DUAL FUEL

V.Krishnavel[1], V.Karthick Stephen[2]
Assistant Professor, Mechanical Engineering, Dr.Sivanthi AditanarCollege of Engineering,Tiruchendur,
[1]Krish16.energy@gmail.com, [2]stephenvincent10@gmail.com

ABSTRACT

For reducing soot and nitrogen oxides, from direct injectionDiesel engines, engineers have proposed various solutions, one of which is the use of a gaseous fuel like CNG as a partial replacement for diesel. The engines using this technology are known as dual fuel combustion engines, that is, they use the conventional CI engine that runs on two fuels at a time, namely, diesel and a gaseous fuel. Thistechnology is currently used for diesel-CNG dual fuel engines. Usingnatural gas in diesel engines provides both economical and environmental benefits. CNG has clean burning properties, and CNG vehicles generate fewer exhaust and greenhouse gas emissions than their gasoline- or diesel –powered counterparts. CNG also costs about 15%-40% less than gasoline or diesel. Dual fuel engines offera number of potential advantages like fuel flexibility, lower emissions, higher compression ratio, better efficiency and easy conversion of existing engines.

1. INTRODUCTION

The dual fuel CI engine has been employed in a number of applications utilizing various gaseous fuels due to their cleaner nature of combustion compared to conventional liquid fuels. Natural gas seems to be an excellent candidate because of its worldwide usage. It has a high octane number; therefore, it is suitable for engines with relatively high compression ratio. Moreover, it mixes uniformly with air, resulting in efficient combustion and a substantial reduction of emissions in the exhaust gas. Dual fuel technology can be applied on conventional direct injection (DI) diesel engines with minor modifications. Furthermore, dual fuel combustion using natural gas is a technique that results in the reduction of both pollutants NO and soot, which is extremely difficult to achieve in DI diesel engines. Dual fuel engines also contribute to the reduction of carbon dioxide due to the low C/H ratio.

In dual fuel, compression ignition (CI) engines operating with gas as primary fuel and a "pilot" amount of liquid diesel fuel as an ignition source, the gaseous fuel is inducted along with the intake air and is compressed like in a conventional CI engine. The mixture of air and gaseous fuel does not autoignite due to its high autoignition temperature. A small amount of liquid diesel fuel is injected near the end of the compression stroke to ignite the gaseous mixture. Diesel fuel autoignites and creates ignition sources for the surrounding air – CNG mixture. The pilot liquid fuel, which is injected by the conventional DI equipment, normally contributes only a small fraction of the engine power output. The dual fuel engine is a conventional diesel engine of the compression ignition type in which some of energy released comes about from gaseous fuel, while the diesel liquid fuel continues to provide energy throughout, the remaining part of energy release. The term "dual fuel" should not be confused with bi-fuel applications of spark ignition (SI) Engines, where the liquid fuel is not combusted simultaneously with the gaseous fuels. The dual-fuel engine is an ideal multi-fuel engine that can operate effectively on wide range of different fuels while maintaining the capacity for operation as a conventional diesel engine. Normally, the change over from dual-fuel to diesel operation and vice versa can be made automatically even under load.

2. HISTORY OF DUAL FUEL TECHNOLOGY

Operation of diesel engines on gaseous fuels is not a recent phenomenon. It is possible to trace its origin back to the beginning of 20th century, when Dr.Rudolph Diesel patented a CI engine to run on gaseous fuel-coal gas. Subsequently, more successful commercial applications appear to have been made, mostly for stationary applications, prior to the World War. During World War II, some efforts were directed towards using coal gas mixtures, sewage gas or methane as well as stocks of poor quality gasoline in the form of gasified vapour to run conventional diesel engine for a variety of applications. After the war, interest in these applications fluctuated depending on relative cost of such fuels and the extent of competition from other conventional fuels. Dual-fuel engines, which were first introduced into the American market in 1944-45, solved this cost problem by permitting the efficient use of gas fuel instead of oil engines that were only slightly modified from ordinary diesels.

3. APPLICATIONS OF DUAL FUEL TECHNOLOGY

Over the years the dual-fuel engine has been employed in a very wide range of applications. Numerous stationary installations are being used for power production, co-generation, compression of gases and pumping duties. In transport, limited examples of conversions can be seen in long and short haul trucks, municipal and school buses and in commercial delivery vans and taxis. Other successful application can be found for marine transport in cargo ships, ferries and fishing vessels and in some limited locomotive traction duties. Some notable agricultural applications on farm, involving the operation of machinery and tractors, have also been made. The problem of on board compact storage facility for gaseous fuels in mobile applications remains a bottleneck. If solved, it has the potential to open the market, particularly the transport sector, to the dual fuel engine.

4. DUAL FUEL ENGINE OPERATION

The dual fuel engine is a CI engine. The gaseous fuel is injected during the intake stroke in the engine cylinder. The air fuel mixture is then compressed in the engine raising its temperature above the auto-ignition temperature of the diesel fuel. Subsequent injection of a small quantity of diesel ignites the engine charge, which is a lean mixture of the gaseous fuel in the air. The objective is to maximize the use of gaseous fuel components and economize the relative use of diesel, which is termed as a "pilot". This approach used in most stationary dual fuel engine is called the fuel substitution strategy. Diesel fuel is replaced by the gaseous fuel as the load increases. The substitution limit is up to 80%. Refer to figure 4.1 for the dual fuel cycle. In case of transportation engines, gaseous fuel is added to the incoming air in the fully operational CI engine

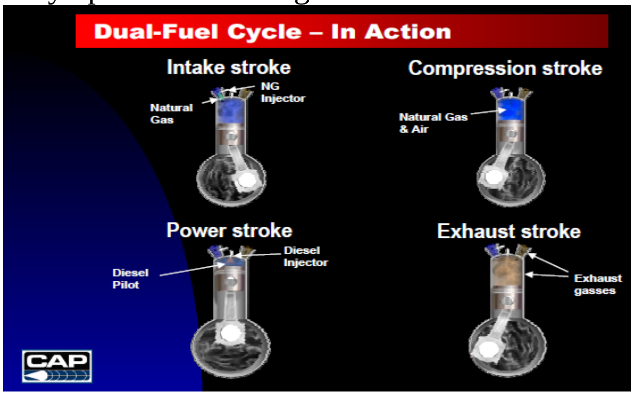


fig 4.1

So as to provide extra fuel loading, and produce additional power. This supplementary fuelling, which is applied to a CI engine with little or no alterations to existing injectionequipments , tends to have the advantage of being flexible. No supplementary gaseous fuel is usually employed at light loads, but at some prescribed load level, an increasing amount of supplementary fuel is introduced with the air. Normally, the maximum allowable fraction of energy release is limited eventually by the onset of knocking.

5. POWER RATING OF DUAL FUEL ENGINE

The amount of load that a dual fuel engine carries is limited by detonation. The reason is simple: As the load increases , more fuel must be introduced to develop the increased power. Thus, if the load increases on dual fuel engines (when it is running with maximum proportion of gas and minimum proportion of pilot oil), the governor causes more gas to be admitted.

Since the amount of air in the cylinder remains constant, the ratio of gas to air increases. At some point of increased load, the gas air mixture ratio becomes rich enough to enter the explosive range, where they detonate. Generally, the commercial power rating of dual fuel engine is same or slightly more than that of the same size engine running as a diesel or oil fuel only.

6. DUAL FUEL VERSUS SI ENGINE OPERATION

Table 6.1 Comparison between dual fuel, SI, and CI engines Dual fuel:

Diesel(CI)	CNG (SI)	DUAL FUEL
Ignition system is not required.	Ignition system is required.	Ignition system is required.
Compression ratio above 17.1	Compression ratio below 12:1.	Compression ratio above 17:1
High PM and smoke emissions.	No PM and smoke emissions.	Low PM & smoke emissions.
No power drop.	Power drop 15%-20% as compared to CI.	Power drop 5% to 10% as compared to SI.
Excess air is required.	Excess air is not required.	Excess air is required.
One fuel is injected.	One fuel is injected or carburetted.	Two fuels is injected.

7. ADVANTAGES OF DUAL FUEL TECHNOLOGY

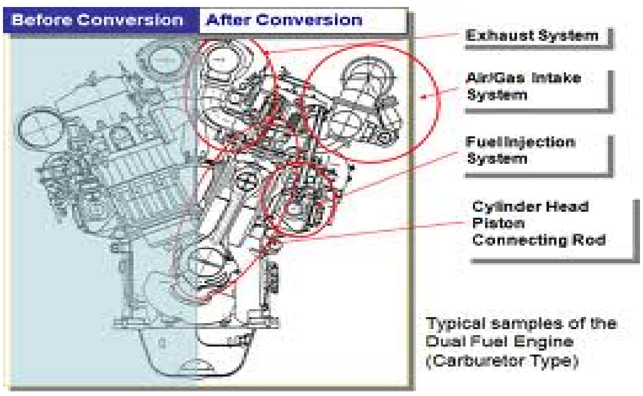
a. Low cost engine development.
b. Less CNG storage required compared to mono-fuel vehicle (results in low vehicle weight)
c. Higher reliability as diesel mode serves as a backup.
d. Lower emissions of PM and smoke.
e. Driveability comparable to that of diesel engines.
f. Better resale for base vehicle.

8. DISADVANTAGES OF DUAL FUEL TECHNOLOGY

a. Poor part load efficiency.
b. Dependence on fossil fuel.
c. Higher emission than CNG engines.
d. Complexity in operation.

9. CONVERSION OF A CI ENGINE TO A DUAL FUEL ENGINE

The motivation to run diesel engines on gaseous fuels is largely economic. The dual fuel engines enable the utilization of relatively cheap gaseous fuel resources while saving on the consumption of good quality diesel fuel. Much of the superior qualities and advantages associated with diesel engine can be maintained in dual fuel engines while using existing standard diesel engine installations with little modifications. It can be shown that the dual fuel engine with appropriate conversion methods has indeed, in principle, superior characteristics to those of the straight diesel engine operation. Currently, there are a number of commercially available diesel conversion systems developed to operate on a range of gaseous fuels such as CNG, LPG, or LNG. These systems, also referred to as dual fuel kits, optimize the engine in terms of power, fuel consumption, and emissions. The control system of the dual fuel kit has to be matched both to the characteristic of the engine to be converted and the fuel to be consumed, which imposes serious limitations on such conversion equipments. Adequate controls need to be provided to the dual fuel engines, adding to the complexity and cost of installation. Such controls must cater simultaneously to diesel operation, pilot injection, gaseous fuel introduction and providing protection against operational hazards such as engine over- speed, gaseous fuel leakage and accumulation during starting, etc. There is much room for innovation and improvements in this field to provide economic, reliable and simple controls. Accordingly, the question of the cost of conversion of typical diesel engines to operate on the dual fuel principle remains too complex to be answered adequately even in general terms.



The cost of conversion depends on factors such as type of engine to be converted, gaseous fuel used, gas- diesel operation ratio, application area, level of automation, etc. The special features that distinguish dual fuel engines from ordinary diesel engines are listed below:

a. Means of admitting the gas fuel.
b. Means of reducing the airflow at partial loads.
c. Modification of oil injection system.
d. Governor modifications
e. Gas valves and proportioning scheme

To obtain uniform injection of pilot diesel in dual fuel engines, the fuel pumps have to be adjusted no deliver more than be minimum amount required for ignition purposes. One simplest solution was to substitute injection nozzle tips of smaller capacity, capable of pulling only one half of oil diesel rating. Governors of dual fuel engines must be able to control the delivery of either gas or oil or combination of both. For running on gas, the governor connects to the gas throttle valve of supply; for running on oil, the governor connects to a usual basic diesel oil injection regulating system. The engine operator shifts a fuel selection lever, which moves the pivot in governor linkage, and thus transfers the governor's control action from one fuel to other. A butterfly valve is used for regulating the engine's total intake of gas and dividing it among the cylinders. The valve is located in the entrance to the main gas manifold to throttle the gas flow to suit the engine load, together with the individual proportioning valves or nozzles in gas intake and lines to each cylinder.

On a dual fuel engine it is usually desirable to operate on minimum oil fuel, but practical limitation makes it necessary to operate at a higher percentage of oil on a multi-cylinder engine than on single cylinder, owing to the difficulty to balancing fuel oil injection pumps in the light load position as well as in the full load position. To overcome this difficulty, two fuel oil injection pumps per cylinder are used. One is the standard fuel pump for operating oil; the other is smaller fuel pump, which delivers the normal amount of ignition oil at about three quarters of its full capacity.

10. SAFETY PROVISIONS FOR DUAL FUEL ENGINES

Dual fuel engines require protection from damage caused by low lubricating oil pressure, high water jacket temperature or over speed. If such a protective device shuts down the gas-burning engine, it is important that the gas admission valve be closed at once to prevent gas accumulating in and around the engine. Furthermore, the dual fuel engine should be stopped quickly if the diesel supply should fail, because there would be no pilot oil injected to ignite the gas. For these reasons, most gas burning engines are fitted with automatic devices to shut off gas supply whenever the engine stops or if the diesel supply fails.

11. DUAL FUEL VEHICLE EMISSIONS

Researchers in Malaysia observed that by using the dual fuel system, NOx, CO, and CO2 concentrations in the exhaust gases were, on an average, reduced by 54%, 59%, and 31% respectively as compared to neat diesel operation at maximum- load operating conditions. Researchers in Brazil observed a reduction in PM emissions by 75% as compared to Diesel fuel at full loads. However, HC and CO emissions are higher for dual fuel engines at lighter loads as observed by researchers in Greece. Researchers in China obtained the following emissions on a standard 13 mode ESC cycle (refer to table 11.1).

Table 11.1 Diesel versus dual fuel emissions

Emission	PM	CO	NOx	THC
(13 mode test)	g/kWh	g/kWh	g/kWh	g/kWh
Diesel	0.87	0.41	12.57	1.14
Dual fuel	0.60	0.37	8.51	8.4

12. DUAL FUEL VEHICLES

Three 1997 Vintage buses from Motor Coach Industries (MCI) in the USA were converted to dual fuel operation. The buses were equipped by the Caterpillar C-10 diesel engines, which were converted to dual fuel operation using dual fuel operating system manufacturing by Power Systems Associates (PSA).

The C10 dual fuel (DFNG) engine produces peak horsepower and torque ratings of 350hp and 1,075ft-lbs in the dual fuel mode.

The engines were derated to 300 HP when operating in the diesel-only mode. Derating was intended to foster maximum dual-fuel operation. The three buses were each fitted with four CNG cylinders for a total CNG capacity of 48 Diesel Equivalent Gallons (DEGs) at 3,000 psi. A diesel equivalent gallon is defined as the quantity of CNG at a specified pressure with the same energy content as one gallon of diesel. The bus range was approximately 460 miles in dual fuel mode (based on the average 56% CNG substitution rate and 5.3 miles/DEG obtained over the demonstration period). Dual fuel vehicles were also developed in China by Jeifang Company. Figure 39.6 shows a Jeifang Dual fuel truck and bus.

Dual fuel combustion using diesel natural gas is a promising technique for controlling both NO and Pm emissions even on existing DI diesel engines and requires only slight modification of the engine structure. This is an important advantage over the CI operation due to the NOx-PM trade off, that is, difficulties in simultaneously controlling both pollutants, NO, and PM in DI diesel engines. The penalty in BSFCexperiencedby dual fuel engines is partially compensated by the lower price of natural gas. The observed disadvantages concerning BSFC, HC, and CO can be possibly reduced by applying modifications in engine tuning, that is, injection timing of the pilot diesel fuel at part load conditions. Dual fuel technologies have a promising future due to their fuel flexibility, lower emissions, higher compression ratio, better efficiency and easy adaptability.

REFERENCES

1. Paper “Combustion and exhaust emission characteristics of a dual fuel compression ignition engine operated with pilot Diesel fuel and natural gas.’’ R.G. Papagiannakis and D.T. Hountalas, Energy Conversion and Management, No.45 (2004) pp. 2971-2987.
2. Presentation by Harvey Reid, Diesel Gas Company, New Zealand.
3. SAE Paper 2000-01-1386, “Demonstration of Caterpillar C10 Dual Fuel Natural Gas Engines in Commuter Buses.’’ J.M. Addy et.al. USA.
4. SAE Paper 2001-01-0145, “The Studies of an Electronically Controlled CNG System for Dual Fuel Engines.” Y. Zhang et.al, Beijing Institute of Technology, China.
5. SAE Paper 2001-01-1189, “Experimental Investigations on the Performance Characteristics of a producer Gas Fuelled Spark Ignition Engine, P.G. Tewari et.al.
6. SAE Paper 2001-01-1808, “Engine Performance and Exhaust Gas Emission Characteristics of (CNG/Diesel) Dual –fuel Engine.” T.F. Yusaf et. Al.-University of Southern Queensland, Australia.
7. SAE Paper 2006-01-3427, “Control System for Diesel – Compressed Natural Gas Engines.” O. Volpato ET. al., Delphi Automotive Systems Brazil.
8. Alternative fuels S.S Thipse, Jaico publisher.