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Spider Web Shape of Brass Catalytic Converter for Reducing Exhaust Gas Emission

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Abstract

The rapid increase of the number of motor vehicles, especially motorcycles, makes serious problem caused by the pollution from gas emission of fossil fuel combustion. The problems related to human health and the erosion on ozone layer is credited to its gas emission. Several dangerous and toxic gasses such as Hydrocarbon (HC), Carbon Monoxide (CO), and Nitrogen Oxide (NO_X), Sulphur Dioxide (SO2), and Lead (Pb) are emitted during IC engine operation.

To manage those dangerous gasses, catalytic converter which converts the gasses into more eco-friendly CO_2H_2O and N_2 may be employed. In this research, a specially designed catalytic converter made from brass (CuZn) wire in the form of spider web pattern was fitted into exhaust system of a standard motorcycle. The performance of the converter for several engine rotation speeds was examined by measuring CO and HC of exhaust by using Gas Analyzer.

By comparing the exhaust of a standard exhaust system and modified exhaust system (fitted with converter), it can be concluded that the converter was able to decrease the exhaust emission gas. For HC content, the percentage of decrease was as much as 36,88 % for converter fitted exhaust system compared to 61.12% for standard one. For CO content, the decrease percentage was 19.90% compared to 80.10% for standard one.

Keywords*: spider web, brass, catalytic converter, gas emission*

1. INTRODUCTION

Motor vehicles are the main transportation mode in the modern era. In line with the more efficient of automotive industries make the production volume of motor vehicle becomes higher with cheaper prices. This condition makes motor vehicles become more affordable to the most people. As the results, the pollution caused by exhaust gas emission becomes dangerously higher.

An internal combustion (IC) engine produce exhaust gas which typically comprised of Hydrocarbon (HC), Carbon Monoxide (CO), and Nitrogen Oxide (NOx), Sulphur Dioxide (SO2), and Lead (Pb). The most dangerous gas from the exhaust is CO as product of imperfect combustion which fatal to human when inhaled [1].

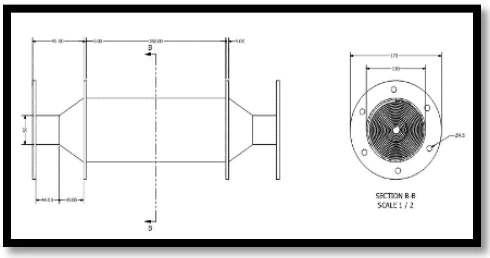
To reduce the risk of this dangerous gas, Environmental Sustainable Transportation (EST) program offered 12 programs or approaches to reduce the problem of air pollution, especially caused by transportation sector. One of the programs is to modify the exhaust system of motor vehicle by adding catalytic converter. The converter work is based on converting gas (such as CO) by oxidation process to friendlier CO_2 by chemical reaction in a medium which has catalyst property [2]. For reducing gas pollution from exhaust gas of IC engine, especially gasoline one, catalytic converter has also found its application [3]. Other techniques to reduce gas pollution in IC engine are modification of the IC Engine, fuels or combustion system, other than modification on the exhaust system [4].

Previous researches, showed that catalyst from Copper (Cu) and Brass (CuZn) could be employed to reduce the content of CO and HC from exhaust gas for range of engine rpm and number of catalyst cells. The several configuration of catalyst such as 12 (twelve) inline catalyst cells [5], perforated pipe of brass [6], and catalytic converter in shape of spider web made of Copper applied to Supra-X 125 motorcycle [7]. In other research, the effectiveness of substrate materials of catalyst, i.e. Brass, in reducing NO_x for gasoline IC engine has been shown [8].

In this research, cheaper material (CuZn) was employed to filter the exhaust gas rather than using more expensive one such as Platinum (Pt) and Rhodium (Rh). CuZn is effective as converter as shown in above previous research. The solid CuZn in form of wire was employed as catalyst because its availability and versatility to employ for different shape. The spider web shape was employed with the consideration of good strength and filtering capability of the shape.

