A REVIEW ON RECENT TRENDS IN INTERNAL COMBUSTION ENGINE

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Abstract: Internal combustion engines are widely used worldwide for transportation, shaft energy production, marine applications etc**.** Increasing the efficiency of internal combustion engines is one of the most promising and cost-effective approaches to dramatically improving the fuel economy of the on-road vehicle fleet in the near- to mid-term. The present paper gives a brief introduction of an Internal Combustion Engine and its application, Investigation of the effect of addition of browns gas to air fuel mixture in combustion of 4 stroke SI Engine, The porous medium technology for an IC engines, concept of Nano Internal Combustion Engine, Novel Otto cycle engine concept and S.I.Engine with Quasi-constant volume Cycle (QCV).

***Index Terms* – Internal Combustion Engine, Fuel Economy, Brown Gas, Nano Engine, Novel Otto Cycle.**

1. INTRODUCTION

A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work. It is classified into two types. **Internal combustion engine and External combustion engine.**

The Internal combustion engine is a heat engine that converts chemical energy in a fuel into mechanical energy, usually made available on a rotating output shaft. Chemical energy of the fuel is first converted to thermal energy by means of combustion or oxidation with air inside the engine. This thermal energy raises the temperature and pressure of the gases within the engine and the high-pressure gas then expands against the mechanical mechanisms of the engine. This expansion is converted by the mechanical linkages of the engine to a rotating crankshaft, which is the output of the engine. The crankshaft, in turn, is connected to a transmission and/or power train to transmit the rotating mechanical energy to the desired final use. [1]

1.1 Classifications of IC Engines:

I.C.Engines can be classified according to:

a. Number of cylinders – 1, 2, 3, 4, 5, 6 to 16 cylinder engines.
b. Arrangement of cylinders – Inline, V-type, Flat type, etc.
c. Arrangement of valves and valve trains – In-block camshaft, OHC, DOHC, etc.
d. Type of cooling – Air-cooled, Water-cooled, etc.
e. Number of strokes per cycle – 2-stroke, 4-stroke engines.
f. Type of fuel burned – Petrol, diesel, CNG, etc.
g. Method of ignition – Spark Ignition (SI), Compression Ignition (CI).
h. Firing order – 1-3-4-2, 1-2-4-3, etc.
i. Primary mechanical motion – Reciprocating, rotary.

1.2 Comparison between external combustion engine and internal combustion engine:

Table 1-1.1 Comparisons between E.C.Engine and I.C.Engine

External combustion engine	Internal combustion engine
Combustion of air-fuel is outside the engine cylinder.	Combustion of air-fuel is inside the engine cylinder.
The engines are running smoothly and silently due to outside combustion	Very noisy operated engine
Lower efficiency about 15-20%	Higher efficiency about 35-40%
It can use cheaper fuels including solid fuels	High grade fuels are used with proper filtration
Working pressure and temperature inside the engine cylinder is low; hence ordinary alloys are used for the manufacture of engine cylinder and its parts. High starting torque	Working pressure and temperature inside the engine cylinder is very much high; hence special alloys are used IC engines are not self-starting
Lower efficiency about 15-20%	Higher efficiency about 35-40%

1.3 Cycle of operation of 4-stroke and 2-stroke Engine.

1.3.1 Four stroke engine

Cycle of operation completed in four strokes of the piston or two revolution of the crank.

i. Suction stroke (suction valve open, exhaust valve closed)-charge consisting of fresh air mixed with the fuel is drawn into the cylinder due to the vacuum pressure created by the movement of the piston from TDC to BDC.

ii. Compression stroke (both valves closed)-fresh charge is compressed into clearance volume by the return stroke of the piston and ignited by the spark for combustion. Hence pressure and temperature is increased due to the combustion of fuel
iii. Expansion stroke (both valves closed)-high pressure of the burnt gases force the piston towards BDC and hence power is obtained at the crankshaft.
iv. Exhaust stroke (exhaust valve open, suction valve closed)- burned gases expel out due to the movement of piston from BDC to TDC.

