International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Effect of Hydrogen Induction on Combustion, Performance and Emission Behaviour of Compression Ignition Engine Using Used Transformer Oil as a Main Fuel

Anand Prakash Verma[1], Atul Kumare Tiwari[2]

M.Tech. (ME) Scholar, Sagare Institute of Technology and Management Barabanki U.P. India 225001

Abstract: ***Our gift fuel resources aren't about to be around forever and with the ever increasing consumption their extinction is almost inevitable. Additionally our fuel resources that are principally created from fossil fuels aren't renewable in nature. Within the gift study gas at a relentless flow of 4lpm was inducted within the suction, at a ways fare from the manifold, beside air. 2 completely different fuels on volume basis were tested as main fuels during a single cylinder, 4-stroke, air cooled, direct injection ICE developing an influence of four.4 kW, at a rated speed of 1500 rate. One fuel was the only real used electrical device oil (UTO/UTO100) and therefore the alternative one was the UTO at four-hundredth intermingled with hour fuel (UTO40). The combustion, performance, and emission parameters of the engine were obtained within the investigation and compared with the baseline fuel. The results indicated increase in brake thermal potency for each the most fuels once gas is inducted and additionally high reduction in smoke levels.***

Keywords: gas, Used electrical device oil, Performance, Emission, Combustion

1. Introduction

1.1 General

The present energy state of affairs has stirred up active analysis interest in non-petroleum, renewable and non polluting fuels. Abundant of the current world's energy demand should be provided by exhaustible fossil fuels (natural gas, oil and coal), that are the fabric basis for the industry. It's documented that combustion of fuel causes pollution in cities and acid rains that damages forests, and additionally results in manufacture a lot of dioxide ensuing environmental degradation. In recent year, the priority for cleaner air, due to strict pollution regulation and also the need to scale back the dependency on fossil fuels. Several tries are created to search out varied new and renewable energy sources to exchange the prevailing oil fuels. Various fuels are out there within the type of solid, liquid, and gas. Biomass, biodiesel from totally different vegetable oils and LPG are a number of the examples for solid, liquid and gaseous various fuels severally that are unremarkably accustomed run the interior combustion engines. Though these fuels are used, they generate considerable pollutants from the interior combustion engines. Gas is found to be cleaner fuel among all different various fuels. Gas is essentially out there and renewable in nature.

1.2 Various fuels

In view of the matter of quick dwindling reserves of irreplaceable oil fuels and also the hazards of environmental pollution caused by their combustion, tries should be created to develop the technology of alternate clean burning artificial fuels. These fuels ought to be specified they need attributes of perennial renewal, they perform well within the engine, and their potential for environmental pollution ought to be quite low. Some various fuels within the type of solid, liquid and gaseous fuels are studied.

1.2.1 Solid Fuels

The best example of solid various fuel is energy from biomass. Biomass in its ancient solid mass (wood and agriculture residue) and biomass in its non ancient type (converted into liquid fuel). The primary class is to burn the biomass directly and acquire the energy. The second class, the biomass is regenerate into grain alcohol and fuel to be used as liquid fuels in engines. The third class is to ferment the solid biomass anaerobically to get a gaseous fuel known as bio gas. 3 solid bio fuels- wood, straw associated refuse are being burnt on an increasing scale in several countries to supply helpful energy. Wood within the type of cut logs, chips, and saw dirt is presently used as a solid bio fuels. Currently a day's straw burning chambers are common in several countries. Municipal refuse is way from a perfect fuel. It mussy to handle and encompasses a low and variable energy content on the average solely concerning one third of that of coal.

1.2.2 Liquid fuels

Alcohols and derivatives of vegetable oils are the most effective samples of this class, Replacing gas and diesel as transport fuels in several countries and this method is probably going to accelerate as oil costs rises.

