Fuel 203 (2017) 894–914

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Full Length Article

Effect of premixing ratio, injection timing and compression ratio on nano particle emissions from dual fuel non-road compression ignition engine fueled with gasoline/methanol (port injection) and diesel (direct injection)

Mohit Raj Saxena, Rakesh Kumar Maurya *

Advanced Engine and Fuel Research Laboratory, Department of Mechanical Engineering, Indian Institute of Technology Ropar, Rupnagar 140001, India

HIGHLIGHTS

- Effect of premixing ratio, injection timing & compression ratio on soot particles is investigated.
- Study conducted using gasoline and methanol premixing in a stationary diesel engine.
- Total particle number concentration increases with increase in fuel premixing ratio.
- Increase in premixing ratio increases the nucleation mode particle numbers.
- Methanol-diesel dual fuel operation has a higher particle number as compared to gasoline.

ARTICLE INFO

Article history:
Received 26 February 2017
Received in revised form 3 April 2017
Accepted 3 May 2017
Available online 17 May 2017

Keywords:
Dual fuel
Gasoline
Methanol
Diesel engine
Soot particles
Combustion

ABSTRACT

In present study, the effect of fuel premixing ratio, direct fuel injection timings and engine compression ratio on the soot particle emissions in nano-size range from a non-road compression ignition engine is investigated. Experiments are conducted on modified dual fuel single cylinder engine at 1500 rpm. To run the engine in dual fuel mode, port fuel injection (PFI) system is installed by modifying intake manifold of the engine and developing a PFI controller. Experiments are conducted for various fuel premixing ratio of gasoline/methanol-diesel at different engine load, diesel fuel injection timing and compression ratios. Differential mobility spectrometer based particle sizer is used for investigation of the soot particle number-size distribution, surface area-size distribution, particle mass-size distribution and total particle number concentration from the engine exhaust at various test conditions. Results revealed that total particle number concentration is higher at full engine load and increases with fuel premixing ratio (especially in case of methanol-diesel dual fuel operation). Additionally, the peak particle number and mass concentration reduces with an increase in compression ratio of the engine.

1. Introduction

Urbanization and expansion of economy leads to increase in number of vehicles, while the petroleum resources are depleting rapidly. Transportation sector is one of the major source of air pollution throughout the world, which is increasing with increase in number of vehicles running on fossil fuels. Rapid depletion of crude oil resources and stringent emission mandates demands an alternative fuel and/or alternative combustion strategy for combustion engines. Diesel engines are widely used in automotive vehicles as well as in power generation due to their higher thermal efficiency and power output. Main demerit of diesel engines are higher emissions of nitrogen oxides (NO_x) and soot particles. These emissions have a detrimental effect on the human health [1] as well as on the environment. To meet the emission mandates, presently vehicles are equipped with post-treatment devices (such as the diesel particulate filter, lean NO_x trap etc.). However, these devices have a negative impact on the fuel economy of the engine. In the past few decades, several alternative fuels are proposed for diesel engine such as biodiesel, butanol, methanol etc., which can be used as either blended or dual injection mode [2–7]. Alptekin [2] investigated the combustion and emission characteristics of common rail direct injection diesel engine fueled with canola-safflower

* Corresponding author.
E-mail address: rakesh.maurya@iitrpr.ac.in (R.K. Maurya).

http://dx.doi.org/10.1016/j.fuel.2017.05.015
0016-2361/

biodiesel + additives (such as solketal and ethanol)/diesel blends at different engine speeds. Their results indicate that biodiesel/diesel blends have higher brake specific fuel consumption (BSFC) as compared to neat diesel. Study also reported that the fuel injection timing highly depends on fuel type and engine speed. Additionally, biodiesel emits higher carbon dioxide (CO_2) and nitrogen oxide (NO_x) emissions while total unburned hydrocarbon (THC) and carbon monoxide (CO) were reduced as compared to diesel [2]. Gharehghani et al. [3] experimentally investigated the effect of biodiesel/diesel blends on the combustion and emission characteristics of diesel engine. Their results reveal that biodiesel leads to higher peak in-cylinder combustion pressure and shorter heat release rate duration as compared to diesel. Results demonstrate that for all the tested load conditions, biodiesel has a 2.92% higher gross indicated thermal efficiency as compared to diesel fuel. CO and unburnt hydrocarbon (uHC) emissions were reduced with biodiesel/diesel blends while CO_2 and NO_x emissions increases [3]. A study demonstrates that the alcohol blended fuels have a slightly higher thermal efficiency as compared to neat diesel [6]. Additionally, CO and HC emissions can be reduced with biofuel/diesel blended fuels. A study also reported that NO_x emission increases while particulate matter emission reduces with alcohol/diesel fuel blends [6]. These studies [2–7] mainly focuses on the performance, combustion and emission characteristics of the diesel engine fueled with various blended fuels in different proportions. However, due to some limitations (such as the higher viscosity of biodiesel, clogging of deposits in engine, large scale production etc.), proposed alternative fuels are not presently used in commercial vehicles on very large scale in most of the countries. Currently, methanol has been investigated very intensively because of its inimitable properties (such as higher oxygen content and latent heat of vaporization etc.) and it is a renewable fuel. Alcohols such as methanol, ethanol can be used in diesel engines in two ways, i.e. either blended with diesel and additives or separately injected. Conventional diesel engine has long struggled NO_x and PM trade-off. Dual fuel combustion mode has a potential to reduce the NO_x and soot emissions simultaneously [25].

Various studies have been conducted to explore the different aspects of combustion and emission characteristics of dual fuel based diesel engine [8–22]. Prashant et al. [8,9] focused on the combustion characteristics of the diesel engine fueled with blends of ethanol/diesel and methanol/diesel. Their results demonstrate that pressure rise rate increases with ethanol/methanol substitution as compared to neat diesel. Studies [11,12] investigated the performance, combustion and emission (CO, HC, NO_x, CO_2 and smoke) characteristics of the dual fuel diesel engine. Senthilraja et al. [11] investigated the impact of ethanol, diesel, cotton seed oil methyl ester and CNG on the combustion, performance and emission characteristics of normal as well as on dual fuel combustion mode. Their results demonstrate that CO_2 and NO_x emission decreases at all the tested conditions with blended fuel and dual fuel (blended fuel with CNG) while HC and CO emissions were higher for both the combustion modes. Bora et al. [13] investigated the impact of compression ratio on the performance, combustion and emission characteristics of raw biogas-diesel dual fuel engine. They reported that the brake thermal efficiency decreases with reduced compression ratio and it is lower in dual fuel combustion mode as compared to the normal diesel combustion mode. Their results also reveals that CO and HC emissions decreases while CO_2 and NO_x emission increases with change in compression ratio from 16 to 18.

A study was carried to determine the impact of compression ratio (CR) on performance, combustion and emission (CO, CO_2, NO_x and HC) characteristics of biogas and rice bran biodiesel dual fuel diesel engine [14]. This study also showed that CO and HC emissions are reduced in dual fuel combustion mode while NO_x and CO_2 emission increases as compared to neat diesel fuel for the same compression ratio. In another study Bora and Saha [15] optimized the fuel injection timing and compression ratio of biogas-diesel dual fuel engine. Their results demonstrate that a combination of 18 compression ratio and 29° bTDC injection timing is an optimum combination for maximum brake thermal efficiency with biogas-diesel dual fuel engine. Yaliwal [16] determined the impact of nozzle and combustion chamber geometry on the performance and emission characteristics of honge methyl ester-producer gas and diesel-producer gas dual fuel engine. Maximum performance was observed for 200 bar fuel injection pressure, 0.25 mm nozzle orifice with 4 holes and re-entrant type combustion chamber. The impact of compression ratio, fuel injection timing and CNG flow rate on the performance, combustion and emission characteristics of honge oil methyl ester and CNG dual fuel engine was investigated [17]. The study indicated that an increase in the CR with advanced fuel injection timing and low CNG flow rate, leads to improve the performance of honge oil methyl ester and CNG dual fuel engine and reduces the HC, CO and smoke emissions while NO_x emission increases. Wei et al. [18] experimentally investigated the impact of pilot injection on the combustion and regulated-unregulated emissions in a methanol/diesel dual fuel turbocharged diesel engine. Their results indicate that pilot injection may reduce the cyclic variations. In addition to this, CO and THC emissions are reduced while NO_x emission increases with pilot injection. With an advanced pilot injection timing and higher fraction, pilot injection fuel leads to increase in the NO_x emission while HC and CO emissions reduces. However, these studies mainly focus on the performance, combustion and gaseous emission characteristics of dual fuel diesel engine fueled with different combination of fuels. Wang et al. [19] investigated the combustion characteristics of methanol-diesel dual fuel diesel engine. An increase in the fraction of methanol leads to reduce the temperature at bottom dead center (BDC) and top dead center (TDC) as well as reduce the polytropic index during compression stroke. It results in longer ignition delay for same engine operating conditions as compared to single diesel fuel operation [19]. Their results indicate that NO_x and smoke emissions reduces while CO and HC emissions increase with methanol-diesel dual fuel operation [19]. A study numerically investigated the impact of methanol addition (in the intake manifold) on the performance and NO_x emissions characteristics of diesel engine using one-dimensional simulation [20]. Their results indicate that peak in-cylinder pressure and temperature decreases with increase in the fraction of methanol. Moreover, lower combustion efficiency obtained with methanol-diesel dual fuel operation and significant increase in NO_x emission observed with methanol-diesel dual fuel operation [20]. Chen et al. [21] experimentally investigated the effect of methanol fuel injecting position on cylinder to cylinder variations in methanol-diesel dual fuel engine. Their results reveal that with retard diesel injection timing cyclic variations in each cylinder were reduced. Variations were also lower when methanol injectors were installed at intake manifold and at distal end of inlet duct as compared to when injectors were installed at the end of inlet duct. With an increase in the methanol fraction, the cylinder to cylinder variations were increased. Results also indicate that THC and CO emissions were increased while soot emissions were reduced with increase in methanol fraction [21]. Li et al. [22] investigated the impact of direct fuel injection events on the combustion and emission characteristics of heavy-duty methanol-diesel dual fuel engine. Their results reveal that fuel injection events has a significant effect on the rapid combustion fraction. It increases with an increase in fuel injection pressure and decreases with increase in diesel fuel fraction or with advanced diesel injection timing [22]. Their results also indicate that smoke and NO_x emissions are lower in methanol-diesel dual fuel combustion while HC and