2. Methodology

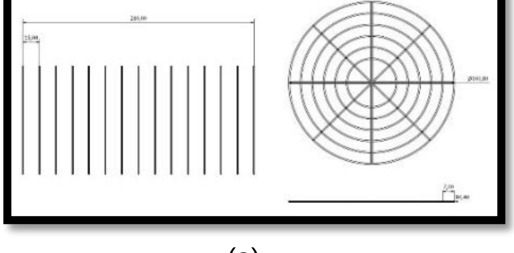
Specially designed catalytic converter as shown in Figure 2.1 was examined for its effectiveness in reducing dangerous gasses in exhaust of IC engine. The casing was designed in accordance with the shape of standard exhaust system of motorcycle. Also the inner diameter and thickness of casing wall followed the standard to maintain the functions of exhaust system as effective as standard one to dissipate heat and flow the exhaust.



(a) (b)

Figure 2.1 Casing of catalytic converter, a. Drawing, b. Actual.

The catalytic converter was assembled from Brass (CuZn) wire with diameter of 0.8 mm and Copper (Cu) wire with diameter of 0.4 mm and takes the shape of spider web with 13 row of converter as depicted in Figure 2.2.



(a) (b)

Figure 2.2 Design of catalytic converter, a. Drawing, b. Actual.

The research has been carried out by employing experimental methods. The catalytic converter then was installed in motorcycle exhaust system. The contents of HC and CO were measured using Gas Analyser for standard exhaust system and catalytic converter installed one. The variables for the experiment were given in Table 2.1 below. The fuel for the research was Pertalite^{TM}, and the research was executed by varying the engine rpm to several values. Variable response for the research was the content of exhaust gasses as measured by Gas Analyser. The flowchart of the research was given in Figure 2.3.

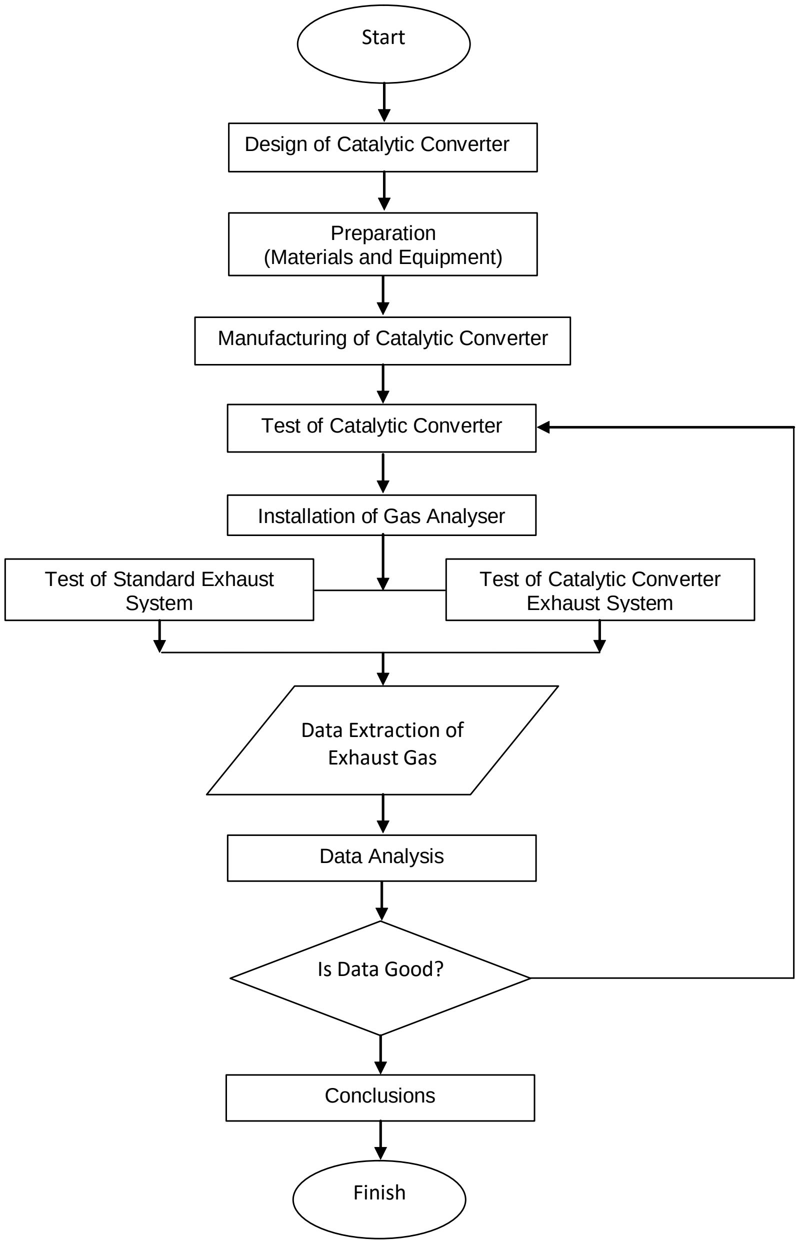


Figure 2.3 Flowchart of the experiment of catalytic converter

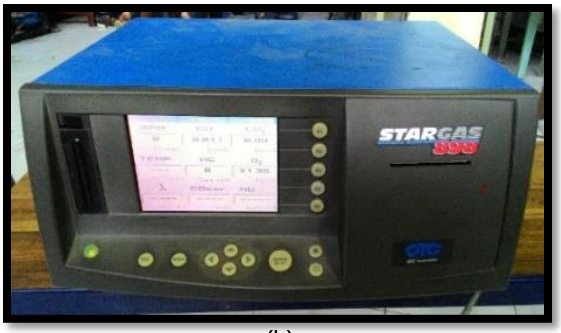
To execute the research, the experimental design was given in Table 2.1 below. It compared two exhaust systems, the standard one and catalytic converter installed one. The fuel for the experiment was Pertalite^{TM} from Pertamina with 5 replications per cell.

Table 2.1 Variables for the experiment

Exhaust System	Fuel	Engine rpm			
		1500	2000	2500	3500
Standard	Pertalite	D_{111}	D_{121}	D_{131}	D_{141}
		D_{112}	D_{122}	D_{132}	D_{142}
		D_{113}	D_{123}	D_{133}	D_{143}
		D_{114}	D_{124}	D_{134}	D_{144}
		D_{115}	D_{125}	D_{135}	D_{145}
Spider web converter	Pertalite	D_{211}	D_{221}	D_{231}	D_{241}
		D_{212}	D_{222}	D_{232}	D_{242}
		D_{213}	D_{223}	D_{233}	D_{243}
		D_{214}	D_{224}	D_{234}	D_{244}
		D_{215}	D_{225}	D_{235}	D_{245}

The experimental runs were depicted in Figure 2.3 below and were taken on 9 January 2017 in Automotive Engineering Laboratory, State University of Malang.

(a)



(b)

Figure 2.3 Experimental runs, a. Test stand, b. Gas analyser.

The data measured for the experiment were content of HC, CO, CO_2, and O_2.

3. Result and Discussion

The data of exhaust system content was depicted in Table 3.1 and Table 3.2 below.

Table 3.1 Content of exhaust gas for standard exhaust system

Engine rpm	Data	HC (ppm)	CO (%)	CO_2 (%)	O_2 (%)
1500	average	214.4	2.978	3.66	14.84
2000	average	228.0	2.874	3.40	15.52
2500	average	251.8	2.430	2.86	16.28
3500	average	260.6	3.330	3.68	14.22

Table 3.2 Content of exhaust gas for catalytic converter installed exhaust system

Engine rpm	Data	HC (ppm)	CO (%)	CO_2 (%)	O_2 (%)
1500	average	162.8	2.254	3.34	16.32
2000	average	263.2	1.448	1.94	18.12
2500	average	260.6	2.192	2.58	16.06
3500	average	265.8	2.950	3.28	14.90

After data on the contents of gasses have been acquired, the next step was to count the percentage of emission and percentage of emission reduction according to the Equation 1 and Equation 2.

$$Percentage\ of\ emission = \frac{emission\ average\ with\ catalyst}{emission\ average\ with\ catalyst} \times 100\ \% \qquad (1)$$

and

$$Percentage\ of\ emission\ reduction = 100 - Percentage\ of\ emission \qquad (2)$$

The results were presented in Table 3.3, Table 3.4, and Table 3.5 below.

Table 3.3 Percentage of emission

Exhaust System	HC (ppm)	CO (%)	CO_2 (%)	O_2 (%)
Standard	238.7	2.903	3.400	15.215
Catalytic Converter	238.1	2.211	2.785	16.350
Value	**99.75**	**76.16**	**81.91**	**107.00**

Table 3.4 Percentage of emission reduction

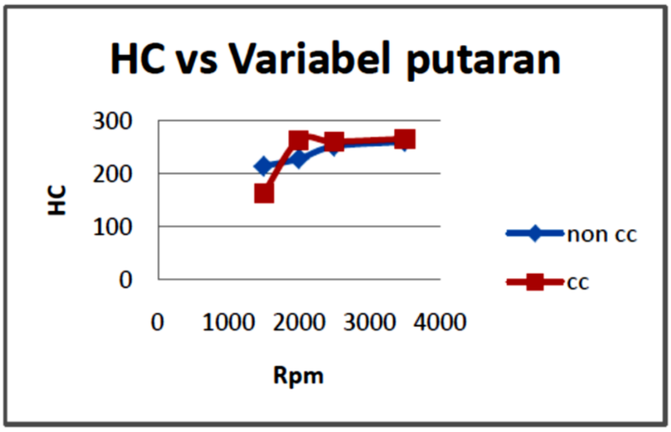
	HC (ppm)	CO (%)	CO_2 (%)	O_2 (%)
	99.75	76.162	81.912	107
Value	**0.25**	**23.837**	**18.088**	**-7**

Table 3.5 Comparison of percentage of emission reduction

Materials	HC (ppm)	CO (%)
Brass	0.25	23.837
Copper	18.24	38.696

4. CONCLUSION

From the research, the relationship between HC and engine rpm was depicted in Graphic 4.1.



Graphic 4.1 Relationship between emission of HC and engine rpm

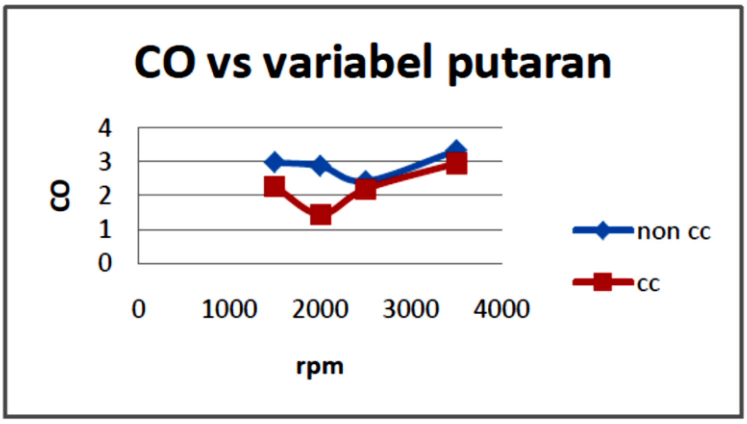
Reduction in HC emission for catalytic converter could be considered insignificant since only 0.25 ppm of reduction was achieved. This trend may be caused by the mechanism of combustion which unable to combust all available fuel (imperfect combustion) in combustion chamber or maybe misfire. Another cause may be there was failure/trouble in firing system such as bad plug or its wire, early combustion or low compression pressure.

Also, from Graphic 4.1 it was shown that reduction of HC emission is not consistent since for 1500 rpm it decreased significantly from 214.4 ppm for standard exhaust system to 162.6 ppm for catalytic converter installed exhaust system. But, in higher rpm the trend of HC emission was always above the standard emission. In general, the catalytic converter converts HC into water (H2O) and carbon dioxide (CO2) thru oxidation process as follows:

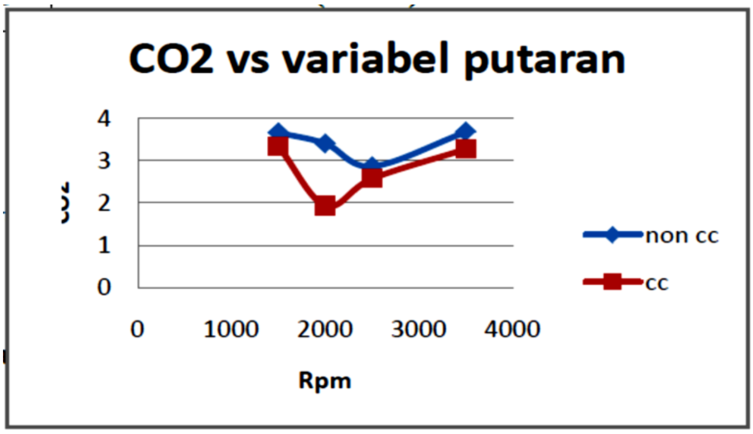
$$CH + C_2 \rightarrow H_2O + CO_2 \qquad (3)$$

The surface contact of the catalyst gives activation energy to oxidate HC (hydrocarbon) into H_2O (water) and CO_2 so that reduction of CH is achieved.

