International Journal of Engineering & Technology, 7 (3.6) (2018) 306-310

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Diesel to Dual Fuel Conversion Process Development

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Abstract

This paper aims to develop a process for conversion of Diesel Engine for Dual Fuel operation which is basically designed to reduce the economic costs and pollutant Emissions. The increasing cost of Diesel Fuel leads to the necessity of an Alternate fuel, i.e Compressed Natural gas (CNG). In this research a 16 cylinder, 50.25liter, Turbocharged After cooler V-shaped Engine is used for the conversion into Dual Fuel Engine. Dual fuel engine can be operated on both Diesel and CNG modes simultaneously. In this Engine the Air and CNG are mixed in required ratios in an Air- Gas mixer and the mixture is injected into the Combustion chamber. As Gaseous fuel CNG cannot self-ignite itself because of its high Auto ignition temperature a required amount of Diesel is injected into the Combustion Chamber at the end of compression stroke for ignition purpose which is known as Secondary fuel or a PILOT FUEL. This paper tries to show the process development of converting Diesel Engine for dual fuel operation on multiple platforms.

Keywords: *CNG, conversion kit, pilot fuel, process development.*

1. Introduction

The Gaseous fuel (Compressed natural gas) is mixed with air in the mixer before the turbocharger and allowed it to pass through the intake valve. As Natural gas has high auto ignition temperature of about 580°C it can't ignite itself in the compression stroke. So, a secondary fuel, Diesel (also called PILOT Fuel) is injected for the ignition purpose. The Gaseous fuel CNG is lighter than air and it is cheaper than Diesel. The conversion process doesnot requireinternal modifications to the engine. It includes only the external modifications which helps for conversion. If there is a shortage or leakage in gaseous fuel the provided kit helps the engine to run on Diesel mode by switching OFF the Dual Fuel operation.

Abhay Tiwari[1] has worked on Converting a Diesel engine to Dual-fuel engine using Natural gas in 2015. The main objective of this paper is to convert a diesel engine to dual fuel engine with CNG as an alternate fuel which will reduce the global warming and Cost. An overview of chemical compositions of Diesel, Gasoline and Natural gas is described to understand the properties of CNG. It is inferred that fumigation is the simplest principle to use CNG in conversion and the emission characteristics is low compared to other technologies and also by using suitable ECU system the dual fuel CI engine performs well.

Saket verma et al.[2] has worked on a comparative exergetic performance and emission analysis of pilot diesel dual-fuel engine with biogas, CNG and hydrogen as main fuels in 2017. It is inferred that IT's required to give highest efficiency or lowest emissions varied with the type of main fuel and also the engine loads. At low load condition, CNG-DF increases when compared to other alternate fuels used whereas at high load condition, H_2-DF increases. It is also inferred that the low load performance can be improved with IT advance.

Avinash kolekar [3]has worked on Development and validation of power performance prediction chart for conversion of Diesel engine to Dual fuel engine in 2014. The main objective of this paper is to enable dual fuel engine performance with respect to fuel-air equivalence ratio and diesel substitution limits. Mainly these charts are useful for gas interchangeability which is a major issue. Also inferred that the maximum air standard temperature is obtained by dual fuel air standard cycle and LFL has been obtained through the relation between LFL, R and Fuel- air equivalence ratio.

Jie Liu et al.[4]worked on effects of pilot quantity on the emissions characteristics of a CNG/Diesel dual fuel engine with optimized pilot injection timing in 2013. It is inferred that using dual fuel CO emissions are higher than diesel operation at high loads which are caused by flame quenching of lean premixed natural gas- air mixture. No_x emissions are reduced by 30% when compared to diesel mode due to low combustion temperature. At low and medium loads, the unburned HC emissions are higher than in diesel mode. PM increased with the increase of pilot fuel quantity and are considerably lower in dual fuel operation than Diesel operation.

2. Modifications in the Demu Engine

A. Modifications in the DEMU Engine

The Existing engine in general is a Diesel Engine. While in the Conversion of Diesel to Dual Fuel mode; the Engine compartment is modified in to four Cabins which are as follows:

1) Motorman Cabin
2) Engine Cabin
3) LTA Installation system
4) Gas Train system

B. Layout of DEMU Engine in Diesel Mode

The figure A shows the layout of a Locomotive engine in Diesel mode which includes the operation of the engine only with the

Diesel fuel. The passenger compartment remains same in the Diesel operation.

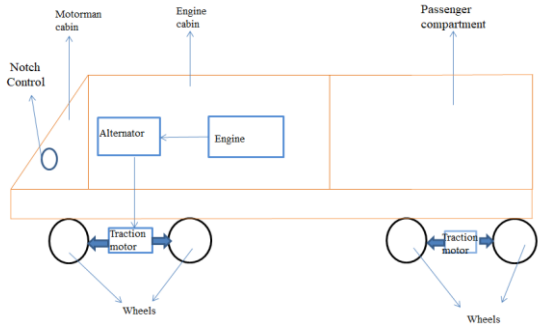

Fig. A: Layout of DEMU engine in diesel mode

C. Layout of DEMU Engine in Dual Fuel Mode

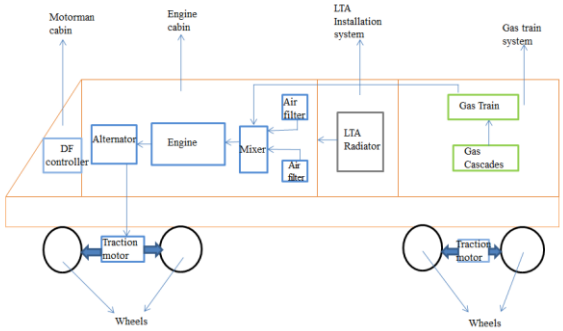

Fig. B: Layout of DEMU engine in dual fuel mode

The figure B shows the layout of Locomotive Engine in dual fuel mode after the conversion. Here the passenger compartment is also modified by replacing it with the gas train system. Each cabin operation is explained in detail below:

Motorman Cabin

Motorman cabin is a driver's cabin where the notches, Dual Fuel controller, Brake controller, Speed controllers and checks the Safety alarm systems if any damage are controlled.

Engine Cabin

The Existing engine in this cabin which is on Diesel mode is converted into dual fuel mode with external modifications. As the temperature inside the Engine cabin is more, for safety requirement Air ducts are provided around the Engine for cooling purpose.
The Engine Cabin room consists of main components like:

1) Engine
2) Alternator
3) Air ducts around the Engine
4) Air Filters
5) Gas + Air Mixer ducts
6) LTA Core lines
7) Alternator supply to compartment

LTA Installation System

LTA means Low temperature after cooler which is used to maintain intake manifold temperatures in the Engine. LTA system is separately installed in a small cabin from where the LTA core lines are passed through the Engine cabin. Though there are many services provided for cooling purpose there will be some more heat generated by the Engine in running condition. So for cooling purpose this LTA system is used.

LTA installation system consists of:

1) LTA Radiator
2) LTA Core lines

Gas Train System

The Gas train system consists of around 40 Gas cascade cylinders of capacity 3000 liters. The passenger compartment is modified for Gas cascades mounting. Gas train is a safety system which helps in reducing the gas pressure. The Gas lines are passed in to the Engine cabin through the Gas cabin which is passed through inside and above the cabins.
The Gas Train system consists of:

1) Gas Cascades
2) Gas lines
3) Pressure filters
4) Gas Actuator
5) Slam shut off valve
6) Pressure regulator

3. Properties of Diesel and CNG

Table I: Properties of Compressed Natural Gas and Diesel Fuels

S.NO	Properties	CNG	Diesel
1.	Chemical formula	CH_4	C_2H_6
2.	Density(kg/m^3)	0.7-.9	820
3.	State	Gas	Liquid
4.	Cetane number	0	40-55
5.	Lower heating value(MJ/kg)	38-50	42.31
6.	Octane Number	120-130	15-25
7.	Boiling point(°C)	-162	140-360
8.	Auto-ignition temperature(°C)	540	210
9.	Stiochiometric A/F ratio	17.19:1	14.5:1
10.	Carbon content (Wt. %)	73.3	87
11.	Hydrogen content (Wt. %)	23.9	13
12.	Oxygen content (Wt. %)	0.4	0

4. Engine Specifications and Duty Cycle of DEMU Engine

A. Engine Specifications

Table II: Engine Specifications

S.NO	Description	Configuration
1.	Engine Configuration	60°, V-shape
2.	Engine Aspiration	Turbocharged After cooler
3.	Application	Locomotive
4.	Displacement	50.25 lit
5.	Cylinder block	16 cylinder
6.	No. of Notches	8
7.	Rated power	1400hp
8.	Maximum speed	1800 rpm
9.	Bore x stroke	159x159 mm

B. Duty Cycle of DEMU Engine

There are 8 notches involved in the Locomotive Engine which is allowed to maintain the speed from 750(min.) to 1800 (max.) rpm.

1) 1st notch- Only Diesel (at 750 rpm). Because of excess THC (Total hydrocarbons) produced there is no substitution of Diesel with gas.
2) 2nd notch- (1000 rpm) % Gas throttle opening
3) 3rd-5th notches-(1200- 1400 rpm) Total thermal energy balance is excess in Dual fuel mode than in Diesel mode
4) 6th notch- (1500 rpm) % Gas throttle opening.
5) 7th notch- (1650 rpm) Due to high Peak cylinder pressures the gas mode is OFF and fully operated in Diesel mode.
6) 8th notch- (1800 rpm) Due to high Peak cylinder pressures and turbine inlet temperatures the gas mode is OFF and runs on only Diesel mode.

5. Conversion Process of Diesel to Dual Fuel Engine

A. Conversion Process of Diesel to Dual Fuel Engine

The conversion process of Diesel to Dual Fuel mode involves the external mounting equipment. No changes are necessary to the existing engine. Only the retrofit kit is to be added for converting it into Dual Fuel mode. The conversion kit plays a major role and cost of the equipment may be more initially but the savings later are higher when compared with Diesel Engine.

B. Conversion Kit

The conversion kit which is used to mount externally on the Engine consists of the following equipment's:

1) Gas Cascades
2) Gas Train system
3) Dual Fuel Controller
4) Air+ Gas Mixer ducts
5) LTA system
6) Flame proof kit
7) Gas detection system

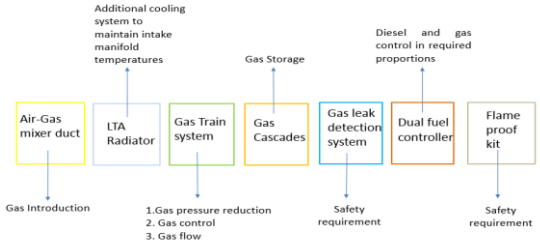

Fig. C: Conversion kit

Gas Cascades

The passenger compartment is modified for the Gas Cascades fitting. Around 14 seats are removed to modify the System. No. of Gas cylinders used in the conversion process are around 40 of 3000 liters capacity.

Gas Train System

The main use of Gas Train system is to control the pressures before mixing with air in the Mixer duct. The Gas Cascades has a high pressure of around 220 to 250 bar. This high pressure is reduced to 100 milli bar by using Low pressure regulator. After reaching this pressure it will be regulated to Zero pressure by using Zero pressure regulator. The Gas train system lines are connected to the Engine cabin from above the Gas Cascade compartment. These lines are connected to the Air- Gas Mixer duct where the Gas and Air are mixed in equal proportions.

