Research article

Effect of Ethanol-Blended Gasoline on the Concentration of Polycyclic Aromatic Hydrocarbons and Particulate Matter in Exhaust Gas of Motorcycle

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Abstract This study focuses on the characteristics of polycyclic aromatic hydrocarbons (PAHs) and fine particulate matter (PM) in six four-stroke motorcycle exhaust emissions. Blend gasoline contains 85% (vol) ethanol (Gasohol E85) and 10% (vol) ethanol (gasohol 91) was used as test fuels. The test motorcycle was driven on a Chassis dynamometer to evaluate the effect of ethanol-gasoline blend on gaseous pollutant emissions. The dynamometer system comprised a cooling fan, a dynamometer, a dilution tunnel, a constant-volume sampler (CVS) unit, a gas analyzer and a personal computer. The exhaust from the test motorcycle was passed to the dilution tunnel. The emissions of PAHs and criteria air pollutants (THC, CO, and NOx) were measured. Measurements were performed on a standard driving cycle. The results show that in comparison to gasohol 91 fuels, the use Gasohol E85 fuels achieved reduction of THC and CO emissions. The emission of THC from gasohol E85 reduced by 4-60% (average 43%) compared with those of gasohol 91 fuels. CO emissions also showed a reduction by 40-95% (average 75%). The concentrations of naphthalene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, and Benzo(g, h, i)perylene were also determined.

Keywords ethanol-blended gasoline, polycyclic aromatic hydrocarbons (PAHs), particulate matter (PM), exhaust emission

INTRODUCTION

Increasing industrialization and motorization have turned polycyclic aromatic hydrocarbons (PAHs) into omnipresent environmental pollutants. PAHs are organic compounds, the derivatives of which are widespread and harmful compounds formed by incomplete combustion. Some PAHs are potential mutagens and carcinogens, and are probably a significant cause of allergic responses and cancer**.** In addition, the oxidized and nitrated reaction products of these compounds have been found to be more potent carcinogens and mutagens than their parent PAHs. Motor vehicles are known to represent a significant source of PAH emissions. Most carcinogenic PAHs have been found to associate with particulates, predominately with fine particulates.

The effects of ethanol-gasoline blend on air pollutant emissions had been investigated in many studies (Al-Hasan, 2003; He et al., 2003; Hsieh et al., 2002; Yüksel and Yüksel, 2004). Most of the studies indicated that ethanol-blended gasoline produced lower CO and THC levels than unleaded gasoline on SI engines. Ethanol-blended gasoline also decreased emissions of air toxic, such as benzene, 1,3-butadiene, toluene, and xylene, with ethanol levels increasing. Air quality issue

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caused by emissions from motorcycle in urban area is critical in Asian cities: China, India, Taiwan, Thailand, and Vietnam. Such as motorcycles contributed up to 30% of CO and 70% of THC among all gasoline powered vehicles in Bangkok (Xie et al., 2004), and account for 28% of CO, 52% of THC, and 19% of NOx in Taiwan (TEPA, 2011). Emission from motorcycle correlates with many parameters, such as fuel property, engine type, driving mode, and exhaust catalyst. However, to our knowledge, there are no data on the particulate matter and PAHs distribution pertaining to emissions from motorcycles for Bangkok and the surrounding province of Thailand in current literature.

This study investigated the effects of ethanol-gasoline blends applied in four-stroke motorcycle on engine exhaust emissions. The Gasohol E85 (E85) and Gasohol 91 (E10) were used as test fuels. The study was to measure only mass of PM and selected gaseous pollutants (THC, CO, CO_2 and NOx). PAHs in the exhaust are also discussed. Emissions inputs are calculated from Thailand's PCD (Pollution Control Department).

OBJECTIVES

1. To analyze PAHs from Gasohol E85 and Gasohol 91 in four-stroke motorcycle exhaust
2. To measure mass of PM and THC, CO, CO_2 and NOx emissions

METHODOLOGY

Table 1 Emission analysis system

Measurement	Pollutants	Analyzer
Direct Measurement	CO/CO_2	Non-Dispersive Infrared(NDIR)
	HC	Non-Dispersive Infrared(NDIR)
	NOx	Chemiluminescence Detector(CLD)
CVS Measurement	CO/CO_2	Non-Dispersive Infrared(NDIR)
	THC	Flame Ionization Detector(FID)
	NOx	Chemiluminescence Detector(CLD)
Weighing	Particulate Matter(PM)	Micro Balance

