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A Review on Performance Investigation of Dual Fuel Engine

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Abstract **A dual fuel engine is a compression ignition (CI) engine where the primary gaseous fuel source is pre-mixed with air as it enters the combustion chamber. This homogenous mixture is ignited by a small quantity of diesel; the 'pilot'; that is injected towards the end of the compression stroke. In the present study, a direct injection CI engine, was fuelled with three different gaseous fuels; methane, propane and butane. Alternative fuels have been getting more attention as concerns escalate over exhaust pollutant emissions produced by internal combustion engines, higher fuel costs, and the depletion of crude oil. Various solutions have been proposed, including utilizing alternative fuels as a dedicated fuel in spark ignited engines, diesel pilot ignition engines, gas turbines, and dual fuel and bi-fuel engines. Among these applications, one of the most promising options is the diesel derivative dual fuel engine with natural gas as the supplement fuel. This study aims to evaluate diesel and dual fuel combustion in a natural gas-diesel dual fuel engine. More dual fuel engines are being utilized due to stricter emission standards, increasing costs of diesel fuel and decreasing costs of natural gas. Originally sold as diesel engines, these units are converted to natural gas-diesel fuel engines using an aftermarket dual fuel kit. As natural gas is mixed with air intake, the amount of diesel used is reduced. The maximum natural gas substitution is limited by knock or emissions of carbon monoxide and total hydrocarbons.**

Keywords: **T, BP, Bmep, Bsfc, η_{th}, DDF, NG, EGR, CO, CO_2, O_2, NO_x , COV**

I. INTRODUCTION

The term "dual fuel" refers to a CI engine where a homogenous mixture of gaseous fuel and air is ingested. The ignition source is the injection of a small quantity of diesel fuel, and the overall combustion process is similar to that of a diesel engine. The objective of this technique is to reduce problematic diesel engine emissions of NO_x and smoke. The drawback is that this reduction is often accompanied by an increase in emissions of CO and unburned hydrocarbons (UHC).[6]

The first stage is due to the combustion of approximately half of the pilot fuel and a small amount of gaseous fuel entrained within it. The second is due to diffusive combustion of the remaining pilot fuel and the rapid burning of gaseous fuel in the immediate surroundings. The third stage is due to flame propagation through the remainder of the cylinder charge. This description allows some explanation of dual fuel exhaust emission trends. For example, oxides of nitrogen (NO_x) formation is known to be strongly dependent on local temperatures, so most NO_x would be formed in the region around the pilot spray where high temperatures exist.[6]

Dual fuel engines typically use either natural gas/methane or LPG/propane as the primary fuel. The performance of different gaseous fuels as compared with each other is the subject of this present research, as they have not been directly compared in modern a DI diesel engine. For varying pilot quantity and gaseous fuel concentrations, three different fuels (methane, propane and butane) are compared as these factors have been identified as amongst the most important parameters influencing the dual fuel combustion process. Methane, the main constituent of natural gas (typically 94% by volume in the UK), is a preferred fuel for use in dual fuel engines as it is highly knock resistant and contains more energy per unit mass than other conventional fuels, whilst fuel cost savings generally offset the cost of engine conversion . It is the simplest and most stable hydrocarbon and its gaseous nature allows excellent mixing with air resulting in an even charge distribution and smoother heat release rates. Methane has a wide flammability range, low global toxicity (as compared to diesel) and has low photochemical reactivity. Most of the

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unburned hydrocarbon emissions from these engines are methane. Although it is chemically resistant and toxicologically inert, it has 12 to 30 times the greenhouse effect of carbon dioxide and so requires control.

Propane is the main constituent of LPG, and is attractive for use in dual fuel engines as it is a single, relatively simple species so engines and after treatment systems can be designed to utilize it cleanly. It can be stored at atmospheric pressure so there are no evaporative losses. Propane has a good volumetric energy content and a road octane number of more than 100. Consequently; it is considered that the most suitable use of LPG in engines is via dual fuel rather than bi fuel. Although propane is normally regarded as a fast reacting fuel, it has an extended ignition delay period compared to methane, and although it tends to produce slightly higher power due to the fast burning rates, it is ultimately possible to achieve higher power outputs with the more knock resistant methane.

Butane (a by-product of gasoline production) has a greater volumetric energy content than propane and it has a relatively low reactivity in the atmosphere. Gota e a butane/diesel dual fuel engine had a higher thermal efficiency than when fuelled with propane, and much reduced quantities of diesel were needed for ignition. Almost the same output was achieved with butane as with diesel alone over a wide load range, without smoke, and dual fuel operation was satisfactory at idle with 70% of the total heating value being supplied by butane. The butane/diesel engine had the same specific fuel consumption and reduced NO_x emissions compared to diesel; however carbon monoxide levels were greatly increased. It was suggested that this effect was caused because butane acts as a reducing agent for NO_x, but is itself oxidized to CO.[6]

II. LITERATURE SURVEY

A. Natural Gas

Natural gas has been known for many centuries. It was first found by the people of Mount Parnassus in ancient Greece. Around 500 B.C., it is known that the Chinese started using natural gas that seeped to the surface to boil sea water for drinking water.

B. Dual Fuel Background

The discovery of the dual fuel engine is credited to Cave in 1929 and Helmore et al. in 1930 when hydrogen fuel was introduced as a supplementary fuel in diesel engines. However, at that time, dual fuel had limitations which made it less popular for commercialization. The challenges included mechanical complexity, expensive components, large inefficiencies, and significant knocking.[5]

C. Diesel Engine

The combustion process of a diesel engine starts when fuel is injected into the cylinder at the end of compression

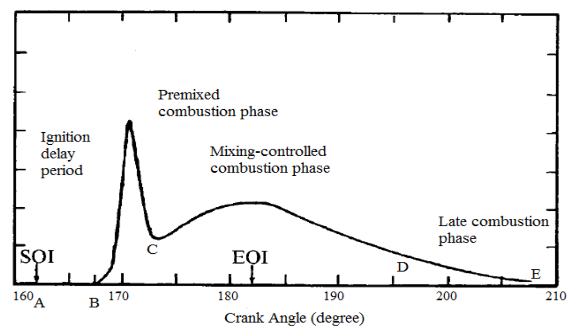

Figure 2.3.1: Diesel combustion stages.[5]

stroke. During the compression stroke, pure air is compressed with a high compression ratio, heating the gas above the diesel self-ignition temperature.

III. DUAL FUEL OPERATION

In dual fuel operation, combustion ideally consists of a diesel fuel flame progressing through a lean premixed air and gaseous fuel mixture which is locally homogenous. The premixed air and gaseous fuel burn in the presence of the diesel flame and a premixed flame is initiated by the diesel flame and propagates through the remaining air and gaseous fuel mixture. During the compression stroke, the premixed mixture's temperature and pressure is

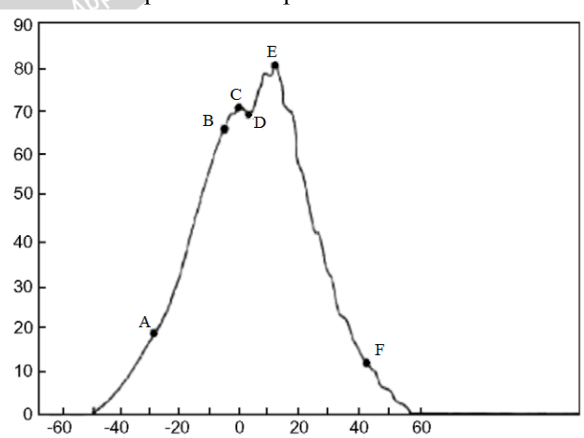

Figure 3.1.1 Combustion process of a dual fuel engine[5]

greatly increased, forming the pre-ignition reaction environment. During this phase, partial oxidation products can form at the end of compression to induce diesel fuel ignition

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and combustion. The spread of the diesel flame front is greatly influenced by turbulence, swirl, and squish within the cylinder. Pressure (Bar) Vs. Crank Angle θ (Degree).

The combustion phases of a dual fuel engine are illustrated with a cylinder pressure trace in Fig 3.1.1. After diesel fuel is injected at point A, a longer ignition delay period AB is observed in dual fuel combustion than in conventional diesel engines due to the reduction in oxygen concentration resulting from the introduction of natural gas to the intake charge. The premixed combustion phase BC in dual fuel is slower compared to conventional diesel premixed combustion. This is because the dual fuel engine is injecting a smaller amount of liquid fuel, therefore a smaller amount of burning mixture is added to the fuel. Period CD shows a decrease in pressure until it rises at period DE. Period CD is described as the primary fuel (premixed air and natural gas fuel) delay period. The DE phase is the actual combustion of the natural gas fuel starting with the flame propagation initiated by the spontaneous liquid fuel ignition. The principle of working of a four stroke engine is given by fig.3.1.2

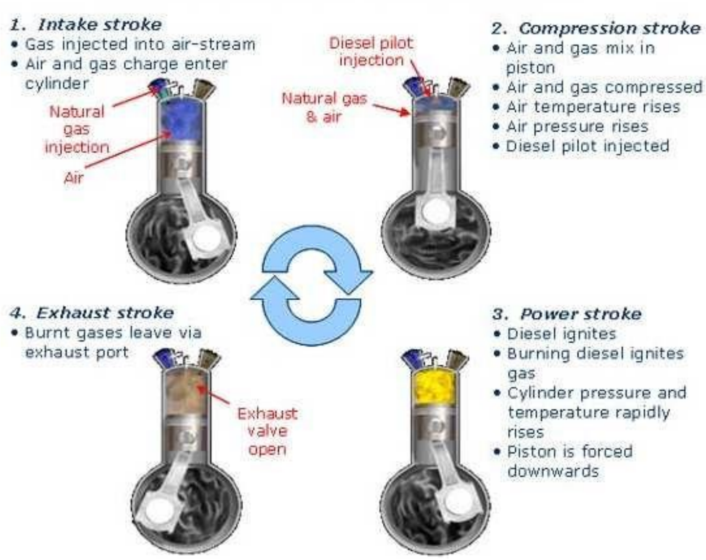

Figure 3.1.2 Four-stroke Dual Fuel Diesel-Gas Cycle.Principle of working of a four-stroke engine.[5]

IV. PERFORMANCE OF THE ENGINE USING DUAL FUEL WITHOUT EGR

In this stage of study the engine was tested as a dual fuel engine at different Diesel/NG ratios. Fig.6.1.1 shows the brake specific fuel consumption (BSFC) based on diesel thermal equivalent as mentioned earlier. The figure shows clearly an increase in the BSFCas the natural gas fraction increased. This can be explained by the higher ignition delay of natural gas compared to diesel fuel which results in a late peak combustion pressure obtained in the expansion stroke. In addition to that it is well known that instead of having a spontaneous combustion of diesel fuel, a flame propagation speed has to be considered in case of NG. Accordingly, for mixtures with higher ratios of natural gas it is expected to have slower speeds. This will lead to delay the energy released from the combustion of natural gas towards the end of expansion stroke which results in lower pressures and less outputs. This is supported by fig. 6.1.2 where the peak cylinder pressure is reduced as natural gas is used. When using the same amount of fuel consumption (0.76 kg/h) with different percentages of (diesel/natural gas), different values of BMEP were generated (3.6 bar at 100% diesel, 3.2 bar at 60% diesel and 2.8 bar at 30% diesel). Fig.6.1.3 shows a maximum reduction of 5-8 % in the absolute engine efficiency over the entire window of applied loads and Diesel/NG ratios. [1]

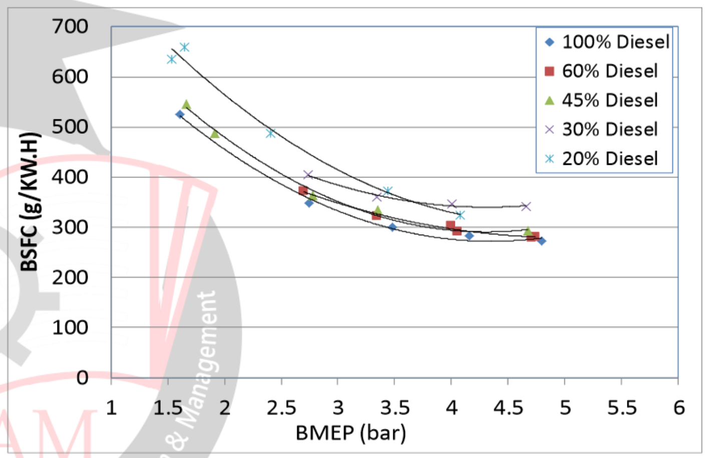

Figure 6.1.1 BSFE at different load and Diesel/NG ratio[1]

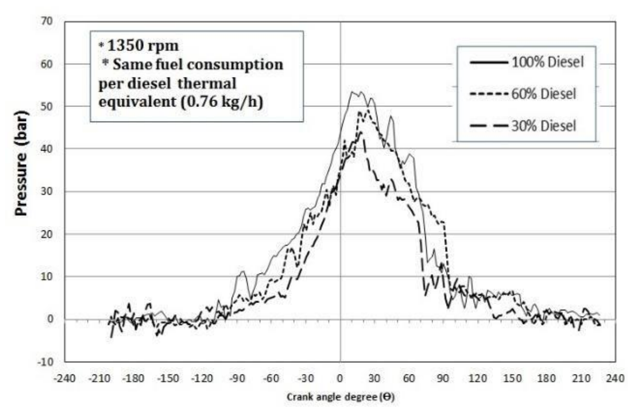

Figure 6.1.2 Pressure variation with Crank angle.[1]

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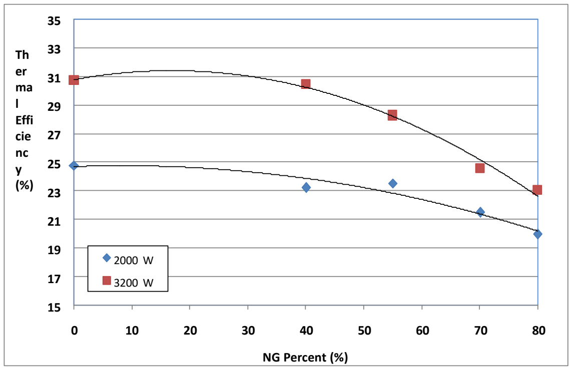
Figure 6.1.3 Thermal efficiency at different NG percent.[1]



V. CONCLUSION

The conclusion from this report the performance of a small dual fuel engine where a single cylinder diesel engine is converted to run on a dual fuel of diesel and compressed natural gas (CNG). Exhaust gas recirculation (EGR) was utilized in this study. Based on the obtained experimental results, it can be concluded that The total reduction in engine thermal efficiency increases as the ratio of the used natural gas increases. A maximum reduction of 5-8 % in the absolute engine efficiency was recorded over the entire window of applied loads and NG/diesel ratios.

When 15 % EGR was considered, more than 28 % reduction in the thermal efficiency was recorded when NG was used at relatively low loads.

At high loads however, the adverse effects of NG addition is less (about 14 % reduction in thermal efficiency).

The increases in NG fraction and EGR generally reduce the rate of reaction and thus increase CO emission except at high loads, where CO emissions tend to decrease with adding EGR. NO_x decreases as NG contents increase at medium loads while at high loads NO_x emission tends to increase with increasing NG contents. Also, NO_x decreases with EGR for the entire range of loads however, at high loads the increase in NG content becomes dominant and takes the rule of increasing the final NO_x emission.

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