Energy Conversion and Management 152 (2017) 57–64

Contents lists available at ScienceDirect

Energy Conversion and Management

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

Thermodynamic process and performance of high *n*-butanol/gasoline blends fired in a GDI production engine running wide-open throttle (WOT)

Zheng Chen, Yanqun Zhang, Xiaotai Wei, Quanchang Zhang*, Zhenkuo Wu, Jingping Liu

State Key Laboratory of Advanced Design and Manufacturing for Vehicle Body, Hunan University, Changsha 410082, China
Research Center for Advanced Powertrain Technology, Department of Energy and Power Engineering, Hunan University, Changsha 410082, China

ARTICLE INFO

Keywords:
Gasoline Direct Injection (GDI)
n-Butanol
Ethanol
Combustion
Efficiency
Wide-open throttle (WOT)

ABSTRACT

A turbocharged Gasoline Direct Injection (GDI) engine fueled by *n*-butanol/gasoline blends is studied under the condition of wide-open throttle (WOT) in this paper. The effects of high *n*-butanol content (30% and 50% *n*-butanol by volume, i.e. Bu30 and Bu50) on the thermodynamic process and fuel efficiency of the GDI engine are discussed, as well as the engine emissions. Also, the results are compared with RON 93 gasoline and 10% ethanol/gasoline blended fuel (E10), which have been widely used in cars. The results show that high content of butanol addition can be realized in the GDI engine without any modification to its structure and control. Moreover, the maximum BMEP of the engine can increase to 1.99 MPa with Bu50. As compared with the gasoline and E10, high *n*-butanol/gasoline blends increase in-cylinder combustion pressure and pressure rise rate, promote ignition, and shorten burning duration. What is more, high *n*-butanol/gasoline blends improve combustion stability and decrease exhaust temperature, but they cannot deteriorate anti-knock quality. However, high *n*-butanol/gasoline blends increase Brake Specific Fuel Consumption (BSFC), and they decrease combustion efficiency and Brake Thermal Efficiency (BTE) at WOT. As for the engine emissions, high *n*-butanol/gasoline blends increase UHC and CO emissions but reduce NOx and CO_2 emissions. The study implies that 0–50% butanol/gasoline blends can directly replace the existing engines fueled with regular RON 93 gasoline or E10.

1. Introduction

In order to face the fossil fuel shortage and the increasing strict emission regulation, there is a great interest to find the clean and renewable energy, especially in the automotive industry. Represented by the United States, Renewable Fuel Standard (RFS) program, which was created in 2005 and modified in 2007, demands 36 billion gallons renewable fuel to be blended into gasoline and diesel by 2022 [1]. There are all kinds of renewable fuels including hydrogen, natural gas, alcohols, and so on. The utilization of alcohols, which are oxygenated, has been important because of their low global warming potential, good combustion characteristics and availability [2]. Ethanol, as one kind of alcohol fuel, is most commonly used along with gasoline in Spark Ignition (SI) engines due to its high octane number, high volatility and diesel insolubility [3]. E10 (10% ethanol) and E85 (85% ethanol) ethanol/gasoline mixtures are widely used as substitutes for gasoline by the US and many other countries [4].

Butanol, attracted much attention in recent years, has things in common with ethanol. Both of them are oxygenated and can be blended with gasoline in SI engines. In addition, butanol and ethanol can be produced in a similar renewable process [5], so they are considered as potential biofuels. Compared with fossil-based gasoline, especially, corn-based *n*-butanol as a transportation fuel could save about 39–56% fossil fuel while reducing greenhouse gas emissions by up to 48% on a lifecycle basis [6]. However, butanol also has some advantages over ethanol. Firstly, butanol has higher energy density, higher viscosity and better blending ability than ethanol, so it is more suitable as blended fuel with both gasoline and diesel. And it can be used alone in SI engines without great modification due to its closer resemblance to gasoline in fuel properties [1,7]. Furthermore, butanol is less corrosive and hygroscopic than ethanol, so it can be blended more easily with gasoline without phase separation, which will be compatible with the current fuel distribution infrastructure [8]. Recently, the productivity of butanol has been greatly improved through the utilization of gene technologies on bacteria [9,10], which makes butanol become a promising alternative fuel.

n-Butanol, which has a straight-chain structure with the OH at the terminal carbon, is one of the four isomers of butanol. Many researchers have been investigated the *n*-butanol as the fuel for engines. In diesel engines, the research teams such as Yao et al. [11], Zheng et al. [12],

* Corresponding author.
E-mail address: bmd_2007@163.com (Q. Zhang).

http://dx.doi.org/10.1016/j.enconman.2017.09.037
Received 10 July 2017; Received in revised form 8 September 2017; Accepted 14 September 2017
0196-8904/ © 2017 Elsevier Ltd. All rights reserved.

Nomenclature

Definitions, acronyms, abbreviations

BMEP	Brake Mean Effective Pressure
BTE	Brake Thermal Efficiency
BSFC	Brake Specific Fuel Consumption
CO	Carbon Monoxide
COV	Coefficient of Variation
ECU	Electronic Control Unit
GDI	Gasoline Direct Injection
IMEP	Indicated Mean Effective Pressure
KI	Knock Intensity
MON	Motor Octane Number
NOx	Nitrogen Oxides
PFI	Port Fuel Injection
PN	Particle Number
RON	Research Octane Number
SI	Spark Ignition
TDC	Top Dead Center
TWC	Three Way Catalyst
UHC	Unburned Hydrocarbon
WOT	Wide Open Throttle