Blend gasoline contains 85% (vol.) ethanol (Gasohol E85) and 10% (vol.) ethanol (gasohol 91) was used as test fuels. These fuels are a commercial fuel in Thailand. There are 6 motorcycles were selected. The selected four-stroke motorcycles were without any engine adjustment. The motorcycle was placed on chassis dynamometer. The chassis dynamometer was located in a certified laboratory within the motorcycle manufacturer. The main dynamometer system comprises of a dilution tunnel, a constant volume system (CVS) unit, an exhaust gas analyzer and a personal computer. Exhaust samples were collected for the entire cycle; the exhaust gas was initially mixed with air, directed to the CVS unit, and then connected to the sampling bags and analyzer. In this study, the carbon monoxide (CO), unburned hydrocarbons (THC), and oxides of nitrogen (NOx) in the exhaust filtered samples were measured using a non-dispersive infrared analyzer, a flame ionization detection analyzer, and a chemiluminescence detection analyzer, respectively. Particulate matter (PM) emissions were sampled on fiber filters and measured by means of weighing (see Table 1).

PM and particulate PAHs were collected by quartz microfiber filters (diameter 70 mm, flow rate 60 liter per minute for 20 minutes). Two sets of filter holders were employed in this system. Back-up filters were used in each holder downstream the sampling filters to check the breakthrough effects. Two glass cartridges containing polyurethane foam (PUF) plug and XAD-16 resin were used to collect the gaseous PAHs. Before taking the samples, the cleaned filters were stored in a desiccator for at least 8 h for moisture equilibrium before weighing. After the experiments, the filters were brought back to the laboratory and put in a desiccator for 8 h to remove moisture. They were weighed again to determine the net mass of particles collected. After final weighing (only for filter samples), each PAH-containing sample was extracted with a mixed solvent (acetonitrile:

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dichloromethane = 10: 90% v/v) by accelerated solvent extractor (ASE). The extract was then concentrated by purging with ultra-pure nitrogen 130 psi for 60 second to 2 mL for cleanup procedure and re-concentrated to 1.0 mL by evaporator. The concentrations of the following PAHs were determined by a high performance liquid chromatography (HPLC DAD/FLD).

RESULTS AND DISCUSSION

All motorcycles fueled with gasohol 91 (E10) and gasohol E85 (E85) were tested. The results are shown in Fig. 1-Fig. 5 and Table 2. Figure1 shows that a quantity of PM content in the test motorcycle exhaust decreases when adding more ethanol in fuel.

Figure 2 shows that THC emission from all motorcycles fueled with E85 decreases by 4-60% compared to E10 and it was found that the THC emission decreases when adding more ethanol in fuel. Figure 3 shows that CO emission from the motorcycles fueled with E85 decreases around 40-95% compared to fueled with E10 and it was found that E10 has CO more than E85 because incompletely burning of oil unfit engine makes more exhaust emission. The result of CO_2 emission is not significant difference as shown in Fig.4. Figure 5 shows that NOx emission from all motorcycles fueled with E85 is 50-400% higher than E10.

