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Reduction of CO and HC Emission on ZSM-5 Catalyst Supported on Activated Carbon in Motorcycle Fueled Gasoline-Ethanol Blends

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Abstract: The aims of this research were to find out the characteristics of motorcycle emissions fueled with gasoline-ethanol blends and also the influence of catalytic converter prepared by loading ZSM-5 on activated carbon as the effort to reduce CO and HC emissions. ZSM-5 were loaded in activated carbon with the fraction of mass 10 and 20% by impregnation method. Experimental study was performed in 97.1 cc motorcycle fueled with gasoline and E5, E10 and E20. Emissions gas were measured from exhaust gas and engine speeds were varied from 1300-9000 rpm. Results showed that when motorcycle was fueled with gasoline-Ethanol blends, the concentrations of CO and HC emissions were decrease significantly, compared to the neat gasoline. Gasoline-E20 blends presented the lowest emissions of CO and HC among all test fuels. In addition, CO and HC decrease and CO_2 increase when ethanol content in gasoline increase. Catalytic converter also affected in reduction of CO and HC emissions. By loading ZSM-5 to activated carbon provide higher conversion of CO and HC to CO_2.

Key words: Emission, ethanol, activated carbon, ZSM-5, gasoline

INTRODUCTION

Carbon monoxide (CO) is a colorless, odorless and tasteless gas which abudantly produced from incomplete or partial combustion i.e., combustion that occurs at places which have limited oxygen. CO is a poisonous gas and its accumulation results in varied constellation of symtoms because of its affinity for hemoglobin with which it combines forming carboxyhemoglobin (COHb) and disrubting oxygen tranport (Prakash *et al*., 2010). Althogh, everyone has CO in their blood about<5% (the saturation concentration), those in certain occupation may reach 10% saturation. Healthy individual can survive with blood saturation of 40% for a min or of 20% for a week. Those fatally exposed to the fumes of an internal combustion engine usually have blood concentration of CO >60% (Karapirli *et al*., 2013).

Because of the increasing demand for energy, national worldwide are actively studying alternative clean energy. One of the clean energy is ethanol which employ to lessen carbon monoxide and hydrocarbon emission combustion and to reduce the depletion of petroleum fuel simultanously. As alternative fuel, ethanol have many adventages i.e., ethanol is renewable energy because it can be produced from agricultural feedstock, ethanol is a chemical compounds composed of an ethyl and hydroxyl groups bonded to carbon atom which favor the further combustion of blended fuels within engine cylinders and then reduce CO and HC emissions and ethanol has high octane number which offer higher energy efficiency (Iodice and Senatore, 2014).

Many researchers have efforts to reduce CO emitted from incomplete combustion of internal combustion engine by blending petroleum oil with ethanol or biodiesel (Najafi *et al*., 2015; Krishna *et al*., 2012). Blending gasoline with ethanol also reduce Hydrocarbon Content (HC) because of its oxygen content in ethanol favors the oxydation reaction to be a complete combustion. In addition, the blending affects in reduction of NOx because the higher bleding of ethanol the lower caloric value of fuel which produce low temperature combustion in spark ignition engine (Masum *et al*., 2013). Diesel oil blending with biodiesel have effects in reduction of CO emission by increasing CO_2 but the blending of diesel, biodiesel and ethanol increase CO emission on exhaust gas (Randazzo and Sodre, 2011).

Catalytic converters have been used in engine exhaust after threatment system for more than two

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decades to reduce pollutant emissions. Currenly, catalytic conveters used in vehicle are able to reduce the CO, HC and NOx emission by about 95% provide the electronic engine management and operating temperatures are adequate (Santos and Losta, 2008). Activated carbon has been used as catalyst support in CO emission reduction (Wan *et al*., 2012). Zeolite catalyst is of prime importance in many industrial processes due to the size and shape selectivity of zeolite crystal. Zeolite were found to be potential catalyst for decomposition of NOx and CO from automotive emission and power plants (Limtrakul *et al*., 2000).

According to the literature studies, CO and HC emission from exhaust can be reduced by blending fuels and using catalytic converter. Zeolite is the attractive catalyst which developed as catalystic converter to reduce exhaust emissions. The aims of this research is to find out the characteristics of ZSM-5 loading over activated carbon in CO and HC emissions reduction in exhaust gas motorcycle fueled with gasoline and gasoline-ethanol blends.

MATERIALS AND METHODS

Catalyst preparations: ZSM-5 was purchased from Zeolist International, USA, characterized by Powder X-ray Diffraction (XRD) using CuKα radiation: λ = 1.540598 Å in 2D range of 10-50°. The operating voltage and current were 40 kV and 30 mA. The result of XRD characterization was showed in Fig. 1. The crystalinity of the ZSM-5 was determined by the surface method using the ratio of crystalline peak to the total area as shown in Eq. 1. The crystaline diameter was calculated from its Full Width at Half Maximum (FWHM) as shown in Eq. 2 (Suyitno *et al*., 2015). The crystallinity and crystalline diameter are provided in Table 1. The activated carbon was made of coconut shell was purchased from Bhrataco.

The ZSM-5 was loaded on support (activated carbon) by wet impregnation in ratio of 10 and 20%.wt with destilated water under stirring for 4 h at room temperature. After the process finished, catalyst was dried in 120°C for 4 h to remove water content and calcined under 600°C for 12 h:

$$\text{Crystallinity} = \frac{\text{Total area} - \text{Crystalline peak area}}{\text{Total area}} \quad (1)$$

$$D = \frac{k\lambda}{B\cos\theta} \quad (2)$$

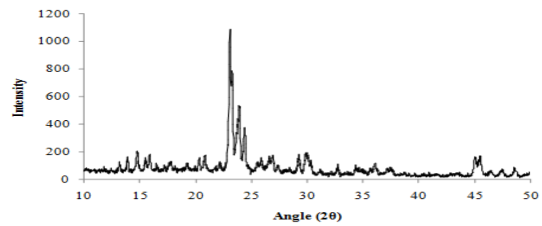

Fig. 1: XRD characterization of ZSM-5

Fig. 2: Catalyst chamber

Table 1: Crystallinity and crystalline diameters of ZSM-5

Peak (2θ)	B (FWHM)	Cristallinity (%)	D (nm)
23.10	0.175	47.94	56.0

Table 2: Fuel properties (Elfasakhany, 2015)

Variables	Gasoline	Ethanol
Molecular formula	C_4-C_{12}	C_2H_5OH
Molecular weight	95-120	46
Oxygen content (%)	0	34.8
Density (kg m^{-3})	740	785
LHV (MJ kg^{-1})	44.3	26.9
Octane number	=88	108
Auto-ignition temp. (°C)	228-470	425
Stoichiometric A/F ratio	14.8	9.00
Latent heat of vapor. (kJ kg^{-1})	305	840
Boiling point (°C)	38-204	78

Preparations of emission tests: Before collecting the test data, the first thing that needs to do were preparing the standard conditions of the machine with tune up, so that the machine was ready to work. Catalyst was placed on exhaust of motorcycle with the modification by adding the catalyst chamber as showed in Fig. 2. The catalyst chamber has dimension 50 mm of diameter and 100 mm of length. Motorcycle cylinder with the bore diameter of 50 and 49.5 mm of stroke was used as engine test to performe the research to find out the emission produced by combustion of gasoline and gasoline-ethanol blends (E5, E10 and E20). The properties of fuels expressed in Table 2. The Engine of motorcycle specifications are summarized in Table 3. The rotation engine speeds were controlled to 1300, 2000, 3000, 4000, 5000, 6000, 7000, 8000 and 9000 rpm. EGA-2000 gas analyzer type was used to measure the emission of CO and HC from exhaust gas of motorcycle. Data obtained from gas analyzer were recorded and drawed graphically to be analyzed.

Table 3: Engine specifications of motorcycle

Engine	SI Engine
No. of cylinders/cycle	One/4 stroke
Ignition system	Spark ignition
Bore x stroke	50×49.5 mm
Displacement volume	97.1 cc
Compression ratio	9.0 : 1
Max. power	7.3 ps @ 8000 rpm
Max. torque	0.74 kg.f @ 6000 rpm
Cooling medium	Air cooled

RESULTS AND DISCUSSION

Effects of fuel blends on emission: Figure 3-5 illustrate the effects of the gasoline-ethanol blends on engine emissions. It is interesting to highlight that by increasing the engine speeds, CO emissions of gasoline and gasoline-ethanol blended fuels are increase by increasing engine speeds until they reach the peak and the they decrease continually until reaching the lowest value while CO_2 increase by increasing the engine speeds. The emissions are related to AFR (Air Fuel Ratio). The stoichiometric AFR for pure gasoline and ethanol are about 14.8 and 9, respectively. Emissions of gasoline and gasoline-ethanol blends are changed with the increase of rotation engine speeds. The emissions are affected by AFR when the engine operate in AFR close to its stoichiometric AFR, it produce low emission due to the complete combustion occur.

The gasoline-ethanol blends fuel show lower emissions of CO and HC. In general, using blended fuels containing ethanol with gasoline results a significant reduction of CO and HC emissions compared to neat gasoline fuel in every rotation speed of engine. The comparation of CO emission for test fuels is shown in Fig. 3. Compare to gasoline, CO emmision of E5, E10 and E20 are reduced by 11.1, 36.8 and 50.2%, respectively in engine rotational speed 5000 rpm. In addition, HC emission on E5, E10 and E20 compared to gasoline are reduced by 40.7, 70.5 and 75.7%, respectively as shown in Fig. 4. The changes in CO_2 emissions have an opposite menner when compared to CO and HC emission. CO_2 emissions increase while the CO and HC emssions decrease as shown in Fig. 5.

The reasons of this trends are ethanol contain oxygen atom in in its basic form. When ethanol added to gasoline fuel, it provide more oxygen for combustion process. Blended fuels can be treated as partially oxidized hydrocarbons. Owning to partially oxidized and the leaning effects of blended fuels, CO and HC emission decrease by increasing of CO emissions. The other reason is about the defference of boilling point between gasoline and ethanol. High boilling point of fuels cause the the fuel may not comprise frictions or components that may not be completely vaporized and burnt, thereby increasing CO and HC emission. Ethanol has lower boliling point than gasoline so, the higher blends ethanol to gasoline composition the lower that the CO and HC emission.

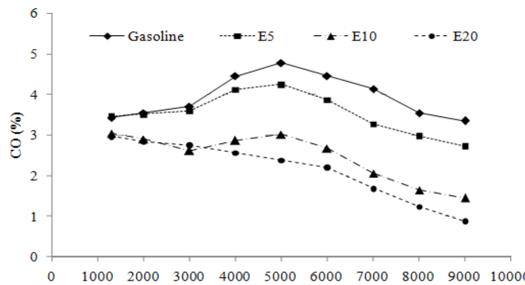

Fig. 3: CO emission on gasoline and gasoline-ethanol blends (E5, E10 and E20)

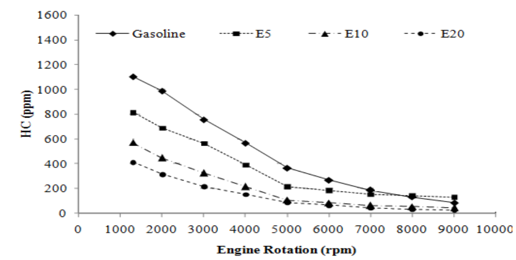

Fig. 4: HC emission on gasoline and gasoline-ethanol blends (E5, E10 and E20)

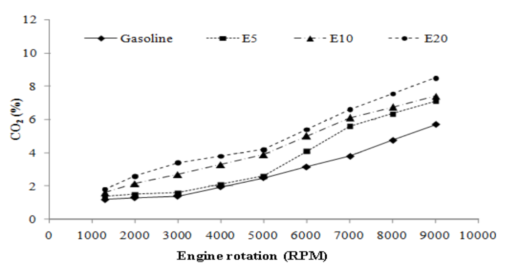

Fig. 5: CO2 emission on gasoline and gasoline-ethanol blends (E5, E10 and E20)

Effects of catalyst on emission: Figure 6-8 illustrate the effect of catalytic conveter toward the emissions of CO, HC and CO_2. Both of CO and HC emissions from exhaust gas are decrease by increasing the engine speeds while CO_2 emissions increase. The increasing engine speeds provide the increasing exhaust temperature which influence the reactions of CO and HC with excess O_2 in catalystic converter surface. The presence of O_2 in exhaust gas favors the direct CO and HC oxidations to CO_2 and H_2O, according to Eq.3 and 4. From Eq. 3 and 4 indicate that the higher conversion CO and HC the higher is CO_2 emited from exhaust gas.

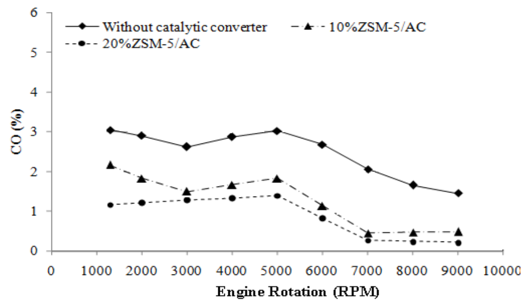

Fig. 6: CO emission on E10

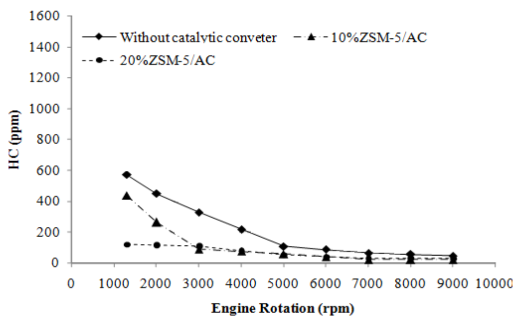

Fig. 7: HC emission on E10

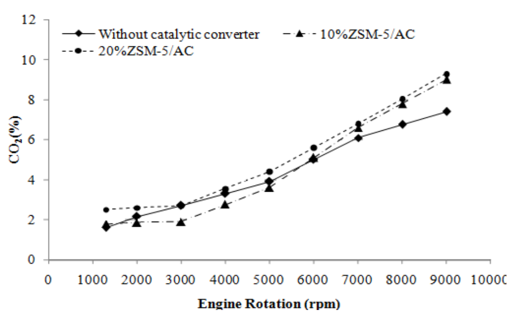

Fig. 8: CO_2 emission on E10

$$2CO + O_2 \rightarrow CO_2 \quad (3)$$

$$C_xH_y + (x + \frac{1}{4y})O_2 \rightarrow xCo_2 + \frac{1}{2y}H_2O \quad (4)$$

Figure 6-8 also show the performance of activated carbon as catalytic converter with the defferent of ZSM-5 loading. The higher ZSM-5 percentage loaded in activated carbon provides higher conversion of CO and HC emissions. The highest reduction of CO and HC performed by activated carbon loaded 20% ZSM-5 catalytic converter, namely 54.0 and 51.9%, respectively in 5000 rpm.

CONCLUSION

The influence of gasoline-ethanol blended fluels and ZSM-5 loaded in activated carbon as catalystic converter have been investigated experimentally. This study results indicated that gasoline-ethanol blends have low pollutant, both CO and HC compared to neat gasoline fuel. However, E20 was the cleaner fuel because it had the lowest emissions CO and HC in every engine speed. Reduction of CO and HC resulted increasing of CO_2 consequenly due to the effect of complete combustion.

Catalystic converter from activated carbon loaded with ZSM-5 was examined in exhaust gas. Activated carbon loaded with 20% ZSM-5 was the most effective catalytic converter to reduce CO and HC emission. In otherhand, by decreasing CO and HC promoted CO_2 emission because of surface oxidation on catalyst.

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