emisi gas buang, itu membuat kinerja mesin menjadi lebih rendah dari yang diharapkan.

Kata Kunci: *catalytic converter*, performa mesin, sepeda motor empat langkah.

ABSTRACT

Emissions produced by motorized vehicles greatly contribute to various environmental and health problems. One of the technology that is currently being developed to reduce the number of emission is the catalytic converter. This technology is proven to be able to reduce exhaust emission, but how big the impact on engine performance (torque and power) still needs further research. The main objective of this study was to determine the impact of using chrome plated copper (CuCr) catalytic converters on engine performance. The vehicle used in the test is a Yamaha Vixion Lightning 150 CC. Engine performance (torque and power) was measured using the Inertia Chassis Dynamometer test instrument with the SAE J1349 standard. The findings of this study indicate that the use of experimental exhaust results in a decrease in vehicle torque and power. It is certainly a compromising factor that must be accepted, considering that installing a catalyst is the same as increasing the exhaust gas flow barrier. The decrease in torque and power is still in the acceptable category, considering that the average decrease only occurs at about 5% for torque and 7% for power. All these arguments show that since the main purpose of using catalytic converters is to lower exhaust emissions, it makes engine performance lower than expected.

Keywords: *catalytic converter, engine performance, four-stroke motorcycle.*

1. INTRODUCTION

Nowadays, more than 100 million vehicles are operated in Indonesia. The increase number of the use of motorized vehicles consistently occurs every year, even in 2019 there was an increase of 7,108,236 units or an increase of 5.3% compared to 2018 [1]. It certainly has a positive impact on improving the economy in Indonesia. However, there are also negative impacts, such as increasing the number of exhaust emissions produced. Emissions produced by motorized vehicles greatly contribute to the emergence of air pollution in the environment, human health problems to global warming [2]. Meanwhile, the age limit for vehicles that are allowed to operate is not strictly regulated, so there are still many old vehicles operating on Indonesia. In this case, the potential for incomplete combustion clearly increases with increasing vehicle age [3]. The occurrence of incomplete combustion causes vehicles to produce more toxic gases such as carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen (NOx) pollutants. Several researchers have investigated several ways to reduce pollutants resulting from exhaust emissions. One of the proposed methods is to use after-treatment technology such as a catalytic converter [4].

Catalytic converters that are widely used by automotive vehicle manufacturers are generally derived from precious metals including platinum (Pt), palladium (Pd), and ruthenium (Rh). It is because the catalyst group of these materials is proven to be able to efficiently convert CO pollutants into CO2, HC into H2O, and NOx into nitrogen [5]. But unfortunately, the various advantages of using precious metals as catalyst base materials still provide a number of drawbacks to be considered, such as the relatively high cost of the base material and low market availability [6]. Efforts to reduce the amount of catalyst as the main ingredient have also been carried out, one of which is by using ceramic supports. This technique proved to be effective with a conversion ability of up to 80%. Unfortunately, the costs required for the fabrication process are quite expensive and are not suitable if applied to some countries that still use fuels with high Pb content [7].

One of the alternative potential materials proposed as the base material for catalytic converters is transition metals. The ability of transition metals in reducing and oxidizing exhaust emissions is certainly not as good as that of precious metals. However, the abundance of basic materials on the market and the relatively low production costs make this material a promising alternative. Sun et al. [8] in their scientific article showed several transition metals that are known to be effective as oxidation and reduction catalysts including Manganese (Mn), Copper (Cu), Nickel (Ni), Ferrous (Fe), Chrome (Cr), Zinc (Zn), and oxides of these metals. There have been many studies related to the ability of transition metal catalytic converters. Irawan et al. [9] investigated the copper catalytic converter coated with manganese. The results showed the best reduction in CO emissions of 79.6%. Besides, Wang et al. [10] examined the copper catalytic converter, the results showed that the best CO emission reduction was 40%. Meanwhile, Manojkumar et al.