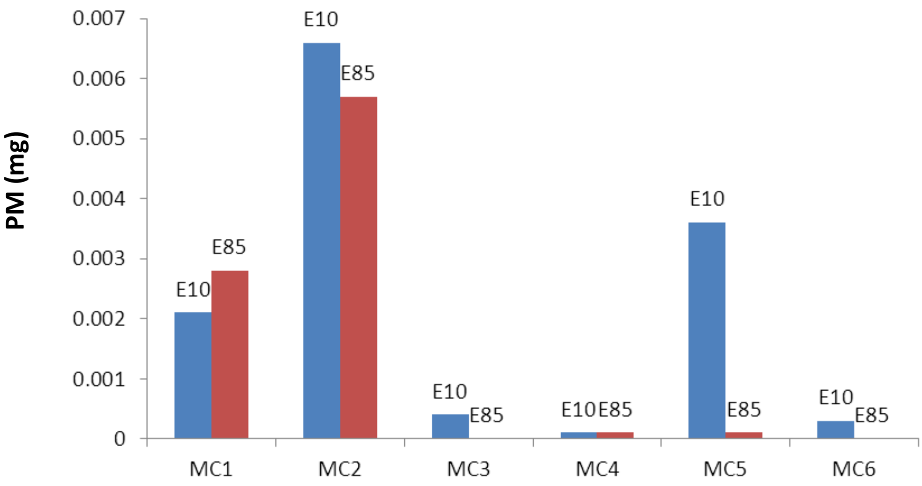

Fig. 1 Emission of PM from four-stroke motorcycle with different fuels

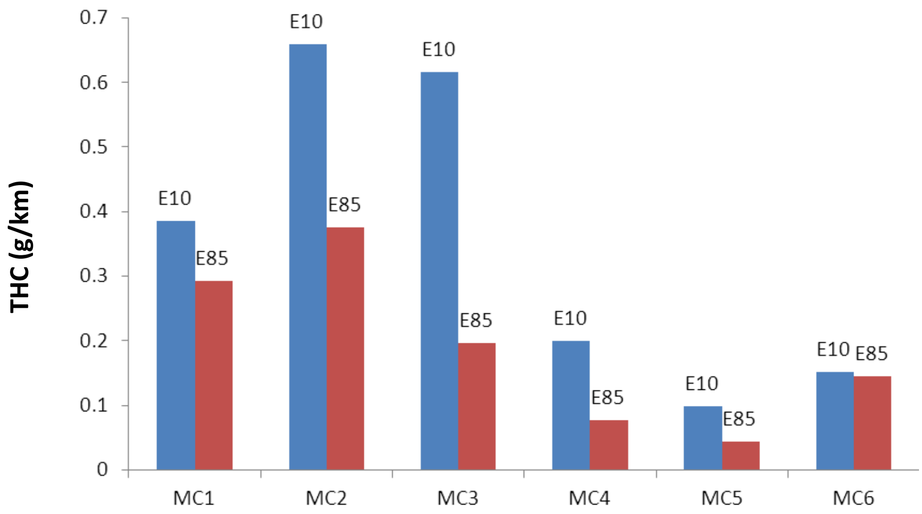

Fig. 2 Emission of THC from four-stroke motorcycle with different fuels

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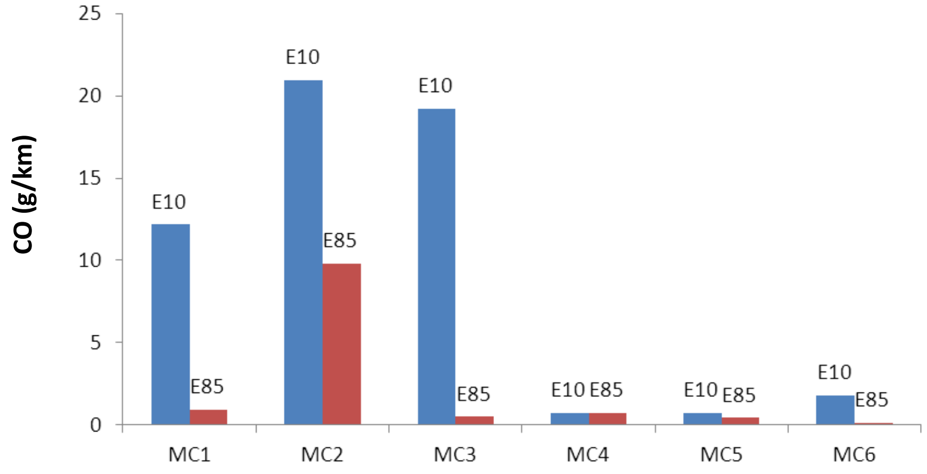