1.2.3 Alcohols

Alcohols are of 2 sorts, grain alcohol and fuel which may be created from sugarcane waste, and lots of different agricultural product (renewable sources). Alcohol springs indirectly from sugarcane however syrup – sugarcane by-product. All starch wealthy plants like maize, tapioca, and potato may be accustomed manufacture alcohol also as plastic waste materials may be used [1]The advantages of victimisation alcohol fuel are that it produces less overall emissions compared to diesel and fuel. Pure alcohol and their mixing with varied proportions with diesel are used on ICE by several researchers. Fuel by itself isn't a decent CI fuel attributable to its high amount, however if bit of diesel fuel is employed for ignition, it may be used with smart results. Grain alcohol has been used as various fuel for several years in varied countries. Brazil is maybe the leading user. Minor engine modifications are necessary for blends containing quite concerning two hundredth alcohol, or for pretty much pure alcohol: these embrace on accrued compression magnitude relation, and altered temporal order etc. [2]

1.2.4 Vegetable oils

Vegetable oils may be used as a alternate liquid fuel for ICE. From crushed seeds and wacky (for example, sun flower and rape seed, peanuts, palm, soya, and corn) may be burnt in unqualified ICE. They'll be homogenized with diesel oil or used directly.

1.2.5 Gaseous fuels

Gaseous fuels as compared to the each solid and liquid alternate fuel have potential to resolve each the issues of energy crisis and pollution. Among all different gaseous fuels like gas, LPG, CNG, Biogas, Fuel gas, gas is best fitted to compression ignition engines. Gas is nearly in exhaustible natural supply gift in water. Additionally gas on combustion produces solely water and Night whose venomous effects are terribly less compared to different fuels.

1.2.6 Hydrogen-Future fuel for IC engines

If we glance at the past 2000 year's history of fuels, usage has systematically captive within the direction of a cleaner fuel: wood → coal→ petroleum→ gas →methane. The fuel molecule has become smaller, throw in carbon and richer in gas. The last major move was methane series, that may be a abundant cleaner burn than fuel and diesel. Thus it's expected hydrogen to be a future fuel for the inner combustion engines [3]. Chemical element has the potential to unravel each the environmental hazard faced by mankind i.e. pollution and warming. Utilization of chemical element for engine application isn't a replacement idea.

1.2.7 Non conventional fuels from waste substances

The polymer energy system is the innovative and appropriate method to get energy from waste substances like plastics, tyres, etc. Previous waste management method like land fill, incineration and recycling failed to provide opportunities for the complete reuse of waste substances. The polymer energy system suits the best way to extract energy from waste substances. It involves special techniques called pyrolysis.

1.2.8 Plastics

Waste plastics are one of the most promising resources for fuel production because of its high heat of combustion and higher availability in local areas. The advantageous property of plastics is that they do not absorb much moisture due to which its water content is very low compared to that of biomass. With the abundance of plastic that ends up in landfills and the ocean, though this could be a great new alternative energy source. After pyrolysis treatment, the waste plastic can be converted into liquid fuel. Pyrolysis is a technique of thermal decomposition of the substances under an inert gas like nitrogen. The pyrolysis of plastics needs around 450 to 550^{0}C temperature inside the reactor.

1.2.9 Tyres

Waste tyre is also another medium from which energy can be obtained. This also involves the technique of pyrolysis at a high temperature inside the reactor. The materials in a tire are heated and separated to be reused or disposed of. A tire has steel fibre in it which makes reuse difficult. But all the organic polymers and stuff give tires a good energy value and some of the organics can be heated and reused.

1.3 Waste/Used Transformer Oil

The oil that is used in the transformers for the cooling purpose is thrown out in the form of waste after use. The waste transformer oil possesses lots of dirt. After cleaning, it can also be used as an alternate fuel for the internal combustion engines. The advantage of this waste transformer oil is that it does not need the technique of pyrolysis.

