A Review on Dual Fuel Engine using Diesel as Primary Fuel and Various Secondary Fuels (NG, Hydrogen and L.P.G.)

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Abstract:-This paper aims to present review about the emission characteristic and fuel consumption of a dual fuel engine. A dual fuel engine uses a primary and secondary fuel . Primary fuel is the pilot fuel such as Diesel and the secondary fuel may be NG, LPG or Hydrogen. Dual fuel engine reduces the pollutant emission as well as fuel consumption. To improve the combustion process in engine and to reduce the emission pollutants during combustion, secondary fuel is premixed with the engine intake air, after the injection of pilot fuel in small amount. In any engine, the emission characteristic of the engine is very important and emission pollutants in atmosphere is a big issue. The paper tries to show the reduction of emission pollutants and fuel consumption by the use of dual fuel engine.

Keywords: - Dual fuel engine, NG, LPG, Hydrogen and Diesel.

1. INTRODUCTION:-

The operation of dual fuel engine is mainly focused on emission characteristics of engine and specific fuel consumption. Dual fuel engine reduce emission of pollutants (such as COx, NOx, HCs etc.) during exhaust after combustion of fuels and specific fuel consumption. Dual fuel engine is operated with a primary fuel and a secondary fuel. Diesel is used as primary fuel and L.P.G., N.G. and Hydrogen are used as secondary fuel. Secondary fuels are used in gaseous form, so secondary fuel is pre-mixed with intake air, this mixture is lean and ignition of this charge is accomplished by injection of small amount of primary fuel. In dual fuel operation a small amount of gaseous fuel releases higher energy during combustion. To reduce emission of pollutants exhaust gas recirculation (EGR) system may be used.

Table.1 Nomenclature:-

ATDC	after top dead center
CFD	computational fluid dynamics
DF	dual fuel
EGR	exhaust gas recirculation
EOI	end of injection
EVO	exhaust valve opening
FD	full diesel
HCCI	homogeneous charge compression ignition
NG	natural gas
SOI	start of injection
LPG	Liquid Petroleum Gas
HC	Hydro Carbon
TMI	Timed Manifold Injection

EGR system is aimed at reducing the exhaust emission that was not being cleaned by the other controls. Oxides of nitrogen (NOx) are formed when temperatures in the combustion chamber get too hot. At 1371 ^{0}C, Or hotter, the nitrogen and oxygen in the combustion chamber can chemically combined to form nitrous oxides, which, when combined with hydrocarbons (HCs) and presence of sunlight , produces an ugly haze in our skies known commonly as smog [1]. Those the exhaust gas recirculation (EGR) system recycles a small amounts of exhaust gas from the exhaust system (usually around 25%) and mixes it with the intake manifold air entering into the combustion chambers. The addition of this inert (or non combustible) exhaust gas limits the peak combustion temperature to a range that is below 1371 ^{0}C, where the formation of nitrogen oxide (NOx) is known to occur [2]. The EGR system is incorporated where the engine is pinging and/or knocking badly from a severe lack of EGR flow, misfires can take place which allow raw hydrocarbons to be released from the tailpipe. Hence EGR is considered as a metered intake leak [3].

2. CHARACTERISTICS OF DUAL FUEL ENGINE

Dual fuel engine has high efficiency and it remains unchanged using secondary fuel, such as NG, Hydrogen and LPG. DF engine uses secondary fuel or gas at low pressure and reduces the emission due to high efficiency, clean fuel and lean burn combustion. The fuels used in DF engine are chemically stable and it may be gas or liquid and DF fuel engine also use bio-fuels. DF engine has double wall gas piping that means the engine room is a gas safe area. DF engine may use EGR system to reduce the exhaust emission.

3. DUAL FUEL (DIESEL/NATURAL GAS) ENGINE

Nowadays, the most critical issues concerning internal combustion engines are the reduction of the pollutant emissions, in particular of CO_2, and the replacement of fossil fuels with renewable sources. An interesting proposition for Diesel engines is the use of natural gas in combination with the conventional liquid fuel [5]. This technology, known as Dual Fuel (DF) combustion, consists in the ignition of a premixed charge of gaseous fuel by means of a pilot injection of Diesel Fuel. With a proper control of the premixed charge composition and of the injection advance, it is possible to achieve a smoke-less combustion, reduce CO and CO_2, and get acceptable levels of nitrogen oxides [6-7].

