

Development of Dual Fuel (Diesel-CNG) Engine for SUV Application in India

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ABSTRACT

Towards the effort of reducing pollutant emissions, especially soot and nitrogen oxides, from direct injection Diesel engines, engineers have proposed various solutions, one of which is the use of a gaseous fuel as a partial supplement for liquid Diesel fuel. These engines are known as dual fuel combustion engines.

A dual fuel (Diesel-CNG) engine is a base diesel engine fitted with a dual fuel conversion kit to enable use of clean burning alternative fuel like compressed natural gas. In this engine diesel and natural gas are burned simultaneously. Natural gas is fed into the cylinder along with intake air; the amount of diesel injection is reduced accordingly.

Dual fuel engines have number of potential advantages like fuel flexibility, higher compression ratio, and better efficiency and less modifications on existing diesel engines. It is an ecological friendly technology due to lower PM and smoke emissions and retains the efficiency of diesel combustion.

Normally natural gas is a cheaper fuel compared to diesel. Cost savings of dual fuel vehicles will depend on the share of gas added. In view of energy depletion and environmental pollution, dual fuel technology has caught attention of researchers as a viable technology keeping in mind the increased availability of fuels like Compressed Natural Gas (CNG).

This paper highlights the methodology and outcomes of the recent experimental research work carried out for development of dual fuel diesel CNG engine for SUV application.

The paper also throws light on present limitations and drawbacks of dual fuel engines and proposed methods to overcome these drawbacks. A parametric study of different engine operating variables affecting performance of diesel-CNG dual fuel engines vis-à-vis base diesel operation is also summarized for a four cylinder engine.

KEYWORDS: Dual Fuel, Diesel-CNG

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INTRODUCTION

During the last years diesel engines are used for automotive applications because they have a lower specific fuel consumption and superior efficiency compared to spark ignition engines. However, in spite of these advantages, NO_x and particulate emissions from diesel engines have caused serious environmental problems in some applications.

With increasing government restriction of tailpipe emissions from vehicles powered by internal combustion engines and a growing concern over the use of imported oil, alternative fuels have gained popularity. Natural gas has become a widely used alternative fuel for a variety of reasons including ready availability and its low emissions potential. Spark-ignited natural gas engines are common but suffer lowered efficiency due to pumping losses from intake throttling and therefore, cannot match the thermal efficiency of diesel engines.

Existing diesel engines may be converted readily to operate primarily on natural gas, using diesel as a spark plug to achieve ignition. The use of diesel fuel allows the retention of the diesel compression ratio and its efficiency while the natural gas contributes to economy and is responsible for lowering emissions. The peak combustion temperature reduces which reduces NOx emissions. Drastic reduction in PM emission has been observed when engine operates under dual fuel mode.

In the present work existing diesel SUV engine is converted to operate on CNG & diesel simultaneously with no changes in the engine compression ratio, cylinder head, or basic operation as a diesel cycle engine. The main aim was to develop a 'bolt on' dual fuel technology that can be removed if necessary, to resell the vehicle as a normal diesel engine and this was done to aim the market where epidemically poor air quality limit exist and need an immediate remedy to pollution caused by urban diesel vehicles

Initially the optimization was carried on engine, and fuel replacement MAPs had been finalized. The engine level learning's & optimized MAPs were used for vehicle level calibration on chassis dynamometer. And comparative results with diesel & dual fuel operation are discussed in details in this paper.

DUAL FUEL METHODOLOGIES

Several methodologies exist for operating a compression ignition under dual fuel mode. These are distinguished by the way gaseous fuel is introduced in to the cylinder and the amount of diesel fuel that is displaced by it [1].

Conventional Dual Fuel

Natural gas is fumigated in the intake manifold and the mixture of CNG and air is compressed in the compression stroke which is then ignited due to auto-ignition of the diesel fuel spray. The quantity of diesel in this case can vary from 100% to 20% and this strategy is preferable on engine which does not have electronically controlled diesel injection. During starting and full load conditions, the engine runs under 100% diesel as a safety measure to avoid knocking, whereas under part load conditions it runs under the dual fuel mode. [1] [2] [3]. Fig. 1 shows operating cycle under conventional dual fuel mode.