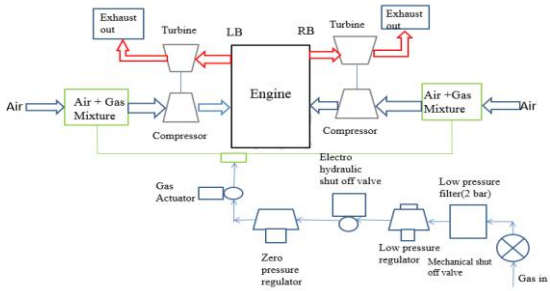

Fig. D: Gas train system

The Gas is regulated to Zero pressure by using Zero pressure regulator before mixing up with air so as to maintain equal proportions. Then the gas is allowed through Gas actuator by controlling proportions and mixed in a mixer with air.

The Air+ Gas mixture is allowed to flow through compressor of the turbocharger in both Left bank (LB) and Right bank (RB). The mixture enters through the intake valve. The exhaust from the exhaust valve will be expelled out through Turbine from both LB and RB.

Dual Fuel Controller

Dual Fuel controller controls all the sensors and sends it's signals to the Dual Fuel Actuator to open the notches for operating the Engine. It is used to control the parameters like Load, Speed, air-fuel ratio, fuel exchange between gas and Diesel mode and return to Diesel. It controls the all type of Dual Fuel engines. Dual fuel technology is most cost- effective than Diesel without losing engine capability, power and its availability.

Air+ Gas Mixer Ducts

The Mixer duct is placed above on the roof panel of the Engine. The air from the air filters and Gas from the Gas train system is allowed into the Mixer duct. The Air and Gas mixes in required ratio's in equal proportions. The duct line is connected to the intake of the Engine. Through this the Air+ Gas mixture is passed into the intake valve and involves in further operations. The gas mixes with air before the turbocharger.

LTA System

LTA system means Low temperature aftercooler. LTA lines are already present to the Engine. Instead to avoid other temperatures in the intake manifold a new pump and new LTA core introduced to maintain the intake manifold temperatures. LTA is another cooling system provided along with the Engine jacket water cooling system. LTA core is installed in separate cabin from where the LTA lines are passed. The LTA radiator helps to maintain the temperature in the intake manifold so as to reduce the heat inside the Engine cabin further.

Flame Proof Kit

A flame proof kit is provided while converting Diesel engine into Dual fuel engine. It is a precaution taken to avoid damage to the engine while in running condition.

Gas Detection System

A Gas detection system kit is provided and installed in the Motorman cabin. This helps in detecting the Gas leakages if any. If any leakage in the Gas cabin or in the Gas lines, a signal is generated in the Motorman cabin. The Motorman detects easily and immediately switch OFF the dual fuel operation and run the engine in Diesel Mode.

6. Process Development Chart of Converting Diesel Engine for Dual Fuel Operation

A. Process Development Chart for Diesel to Dual Fuel Conversion

The figure E below describes the Diesel to dual fuel conversion process development which is divided into different stages as shown in the figure.

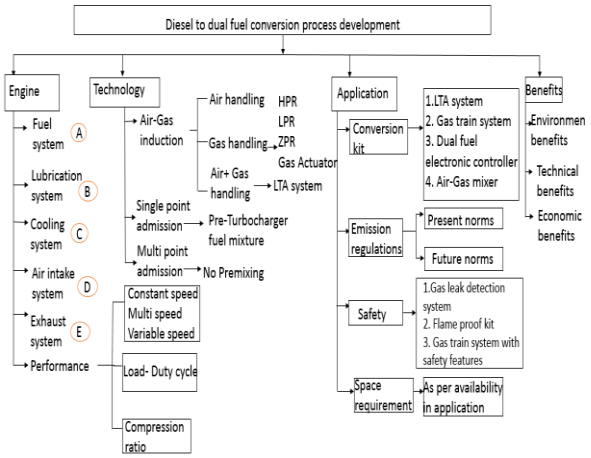

Fig. E: Diesel to dual fuel conversion process development

1) Engine systems architecture is described in detail later.
2) The technology includes Air-gas induction, Single point admission and Multi point admission.
3) Application factors deals with the conversion kit, Emission regulations to be followed while converting engine, Safety measures to be taken and the space requirements to be considered while conversion process.
4) The benefits includes Environmental aspects which reduces the emissions, Technical benefits like no internal modifications to the engine and Economic benefits which includes the reduction in costs.