[11] through their research stated that the copper catalytic converter is only good for the oxidation process. Furthermore, Ariyanto et al. [12] through their research, it is found that the use of chrome-coated copper catalytic converters proved effective in reducing CO and HC emissions. The percentage reduction in CO and HC emissions is 24% and 30%, respectively.

Based on its ability to reduce CO and HC emissions, we can see that the use of copper catalytic converters coated with chrome has proven to be quite effective. However, what is the impact of using this type of catalytic on engine performance? The further research is needed. Therefore, the main objective of this study was to determine the impact of using a chrome-plated copper (CuCr) catalytic converter on the performance of Yamaha Vixion Lightning engine. The results of engine performance testing, torque and power, are also explained to explore the role of each catalyst component.

2. METHODOLOGY

2.1 *Materials*

Figure 1. Test Instruments and Equipment

Engine performance testing was measured on the test vehicle under two conditions - before (standard) and after using the catalytic converter (experiment). It aims to analyze how much impact the use of catalytic converters has on the test vehicle, which is then analyzed in descriptive quantitative. In this case, the testing process engine performance (torque and power) is carried out using the Inertia Chassis Dynamometer test equipment with the SAE J1349 standard. Machine Performance Testing Laboratory, Department of Mechanical Engineering, Faculty of Engineering, Universitas Negeri Surabaya is used as a place to test engine performance with torque and power output. The vehicle used in the test is a Yamaha Vixion Lightning 150 CC, where the vehicle specifications are shown in Table 1. Meanwhile, all test instruments and equipment are shown in Figure 1.

Table 1. Test Vehicle Specifications

No	Specification		Information
1.	Engine Type	:	4 Stroke Liquid Cooled, SOHC
2.	Number of Cylinder	:	Single Cylinder
3.	Diameter x Stroke	:	57.0 x 58.7 mm
4.	Compression Compare	:	10.4 : 1
5.	Maximum Power	:	12.2 kW / 8500 RPM
6.	Maximum Torque	:	14.5 N.m / 7500 RPM

Engine performance (torque and power) was measured using the Inertia Chassis Dynamometer test instrument with the SAE J1349 standard [13]. Besides, the additional equipment such as a blower is also needed to assist in cooling the engine when changing the test sample. The technical specifications of the performance test kits, and ancillary equipment are shown in Table 2.

Table 2. Research Instruments and Equipment Specifications

No	Spesifikasi		Dynamometer	Blower
1.	Merk	:	Rextor Pro-Dyno	Krisbow EF-50S
2.	Voltage/Power	:	220 V 50/60 Hz	230 V 7.60 A
3.	Range	:	6.000 RPM dengan 150 gigi	1200 RPM
4.	Capability	:	15 KHz	50 Hz

2.2 *Manufacturing Catalytic Converter Products and Cases*

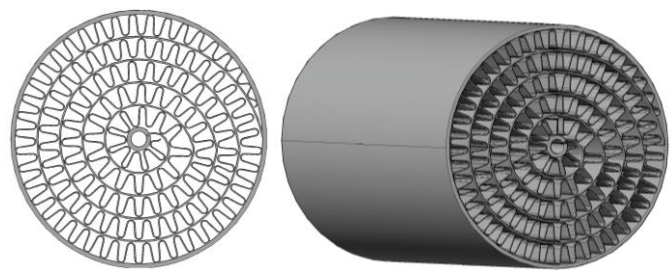


Figure 2. Product Catalytic Converter CuCr

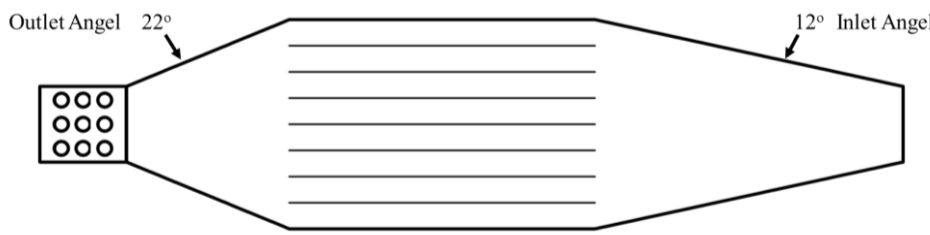
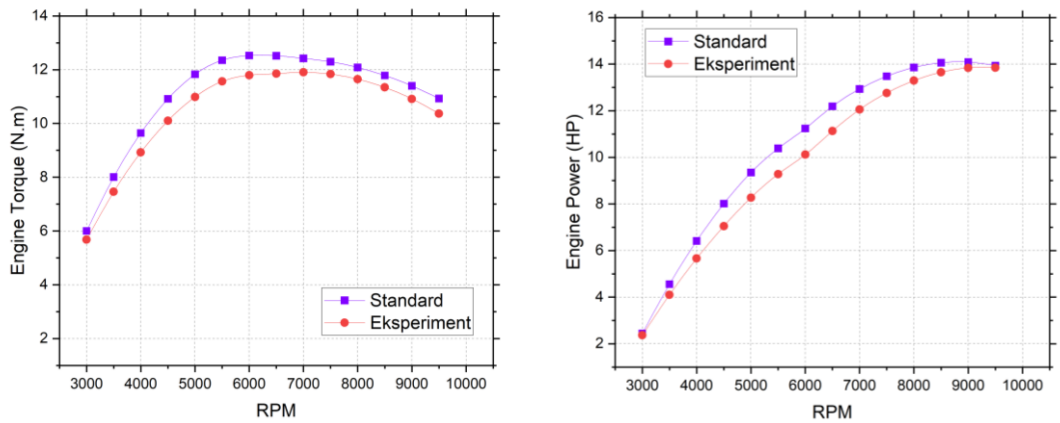


Figure 3. Casing Modification of Catalytic Converter

In the manufacturing process, the configuration of this catalytic converter product is composed with chrome plated copper, the height of the catalyst indentation is 3 mm, the diameter of the catalyst tube is 54 mm, with the length of the catalyst tube is 100 mm. In this case, copper is not used as an oxidation catalyst, but only as a support metal. Meanwhile, the metal that functions as an oxidation catalyst is chrome (Cr) (Figure 2). The choice of chrome as an oxidation catalyst is in accordance with the theory proposed by Obert [14], where chrome is the fifth best oxidation catalyst for the transition metal group. Besides, chrome has several advantages such as corrosion resistance and heat resistance where the melting point reaches 1578^{o}C [15]. The plating chrome process with copper is done by electroplating. Electroplating is a coating process using an electric current to reduce dissolved metal cations on an electrode. In this case, chrome is a dissolved metal that is coated on the copper metal surface [16]. In addition, the manufacturing process is also carried out on the catalytic converter casing. It aims to minimize the occurrence of exhaust gas turbulence when entering and leaving the catalytic converter. Adjustment of the entry and exit angles on the casing is carried out in accordance with the theory put forward by Bell [17] which states that ideally the inlet and outlet angles should be sloping [18]. Considering the space available for the catalytic converter

installation on the exhaust, this study set the inlet angle to the casing to be 12º while the outlet angle was set to 22º as shown in Figure 3.

