Alexandria Engineering Journal (2015) 54, 105–126

Alexandria University

Alexandria Engineering Journal

www.elsevier.com/locate/aej
www.sciencedirect.com

ORIGINAL ARTICLE

LPG diesel dual fuel engine – A critical review

B. Ashok *, S. Denis Ashok, C. Ramesh Kumar

Automotive Research Centre, School of Mechanical and Building Sciences, VIT University, Vellore 632014, India

Received 28 August 2014; revised 14 January 2015; accepted 8 March 2015
Available online 1 April 2015

KEYWORDS

Fossil fuels;
Emissions;
CI engine;
LPG–diesel dual fuel engine;
LPG;
Performance

Abstract The engine, which uses both conventional diesel fuel and LPG fuel, is referred to as 'LPG–diesel dual fuel engines'. LPG dual fuel engines are modified diesel engines which use primary fuel as LPG and secondary fuel as diesel. LPG dual fuel engines have a good thermal efficiency at high output but the performance is less during part load conditions due to the poor utilization of charges. This problem can be overcome by varying factors such as pilot fuel quantity, injection timing, composition of the gaseous fuel and intake charge conditions, for improving the performance, combustion and emissions of dual fuel engines. This article reviews about the research work done by the researchers in order to improve the performance, combustion and emission parameters of a LPG–diesel dual fuel engines. From the studies it is shown that the use of LPG in diesel engine is one of the capable methods to reduce the PM and NOx emissions but at same time at part load condition there is a drop in efficiency and power output with respect to diesel operation.

1. Introduction

Environmental concerns and depletion in petroleum resources have forced researchers to concentrate on finding alternatives to conventional petroleum fuels. Excessive use of fossil based fuels exhausts the reserves and also increases the air pollution. These improve the awareness of the effective use of present reserves and slowly switches over to the alternative fuels, which are environment friendly [1–5,95]. One of the solutions to accomplish this is the use of gaseous fuels in addition to the liquid diesel in CI engine. The use of alternative gaseous fuels e.g. natural gas, liquefied petroleum gas (LPG), etc. is a promising approach for lowering the dependence on petroleum based liquid fuels and to reduce the emissions of CO_2 and other pollutants from diesel engine [6]. LPG is a viable alternative gaseous fuel (also known as "Auto gas") which is a gas product of petroleum refining primarily consisting of propane, propylene, butane and other light hydrocarbons [7–9]. It can be liquefied in a low pressure range of 0.7–0.8 Mpa at atmospheric temperature. So, storage and transportation of LPG is easier than other gaseous fuels. LPG has high calorific value compared to other gaseous fuels and also it has high octane number but a low cetane number. The high octane number of LPG makes it suitable for spark ignition engines. In contrast, the low cetane number of LPG makes it difficult to be used in large proportions in compression ignition engines, mainly due to high cyclic variation [10,11,101]. Hence it can be used in the CI engine in the dual fuel mode only and in this mode it has been extensively studied. It leads to better performance, low particulate and smoke emissions [12]. The engine, which uses conventional diesel fuel and LPG fuel, is referred to as 'LPG–Diesel dual fuel engine'. In this engine, LPG fuel is mixed with the air in the engine

* Corresponding author. Tel.: +91 9865467729.
E-mail address: ashok.b@vit.ac.in (B. Ashok).
Peer review under responsibility of Faculty of Engineering, Alexandria University.

http://dx.doi.org/10.1016/j.aej.2015.03.002

cylinders either through direct mixing in the intake manifold with air or through injection directly into the cylinder [13]. A dual fuel engine is basically a modified diesel engine in which a LPG fuel, called the primary fuel is inducted along with air. This fuel is the main source of energy input to the engine. The primary gaseous fuel is compressed with air, but does not auto ignite due to its high self-ignition temperature. A small amount of diesel, usually called the pilot, is injected as in a normal diesel engine near the end of compression of the primary fuel–air mixture. This pilot diesel fuel, auto ignites first and acts as a deliberate source of ignition for the combustion of the gaseous fuel–air mixture. The pilot diesel fuel, which is injected by the conventional diesel injection equipment normally, contributes only a small fraction of the engine power output. Thus the combustion process in a dual fuel engine is complex as it combines the features of SI and CI engines [15–19]. The dual fuel engines can also be reverted back to straight diesel operation easily [14]. Dual fuel operation has advantages compared to diesel counterparts and spark ignition (SI) engines, theoretically higher thermal efficiency resulted from faster burning, less toxic emissions, high power density, strong ignition sources providing more reliable [20]. By converting diesel engines to run on LPG we can significantly reduce the problem of diesel pollution while also improving emissions of greenhouse gases [21,22]. Such conversions are however not a simple matter of changing the fuel, many technical problems present particularly with availability of specific fuel supply system, fuel injection control and engine optimization to ensure that the engine performance is maintained and the exhaust emissions are minimized [23].

