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PAH emissions and energy efficiency of palm-biodiesel blends fueled on diesel generator

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Abstract

This study investigated the emissions of polycyclic aromatic hydrocarbons (PAHs), carcinogenic potencies (BaP_{eq}) and particulate matter (PM), fuel consumption and energy efficiency from the generator under steady state for seven test fuels: P0 (Premium Diesel Fuel), P10 (10% palm biodiesel + 90% P0), P20, P30, P50, P75 and P100. Experimental results indicated that PAH emission decreased with increasing palm-biodiesel blends due to small PAH content in biodiesel. The mean reduction fraction of total PAHs emission factor ($P0 = 1110\,\mu g\,L^{-1}$) from the exhaust of diesel generator were 13.2%, 28.0%, 40.6%, 54.4%, 61.89% and 98.8% for P10, P20, P30, P50, P75 and P100, respectively, compared with P0. The mean reduction fraction of total BaP_{eq} ($P0 = 1.65\,\mu g\,L^{-1}$) from the exhaust of diesel generator were 15.2%, 29.1%, 43.3%, 56.4%, 58.2% and 97.6% for P10, P20, P30, P50, P75 and P100, respectively, compared with P0. PM emission decreased as the palm-biodiesel blends increased from 0% to 10%, and increased as the palm-biodiesel blends increased from 10% to 100% because the soluble organic fraction of PM emission was high in blends with high palm-biodiesel content. The brake specific fuel consumption rose with rising palm-biodiesel blends due to the low gross heat value of palm-biodiesel. The increasing fraction of BSFC of palm-biodiesel was lower than those of soy-, soapstock-, brassica-carinate and rapeseed-biodiesel. Palm-biodiesel seems to be the most feasible biodiesel. The best energy efficiency occurred between P10 and P20, close to P15. The curve dropped as the palm-biodiesel content rose above P20. Above results revealed that palm-biodiesel was an oxygenated fuel appropriate for use in diesel engines to promote combustion efficiency and decrease PAH emission. However, adding an excess of palm-biodiesel to P0 leaded to incomplete combustion in the diesel-engine generator and inhibited the release of energy in the fuel.

Keywords: Toxic; Carcinogenic potencies; Biofuel; Generator; Exhaust

1. Introduction

Alternative fuels such as biodiesel are popularly discussed in many countries owing to increased environmental awareness and the rising price of diesel. Developing alternative diesel fuels is driven by the necessity to reduce the environmental impact of emissions without modifying engines. Biodiesel

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was produced from animal fats or vegetable oils with methanol or ethanol as the catalyst by transesterification reaction. Using biodiesel instead of diesel reduces the fuel consumption. Furthermore, regarding some countries producing few agricultural products, some unutilized land can be applied to produce non-food products, such as biodiesel, for the domestic energy market to lower imports (Kalam and Masjuki, 2002). US Environmental Protection Agency and Food & Drug Administration verify biodiesel as clean alternative fuel or additional fuel. Additionally, US Congress has passed legislation allowing Federal and State fleet managers to meet the Energy Policy Act (EPACT) alternative fuel vehicle acquisition requirements by using biodiesel added to conventional diesel at a blend of 20% and higher.

Biodiesel is a highly oxygenated fuel that can be used in diesel engines to improve combustion efficiency. Many studies have focused on emission of particulate matter (PM), nitrogen dioxide (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), total hydrocarbons (THC) and polycyclic aromatic hydrocarbons (PAHs) from diesel engines fueled with biodiesels made from coconut oil, olive oil, sunflower oil, Brassica carinara and rapeseed oil. Biodiesel used as alternative fuel in diesel engine can reduce HC, CO, CO_2, SO_2, and PAHs emissions, and slightly increases the brake specific fuel consumption (BSFC) (Wang et al., 2000; Monyem and Van Gerpen, 2001; Cardone et al., 2002; Antolin et al., 2002; Durbin and Norbeck, 2002; Kalam et al., 2003; Dorado et al., 2003; Kalligeros et al., 2003; Beer et al., 2002). However, the positive or negative effect on PM emissions varied significantly among vehicles (Wang et al., 2000; Durbin et al., 2000; Peterson et al., 1996), biodiesel (Kalligeros et al., 2003; Peterson et al., 1996; Schumacher et al., 1996; Mccormick et al., 2001; Haas et al., 2001; Durbin et al., 2000; Lee et al., 2004) and load (Kalligeros et al., 2003). Thus, what biodiesel is better than other biodiesel? How does the addition of different biodiesel fractions affect fuel performance? Palm-biodiesel is cheaper than both soybean-biodiesel and corn-biodiesel (Table 1). The physico-chemical properties of palm-biodiesel meet the requirement of diesel engine combustion, and are comparable with those of other biodiesels such as soybean and rapeseed oils (Kalam and Masjuki, 2002; Wibulswas et al., 1999). Thus, palm-biodiesel has a higher potential for commercial application than other biodiesels.

Table 1
Biodiesel price from various vegetable oil

Biodiesel	Price (US$ tonne^{-1})
Palm-biodiesel[a]	710
Soybean-biodiesel[a]	1100
Corn-biodiesel[a]	1500

[a]Kalam and Masjuki (2002).

Furthermore, the preheating of crude palm oil (CPO) lowered CPO's viscosity, provided smooth fuel flow and avoided fuel filter clogging (Bari et al., 2002). Preheated CPO reduced lower emissions of CO, HC, and PM than ordinary diesel (OD) and CPO emulsified fuels mainly because preheating CPO reduced its viscosity to that of OD, improving the fuel spray and atomization characteristics and resulting in complete combustion. However, preheated CPO increased NOx emission as compared OD and CPO emulsified fuels, as determined from the deposit characteristic result, and showing that preheated CPO increased the highest fraction of ash deposit as compared with OD, which is the reason for the increasing NO_x emission (Kalam and Masjuki, 2004). On the other way, pure palm oil is adaptable for use in diesel-generator. Although reducing exhaust NO_x emission, pure palm oil increased exhaust emissions such as CO, CO_2, HC and resulted in an increase in the specific fuel consumption as compared with diesel oil (Almeida et al., 2002).

Although biodiesel as alternative fuels has been widespreadly investigated in diesel engines, but the emission of PAHs, their carcinogenic potencies (BaP_{eq}) and energy efficiency from the generator fueled with palm-biodiesel blends has seldom been addressed. Generators have been applied for emergent electric power in mansions. Furthermore, industries have expanded rapidly in some countries, but electric cables have not been installed popularly in some area, leading to the widespread use of diesel generators. No known study has focused on the PAH emission from the palm-biodiesel diesel generator. Hence, palm-biodiesel was selected in this study. This study investigates the PAH content in premium diesel fuel. Additionally, the parameters of PAH and PM emission from diesel-generator exhaust are compared and discussed. Finally, the input/output ratio of PAH, energy efficiency, feasibility of palm-biodiesel blends in diesel generators and optimum percentage of biodiesel in fuel blends are assessed.