The dual fuel operation is characterized by a diesel pilot injection to start combustion in a port premixed NG/air blend. In the best conditions up to 90% diesel oil can be replaced by NG. Critical aspects are at idle and low load, where poor combustion quality and high HC emissions usually occur, and at full output as well, where heavy knocking can damage engine. An important target that is reachable applying this technology is to approach the same efficiency of a diesel engine, but with globally lower pollutant emissions. Moreover, lower CO_2 emissions are expected, since methane presents the lowest C/H ratio among all the fossil fuels [8].

In the last years, the dual-fuel combustion system has been studied by many researchers [9-10] but it has not yet reached a great diffusion, essentially due to the HC and CO emissions that are higher than those of a conventional diesel engine, especially at part load. In [11] the authors propose a binary fuel blend in which two fuels with different auto ignition characteristics allow a better combustion timing control in a HCCI engine. They optimize the chemical kinetic mechanisms available for n-heptane and natural gas. In dual fuel engine using diesel and natural gas there are mechanical failure occurs due to auto ignition or knocking, high temperature and pressure of combustion.

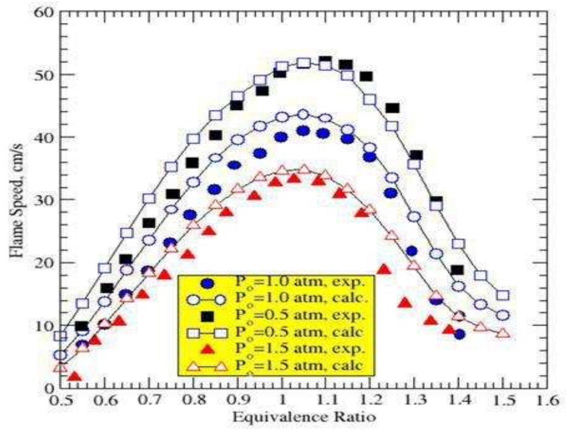

Fig. 1 Flame propagation velocities for NG/air mixtures [12]

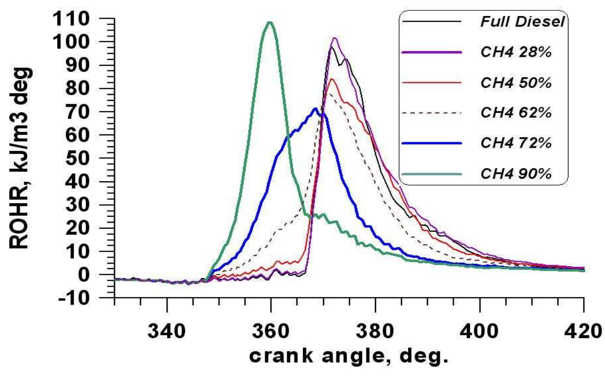

Fig. 2 Heat Releases by varying the NG ratio [8]

NG rates up to 50% the engine behavior is almost similar to that in full diesel operation, both in terms of lean combustion development and as regards the nitric oxide formation. On the other hand, increasing the NG rate at 70 – 90 % level induces an engine behavior that is comparable with the one of spark ignition engines close to knocking conditions with a sudden consumption of the natural gas in the reacting mixture and, consequently with a steep pressure rise [8].In DF combustion construction of pre-mixed natural gas and pilot fuel are varying at different speeds. Diesel/NG DF engine reduce smoke and also allows the reduction of emission, but the only drawback appears the increase of oxides of nitrogen (NOx), which can be reduced or eliminate, using EGR system or by setting of pre-mixed NG concentration and SOI.