In this research, even though the content of CO2 of catalytic converter installed exhaust system is always lower than standard one but the measurement of HC showed the contradictions. It is an interesting one to be examined more in the next experiment.



Graphic 4.2 Relationship between emission of CO and engine rpm



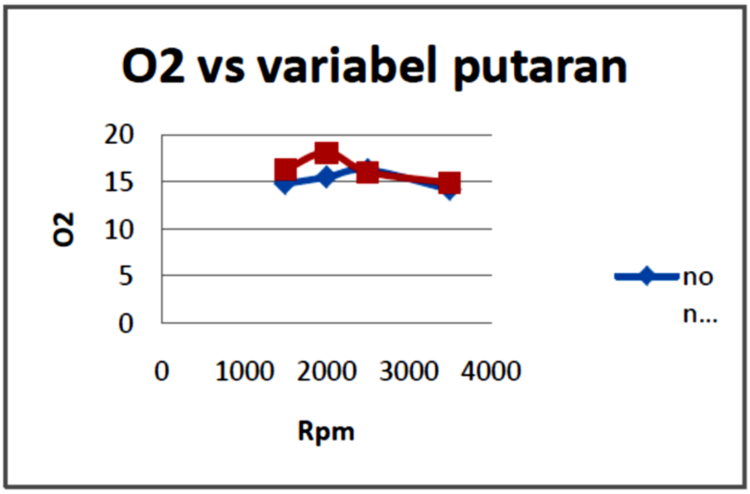
Graphic 4.3 Relationship between emission of CO_2 and engine rpm

The reduction of CO emission could be considered good with percentage of reduction reached 23.837%. The mechanism of CO reduction is as follows:

$$2\ CO + O_2 \rightarrow 2\ CO_2 \tag{4}$$

The trend of reduction in CO was not following the smooth with lowest emission on 2000 rpm. This trend may be caused by non-homogenous mixture of fuel and air in IC engine test bed.

The reduction of CO_2 emission could be considered good with percentage of reduction reached 18.088%. The result also shows that the catalytic converter was able to convert CO into CO_2 so that the emission of CO_2 was better for every rpm.



Graphic 4.4 Relationship between emission of O_2 and engine rpm

The reduction of O_2 emission could be considered well with percentage of reduction reached -7.0% which means there was increase of O_2 emission. This result was contrary to the theory of catalytic converter in which the oxidation process of HC (Equation 3) and CO (Equation 4) and there was a big possibility that the casing of exhaust system supply more O_2 thru some unsealed surface (leaked). In general, the research has proven that the designed catalytic converter was able to reduce the dangerous gas such as CO in all rpm and to some extent the content of HC (on 1500 rpm).

REFERENCES

[1] Wardhana, W.A. Dampak Pencemaran Lingkungan. Yogyakarta: Penerbit Andi. 2004.
[2] Dowden, D.A. et.al. Catalytic Hand Book. New York: Verlag, Inc. 1970.
[3] Heisler, H. Advanced Engine Technology. London: Hodder Headline Group. 1995.
[4] Mathur, S.L. Internal Combustion Engine. Second Edition. New York: McGraw-Hill Book Company, Inc. 1975.
[5] Refkiandi, R. and Mokhtar, A. Catalytic Converter Jenis Tembaga dan Kuningan Berbentuk Plat Sejajar Susunan 12 Sel. Final Project. Malang: Undergraduate Program of Department of Mechanical Engineering UMM 2010.
[6] Mokhtar, A. Catalytic Converter Jenis Katalis Pipa Kuningan Berlubang untuk Mengurangi Emisi Kendaraan Bermotor. Laporan Penelitian, Universitas Muhammadiyah Malang. 2012.

ISSN 2541-6332
e-ISSN 2548-4281

[7] Hafid, L. Catalytic Converter Berbahan Tembaga Berbentuk Sarang Laba-laba Pada Knalpot Supra-X 125 Untuk Mengurangi Emisi Gas Buang. Final Project. Malang: Undergraduate Program of Department of Mechanical Engineering UMM. 2016.
[8] Irawan, B. and Subri, M. Efektivitas Katalis Material Substract Paduan CuZn (Kuningan) Dalam Mereduksi Emisi gas Karbon Monoksida Motor Bensin. Traksi. 2005; 3 (2).