Transformer oil

Transformer oils are an important class of insulating oils. It acts as heat transfer medium so that the operating temperature of a transformer does not exceed the specific acceptable limits. Transformer oils are produced from wax-free naphthenic oils. Although these types of crudes permit production of exceptionally low pour point insulating oils without the need for dew axing or special attention to the degree of fractionation or distillate cut width, they also contain high percentages of sulphur and nitrogen which must be removed in order to satisfy the stringent stability requirements of insulating oils [5]. It has been found that a highly aromatic, low paraffinic content naphthenic crude oil is a suitable raw material to prepare good transformer oil.

Mineral oil is the base material for transformer oil that is used as coolant in transformers in electrical substations and welding transformers. After prolonged use, the transformer oil becomes deteoriated and becomes waste. However, the waste or used transformer oil (UTO) posses a considerable heating value and some of the properties similar to that of diesel fuel [7]. Therefore, it can be used as an alternative fuel in compression ignition engines. But the use of UTO in compression ignition engine gives high vibration. Therefore attempts have been made to utilize the heating value of hydrogen to reduce the viscosity of UTO by inducting hydrogen into the suction.

Transformer oil identification

Product Name: Transformer Oil,
Chemical Name: Severely Hydro treated Heavy Naphthenic Distillate
Chemical Family: Petroleum Hydrocarbon Oil

Colour of Used Transformer oil

The used transformer oil appears to be dark brown in colour and the colour of sole used transformer oil is given in Fig 1. The properties of UTO and UTO40 are given in Table 3.

International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Figure 1: Colour of used transformer oil

Use of Transformer oil in compression ignition engine

Transformer oil is used for cooling purpose and after its application it is thrown out in the form of waste. But, after testing the waste/used transformer oil, it has been seen that the property of used transformer oil are similar to that of diesel. So attempts have been made to substitute the diesel fuel with used transformer oil as an alternative fuel in the engine. . Recently, experiments have been carried out to utilize the used transformer oil as a non conventional in a single cylinder, four stroke, air cooled, direct injection diesel engine. Due to high viscosity of used transformer oil, it was blended with conventional diesel fuel and was tested in the engine. The used transformer oil of 10-60% was blended with diesel fuel at 90- 40% respectively and neat used transformer oil i.e. UTO 100% was also used as alternative fuels [7]. Results indicated that the UTO40 was the most acceptable blend among all the tested used transformer oil based fuels. But while using the neat used transformer oil (UTO), the engine gave a lower performance and higher HC, CO and smoke. Therefore, it is necessary to explore more possible ways to improve the performance and reduce the emissions from a diesel engine fuelled with UTO. Inducting hydrogen is one suchtechnique.

Table 3: Properties of UTO and UTO40

Property	UTO	UTO40
Sp.Gravity at, 27 °C	0.830	0.866
Kinematic Viscosity, cst at 27°C	13	7.3
Gross Calorific Value KJ/kg	39120	41928
Flash Point, °C	150	90
Fire Point, °C	172	102.4
Sulphur Content, %	0.020	0.035
Ash Content, %	NIL	.006
Carbon Residue, %	0.020	0.029

2. Literature Review

L.M.Das [8] studied that the mixture formation method plays a important role for the practical application of a hydrogen fuelled specific engine. The use of cryogenic hydrogen supplied from the liquid hydrogen tank, method of late fuel injection are studied and evaluated. It was suggested that the integrated fuel induction and storage method must be designed for a hydrogen specific engine

N.Saravanan et al. [9] did experiments on DI diesel engine supplemented with hydrogen fuel. Two techniques were adopted to inject hydrogen inside the engine cylinder ;(1) Carburetion technique and (2) TPI –Timed Manifold Injection technique and compared their performance, emission and combustion parameter with sole diesel by adopting both the techniques. It was concluded that TPI technique gives better performance compared to carburetion technique. The knock can occur at high flow rate of hydrogen. They concluded the optimum hydrogen enrichment with diesel was 30% by volume.