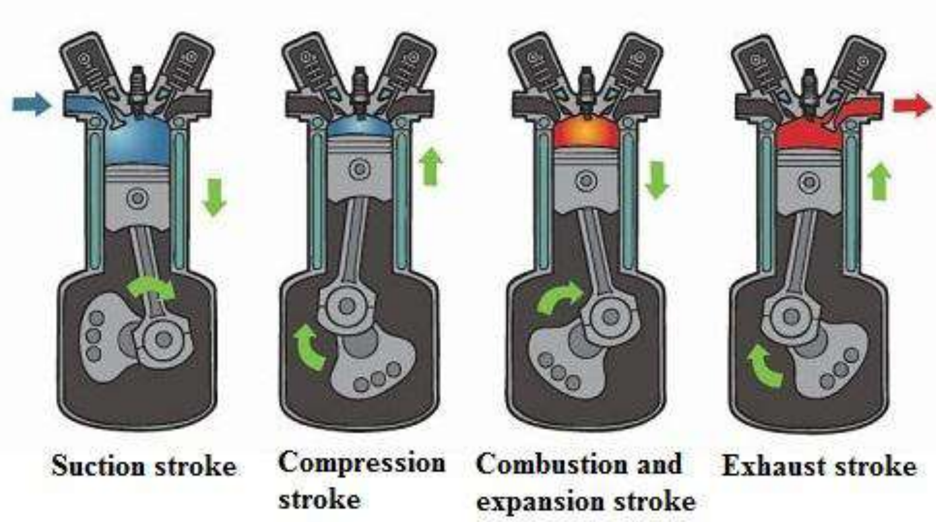

Figure 1.1 Cycle of operation in four stroke engine

1.3.1 Two stroke engine

Cycle of operation in two stroke engine Two stroke of the piston and one revolution of the crank.

- No piston stroke for suction and exhaust operations
- Suction is accomplished by air compressed in crankcase or by a blower
- Induction of compressed air removes the products of combustion through exhaust ports
- Transfer port is there to supply the fresh charge into combustion chamber [2]

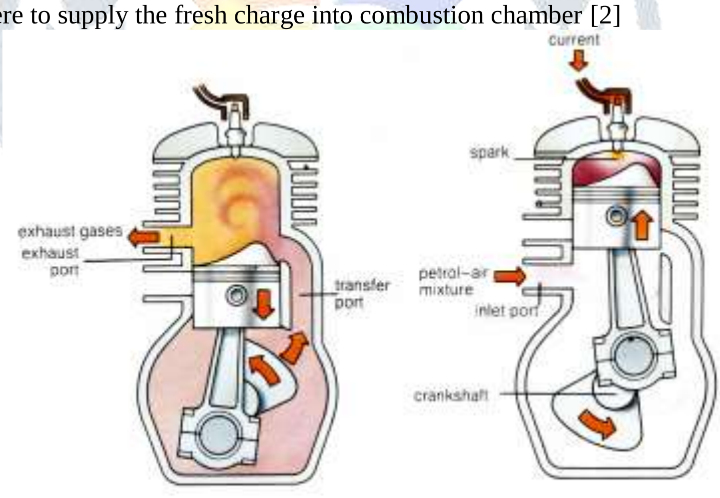

Figure 2.2 Cycle of operation in two stroke engine

2. EMISSION CONTROL IN I.C. ENGINES

Global warming has become a very huge challenge for mankind and one of the reasons for environmental degradation is emission of harmful gases due to incomplete combustion of the fuel. The problem is becoming severe day by day because of increase in the vehicular density. Numerous solutions have been proposed till date to overcome this challenge.

Amruthraj. M, Nataraj J.R. Sushmit Poojary [3] finding the effect of addition of Brown's gas to air- fuel mixture has been investigated. By electrolysis1 process, Brown's gas, a highly combustible gas is generated when water is sent into hydrolyser kit.

Hydrogen is a combustible gas and water on electrolysis splits into two molecules of hydrogen and one molecule of oxygen, hydrogen and oxygen though evolve separately in the electrolysis setup but combines immediately to form Oxy hydrogen gas(HHO) or commonly called as Brown's gas in the collection tube.

The experiment was conducted on a Bajaj RE auto rickshaw of 4 stroke, 180cc displacement, air cooled, and 6BHP S.I.engine. The brown's gas from the hydrolyser kit is sent into the cylinder of the engine, and emission test was done on the exhaust gas from the emerging from the engine. Here the approximation was made on the volume flow rate of the browns gas from the hydrolyser kit, the experiment was performed using two different apparatuses due the high rate of error and the average of these results has been displayed. For this experiment two canisters were connected in series, with both their out lets connected to a common tube using a T valve. Different flow rates were obtained for different values of current through the canisters. The canisters were connected in series with a 12V Variable Supply. The two methods used to measure the flow rate were (1) Gas flow meter and (2) Downward Displacement of Water.

