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Full Length Article

A study on combustion and emission of GCI engines fueled with gasoline-biodiesel blends

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HIGHLIGHTS

- The GCI engine fueled with gasoline-biodiesel blends is studied.
- Various starts of injection with single injection strategy are introduced.
- Injection quantity was not affected by small value of backpressure below 3 MPa.
- The earlier SOI of gasoline-biodiesel blends allowed higher thermal efficiency.
- HC and NOx emission can be reduced by retarded SOI of gasoline-biodiesel blends.

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ABSTRACT

An experimental study was conducted on a single cylinder gasoline compression ignition (GCI) engine for gasoline-biodiesel (GB) blends from 5 to 20% by volume with varying starts of injection (SOI). In particular, the aim was to examine the combustion phenomena and exhaust emissions of the engine for the various SOI and chosen GB blends compared with neat diesel fuel. The engine was running with 1200 rpm, 70 MPa of injection pressure, 800 μs of injection duration and various SOI from early injection timing (before top dead center (BTDC) 75°CA) to around top dead center (TDC) BTDC 18°CA. The results showed that the earlier the SOI of GB blends, the shorter the ignition delay compared to diesel fuel. Besides, the GB blends resulted in almost the same combustion duration as diesel fuel both for earlier and later SOI. The coefficient of variability (COV) of IMEP GB blends (under 3%) for every SOI is clear evidence of combustion stability. Furthermore, the thermal efficiency for GB blends was found to be almost equivalent with diesel fuel for all conditions. In the case of emission, GB blends produce lower HC compared to diesel, as expected, because of their homogeneous mixing capabilities. However, a higher NOx emission from GB blends was observed, which might be a result of excess oxygen in the fuel.

1. Introduction

Gasoline with high volatility has low ignitability and a high octane number, so it is called low reactivity fuel [1]. This fuel is appropriate for spark ignition (SI) or gasoline engines. However, the main problem with this application is knocking combustion as a limitation of the SI engine, which only operates at low compression ratios, around 8–11. The disadvantage of a low compression ratio is that it is low efficient. A spark plug is usually required in a gasoline engine application to provide spark ignition at the end of the compression stroke. Gasoline engines usually operate in near stoichiometric mixtures, which use high-temperature combustion and produce NOx emissions [2].

Contrary to gasoline, which has a low octane number and high cetane number, diesel fuel is the so-called high reactivity fuel. Diesel fuel, with its high carbon levels and heavier molecular weight, has low volatility but high ignitability or high auto ignition characteristics. The requirements for auto ignition are high pressure and high temperature; therefore, diesel engines are usually operated at high compression ratios from 16 to 22. Since a high compression ratio is applied, diesel engines have high thermal efficiencies. However, diesel engines also have many disadvantages. One of the most familiar disadvantages of diesel engines is that they produce large amounts of particulate matter or soot [2–4].

To obtain high efficiency with low emission from a diesel engine, many researchers have been working on homogeneous

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Nomenclature

B	biodiesel	IMEP	indicated mean effective pressure
B100	100% biodiesel	IVC	intake valve closure
BTDC	before top dead center	IVO	intake valve opening
CA	crank angle	LHV	lower heating value
CA50	combustion phasing (50% of heat release)	LTC	low temperature combustion
CI	compression ignition	LTHR	low temperature heat release
COV	coefficient of variability	MOE	Ministry of Education
D100	100% diesel	MPa	mega pascal
EGR	exhaust gas recirculation	N_2	nitrogen gas
EVC	exhaust valve closure	NOx	nitrogen oxides
EVO	exhaust valve opening	NRF	National Research Foundation
G	gasoline	PCCI	premixed charge compression ignition
GB	gasoline-biodiesel	PM	particulate matter
GB00	100% gasoline	PPRR	peak of pressure rise rite
GB05	blend of 95% gasoline & 5% biodiesel	RTD	resistance temperature detector
GB10	blend of 90% gasoline & 10% biodiesel	SOHC	single overhead cam
GB15	blend of 85% gasoline & 10% biodiesel	SOI	start of injection
GB20	blend of 80% gasoline & 20% biodiesel	TDC	top dead center
GCI	gasoline compression ignition	THC	total hydrocarbons
HC	hydrocarbons		
HCCI	homogeneous charge compression ignition		
HRR	heat release rate		

charge compression ignition (HCCI) and premixed charge compression ignition (PCCI) concepts. HCCI is known as an attractive combustion mode for low-temperature combustion achieved under uniformly lean conditions [5]. Premixed Charge Compression Ignition (PCCI) is a combustion concept that is characterized by low temperature, partially premixed combustion using early injections, large ignition delays and high percentages of Exhaust Gas Recirculation (EGR) [6].

In recent years, gasoline compression ignition (GCI) combustion has become a topic of research due to its potential for very high thermal efficiencies with very significant pollution reduction [7,8]. GCI as dual fuel is a new concept, which has more potential than HCCI and PCCI [6,9–12]. The advantages of GCIs are high thermal efficiencies compared to gasoline engines, low NOx and soot emissions and low combustion temperatures [7]. However, there are several disadvantages, including the required high intake temperature, low lubricity and need for a high compression ratio.

It is possible to obtain low temperature combustion (LTC) by using an appropriate modification of fuel properties, for example, a lower cetane number and higher volatility [13,14], such as in the GCI engine concept [15]. The LTC concept offers the potential to reduce NOx and particulate matter (PM). The longer ignition delay of gasoline with high octane number allows sufficient mixing of fuel and air, and then the thermal efficiency is improved by increasing pre-mixing combustion that results in low NOx and soot levels [13]. For this reason, many researchers have been working consistently on the GCI engine. For example, Loeper [16] identified and quantified the effects of varying input parameters on overall engine operation. The input parameters include inlet temperature, inlet pressure, injection timing/duration, injection pressure and variation in engine speed. The results showed that input parameters could be manipulated effectively to maintain low NOx emissions and good combustion stability. In studies of the GCI, Loeper [17] conducted an experimental and computational assessment of inlet swirl effects on a GCI light-duty diesel engine. The most interesting result of the study is that in the light-duty engine application, varying the inlet swirl ratio had significant effects on combustion phasing, i.e., CA50.

Biodiesel has a strong potential to solve several problems in GCI engine applications, such as low lubricity when blended with gasoline. Due to the high oxygen content in biodiesel, complete combustion is also possible [18]. Adams [12] studied the effect of biodiesel-gasoline blends on GCI combustion by using 5 and 10% biodiesel. The study used an engine with a compression ratio of 16.6:1. The double injection model, which consists of early pilot injection followed by main injection, was used in the study. The air intake, oil, and coolant temperature were manipulated to overcome the resistance to auto-ignition of the fuel.

Increasing the compression ratio may result in further improvements in the ignition delay, which may overcome obstacles to auto ignition. By adding biodiesel at an appropriate level to gasoline, auto ignition and combustion performance of a GCI engine can be improved. Further study on the properties of the blends is necessary, especially for stability due to the large density difference between gasoline and biodiesel. According to Misra [18], a key property of biodiesel that currently limits its application to blends of 20% or less is its relatively poor low-temperature properties. A conventional fuel containing 25% biodiesel blend was observed to be the best-suited blend for an engine without heating and without any engine modification [19]. Tinprabath [20] mentioned that fuel blends with less than 5% biodiesel do not affect cold flow properties. However, it is important to understand the behavior of the fuel injector under these conditions for the different fuels. Manipulation at the start of injection is also likely to improve combustion when the CI engine operates in single injection mode.

This study discusses a GCI engine fueled with biodiesel blended into gasoline in some percentage by volume with single injection mode and variable start of injection. The objectives of blending a small amount of biodiesel into gasoline were to increase cetane number, against auto ignition resistance and increase oxygen content to reduce emissions. This study uses a common rail injection system to obtain stable high-pressure fuel with a homogeneous injection process. The injection flow rate of several fuels with various injection pressures is presented and discussed in this paper. Combustion characteristics such as cylinder pressure, heat release rate, combustion stability, ignition delay and emission characteristics were also discussed.