N. Saravanan et al. [10**]** inducted hydrogen in a DI diesel engine adopted EGR technique to reduce NO_X emission. The arrangement was provided in such a way that, some part of exhaust gases is sent back to the engine intake manifold. This arrangement is called as Exhaust Gas Recirculation (EGR). Minimum Concentration of NO_X is 464 ppm with 25 % EGR.

N. Saravanan and G. Nagarajan [11**]** conducted experiment were on a DI Diesel engine with hydrogen in the dual fuel mode The optimized injection timing was found to be 5CA before gas exchange top dead centre (BGTDC) with injection duration of 30 CA for hydrogen diesel dual fuel operation in hydrogen port injection. The optimum hydrogen flow rate is found to be 7.5 lpm based on the performance, combustion and emissions behaviour of the engine. The brake thermal efficiency for hydrogen diesel dual fuel operation increases by 17% compared to diesel at optimized timings. The NO_X emission is found to be similar at 75% load and full load for both hydrogen and diesel operation. However the concentration is lower at lower loads in hydrogen dual fuel operation due to lean mixture operation. The smoke emission reduces by 44% in hydrogen diesel dual operation compared to diesel operation. The CO and HC for hydrogen operation at optimized conditions are same as that of diesel emissions. It was concluded that the engine operated smoothly with hydrogen except at full load that resulted in knocking especially at high hydrogen flow rates.

3. Experimental Procedure

The engine used for the present investigation is a single cylinder four stroke air cooled diesel engine. Initially the engine was operated with neat diesel and the performance, emission and combustion parameters were evaluated. Then the engine was allowed to run with UTO40 and UTO100/UTO respectively without hydrogen. Again the performance, emission and combustion parameters were evaluated. Now for the third test, hydrogen gas is introduced by considering first UTO40 as a main fuel and then UTO100 as a main fuel respectively.

Hydrogen fuel from a high pressure cylinder was inducted through an intake pipe. A double stage diffusion pressure regulator was employed over the high pressure cylinder. The regulator is used to control the outlet pressure. Hydrogen fuel, at a pressure of 2 bars and a constant flow rate of 4 lpm is then supplied to the flame arrester and flame trap and finally to the intake pipe (a distance of 40 cms away from the intake manifold) where it mixes with air and finally, this hydrogen- air mixture get inducted into the engine cylinder. Used transformer oil of 40% blended with 60% diesel fuel

(UTO40) on volume basis is introduced from the fuel tank into the engine cylinder by direct injection. Then engine is allowed to run for different loads. The same procedure is adopted by considering sole used transformer oil (UTO/UTO100) as a main fuel with hydrogen flow rate of 4 lpm. The performance and combustion parameter is obtained by computer provided into data acquisition system. AVL exhaust gas analyser is used to calculate the emission parameter whereas smoke meter is used to get smoke values. Combustion diagnosis was carried out by means of a Kistler make quartz piezoelectric pressure transducer (Model Type 5395A) mounted on the cylinder head in the standard position. The air flow rate is calculated according to the difference in the level of water in the U- tube manometer mounted into the air suction line. The engine specification is given in the Table 4. The test is also carried out by considering diesel as a main fuel without using hydrogen. All the test results of engine using UTO40 and UTO as a main fuel with hydrogen induction were compared with neat diesel fuel and other two main fuels without hydrogen.

Table 4: Test engine specification

Type of Engines	4-stroke cycle, single cylinder, compression ignition engine
Speed, rpm	1500 rpm
Bore, mm	87.5
Stroke, mm	110
Compression ratio	17.5
Method of cooling Injection timing, ^{0} CA Nozzle opening pressure, bar	Air cooled with radial fan 23^{0} before TDC 200 kg /cm^2

3.1 Engine Modification for Hydrogen Operation

Hydrogen admission

The engine was modified to operate on hydrogen. A valve was provided at a distance of 40 cm from the intake manifold. Hydrogen was allowed to pass through this valve. A high pressure hydrogen cylinder is used having inlet pressure of 0-280 kg/cm^2 approximately 280 bars. The hydrogen gas purity is 99.999%.