2.1 Gas flow meter

This method involves connecting the output from the canisters to the input of a gas flow meter. There is a possibility of error due to higher pressure inside the meter hence the reading will be lower than the actual value.

2.2 Downward Displacement of Water

This method involves inverting a measuring cylinder filled with water in a trough containing water. The outlet from the canisters is introduced into the measuring cylinder. As the gas is evolved the water level decreases and hence we can evaluate the gas evolved per unit time. The lower pressure inside the measuring cylinder creates a suction of sorts and hence the reading tends to be higher than the actual value. By taking the average of results error is eliminated to a considerable extent and a graph was plotted (fig. 2.1).

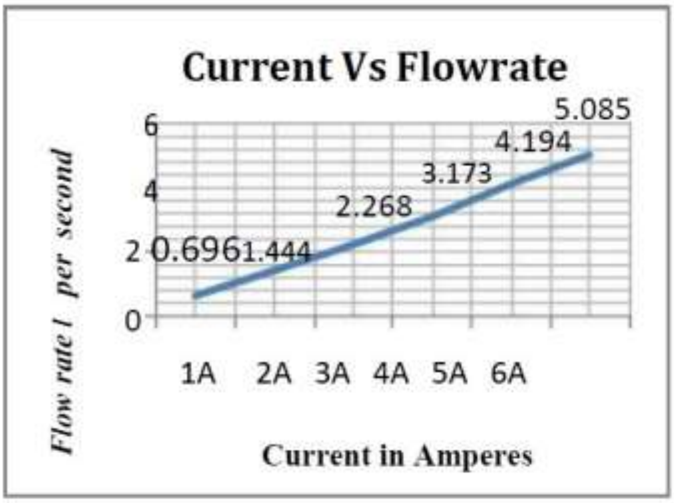

Figure 2.1 Flow rate of browns gas against Current.

Table 2.1 Emission levels before and after passing of Browns gas.

	Emission before passing brown's gas.	Emission after passing brown's gas.
Hydrocarbons	2800ppm	21ppm
Carbon monoxide	2.5%vol	0.0333%vol

The results obtained gives a clear picture on how effective the hydrolyser kit is, as the effluents in the emission gasses are reduced to a very high extent. Due to high combustible nature of the brown's gas, both browns gas and fuel completely burns in the IC engine, hence giving no scope for the incomplete combustion. With the introduction of browns gas a 99% decrease in the unburned hydrocarbons and Carbon monoxide has been observed when compared to exhaust because of air fuel mixture alone (without browns gas).

3. I.C.Engine with Homogeneous Combustion in a Porous Medium

Homogeneous combustion in an IC engine is defined as a process characterized by a 3D-ignition of the homogeneous charge with simultaneous volumetric-combustion, hence, ensuring a homogeneous temperature field.

Balvinder Budania , Virender Bishnoi [4] have proposed a new combustion concept that fulfils all requirements to perform homogeneous combustion in I.C. engines using the Porous Medium Combustion Engine, called "PM -engine".

3.1 Porous medium (PM) technology

The porous medium technology for IC engines means the utilization of specific features of a highly porous media for supporting and controlling the mixture formation and combustion processes in I.C.engines

Generally, the most important parameters of PM for application to engine combustion technology can be summarized as follows: heat capacity, specific surface area, heat transport properties. (radiation, conductivity), transparency for fluid flow, spray and flame propagation, pore sizes, pore density, pore structure, thermal resistance of the material, mechanical resistance and mechanical properties under heating and cooling conditions, PM material surface properties. For IC engine application, the thermal resistance of the porous medium is one of the most important parameter defining its applicability of a given material to combustion in engine.

3.2 Principle of the PM-engine

The PM-engine is defined as an internal combustion engine with the following processes realized in a porous medium: internal heat recuperation, fuel injection, fuel vaporization, mixing with air, homogenization of charge, 3D-thermal self ignition followed by a homogeneous combustion.

PM-Engine may be classified with respect to the heat recuperation as: I.C.Engine with periodic contact between PM and working gas in cylinder (closed chamber).and Engine with permanent contact between PM and working gas in cylinder (open chamber).