Liu et al. [13,14], Rakopoulos et al. [15], Huang et al. [16] and the author et al. [17,18], have investigated combustion and emission characteristics of *n*-butanol/diesel blends applied in the engines. Besides, the majority of studies on *n*-butanol in conventional Port Fuel Injection (PFI) SI engines have been performed either as pure fuel or blended fuel due to its high octane number. Elfasakhany experimented on a PFI engine with gasoline and *n*-butanol-gasoline blends (*n*-butanol was 3%, 7%, 10% by volume respectively) and found that using *n*-butanol–gasoline blended fuels slightly decrease the output torque, power, volumetric efficiency, exhaust gas temperature and in-cylinder pressure of the engine as a result of the leaning effect caused by the *n*-butanol addition [19]. He further studied the effects of using dual alcohols (3, 7 and 10 vol% iso-butanol and *n*-butanol) blended into gasoline and thought that dual alcohols has a higher performance and lower emissions than single alcohol and neat gasoline [20]. Galloni et al. analyzed the performance of the SI engine firing with gasoline-butanol blends (20% and 40% butanol mass percentage) at partial load operation and found that both the engine torque and thermal efficiency slightly decrease (meanly about 4%) when the *n*-butanol content increases [21]. By numerically analyzing the engine behavior fueled with several *n*-butanol/gasoline mixtures (B0 up to B100) at partial load operation, Scala et al. considered that when engine fueling is switched from gasoline to alcohol/gasoline mixture, the engine control parameters must be adapted [22]. Singh et al. [23] investigated the technical feasibility of butanol/gasoline blends with 5%, 10%, 20%, 50% and 75% *n*-butanol by volume on a multi-point-port-fuel-injection SI engine and reported that butanol/gasoline blends have slightly higher BSFC than gasoline. Venugopal and Ramesh [24] compared the effects of 50% *n*-butanol/gasoline adopting simultaneous port injection of two injectors and pre-blended on performance, combustion and emission characteristics of a spark-ignition engine. Furthermore, the effects of *n*-butanol additive on the emissions of PFI engines have also been investigated by some researchers, such as Feng et al. [25], Gu et al. [26], Venugopal et al. [27].

With respect to the PFI engines, the research on Gasoline Direct Injection (GDI) engines has grown due to the better fuel economy and gaseous emissions [28,29]. He et al. [30] studied combustion characteristics of a gasoline engine with independent intake port injection and direct injection systems for *n*-butanol and gasoline, and they found that different injection approaches for *n*-butanol and gasoline affected combustion events. Wallner et al. [31] investigated the emissions with pure gasoline, 10% ethanol, and 10% *n*-butanol blends in a GDI engine and found little difference in HC, CO and NOx emissions between pure gasoline and 10% *n*-butanol due to stoichiometric air/fuel ratio combustion. Zhang et al. [7] investigated that the combustion and Particle Number (PN) emissions of GDI engine fueled with gasoline blends with 10% and 20% butanol, and found that *n*-butanol/gasoline blends degraded anti-knock ability but decreased particle number concentration. Wei et al. [32] studied the knocking combustion characteristics with gasoline, Bu20 (i.e. 20% *n*-butanol blend) and neat *n*-butanol on a GDI engine with stoichiometric air/fuel ratio and recorded that neat *n*-butanol showed better anti-knock ability with more advanced knock limited spark timing, whereas Bu20 slightly deteriorated knock resistance. They further declared that the application of EGR on high intake pressure and high compression ratio *n*-butanol engine could effectively suppress knock combustion [33]. In addition, the author also found that higher *n*-butanol content resulted in slightly higher knock possibility in stoichiometric combustion [1].

In summary, almost all of the related studies focus on the effect of *n*-butanol additive on stoichiometric combustion of SI gasoline engines, but very little research has paid much attention to rich mixture combustion under the condition of full-load, i.e. wide-open throttle (WOT), which also is the difficulty of high *n*-butanol content of gasoline blends applied in commercial SI engines. The influence of butanol/gasoline blends, especially with higher butanol contents, on combustion, fuel efficiency and emission characteristics of a GDI engine running WOT will be investigated. Furthermore, the results will be compared with the RON 93 gasoline and the 10% ethanol/gasoline blended fuel, which have been used widely in cars. Some interesting results are summarized to show the potential of high content of *n*-butanol applied in GDI engines in this paper.

2. Experimental setup and approaches

2.1. Experimental setup

Experiments were conducted on a four-cylinder turbocharged GDI engine. The specifications of the engine are shown in Table 1. The schematic of the experimental setup is showed in Fig. 1. A spark plug pressure sensor (AVL GH13Z-31) combined with a set of charge amplifier and combustion analyzer, was used to measure the cylinder pressure data from 200 consecutive combustion cycles. Furthermore, they were averaged and further analyzed by using a single zone heat-release model [1].

An AVL AMA i60 exhaust analyzer was used to measure the exhaust emissions before three-way catalyst (TWC). In this equipment, the non-dispersive infra-red (NDIR) analyzer is used to analyze Carbon Monoxide (CO) and carbon dioxide (CO_2), the flame ionization detector (FID) analyzer detects Unburned Hydrocarbon (UHC), and the chemiluminescent analyzer (CLA) measures total oxides of nitrogen (i.e. NO

Table 1
Engine specifications.

Engine type	Inline 4 cylinders, 4 valves
Displacement	1.4 L
Compression ratio	11:1
Intake system	Turbocharged, intercooled
Fuel system	Direct injection
Fuel type	Gasoline, E10, Bu30, Bu50
Injection pressure	20 MPa
Operation condition	WOT
Intake pressure after turbo	0.185 MPa

Download English Version:

https://daneshyari.com/en/article/5012327

Download Persian Version:

https://daneshyari.com/article/5012327

Daneshyari.com