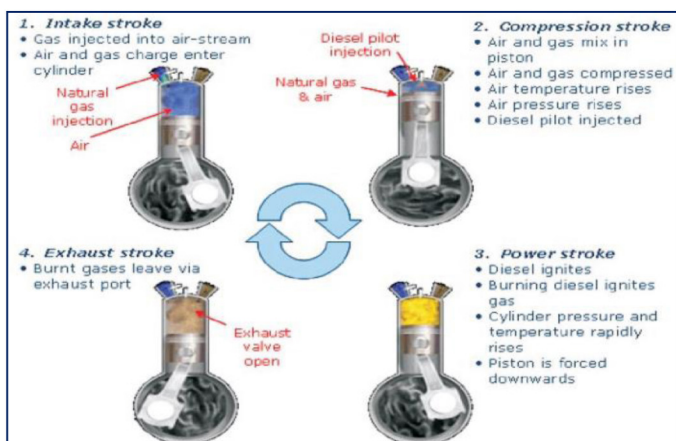


Fig 1. Operating Cycle under Conventional Dual Fuel Mode. [1]

Pilot Ignited Natural Gas Diesel (PINGD)

In this case natural gas is used as the primary fuel and pilot diesel injection serves as an ignition source only. The quantity of diesel is usually limited to 20% and hence the operating mode has found to reduce PM and NOx as compared to conventional dual fuel operation but the power drop is higher and running cost is high [1] [2] [3]. Typical Pilot ignited natural gas diesel (PINGD) engine layout is as shown in fig. 2.

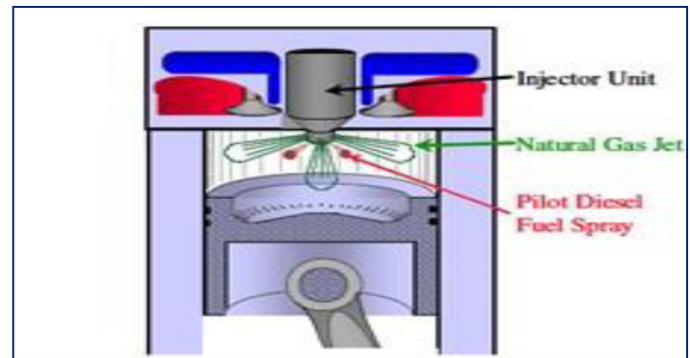


Fig 2. Typical Pilot ignited natural gas diesel (PINGD) engine layout [1]

DUAL FUEL TECHNOLOGY

In present case vehicle has a mechanical type diesel injection system and conventional dual fuel system is used for developed dual fuel vehicle.

Merits of Dual Fuel Technology [1] [2] [3] [4] [5]

- Usage of existing Diesel engine with Minimum Modifications and retaining same Power performance
- Improvement in fuel economy, there by reduction in overall operating costs
- Reduction in harmful exhaust pollutants
- Fuel Flexibility (it is possible to run the engine only on diesel when CNG is not available)
- High engine torque at lower engine speeds
- Lower conversion time
- Seamless transition between Diesel and Dual Fuel modes
- Possibility of adaptation to older generation of CI engines

Issues with Dual Fuel Technology [1] [2] [3] [4] [5]

- Two fuel systems to maintain
- Higher emissions of CO compared to strait diesel. Similar emissions of CO as spark gas (without catalytic converter)