3.3 Thermodynamics of PM-engine

The essential parts of the thermodynamic model to study the proposed engine cycle are presented in Figure 3.1. The model considerations are based on two parts: a cylinder with a working gas and a porous-medium heat capacitor as needed in the working cycle that can be thermally coupled with or decoupled from the cylinder content. It is assumed that no time elapses during the thermal coupling (i.e. heat exchange), and the heat capacitor has a very large heat capacitance in comparison with that of gas in the cylinder.

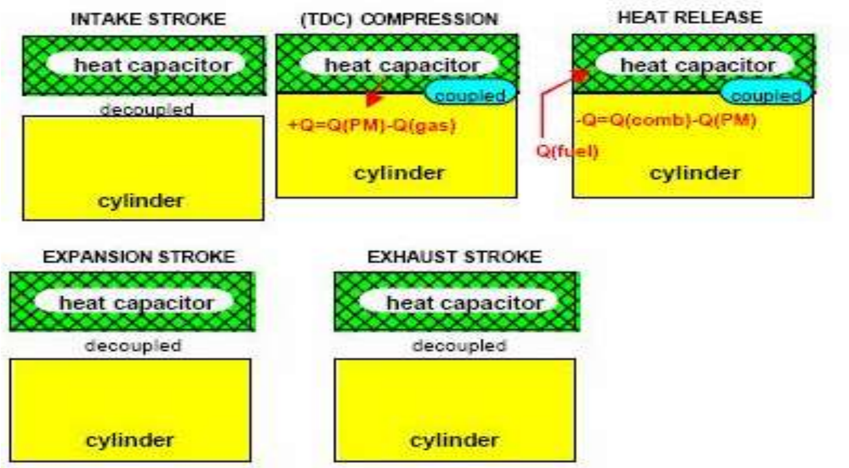

Figure 3.1 Thermodynamic model describing the PM engine cycle

At last author concluded that the PM-engine offers the realization of fully homogeneous combustion with a controlled temperature in the PM-combustion zone independently of the engine operational conditions. The temperature control is directly driven by the heat recuperation in the porous medium (heat capacitor). The significantly constant temperature distribution over the cycle and corresponding cylinder pressure distribution for the PM-engine is responsible for the higher cycle efficiency and very low combustion noise as compared to conventional DI engines.

4. Nano Internal Combustion Engine

One of the emerging aspects dealing Nanotechnology in mechanical field is the internal combustion engine on a nano scale was given by **Prof.Alka Mata [5].**

The Nano is a 0.1cc (that's less than 0.01 cu in) compression ignition engine.

Figure 4.1 Nano Internal Combustion Engine

Fig 4.1 gives an idea of the size of the nano internal combustion engine. If you observe, the length from the back plate to washer is less than an inch. There are no exotic materials required.

It has high precision, cost effective, high speed [up to 40000 rpm .The various applications can be spotted from race cars to space crafts. It can also be applied to various fields like agricultural pump sets, industrial applications, Hospitals, constructions civil engineering equipments etc.

4.1 The Components Used

4.1.1 Crankcase and Cylinder rough-out

Figure 4.2 Roughing out process

The crankcase starts off as a chunk of aluminum bar of about 1-1/2" diameter, sawn to length, plus a little bit. The first step is to finish turn the front section with a 1/4" radius where the journal blends into the body. The Fig 4 shows the roughing out process. Note that the tool is raked back sharply while "Hogg in great cuts" are made so that if it digs in, the cut will be forced shallower, not deeper compass could achieve the same result with about the same effort.

4.1.2 Back Plate

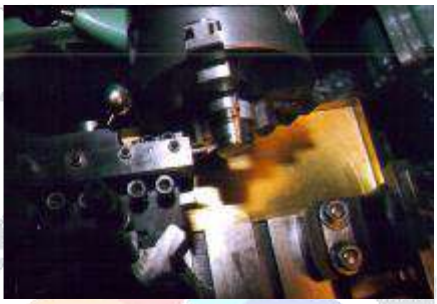

Figure 4.3 Back Plate

The back plate is simple turning with only some aspects of work holding posing any problems as shown in Fig 4.3.

In this first shot, the back plate profile has been turned on a piece of bar stock with the interior face oriented towards the tailstock. This means we will be screw cutting towards the shoulder formed by the back plate rim, so a thin (0.020") run out groove is first cut at the thread/rim junction to the depth of the thread form. This also assures the back plate will form a tight seal against the rear of the crank case. The thread cutting tool is a piece of 1/4" diameter HSS steel, ground to a 60 degree point with seven degrees of side rake, mounted in a tracting tool holder. This magnificant gadget takes a while to make but is absolutely invaluable to thread cutting. The little ball lever actuates a spring loaded, over center cam - just requiring a flick to retract the tool bit by about 3/16". This allows the saddle to be repositioned for the next cutting pass without having to twiddle dials and remember settings.