3. RESULTS AND DISCUSSIONS



(a) (b)

Figure 4. (a) Torque Testing Trends and (b) Power Testing Trends at Various Engine Speeds

Figure 4a shows the trend of torsion testing on vehicles with standard exhaust (without catalyst) and experimental exhaust (CuCr catalyst) installed. The maximum torque on the standard exhaust is produced at 6000 rpm which is 12.53 N.m. Meanwhile, in the experimental exhaust, the torque produced tends to be lower at 11.90 N.m at 7000 rpm. On average, there was a decrease of 7% when compared before and after installing the experimental exhaust. Figure 4b shows the trend of power testing between vehicles fitted with standard exhausts and experimental exhausts. In both types of exhaust, the maximum power is equally generated at 9000 rpm, where the standard exhaust produces 14.09 HP of power while the standard exhaust produces 13.84 HP of power. In depth, we can see that the experimental exhaust produces lower power than the experimental exhaust. When averaged over the entire engine speed, the power produced by the experimental exhaust tends to be 5% lower than the standard exhaust. Ozgenel [19] shows that power is directly proportional to torque, when the torque produced tends to be low, the power produced also tends to be low. Therefore, it can be stated that increasing or decreasing torque will definitely affect the power produced.

Several factors were identified as the cause of the decrease in torque, one of which was the result of adjusting the inlet and outlet angles on the catalytic converter casing. If it is reviewed based on the theory put forward by Bell [17]. It has been explained that the angle adjustment of both the inlet and outlet of the catalytic converter casing must be made sloping. Meanwhile, due to the limited space for catalytic installation, in this study the inlet and outlet angles of the catalytic converter casing were set at 12º and 22º, respectively. The output angle, which tends to be steeper (22º) allows the exhaust gas flow to be blocked and collected in the casing area. Moreover, the turbulence that occurs tends to be large and causes the exhaust gas to lose flow [20]. This condition causes an increase in exhaust gas pressure which returns to the combustion chamber during overlapping (Figure 5), in which the two valves open together at the beginning of the intake valve opening and the end of the exhaust valve closing [21].

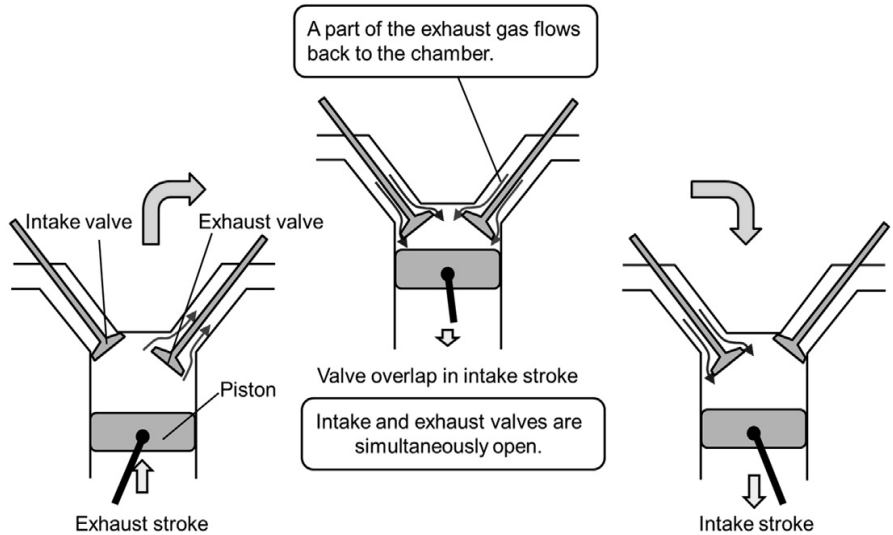


Figure 5. Schematic of Overlapping in Internal Combustion Engine [19]

4. CONCLUSION

In this study, the catalytic product of the CuCr converter was produced through an electroplating process. The choice of chrome as a coating metal is based on its advantages as an oxidation catalyst that is resistant to corrosion and heat. Unfortunately, when compared to standard exhausts (without catalyst) the use of experimental exhausts results in a decrease in vehicle torque and power. It is certainly a compromising factor that must be accepted, considering that installing a catalyst is the same as increasing the exhaust gas flow barrier. The decrease in torque and power is also still in the acceptable category, considering that the average decrease only occurs at around 5% for torque and 7% for power. All these arguments show that since the main purpose of using catalytic converters is to lower exhaust emissions, it makes the engine performance lower than expected.

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