METHODOLOGY FOLLOWED

Step by step methodology adopted is given below,

1. Selection of base diesel SUV
2. Study of base performance & mass emission test on chassis dynamometer



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3. Study of base diesel engine performance parameters e.g. full throttle performance, part throttle performance, throttle and engine speed response w.r.t. accelerator pedal position.
4. Dual fuel system development
The kit used for the dual fuel application is different from the conventional CNG kits; therefore the complete understanding of working of kit was carried out.
5. Adaptation of kit
The dual fuel kit is mounted on the engine with slight engine peripheral modification like mounting of gas air mixer in intake air path, RPM sensor positioning, Fuel lever positioning, Engine coolant temperature etc. so complete working of kit well understood in this phase.
6. Diesel replacement strategy with base line engine test
By conducting the literature survey and with the help of expertise the gas supplement ratio (GSR) variation strategy is decided in this phase. Engine is tested for dual fuel mode by adapting the GSR (20%, 40%, 60%, and 80%) strategy at different speed and load conditions and all performance data is recorded for analysis [1].
7. Selection of average replacement points for dual fuel mode by analyzing the base line data the optimum points were selected for dual fuel mode such that at those points engine will perform as good as compared to diesel mode.
8. Vehicle level trials on (Modified Indian Driving Cycle) MIDC cycle for emission & performance point of view on chassis dynamometer
Fuel replacement MAP finalized on the basis of engine performance is again verified on vehicle level trials to compare with the base vehicle performance & emission levels.
9. Comparative Road trials to find out the drivability & actual cost benefit

Engine Details

Details of the engine under consideration is shown in [table 1](#).

Table 1. Engine Description

Engine type	Turbocharged water cooled, DI, Diesel engine
No. of Cylinders	4, Inline
Bore / stroke	97 mm x 100 mm
Capacity	2956 cc
Max. Engine output	50 – 52 kW @ 3000 rpm
Max. Torque	223 Nm @1600-2200 rpm
Compression ratio	19 : 1
Firing order	1-3-4-2
Fuel Injection Pump	Mechanical Rotary Fuel Injection Pump
Timing	With automatic advance
Governor	Centrifugal type variable speed
Engine model	BS – III, Turbocharged

Base Emission Test on Chassis Dynamometer

The base SUV was as it is tested for mass emission test according to MIDC cycle and results are shown in [fig.3](#).

Results found were as below

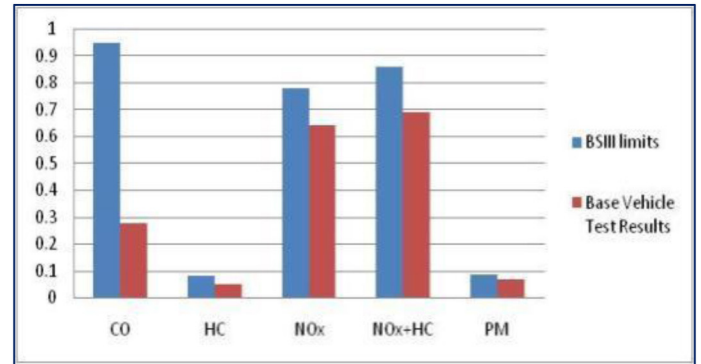


Fig 3. Base Emission test on chassis dynamometer

Base Engine Test on Engine Dynamometer

The test was carried over the entire engine operating speed range starting from 1000 to 3000 rpm. This test was conducted in α mode. (N - Engine RPM; α - Torque)

In α mode the engine speed was maintained and α was set to 100% (full throttle) to obtain the full load condition at the corresponding engine speed.

Parameters like air flow rate, fuel flow rate, torque, Diesel % were recorded and discussed in later part of the paper. A typical Dual Fuel engine on Engine Dynamometer is shown in [fig 4](#).



Fig 4. Typical Dual Fuel Engine on Engine dynamometer

DUAL FUEL SYSTEM DEVELOPMENT

As stated earlier, the main aim was to develop a 'bolt on' dual fuel technology that can be removed if necessary, to resell the vehicle as a normal diesel engine. The CNG kit used was a 1st generation CNG kit where the CNG flow is dependent on the engine suction. The engine suction which vary at different engine speed meter the CNG flow rate accordingly. Below are the component finalized to convert an existing diesel engine for dual fuel operation.