4.2. Applications.

i. It can be controlled in aero planes/satellites/space ships etc., the timing of inlet and exhaust valves.

ii. According to NASA reports they are experimenting about the use of nano engine in nano & pico satellites.

iii. Incase of a mine tragedy where harmful gases are emitted ,these Nano I.C.Engines can be employed as powerful blowers to blow out these gases is a less time saving the lives of trapped miners .We require at least 5-6 blowers to blow these gases where as two Nano I.C.Engines could do the tick in less time.

4.3. Conclusion

With nanotechnology, fuel transforms at the Nano-level to achieve a more complete combustion, resulting in increased fuel economy, more driving power, and fewer palliative emissions.

5. New Internal Combustion Engine

Jovan Doric, Nebojsa Nikolic [6] presented a novel Otto cycle engine concept in which intake and compression are carried out through unconventional piston mechanism.

5.1 S.I.Engine with Quasi-constant volume Cycle (QCV).

In real engine ideal Otto cycle have certain disadvantages because there are a lot of heat losses in case when full combustion is obtained in TDC. Optimal heat addition should be found somewhere between pure constant volume combustion and combustion at variable volume-quasi constant volume combustion.

A practical method is to reduce the engine crank rotation velocity at the TDC position to provide extra time for completing the combustion. This will then generate a new combustion cycle, quasi-constant volume (QCV), that sit between conventional IC engine combustion cycle and ideal Otto constant volume combustion cycle. Such unconventional SI engine is presented on fig. 5.1. Main parts are: 1- engine block, 2-engine head (with valves and camshaft), 3-flywheel, 4-crankshaft, 5-double acting piston, 6-piston rings, 7-piston disc and 8-cylinder liner.

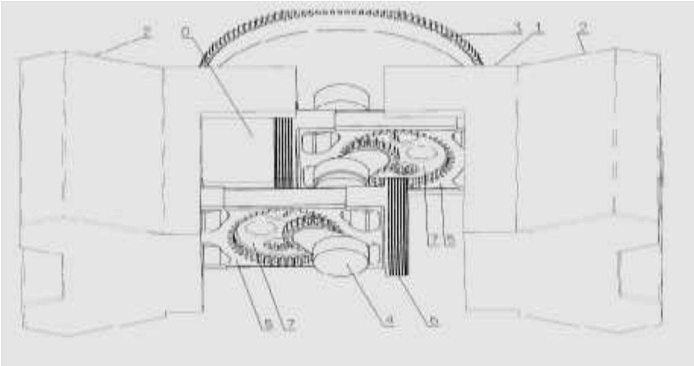

Figure 5.1 Main engine parts

Dwell time or dwell angle is important fact during combustion process. In conventional engine this dwell angle can be changed due to variations of ratio between connecting rod and crank radius. Piston dwell at TDC and at BDC are often mentioned, it should be noted that strictly, there is no dwell period in ordinary mechanism. The piston comes to rest at precisely the crank angle that the crank and rod are in line (TDC and BDC), and is moving at all other crank angles. At crank angles which are very close to the TDC and BDC angles, the piston is moving slowly. It is this slow movement in the vicinity of TDC and BDC that give rise to the term piston dwell.

5.2. Conclusion

With longer piston dwell near TDC and eliminating normal force on cylinder wall it can be expected that thermal efficiency and mechanical efficiency will be increased.

6. Alternative Fuels

Rasika Kulkarni, Sudhakar S. Umale [7] compare effects of various alternative fuels on engine emission including Hydrogen, Di Methyl Ether (DME) and Biodiesels from Karanja, Jatropha and Rapeseed oil.

Majority of the energy used today is obtained from fossil fuels. During last decade, energy consumption has largely gone up due to developments in technology, increase in population. The global consumption of energy in terms of fuels is increasing thus; the emission level also is found more. G20 countries were responsible for 81.5 % CO_2 emissions in 2015.

6.1 Engine Emissions

Comparative study of various biodiesels has been done. The emissions like CO, HC, NOx, and PM from these biodiesels when used in engines show some specific characteristics.