B. Fuel System

The figure F below describes the schematic of fuel system changes in both Diesel and dual fuel modes. Fuel system is again divided into PT STC and MCRS system and their subsystems divided in to diesel and dual fuel modes. The dual fuel mode fuel flow is same in both systems while there is a little changes in the fuel flow in Diesel mode in both systems.

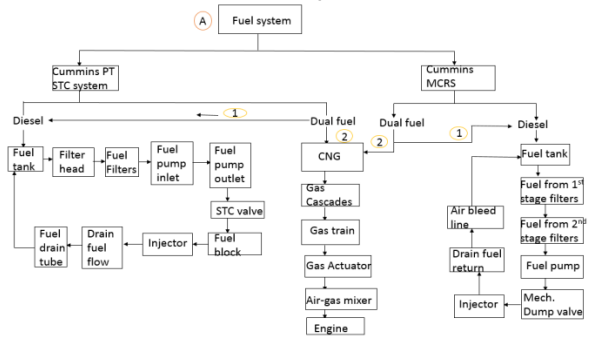

Fig. F: Schematic diagram of fuel system changes in diesel and dual fuel modes

C. Lubrication System

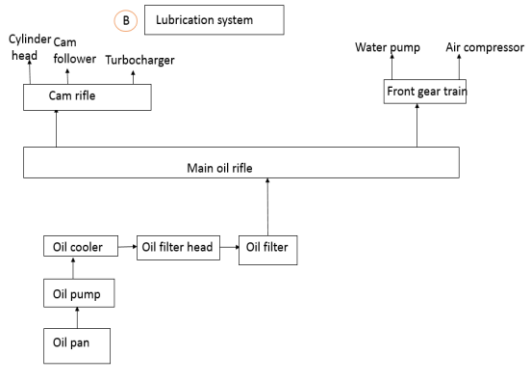

Fig. G: Lubrication system

The figure G describes the Lubrication system which is similar in Diesel and Dual fuel modes. It shows the Oil flow completely in the engine.

D. Cooling System

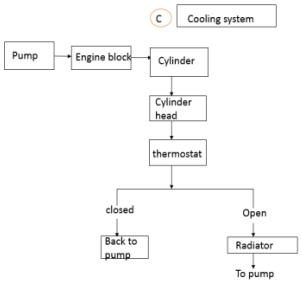

Fig. H: Cooling system

The figure H below describes the cooling system which is necessary to maintain the thermal limits so as to avoid the damage to the engine.

E. Air Intake System and Exhaust System

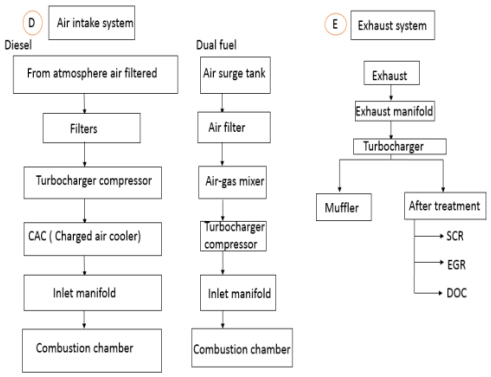

Fig. I: Air Intake and exhaust system

The figure I describes about the Air intake system and exhaust systems. There are some changes made for Air intake system in Dual fuel mode which is shown in the diagram while the exhaust system is similar in Diesel and Dual fuel mode.

7. Conclusion

The usage of CNG as the primary fuel reduces the emissions, fuel consumption and cost. The CNG conversion kit equipment is discussed in detail which plays a major role in the conversion of Diesel Engine to a Dual fuel Engine. The main role is that there is no necessity for any internal changes to be made to the existing engine; only external modifications are done. Process development for converting the diesel engine to operate on dual fuel mode is discussed in detail which helps in understanding the critical factors to look after in conversion process. By this conversion process there are lot of achievements which includes reduction in emissions, overall cost, Substitution of Diesel with gas which reduces the fuel consumption and thereby the overall cost also decreases.

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