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Experimental Investigation of Fuel Consumption in Four-Stroke Engines Using Nickel-Plated Copper Catalytic Converters

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Abstract. This study aims to evaluate the ability of nickel-plated copper catalytic converters to the fuel consumption of a four-stroke engine. This experimental research uses Yamaha Vixion Lightning as the object of research. Research instruments used include chassis dynamometer, and fuel flow meter. Fuel consumption measurements are carried out based on SNI standard 7554:2010. Results from this study showed that the metallic catalytic converter's ability to fuel consumption on a four-stroke motorcycle is no better than a standard exhaust. Fuel consumption is 87% more wasteful on MCC technology. This is because the shape of the outlet on the MCC case is steeper, making the back pressure higher and causing an increase in fuel consumption on four-stroke motorcycles.

Keywords: Metallic catalytic converter · Copper · Nickel · Fuel consumption · Four stroke motorcycle

1 Preliminary

Petroleum production in Indonesia in the last 10 years has decreased, in 2009 petroleum production amounted to 346 million barrels and to about 283 million barrels in 2018. The decline in petroleum production is caused by petroleum's main production wells that are generally old and the production of new wells is relatively limited. In fact, to cover the needs of petroleum reaching 450 million barrels, Indonesia must import petroleum from several countries in the Middle East [1]. The problem of energy security in Indonesia, exacerbated by the increasing number of motor vehicles. The number of motor vehicles increased by 46% from 2017 to 2019 [2]. The increasing number of motor vehicles not only exacerbates energy security problems, but also has a bad influence on

the environmental sector, namely air pollution [3]. Evidently in March 2020, air quality in the capital city of Jakarta is the worst in the world with an air quality index value of 166 in the unhealthy category. Poor air quality caused by exhaust emissions produced by motor vehicles and the main source of air pollution comes from motorcycles then followed by bus vehicles [4].

Congestion that occurs in almost every major city in Indonesia is also caused by the increasing number of motor vehicles. Congestion also causes vehicle fuel consumption to become increasingly wasteful, research [5] stated fuel consumption losses due to congestion of 147.13 L per day for gasoline-fueled vehicles and 777.82 L for diesel vehicles. Not only that, but wasteful fuel consumption also causes economic losses to reach Rp. 9,940,000.

Therefore, it should use technology that is able to overcome the above problems. One technology that is able to reduce fuel consumption on motorized vehicles is a metallic catalytic converter. Metallic catalytic converter is a technology that has the main function to reduce exhaust emissions of motor vehicles applied to exhaust, but this technology is proven to reduce fuel consumption on motorcycles by 30% when compared to standard motorcycles [6, 7].

Based on the description above, researchers are interested in analyzing the ability of metallic catalytic converters made of nickel-plated copper (CuNi). However, the focus of this research refers to the metallic catalytic converter's ability to fuel consumption on four-stroke motorcycles.

2 Materials and Methods

The general procedure used to evaluate the effect of using a metallic catalytic converter (MCC) CuNi on fuel consumption is by measuring the expiration time of the fuel placed in the burette every 10 ml. The data collection process is carried out at least three times for each combination. Then the results are compared between before and after using a metallic catalytic converter.

2.1 Metallic Catalytic Converter

The catalytic converter used is a three-way catalytic converter. The design used is in the form of a honeycomb. Experimental design has specifications of 2 mm indentation height, 54 mm tube diameter, and 100 mm tube length. The main material used is copper which is then coated with nickel (CuNi). More clearly, the MCC used in this study can be shown in Fig. 1.

2.2 Apparatus

Metallic Catalytic Converter Nickel-plated copper (MCC CuNi) has been included in the Yamaha Vixion Lightning exhaust muffler. Then the test vehicle is positioned above the Inertia chassis dynamometer. The fuel meter is checked to ensure there are no leaks and is placed close to the test vehicle. Next, the fuel hose from the fuel meter is connected to the connector on the fuel tank (Fig. 2).

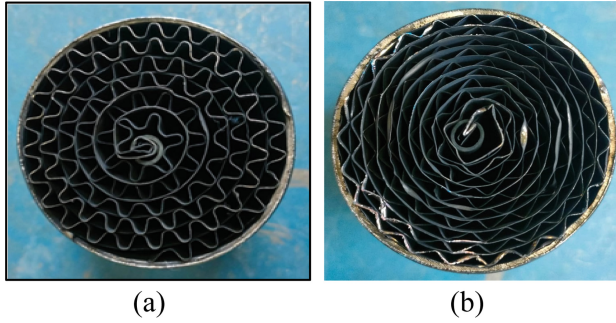


Fig. 1. MCC Nickel-plated Copper.

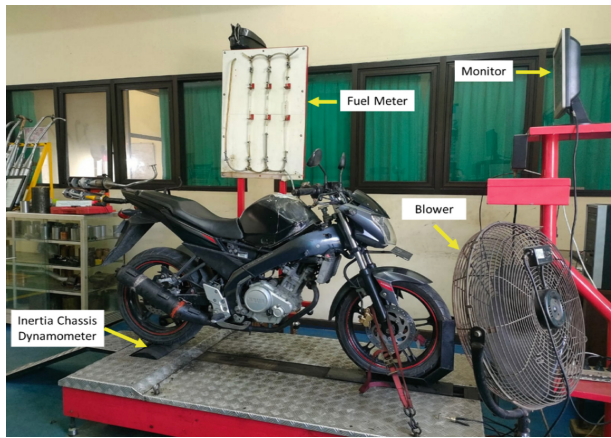


Fig. 2. Research Equipment and Instruments.