6.1.1 Karanja Biodiesel

Shrikant baste, S. S. Umale [8] showed, for biodiesel (B10) and biodiesel (B20) CO emission increases for 20% load but, gradually decreases as load increases. The CO emission reaches to 54.7%, for biodiesel blend (B50). For biodiesel, (B100) the CO emission decreases as compared to diesel engines.

Table 6.1. Experimental results of variation in CO emission for Karanja Biodiesel.

CO (%) LOAD (%)	Diesel	B10	B20	B50	B100
0	91.5	78.9	88.1	88.7	91
25	81.8	96..2	94.9	57.2	93.4
50	94.4	75.45	75.05	53.1	85.5
100	59.4	54.7	55.2	55.3	76.7

Limitations of Karanja oil have been observed as follows:

- Higher viscosity of oil causes problem in fuel injection.
- Collection of Karanja seed is a manual operation and hence requires more time.
- Problem of carbon deposits and oil ring sticking can be found on prolonged use.

6.1.2 Jatropha Biodiesel

Jatropha Biodiesel is produced from seeds of Jatropha Plant. **Faizan [9]** showed vibration and noise analysis of Jatropha oil in CI Engine. Noise is minimum for B100 blend (100% Jatropha oil) which was recorded as 85.8 dB at 0 kg load. The maximum noise reduction was recorded as 2.7 dB (approximately 3 %). **Tan [10]** evaluated different emissions in the experimentation and the HC emissions were observed to have continuously reducing trend with increasing biodiesel blend ratios. The reactions forming NOx are highly temperature dependent, so the NOx emissions have a close relation with the engine load. The NOx emission tends to increase with engine load. The CO emissions of different blends continuously decrease with increasing engine load but don‟t show consistent results with increasing biodiesel blends.

Limitations of Jatropha are observed:

- Similar to Karanja oil, Jatropha oil also, has greater viscosity than diesel.
- Collection of seed and production of Jatropha oil is time consuming.

6.1.3 Rapeseed Methyl Ester (RME)

The rapeseed oil is chemically known as Rapeseed Methyl Ester (RME). The compound is made by trans esterification Process. **[11]**. the larger oxygen content of these biodiesels, results in reduced HC and CO emissions. The NOx emission does not show a special trend in case of biodiesels. But it was observed in experimentation, that NOx emission had increased for lower engine speeds. The NOx emission was observed less for higher engine speed. Rapeseed biodiesel is effective in reducing particle mass concentration because of both larger oxygen content and lower aromatic compound. It is less toxic to human body when compared to conventional diesel engine.

Limitations of RME

- Compared to conventional diesel fuel, RME has low heating value.
- As load increases, the consumption of RME biodiesel increases to fulfill the lad condition.

6.1.4. Dimethyl ether

HC emission from DME is lower than or sometimes equal to diesel engines. The combustion efficiency of DME is greater hence; the un burnt carbon is less in exhaust **[12].** DME has good mixing characteristics, hence tendency of formation of homogeneous mixture was observed. The tendency of complete combustion was observed and the quantity of CO emission was reduced.

The oxygen content in DME is found to be more. There is no chance of incomplete combustion. Soot formation in DME-fuelled engine is almost zero.

Limitations of DME:

- Lower heating value than diesel engine.
- Engine performance is found to be less than diesel engine due to low heat content. Therefore there is chance of improvement in engine performance by adding some additives or blends in DME.

Hydrogen has highest heat content per unit mass among all fuels. It has many advantageous properties such as high flame speed, short quenching distance and high diffusivity. PM emission could be reduced significantly along with thermal efficiency improvement using hydrogen in the engines under dual fuel mode (diesel-hydrogen). In hydrogen dual fuel engines, other emissions including HC, CO and smoke decrease to near zero level whereas greenhouse gas emissions CO_2 and CH_4 from CI engines decrease substantially. In addition to this, NOx emission in the engine under dual fuel mode is higher (about 29–58%) than conventional diesel mode due to high localized in-cylinder temperature.

Limitations of hydrogen fuel:

- High levels of NOx emission due to high temperature in the cylinder during combustion.
- Knocking at high amount of hydrogen substitution due to pre-combustion.
- A limited hydrogen energy share (6-25%).

Finally from different literatures and overview of conclusions, it is found that alternative fuels are better than conventional diesel fuel from emission point of view. It is also observed that these alternative fuels may be used as regular fuel in future to overcome the shortage of conventional diesel fuel.

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