Hydrogen Supply

The hydrogen gas is allowed to pass through the intake pipe at an outlet pressure of 2 bare pressure and al flow rate of 4 lpm. The pressure is regulated by a double stage diffusion pressure regulator mounted on to the hydrogen cylinder. The specification of pressure regulator is given below:

Inlet Pressure Max 0-280 kg/cm^2 Outlet pressure Max 0-07 kg/cm2 Inlet Connection: 5/8" BSP (M) LH Outlet Connection: ¼ inches OD Tube Gas Service: Hydrogen

Flash back arrester

A flash back arrestor is a safety device that shuts off gas flow in event of flash back. Flashback is the combustion of a flame mixture that can occur within your gas management system. This can travel back through the line of the gas management system to the gas source if flash back arrestor is not in line. A flash back arrestor shuts off gas flow and extinguishes the flame before it can reach your gas source. Several factors can cause flash back, including failing to purge line properly, using improper pressure, leaks in your gas management system and improper system operation.

Flame trap fabrication

Water filled flame trap was utilized to suppress any flash back from the intake manifold. The flame trap is essentially a metal container with water and fitted with a diaphragm on the wall. In the event of any severe flash back, the diaphragm would burst and prevent any pressure built up leading to an explosion. The specification of flame trapper is given below:
Tank Size= 300 mm × 300 mm
Thickness = 2 mm
Flange diameter= 1 inches
Inlet and Outlet pipe diameter= ½ inches Level of water = 150 mm from the bottom

The pictorial representation of the experimental set up is shown in the Fig 2. and the pictorial schematic representation of the set up is shown in Fig 3. respectively.

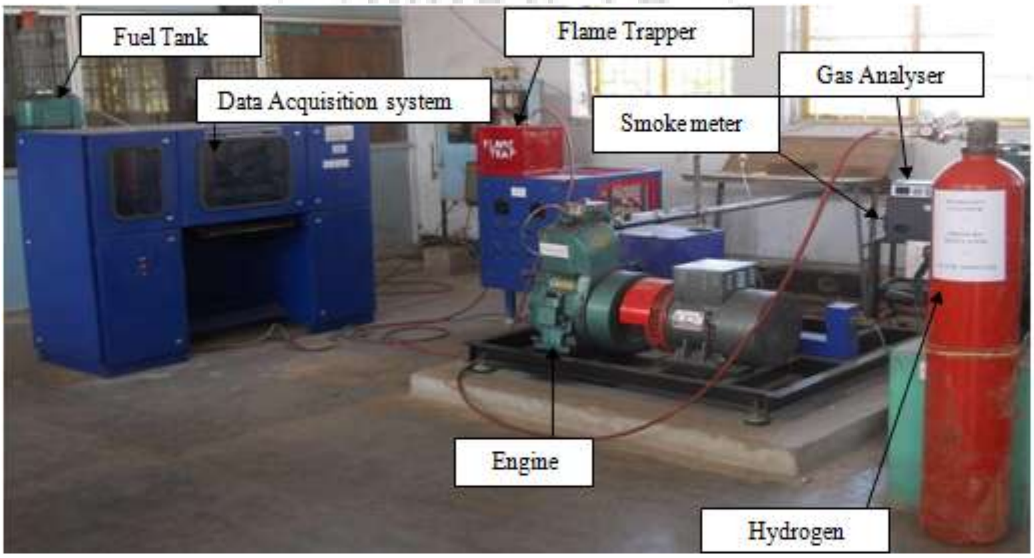
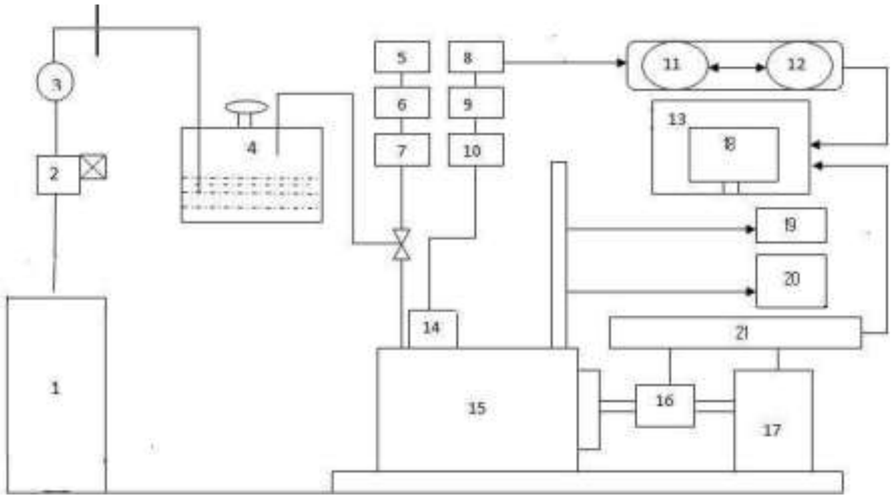


Figure 2: Photographic view of experimental set up



1.Hydrogen cylinder	8.Fuel tank	15. Engine
2.Pressure regulator	9.Fuel filter	16. Alternator
3.Flashback arrester	10.Fuel ump	17.Dyanamometer
4.Flame Trap	11.Fuel sensor	18. Computer
5.Air filter	12.Burrette	19.Exhaust gas Analyzer
6.Air box	13. DAS	20.Smoke meter
7.Airflow sensor	14 Injector	21.control panel

Figure 3: Schematic layout of experimental set up

4. Result and Discussion

In the present work, hydrogen gas- air mixture is used for compression ignition engine where UTO40, UTO100 respectively is used as a main fuel for. The performance, emission and combustion characteristics of UTO40, UTO100 respectively with and without hydrogen are compared with diesel operation.

4.1 Performance Parameters

4.1.1 Brake Thermal Efficiency

The variation of brake thermal efficiency with brake power is shown in Fig 4.The brake thermal efficiency for hydrogen with UTO40 is 42.14% at full load with a flow rate of hydrogen is 4lpm. Whereas that of UTO40 is 32.01% and that of diesel is 28.64%. UTO100 exhibits the brake thermal efficiency of 31.72% at full load, and that get enhanced after supplying hydrogen to 38.91%. Higher brake thermal efficiency is due to better mixing of hydrogen with air which results in better combustion and also due to wider ignition limit and high burning velocity [9]. The brake thermal efficiency of both the fuel UTO40 and UTO100 is found to be 10% more after supplying hydrogen compared to baseline diesel.

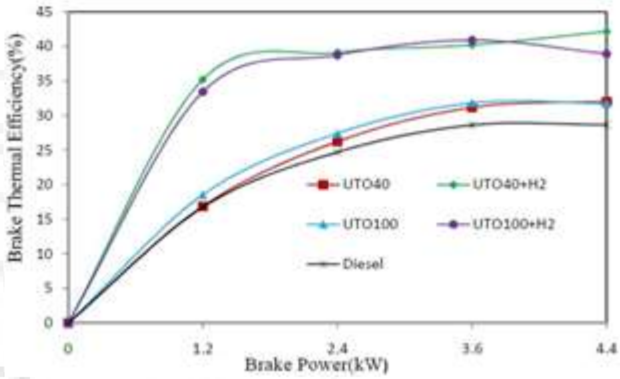


Figure 4: Variation of brake thermal efficiency with brake power

4.1.2 Brake Specific Energy Consumption

Fig 5. