Fuel 223 (2018) 277–285

Contents lists available at ScienceDirect

Fuel

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

Full Length Article

Evaluation of the effect of gasoline fumigation on performance and emission characteristics of a diesel engine fueled with B20 using an experimental investigation and TOPSIS method

Marziyeh Hoseinpour[a], Hassan Sadrnia[a,*], Mohammad Tabasizadeh[a], Barat Ghobadian[b]

[a] Department of Biosystems Engineering, Ferdowsi University of Mashhad, Iran
[b] Department of Biosystems Engineering, Tarbiat Modares University, Iran

ARTICLE INFO

Keywords:
Diesel engine
Gasoline fumigation
Biodiesel
Performance
Emission
TOPSIS method

ABSTRACT

Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) method was used to comprehensively evaluate performance and emission characteristic of DI diesel engine with fumigation gasoline under different engine operating conditions. Diesel and B20 fuel were considered as baseline fuels and gasoline was inducted as fumigation in intake manifold at two different ratio, so that at each operation point, six cases of fuel were tested. The experimental results showed that gasoline fumigation method for both baseline fuels of diesel and B20 results in a significant increase in UHC and CO emissions, and decrease in exhaust gas temperature, smoke opacity and NO and CO_2 emissions. Also, gasoline fumigation increased the brake thermal efficiency at medium and higher loads to about 5% for diesel baseline fuel, while the brake thermal efficiency decreased slightly in case of the B20 baseline fuel with gasoline fumigation. Moreover, the using B20 as an alternative fuel to diesel fuel in modes of with fumigation gasoline reduced the UHC and CO emissions, smoke opacity, exhaust gas temperature respectively to about 20.5%, 16.4%, 9% and 1.1% on average throughout engine loading. While, NO emission of B20 was up to 5% higher than diesel at modes with fumigation gasoline. Finally, all criteria of performance and emission were considered and the evaluation process done to obtain final ranking and choosing the best alternative or the best combination of fuel. From the analytical results it was determined that case of B20 with fumigation gasoline results in desirable performance and minimum emissions at some operation points.

1. Introduction

The diesel engines are widely used in various sectors such as agriculture, transportation, and industry in regard to their higher fuel economy, durability, reliability, and specific power output. However they are also known to be major emitters of nitrogen oxides (NO_x) and particulate matters (PM) [1–3]. Methods of reducing pollution from automotive vehicles using alternative fuels have been investigated in order to meet strengthened emissions regulations; the alternative fuels are natural gas, alcohols, and biodiesel and biogas, in a conventional or modified internal combustion engine. The two most common types of biofuels in use today are ethanol and biodiesel. Alternative fuels can be used in diesel engines by applying four different methods such as blending, fumigation, dual fuel and direct using [4–7].

It is well-known that gasoline is not an alternative fuel, and it constitutes the main fuel of spark-ignition engines. However, gasoline gives good results with respect to engine performance characteristics and exhaust emissions when it is used as an additive to diesel fuel using different techniques [8]. Due to limitations on the using of gasoline in compression ignition engines, recent interests have been focused on the partial replacement of the diesel fuel with gasoline as fumigation fuel or injected into the air intake (premixed injection). These methods, which involve either fuel reformulation or minor engine modification, can be readily applied to in-use diesel engines.

Recently, many experimental [8–21] and some theoretical [19,22] studies have been done on light fuels fumigation such as gasoline, ethanol and methanol in compression injection engine. Park et al. [16,17], Sahin et al. [8,18,20,21] examine the effects different ratios of bioethanol and gasoline as a premixed injection source on the combustion performance and exhaust emissions characteristics of a diesel engine at different operation conditions. In the existing works, most of the researchers have discussed their operating fuel with reference of NO_x, UHC, CO, soot, brake thermal efficiency, specific fuel consumption, and exhaust gas temperature, without offering an optimum state. To overcome the existing shortcomings of the research, performance and emission characteristics should be considered simultaneously and

* Corresponding author.
E-mail address: hassan.sadrnia@um.ac.ir (H. Sadrnia).

https://doi.org/10.1016/j.fuel.2018.02.044
Received 6 December 2016; Received in revised form 21 September 2017; Accepted 8 February 2018

the evaluation process done to choose the best alternative or the best combination of fuel.

In view of the number of parameters monitored, multivariate data analysis techniques can be applied, in order to rank the engine settings under investigation. As a mathematical analysis approach, decision-making problem is the process of finding the best option from all of the feasible alternatives. In almost all such problems the multiplicity of criteria for judging the alternatives is pervasive. That is, for many such problems, the decision maker wants to solve a multi-criteria decision making (MCDM) problem [23,24]. Recently, different MCDM techniques, including TOPSIS, VIKOR, AHP and ELECTRE were implemented to management and optimization in various energy conversion systems [25–28]. The application of MCDM in automobile engineering has been gradually increasing in the past few decades. Tzeng et al. [29] applied TOPSIS method to determine the best alternative fuel for public transportation. Dinh et al. [30] applied AHP for the evaluation of biodiesel production. Hambali et al. [31] proposed AHP for selecting the suitable composite material for automobile bumper beam. Rassafi et al. [32] applied MCDM techniques for selecting alternative fuels for the transportation sector. Sakthivel et al. [33,34] applied multi-criteria decision modelling approach for biodiesel blend selection based on hybrid multi-criteria decision support systems.

In the literature, there is no trace of research that deals with selection of suitable fuel blend based on the performance and emission characteristics using MCDM technique at diesel engine fueled with biodiesel and gasoline fumigation. In this study, a CI engine is equipped with a port fuel injection system and then effects of fumigation gasoline on performance and emission of a DI diesel engine fueled with biodiesel (B20) is investigated. Also, a comprehensive evaluation of performance and emission characteristics was performed by using Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) method which was established in order to tackle problems in multiple criteria decision making.

2. Material and method

2.1. Experimental setup and procedure

The engine used in this research is a four cylinder diesel engine. The detailed specifications of the test engine are given in Table 1.

The schematic diagram of the experimental setup is shown in Fig. 1. A gasoline fuel rail and four fuel injectors were added to the air intake manifold of the engine. Gasoline was injected into the intake manifold at a pressure of 0.3 MPa to form a lean gasoline/air mixture. A fuel pump controlled by an electronic control unit was used to supply gasoline to the fuel injectors. The engine was coupled with a hydraulic dynamometer and the engine speed and torque were controlled. Fuel consumption was measured using an electronic balance with a precision of 0.01 g. The gaseous species including UHC, NO, CO, CO_2 and smoke opacity were measured using online exhaust gas analyzer AVL Ditest1000. Exhaust gas temperature was measured with PT100 sensor thermocouple.

Table 1
Engine specifications.

Engine brand	Motorsazan-Iran G4.248
Engine type	Naturally aspired, water-cooled
Operating principle	Four stroke, direct injection
Number of cylinder	Inline four cylinders
Fuel injection pump	Mechanically controlled in rotary type
Rated power, Kw	51 kW at 2000 rpm
Rated torque, Nm	267 Nm at 1300 rpm
Bore × Stroke	101 × 127 mm
Compression ratio	16:1
Injection timing	336
Intake valve opening	713
Intake valve closing	213
Exhaust valve opening	485
Exhaust valve closing	5

At each mode of operation, the engine was allowed to run for a few minutes until the exhaust gas temperature, the lubricating oil temperature, and the cooling water temperature have attained steady-state values and data were measured subsequently. All the gaseous emissions were continuously measured for 2 min and the average results are presented. Each experiment was repeated twice and the results were found to agree with each other within the 95% confidence level. The specifications of equipment and measurement accuracies are given Table 2.

In this study, the engine was operated at steady states with different BMEPs, corresponding to around 25%, 50% and 75% of full load at two speeds of 1300 rpm and 2000 rpm, respectively speeds of maximum torque and maximum power. Diesel and B20 were considered as baseline fuels and gasoline was inducted as fumigation fuel for two different ratio at each testing point. On the other hand, the experiments were performed on the test engine under the following conditions:

A) Engine runs on only diesel fuel (“Diesel”)
B) Engine runs on diesel fuel as main fuel and gasoline as fumigation fuel (“D + FG”)
C) Engine runs on biodiesel-diesel fuels blends (80% diesel fuel and 20% biodiesel) (“B20”)
D) Engine runs on B20 as main fuel and gasoline as fumigation fuel (“B20 + FG”)

At a given engine speed, the gasoline flow rate was fixed in two cases. Therefore at every operation conditions, six types of fuel were tested. These were called on figures and tables as “Diesel”, “D + FG1”, “D + FG2”, “B20”, “B20 + FG1” and “B20 + FG2”. The detailed operating conditions of each mode and the mass consumption rate of main fuel (diesel or B20) and gasoline are shown in Table 3. Also, the general properties of diesel, gasoline and biodiesel fuels are presented in Table 4.

2.2. TOPSIS evaluation method

Decision making is the study of identifying and selecting alternatives based on the values and preferences of the decision maker. A decision making matrix is applied as one of the powerful tools for decision process designed based on a rectangular array of elements, arranged in rows and columns. First, list all of your options as the row labels in the table, and list of factors that you need to consider as the column headings. In this study, six types of fuel, according to Table 3, are alternative and performance and emission characteristics including BTE, EGT, CO, UHC, CO_2, NO and smoke opacity are factors or criteria. Next, the result each option for each of the factors in your decision.

TOPSIS is an MCDM method to identify solutions from finite set of alternatives based upon simultaneous minimization of distance from an ideal point and maximization of distance from a nadir point [24,35,36]. TOPSIS is relatively simple and fast, with a systematic procedure. The procedure of TOPSIS method is as follows:

Step (1): Establish a decision matrix for the ranking

	C_1	………	C_j	………	C_n
A_1	r_{11}	……..	r_{1j}	……..	r_{1n}
…….	……..	……..	……..	……..	……..
A_i	r_{i1}	……..	r_{ij}	……..	r_{in}
…….	……..	……..	……..	……..	……..
A_m	r_{m1}	……..	r_{mj}	……..	r_{mn}

Where A_i illustrate the alternatives i, $i = 1,2,……,m$; C_j represents jth