Fig. 3 Emission of CO from four-stroke motorcycle with different fuels

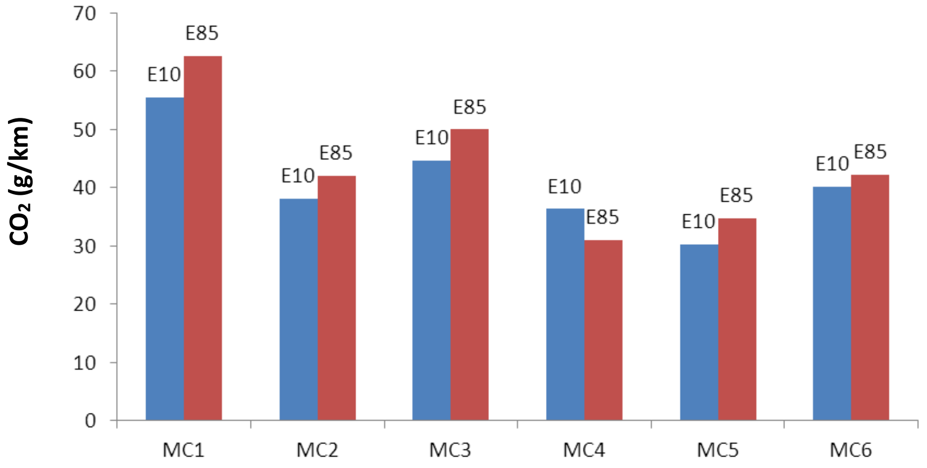

Fig. 4 Emission of CO_2 from four-stroke motorcycle with different fuels

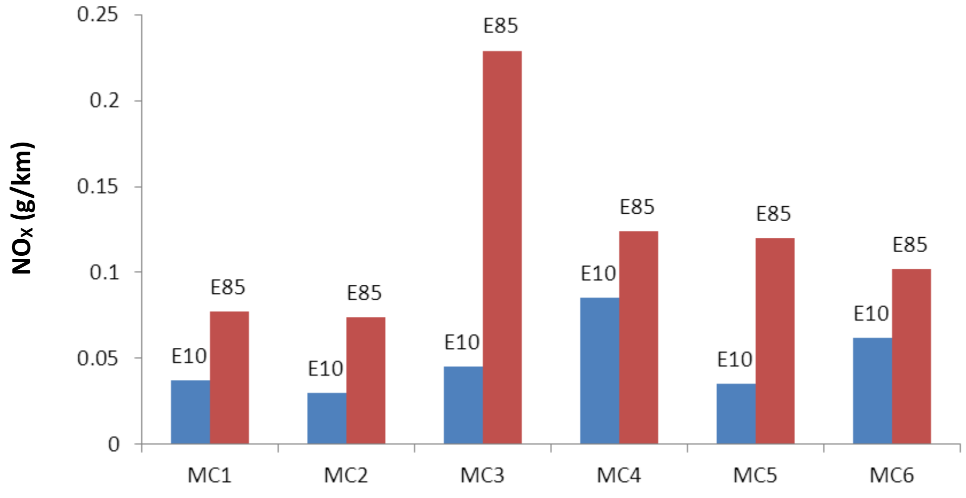

Fig.5 Emission of NOx from four-stroke motorcycle with different fuels

Our findings according to previous studies, it was found that ethanol-gasoline blended fuels (3-30 vol.%) and pollutant emissions are correlated. In general, exhaust HC and CO emissions are lower with oxygenated fuels, but comparable or higher NOx emissions are produced (Furey and

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King, 1980; Hsieh et al., 2002; He et al., 2003). The extent of pollutant reduction depends on ethanol content, air-fuel ratio (AFR), engine operating conditions, type of cars and whether closed-loop fuel is used (Zervas et al., 2002; Al-Hasan). The effect of using an ethanol gasoline blend fuel (ethanol 10 vol.%) on four-stroke motorcycle exhaust emission using chassis dynamometers had been investigated that indicate reductions in CO and HC emissions with an insignificant effect of ethanol on NOx emission(Jia et al., 2005). In addition, the high ethanol-gasoline blend ratio (20%) resulted in a less emission reduction than those of low ratio blends (<15%)(Yao et al., 2009). Furthermore, the effect of ethanol blended gasoline fuel on emission was investigated in Thailand (Sukajit et al., 2011). The exhaust emissions tests on four-stroke motorcycle fueled with E0, E10 and E20 results show that the ethanol blended gasoline fuel results in decreasing of CO emission by 40-70% and it was found that CO emission decreases when adding more ethanol in fuel. Other emissions show no difference.

According to Table 2, it could be seen that many compounds were detected in the exhaust emissions tests on four-stroke motorcycle fueled with E10 and E85. In this study, based on emission amount, the top-5 aromatic hydrocarbons detected were as follows: Naphthalene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene and Benzo(g, h, i)perylene. It was found that ethanol of E10 fuel plays insignificant effect on aromatic emissions, as compared to E85.

Table 2 Emission of PAHs from four-stroke motorcycle with different fuels

PAHs(mg/m^3)	Gasohol 91(E10)					
	MC1	MC2	MC3	MC4	MC5	MC6
Naphthlene	0.03	0.05	0.04	0.04	0.03	0.03
Chrysene	‹0.025	1.51	0.15	‹0.025	‹0.025	0.05
Benzo(a)anthracene	‹0.025	1.3	0.03	ND	ND	0.03
Benzo(b)fluoranthene	‹0.025	1.33	0.14	ND	‹0.025	0.04
Benzo(g,h,i)perylene	0.06	1.87	0.47	ND	‹0.025	0.05
	Gasohol E85 (E85)					
PAHs(mg/m^3)	MC1	MC2	MC3	MC4	MC5	MC6
Naphthlene	4	0.1	‹0.025	0.06	0.04	0.04
Chrysene	<0.025	1.25	ND	0.04	ND	ND
Benzo(a)anthracene	ND	0.96	ND	<0.025	ND	ND
Benzo(b)fluoranthene	ND	1.33	ND	<0.025	ND	ND
Benzo(g,h,i)perylene	ND	2.16	ND	ND	ND	ND

CONCLUSION

This study investigated the emissions of THC, CO, CO_2 and NOx emissions for four-stroke motorcycles using E10 and E85 gasoline/ethanol blended fuels. In comparison with E10, using E85 as fuel reduces the emission of THC and CO by 4-60% and 40-95% respectively. In contrast, the emission of NOx emission is increased by 50-400% using E85. The CO_2 emissions are not significant difference. The PM and PAHs were analyzed. The results were found that PM decreases when fueled with E85 and PAHs: Naphthalene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene and Benzo(g, h, i)perylene emissions for four-stroke motorcycles using E10 and E85 as fuels are not significant difference.

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