However, the dual fuel engine has some pitfalls such as the poor utilization of the LPG fuel at low and intermediate loads which results in poor engine performance (drop in engine efficiency), high HC, CO emissions and misfiring at higher gas inducted levels. Poor part load performance results from incomplete combustion of LPG. Due to this poor thermal efficiency high level of unburnt hydrocarbons in the exhaust is found [24–26,100,102]. The performance of a dual fuel engine at idling and low loads can be improved by optimizing some engine operating and design parameters, such as engine speed, load, pilot fuel quantity, injection timing, intake manifold condition and intake gaseous fuel compositions [27,28]. In this literature review, studies with wide range of diesel engine sizes and different types investigated at different operation conditions are reviewed. Similarly, different percentages of LPG were applied to optimize the engine output. Engine performance, combustion and emissions characteristics are discussed at different sections to get the clear scenario on the effects of using liquefied petroleum gas (LPG) in diesel engine in dual fuel mode.

2. LPG–diesel dual fuel operation

All internal combustion (IC) reciprocating engines operate by the same basic process. A combustible mixture is first compressed in a small volume between the head of a piston and its surrounding cylinder. The mixture is then ignited and the resulting high-pressure products of combustion push the piston through the cylinder. There are two ignition methods used in reciprocating IC engines, compression ignition (CI) and spark ignition (SI). The existing method of operation of diesel engine is by compression ignition method, where the intake air alone is compressed and at the end of the compression stroke the diesel fuel is directly injected at high pressure over the compressed air inside the combustion chamber which leads to ignite easily by virtue of its ignition temperature. But the LPG–diesel dual fuel engine utilizes the concept of both compression ignition and spark ignition principles to burn the mixture of primary gaseous (LPG) fuel and liquid pilot fuel [29–31].

In case of LPG–diesel dual fuel engine, the air-to-LPG mixture from the intake is drawn into the cylinder, just as it would be in a spark-ignited engine and this mixture is compressed in order to increase the temperature and pressure. At the end of the compression stroke the mixture is ignited by the injection of small quantity of pilot diesel fuel as shown in Fig. 1. This pilot injection acts as a source of ignition. The LPG gas-air mixture in the vicinity of the injected diesel spray ignites at number of places establishing a number of flame-fronts. Thus the combustion starts smoothly and rapidly. It is interesting to note that in a dual-fuel engine the combustion starts in a fashion similar to the CI engine but it propagates by flame fronts, i.e. in a manner similar to the SI engine. The power output of the engine is normally controlled by changing the amount of primary LPG gaseous fuel added to inlet manifold. The quantity of diesel fuel used will be varied depending upon the engine operating conditions and its design parameters, and generally the amount of pilot diesel required for the ignition is between 10% and 20% of operation on the diesel fuel alone at normal working loads [32,33]. The mass fraction of the LPG used in dual fuel mode is calculated by using the following expression, 'Z':

$$Z = \frac{m_{LPG}}{m_{Diesel} + m_{LPG}} * 100\%$$

where m_{Diesel} is mass flow rate of diesel and m_{LPG} is mass flow rate of LPG. And $z = 0\%$ represents diesel operation, $z = 10\%$, 20%, 30%, 40% represent the LPG mass fraction used in dual fuel mode [34–39,98].

3. Diesel engine modifications

Diesel engines can be readily configured to run on LPG–diesel dual fuel mode, where LPG is mixed into the air intake, while the normal diesel fuel injection system still supplies a certain amount of diesel fuel, but at a reduced rate [9,96]. The engine has to be modified to work in the dual fuel mode by attaching an LPG line to the intake manifold along with an evaporator

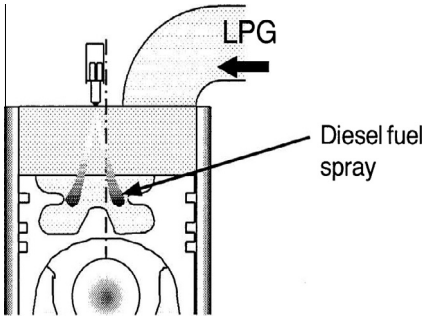

Figure 1 LPG diesel dual fuel engine [46].