2.3 Test Procedure

Measurement of fuel consumption using a fuel flow meter, measurements are carried out using the standard SNI 7554: 2010 [8]. The measurement method uses a 10 ml measuring glass, then the motor is operated at a speed changing multiple of 1000 RPM and uses a load in gear 5. The fuel consumption test procedure is carried out in stages starting from (1) preparing test equipment: burette, fuel hose, and stopwatch; (2) fill the measuring cup with fuel and attach the fuel hose from the test equipment to the vehicle's fuel tank; (3) start the engine until it reaches the working temperature; (4) collect data on fuel consumption from the idle rotation of the top gear transmission position; (5) record the time out of fuel every 10 ml; (6) perform the test at each rpm from idle to maximum rotation with an increase of every 1000 rpm.

3 Results and Discussion

3.1 Results

Based on Tables 1 and 2, it can be seen that there are differences in fuel consumption both when using a standard exhaust and using an experimental exhaust or when using MCC CuNi. To be clear, the differences in fuel consumption in each experiment can be seen in Fig. 3.

The data in Table 2 and Fig. 3 above show that there is a significant difference between the standard exhaust and the use of the MCC CuNi experimental exhaust. Experimental exhausts tend to be more fuel-intensive compared to standard exhausts. After using MCC CuNi, fuel consumption tends to be 87% more wasteful than standard exhaust.

Table 1. Fuel Consumption Time in 10 ml

RPM	STD		EXP	
	Min	Sec	Min	Sec
1500	9	5	4	22
2000	8	14	3	24
3000	4	27	2	17
4000	3	32	1	46
5000	2	34	1	33
6000	2	15	1	15
7000	1	55	1	0
8000	1	41	0	49
9000	0	59	0	46

Table 2. Fuel Consumption Time in Liter/Hour

RPM	STD	EXP
	L/h	L/h
1500	0,05	0,10
2000	0,05	0,13
3000	0,10	0,18
4000	0,12	0,22
5000	0,17	0,28
6000	0,19	0,35
7000	0,23	0,43
8000	0,26	0,53
9000	0,44	0,57

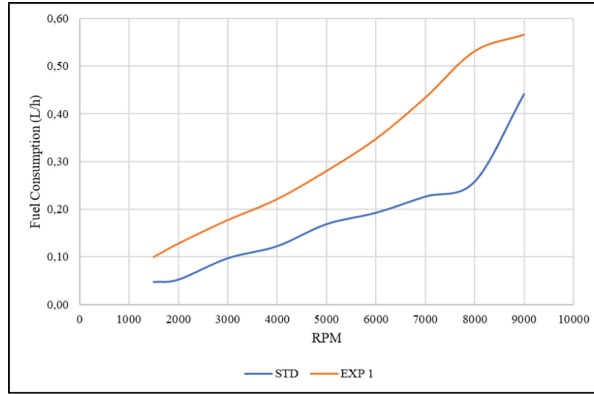


Fig. 3. Fuel Consumption Graph.

The increase in fuel consumption in the MCC CuNi is influenced by the setting of the inlet and outlet angles on the MCC case. In accordance with the theory put forward by Bell [10] and illustrated through Fig. 4, it is known that the outlet angle of the MCC CuNi casing which tends to be steeper (22°) allows the flow of exhaust gases to be inhibited and gather in the MCC casing area. Moreover, the turbulence that occurs tends to be large and results in the exhaust gases losing flow [11].

This condition certainly causes an increase in exhaust gas pressure which leads back to the combustion chamber. Exhaust gases have the opportunity to re-enter the combustion chamber at the time of overlapping, where in this condition the two valves open together at the beginning of the opening of the intake valve and the end of the exhaust valve closure. Jääskeläinen [12] reveals that under certain conditions, back pressure can have negative effects on the vehicle, such as: (1) improved pumping performance; (2) lowering the pressure from the intake manifold; and (3) reduce combustion efficiency.

Ensuring this, the back pressure is measured using the U-tube manometer. The test results showed that the back pressure on the CuNi MCC tended to be higher by 18% when compared to the standard exhaust. As predicted, the main cause is the angle of the MCC CuNi outlet which tends to be steep. As a result, exhaust gases gather in the MCC case and make the average temperature in the optimum exhaust design increase to more than 500°C.

This is in accordance with the results of the study Bhure [13] which states that the higher the back pressure, the lower the engine power. In line with those results, Sapra et al., [14] revealed that high back pressure can reduce engine operating limits, increase fuel consumption, and lead to exhaust emissions at the exhaust end. Further Patil & Chaudhary [15] explained that the increase in back pressure is caused by an increase in pumping performance (pumping work) and the presence of flushing of the back pressure effect in the combustion chamber.

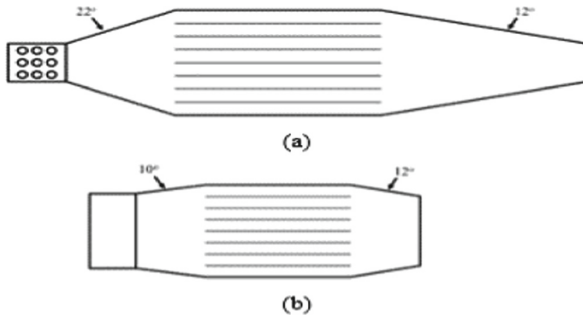


Fig. 4. Desain Casing MCC (a) CuNi dan (b) STD

4 Conclusion

The metallic catalytic converter's ability to fuel consumption on a four-stroke motorcycle is no better than a standard exhaust. Fuel consumption is 87% more wasteful on mcc technology. This is because the shape of the outlet on the MCC case is steeper, making the back pressure higher and causing an increase in fuel consumption on four-stroke motorcycles.

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Authors' Contributions. Warju conceived the original idea. All authors discussed and agreed with the main focus and ideas of this paper.

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