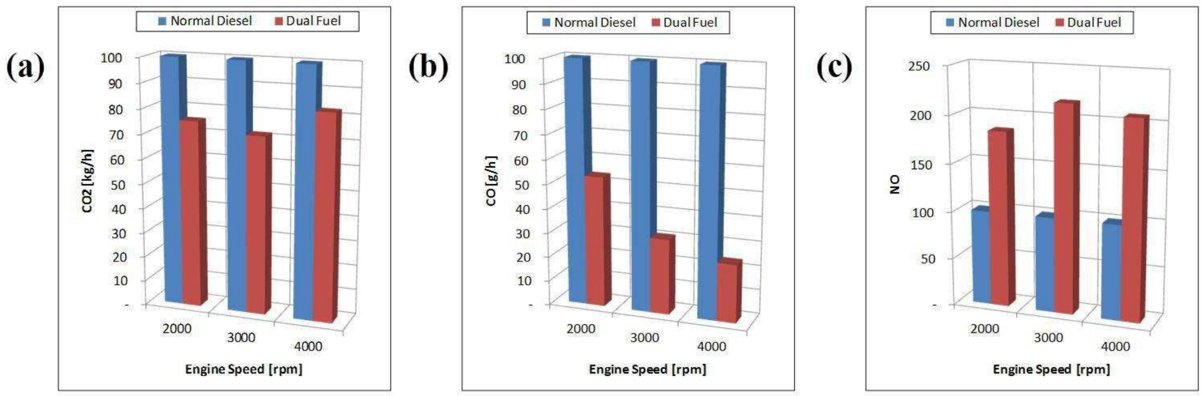

Fig.3 Comparison between normal Diesel and Dual Fuel operation in terms of (a) CO2 emissions, (b) CO emissions, (c) NO emissions[12]

