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PERFORMANCE AND EXHAUST GAS TEMPERATURE INVESTIGATION OF CERAMIC, METALLIC AND FeCrAl CATALYTIC CONVERTER IN GASOLINE ENGINE

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Abstract -- *Catalytic converter (CATCO) and its effect on engine performance and exhaust gas temperature became an exciting field in automotive research. In this study purposed to compare existing CATCO which is ceramic and metallic with FeCrAl CATCO that treated with a combination of ultrasonic bath and electroplating technique in 30 minutes holding time (UB+EL 30 min). This study proposed to select an appropriate CATCO that used in a gasoline engine to increase the performance and to reduce the exhaust gas temperature as well as its potential to reduce the exhaust gas emission. Mitsubishi 4G93 conducted this analysis with 1.8 L and 10.5 compression ratio with a variable speed of 100, 2000 and 3000 rpm and different engine load of 10, 20 and 30%. The result shows that the FeCrAl CATCO was more useful to reduce fuel consumption up to 66.42% and increase torque up to 15.79% as well as reduce exhaust gas temperature up to 30.11% as compared to ceramic and metallic CATCO. It can be concluded that FeCrAl CATCO coated by UB+EL 30 min was recommended to increase engine performance and to reduce exhaust gas emission.*

Keywords: *Catalytic converter; Engine performance; Exhaust gas temperature*

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INTRODUCTION

CATCO have been used in engine exhaust emission more than two decades to reduce the pollutant such as HC, CO, and NO_x (Kaspar et al., 2003 and Santos and Costa, 2008). There are two types of conventional CATCO in the market which are ceramic and metallic CATCO. CATCO is located between the engine manifold and exhaust tailpipe as shown in Fig. 1. The pollutant gases flow out from the engine which is through the chemical process to convert the pollutants to be relatively harmless gases. It can be achieved by the reaction between the gas and wash coated CATCO (Kalam et al., 2009).

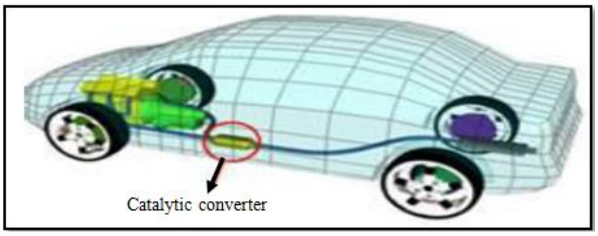

Figure 1. Location of CATCO in a passenger car (Kaspar et al., 2003 and Pardiwala et al., 2011)

Nowadays, a higher level of specific power output, increase reliability and increase its efficiency are required (Alahmer and Aladayleh, 2016; Pranoto, 2015). Improving engine performance and its system regarding minimizing fuel consumption of available fuels is a challenging research area in automobile industries (Cerri et al., 2011). However, most researchers investigate the engine performance and exhaust gas temperature using conventional CATCO either ceramic or metallic CATCO. Mohamad and Geok (2014) study the effect of Malaysian octane blend which named by RON 95 and RON 97 using conventional CATCO on the engine performance regarding the brake torque, brake power and Brake Specific Fuel Consumption (BSFC). The author found that RON 95 shows higher brake torque and brake power compared to RON 97. RON95 shows higher efficiency at more top engine speed and loads. Khalifa et al., (2015) and Binjuwair et al., (2015) explore RON91 and RON95 on the performance of SI fuel injecting engine regarding brake power and BSFC. The results show that RON 91 have higher engine brake power and lower BSFC compared to RON95.

Alahmer and Aladayleh (2016) investigate torque, brake power, and BSFC as well as exhaust gas temperature in different octane number of 90 and 95 and different engine speed of 1100, 1600, 2100, 2600, 3100 and 3600 rpm, respectively. The results show that the lowest

BSFC showed by engine speed of 2600 rpm for 0.28 kg fuel/kWh. In terms of exhaust gas temperature shows that RON 90 is higher than RON 95. The highest exhaust gas temperature observed in engine speed of 3600 rpm for 155^{0}C.

Silva et al., (2006) investigate exhaust gas temperature in different BMEP of 1-5 bar and engine speed of 2000, 3000 and 4000 rpm. The results show that the highest engine speed of 4000 rpm in BMEP 5 bar has the highest exhaust gas temperature of 800^{0}C as well. Geng and Zhang (2015) studied the comparison of gasoline blend and unblended with methanol in different torque of 20 to 160 Nm on exhaust gas temperature and particulate number concentration. Blended and unblended fuel shows higher exhaust gas temperature up to 550^{0}C in higher torque. Moreover, in Low-Temperature Combustion (LTC) is related to mass degradation or effect to the durability of CATCO. Higher large-scale degradation is caused by oxidation and desorption of hydrocarbons. At lower exhaust temperature LTC of 520^{0}C was generated 95% degradation mass as compared to the conventional combustion temperature of 595^{0}C (Jung and Bae, 2015). The main problem in the conventional CATCO is its effect on the degradation performance of the engine, and it caused high exhaust gas temperature performed. Therefore, based on previous research by Feriyanto et al., (2017) that have been developed FeCrAl CATCO. It was very challenging to investigate the comparison between conventional CATCO with FeCrAl CATCO in terms of engine performance and exhaust gas temperature.

MATERIAL AND METHOD

This study was conducted by coating process of FeCrAl CATCO by a combination of ultrasonic bath and electroplating technique for 30 minutes. This coating activity was consisting of two deposition process which is an ultrasonic bath in the frequency of 35 kHz and holding time, electroplating technique with sulphamate solution, pH of 2.5-5, a current density of 8 A/dm^2 and distance between anode and cathode was 25mm.

The engine performance and exhaust gas analysis were conducted by Mitsubishi 4G93 gasoline engine. The specification of the Mitsubishi 4G93 with 1.8 L and 10.5 compression ratio is listed in Table 1. They found that the exhaust gas temperature of emulsion fuel is lower than petroleum oil because it has a low carbon content in the exhaust gas. Those phenomena are observed when using conventional CATCO.

Table 1. Engine specification

Description	Specification
Engine model	Mitsubishi 4G93
Engine type	Petrol 4 stroke, single engine
Bore x Stroke (mm)	81 x 89
Displacement (L)	1.8
Compression ratio	10.8
Maximum output (kW)	81 kW (110 PS; 109 bhp)
Maximum torque (N.M)	154 N.m (114 ft.lbf)

The conventional CATCO (ceramic and metallic CATCO) that has been applied in the market also generated as a comparison with FeCrAl CATCO. The four-stroke cycle engine was used, and it operated at 1000, 2000 and 3000 rpm with various engine loads of 10, 20 and 30% which adjusted using hydraulic dynamometer. The temperature was recorded using thermocouple which placed at downstream of the exhaust valve. The comparison between metallic, ceramic and FeCrAl metallic CATCO is performed to investigate the appropriate material for reducing exhaust emission. From this analysis, Engine performance (torque and fuel consumption), exhaust emission gases and temperature before and after CATCO were analyzed. The schematic of the experimental set up is shown in Fig. 2.

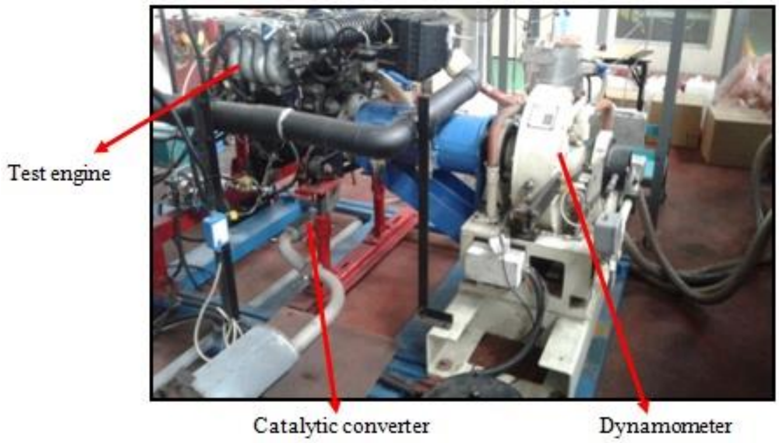

Figure 2. Mitsubishi 4G93 engine with eddy current dynamometer

RESULTS AND DISCUSSION

Fuel Consumption and Torque Analysis

Fuel consumption and torque analysis with various speed and engine load before CATCO are shown in Fig. 3. Fuel consumption (FC) of the ceramic, metallic and coated FeCrAl CATCO is increasing as speed, and engine load increased as well. The lowest FC is shown by ceramic, metallic and coated FeCrAl CATCO on the speed and engine load of 1000 rpm and 10%, respectively for 2.712 L/h, 2.193 L/h and 1.693 L/h. It shows that coated FeCrAl CATCO has lower FC as compared to ceramic and metallic CATCO. It may cause by metallic is consist of 91% open area, and the rest of 9% is a closed area (Kaspar et al., 2003).

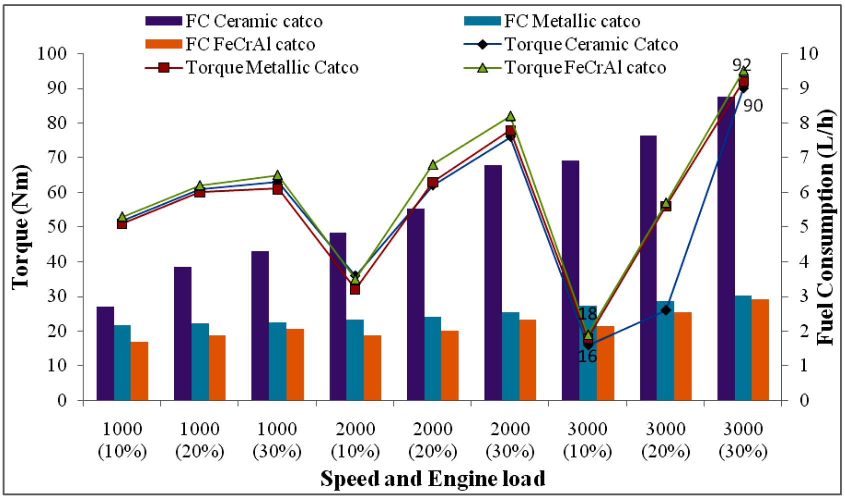

Figure 3. Torque and fuel consumption in various speed and engine load ceramic, metallic and coated FeCrAl CATCO

The torque analysis shows that higher speed and engine load as torque increased as well. However, the lowest torque is shown by the speed of 3000 rpm and engine load of 10% for ceramic, metallic and coated FeCrAl CATCO for 16 Nm, 18 Nm, and 19 Nm, respectively. It approved by the concept that speed is inverse with torque. When speed is increased as torque decreased, moreover, higher engine load in constant speed will increase torque value.

Fig. 3 shows that coated FeCrAl has lower FC and higher torque as compared to ceramic and metallic CATCO. It caused by FeCrAl CATCO more consists of open area, and the hole dimension is higher than conventional ceramic and metallic CATCO (Feriyanto et al., 2017) which led to a laminar flow of exhaust gas from the engine. That flow caused higher engine performance (torque) and decreased FC. It means that coated FeCrAl shows high prospective or potential in reducing FC and increasing torque.

Exhaust Gas Temperature Analysis

Temperature engine inlet and outlet of conventional ceramic, metallic and coated FeCrAl CATCO fuelled by RON 95 are shown in Fig. 4 to 6. The experiment is conducted at a variable speed of 1000, 2000, 3000 rpm and engine load of 10%, 20%, and 30%. The different speed and engine load were selected based on previous research that in high rpm (4000 rpm) and high engine load (40%) will increase exhaust gas temperature, and it can decrease the effectiveness of CATCO in converting exhaust gas emission (Silva et al., 2006 and Alahmer and Aladayleh, 2016). Therefore, this research was performed in low to medium engine load.

For ceramic CATCO shows the temperature increase as engine load and speed increased as well. Conventional ceramic CATCO commonly were developed by a precious metal such as Pt, Pd, Rh and Rd (Benson et al., 2000 and Leman et al., 2017). Lowest temperature inlet and outlet for ceramic CATCO is shown by the speed of 1000 rpm and engine load of 10% for 295.2 and 238^{0}C. The highest Exhaust gas temperature is located at speed of 3000 rpm and 30% engine load. An overall investigation has shown that temperature inlet has higher than temperature outlet. It may be caused by temperature has adsorbed by CATCO at once conversion from exhaust gas emission into the CO_2 and H_2O is occurred by high retention process through coated FeCrAl honeycomb (Pardiwala et al., 2011).

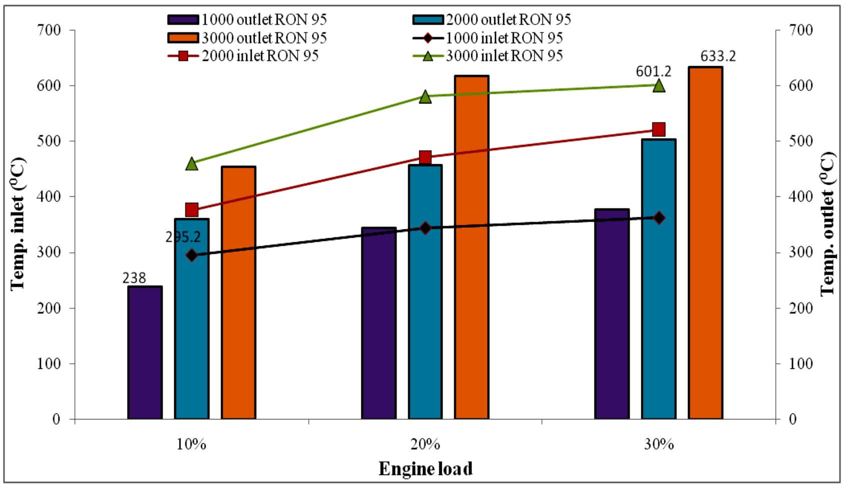

Figure 4. Exhaust gas temperature inlet and outlet of ceramic CATCO fuelled by RON 95

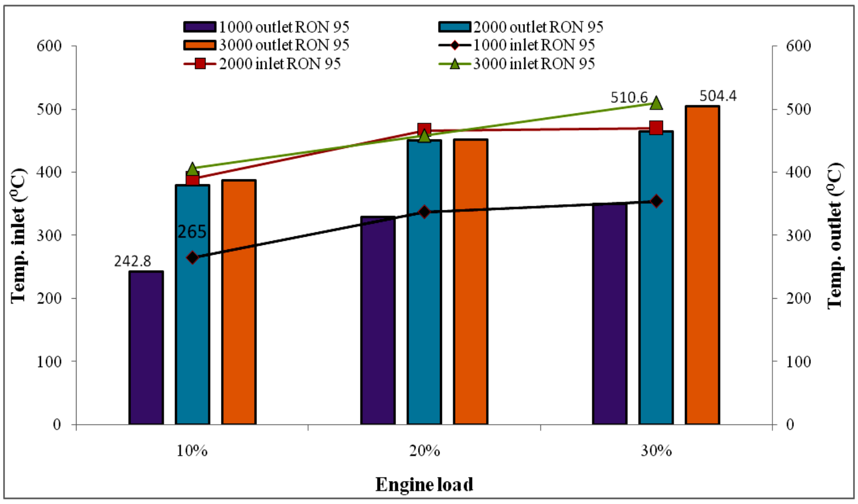

Figure 5. Exhaust gas temperature inlet and outlet of metallic CATCO fueled by RON 95

The exhaust gas inlet temperature of ceramic CATCO is at the range of 295.2 to 601.2 ^{0}C, and the outlet temperature is at the range of 238 to 633.2^{0}C. That temperature is separated by speed and engine load where higher engine load in constant speed was generated higher temperature inlet and outlet. The higher speed of 3000 rpm will increase exhaust gas temperature inlet and outlet due to a higher angular speed of crankshaft as compared to the speed of 1000 rpm. Besides, higher engine load of 30% was increased exhaust gas temperature inlet, an outlet due to it will generate higher torque when compared to an engine load of 10%. Those phenomena may lead to higher fuel consumption because it needs to more fuel injection to the engine (Korczewski, 2015).

Exhaust gas temperature inlet and outlet of conventional metallic CATCO is shown in Fig. 5.

It can be clearly shown that temperature inlet has higher than temperature outlet. In different engine load of 10%, 20% and 30% with constant speed shown temperature increment.

Increment temperature inlet and outlet also showed by speed increment. Therefore, the highest temperature inlet and outlet is located at a speed of 3000 rpm and engine load of 30% for 510.6 and 504.4^{0}C, respectively. Meanwhile, the lowest is shown by the speed of 1000 rpm in an engine load of 10% for 265 and 242.8^{0}C. The decrement of outlet temperature is caused by temperature is flowing through the metallic CATCO.

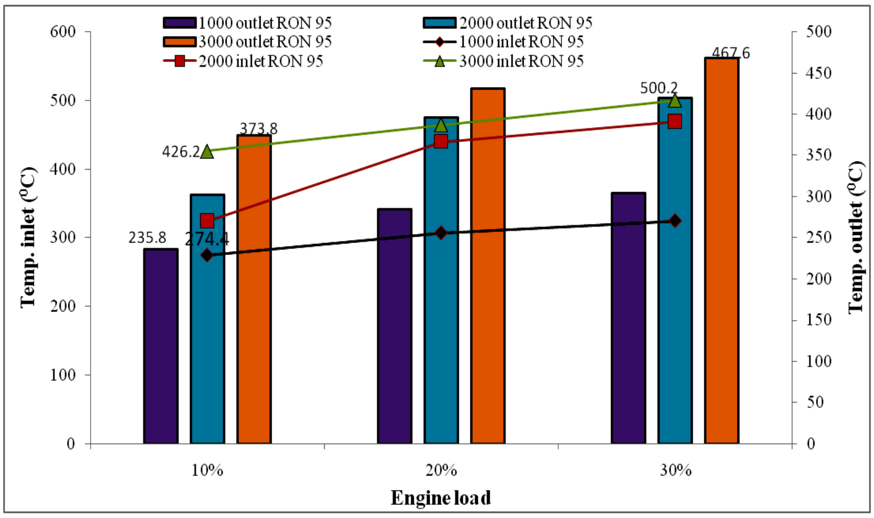

Figure 6. Exhaust gas temperature inlet and outlet of FeCrAl CATCO fuelled by RON 95

Lowest exhaust gas emission of coated FeCrAl CATCO as compared to ceramic and metallic CATCO and the exhaust emission pattern before and after coated FeCrAl CATCO is shown in Fig. 6. Exhaust gas temperature slightly increased in constant speed and higher engine load. It also increased when speed increased and in constant engine load. Exhaust gas temperature of the inlet is more elevated than outlet coated FeCrAl CATCO which means that there is temperature absorption inside coated FeCrAl CATCO. The highest decrement of exhaust gas temperature is located at a speed of 1000 rpm, and engine load of 10% for 14.07% and the lowest decrement is shown by the speed of 1000 rpm and engine load of 30% for 6.28%. It can be concluded that the higher engine load in constant speed will decrease the absorption efficiency. The highest decrement of the exhaust gas temperature potential to reduce the exhaust gas emission such as CO, HC, and NOx due to highest retention time for exhaust gas that flow-through the FeCrAl CATCO.

CONCLUSION

The comparison of ceramic, metallic and FeCrAl CATCO regarding engine performance and exhaust gas temperature has been successfully conducted. The result shows that coated FeCrAl CATCO more effective to reduce FC of 66.42% as compared to conventional ceramic and 3.23% as compared to conventional metallic CATCO. Besides, coated FeCrAl CATCO can increase the torque of 15.79% as compared to conventional ceramic and 5.26% as compared to conventional metallic CATCO. Coated FeCrAl also shows that it has the lowest exhaust gas temperature as compared to conventional ceramic and metallic CATCO. The decrement of exhaust gas temperature of coated FeCrAL CATCO was 30.11% as compared to conventional ceramic CATCO and 20.58% decrement as compared to conventional metallic CATCO. The decrement of exhaust gas temperature related to decrement of FC due to when absorption activity was optimum, then it will increase the performance without increasing the engine load. Therefore, the FC decreased with exhaust gas temperature decreased.

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