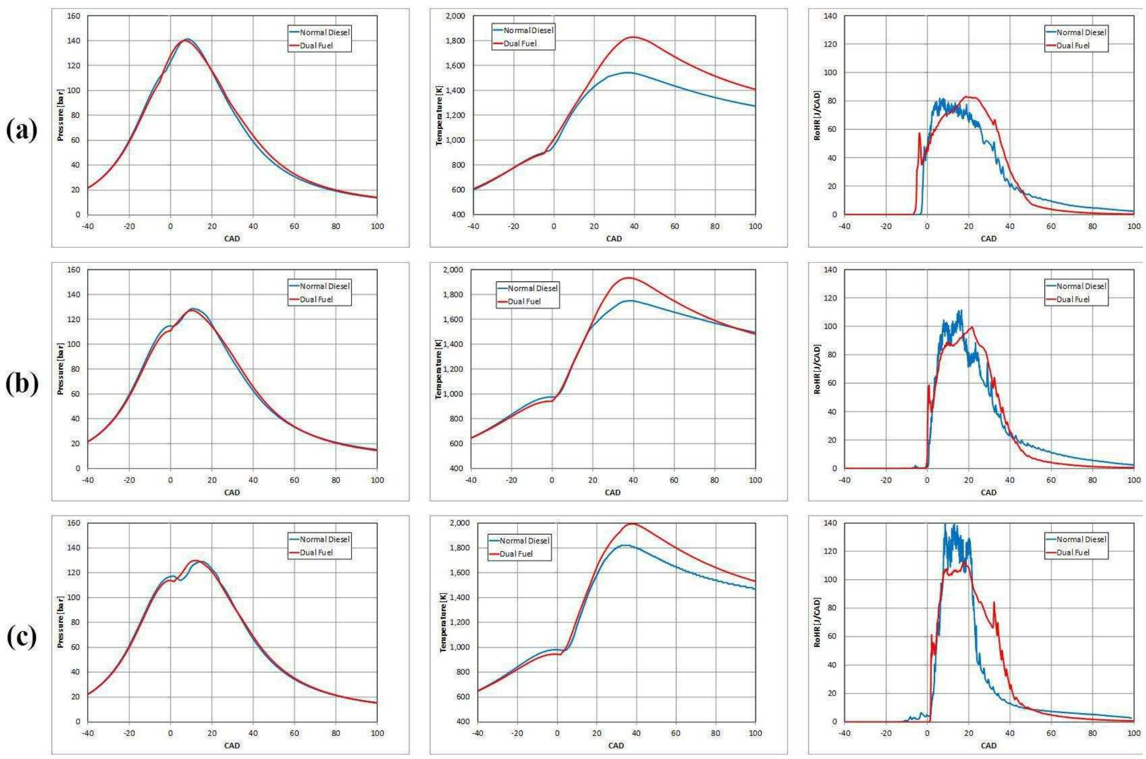

Fig.4 Comparison between normal Diesel and Dual Fuel operation in terms of in-cylinder pressure, temperature and Rate of Heat Release, at (a) 2000 rpm, (b) 3000 rpm, and (c) 4000 rpm.[12]

4. Dual fuel (Diesel/Hydrogen) Engine:-

In diesel/hydrogen dual fuel engine hydrogen is pre-mixed with the engine intake air after the injection of diesel in small percentage to improve the engine combustion and to reduce pollutant emissions during combustion. The advantages of using hydrogen as fuel for internal combustion engine is among other a long-term renewable and less polluting fuel, non-toxic, odorless, and has wide range flammability. Other hydrogen properties that would be a challenge to solve when using it for internal combustion engine fuel, i.e.: low ignition energy, small quenching distance, and low density [4].Hydrogen cannot be used directly in a diesel engine due to its auto ignition temperature higher than that of diesel fuel. One alternative method is to use hydrogen in enrichment or induction. . The engine was run at a constant speed of 2000 rpm and 10 Nm load. Hydrogen was introduced at the flow rate of 21.4, 36.2, and 49.6 liter/minute. Specific energy consumption, indicated efficiency, and cylinder pressure were investigated. At this low load, the hydrogen enrichment reduced the cylinder peak pressure and the engine efficiency [4].

Diesel-hydrogen dual fuel engine can be operated with less fuel than neat diesel operations, resulting in lower smoke level and higher brake thermal efficiency. NO_x emissions were also reduced except at full load operation [13]. Hydrogen induction, particularly when its energy share increased above 15% resulted in a sharp decrease in ignition delay, very high peak pressure rates, increase in smoke and loss in fuel efficiency [14]. The brake thermal efficiency of dual fuel with exhaust gas recirculation (EGR) is higher than that of neat diesel operation. Dual fuel operation without EGR resulted in the lowest smoke and unburned HC. EGR reduced NO_x emission effectively [15]. It was found that CO, FSN, and THC increase with EGR but NOx emission decrease drastically. Inversely, CO, FSN, and THC emission decrease with hydrogen, but NOx increases. This inverse relationship will allow the combination of EGR and hydrogen induction to be optimized to minimize both FSN and NOx [16].

Using Port-injected hydrogen, there was an increase in brake thermal efficiency of the engine with a greater reduction in emissions [17]. Any decrease of emission, especially NOx is likely due to enhancement of turbulent mixing in the cylinder caused by the injection of pressurized hydrogen through the intake valve [18]. Timed manifold injection (TMI) of hydrogen gave higher thermal efficiency and avoided undesirable combustion [19-20]. Hydrogen induction with TMI coupled with EGR results in lowered emission level and improved performance level compared to the case of neat diesel operation [21]. Although research on hydrogen combustion in the internal combustion engine has intensified, the number of published papers in the field of hydrogen-diesel co-combustion is not as rich as for hydrogen used in spark ignited engines [22].

During the hydrogen addition, the load and speed were kept constant. This mode can be realized by setting the dynamometer at fixed load. The engine speed was kept constant by controlling the diesel fuel governor. The percentage of diesel fuel on the energy basis of this load condition is depicted in Fig. 5a. It is noted that the diesel replacement for hydrogen flow rates at 21.4, 36.2, and 49.6 l/minute were around 50, 90, and 97% respectively. More energy was added when hydrogen was introduced. To keep the load and speed constant, the fuel governor was adjusted accordingly to reduce the diesel supply. As a result, part of diesel fuel was replaced by hydrogen enrichment [4].

Figure 5b depicts the variation in specific energy consumption (SEC) at 10 Nm load for different level of hydrogen enrichment. SEC indicates the amount of total fuel energy (diesel and hydrogen) needed to produce 1 kW power for an hour engine operation. The total fuel energy is calculated from the individual fuels (diesel and hydrogen) multiplied by their respective calorific value. An increasing hydrogen flow rate at the low load operation results in a higher SEC. The specific energy is found to be 20.73 MJ/kWh with hydrogen flow rate of 21.4 l/min. A further increase in SEC to 21.70 MJ/kWh is obtained when hydrogen flow rate increase to 36.2 l/min. A slightly increase in SEC to 21.8 MJ/kWh is noticed at hydrogen flow at 49.6 l/min [4].

Figure 5c shows the variation of indicated efficiency at each load when hydrogen was introduced. It relates the indicated power to the supplied fuel energy. At this low load, the efficiency decreases with hydrogen enrichment. The indicated efficiency of 57.9% is achieved at the hydrogen flow rate of 21.4 l/min. Further increase in hydrogen flow rate of 36.2 and 49.6 l/min reduce the efficiency to 54.3 and 49% respectively. The percentage of diesel fuel is reduced significantly with hydrogen enrichment at this low load condition. This low portion of the diesel fuel may not be sufficient to ignite the premixing mixture of hydrogen-air [4]. The efficient combustion cannot be achieved and resulted in increasing SEC as shown in Fig. 5b.

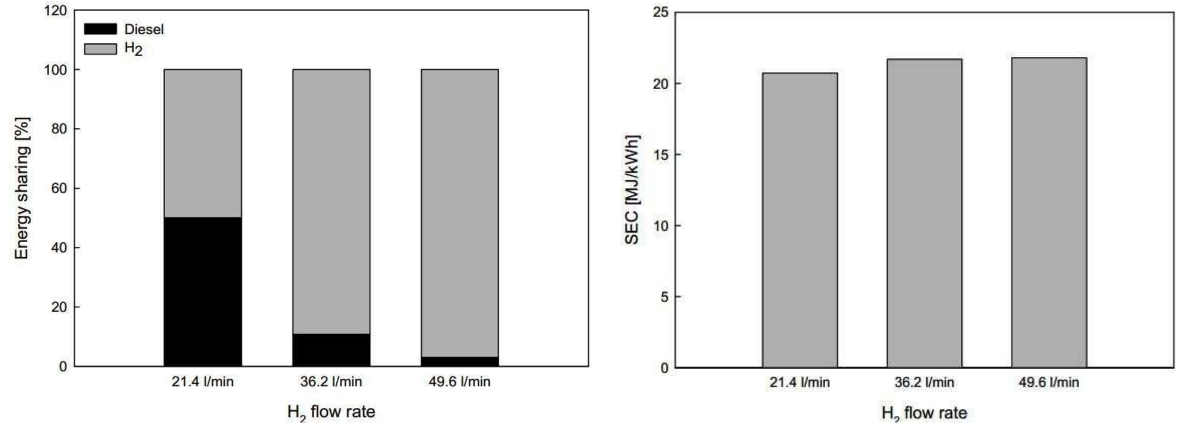

Fig. 5 (a) Diesel energy replacement by hydrogen [4]; (b) Specific energy consumption [4]

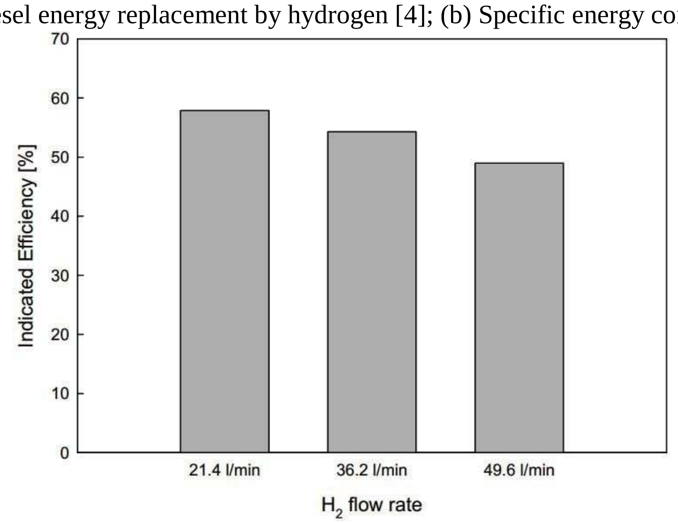

Fig. 5 (c) Indicated efficiency [4]

Increase in hydrogen enrichment to 49.6 l/min reduced the percentage of diesel fuel to 3.1%. These portions of diesel may not be adequate to produce an efficient combustion. The amount of diesel fuel to ignite the premixing of hydrogen with air was reduced and resulted in a late start of combustion as shown in rate of heat release diagram in Fig. 6 [4].

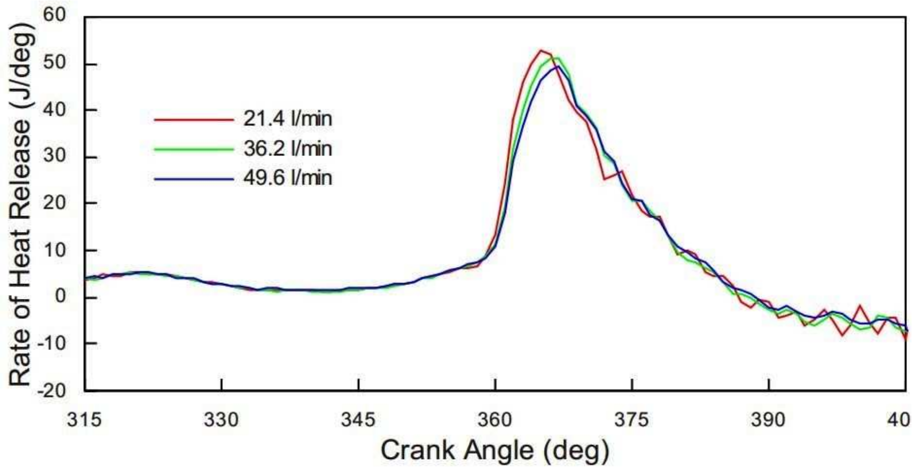

Fig. 6 Effect of hydrogen addition at 2000 rpm, 10 Nm on: Rate of heat release [4]

IV. Diesel/LPG Dual fuel engine:-

In this technique, dual fuel engine uses diesel as primary fuel and LPG as secondary fuel. After the injection of diesel in small quantity, LPG is pre-mixed with the engine intake air, to improve the combustion process on engine and to reduce the emission pollutants during combustion. Diesel/LPG dual fuel engine improves the efficiency by 8% at 60% to 80% load condition [3]. By the increase in mixture temperature, the flame velocity is increases, thus resulting lower emission.

V.CONCLUSION:-

Now a day reduction of the pollutants emission and the fuel consumption concern with IC engine is a very critical issue. An IC engine emits COx, NOx and other non combustible products, which are harmful for both the atmosphere and the human beings. Therefore dual fuel is used to reduce the pollutant emission from an IC engine. A conventional IC engine uses only one fuel, whereas in DF engine two fuels are used. In DF engine a gaseous fuel (NG, LPG or Hydrogen) is premixed with air after the injection of pilot fuel (Diesel), to improve combustion process of engine and to reduce the pollutant emissions. By the use of dual fuel, there is increase in mixture temperature and also and also the flame velocity is increased, which creates a lower emission.

An EGR system may be used on Diesel-LPG DF engine to reduce the emission pollutants. The CO emission is reduced throughout the engine operation with EGR gases in comparison to dual fuel mode of operation. It ranges from 0.6 g/kWh to 0.27 g/kWh and smoke emission in dual fuel mode is 0.2 to 0.92 BSU, whereas it ranges, from 0.2 to 0.72 BSU with EGR system [3]. From the study, it is concluded that DF engine reduces the emission pollutants and fuel consumption and emission of dual fuel engine can be further improved using EGR system with DF engine.

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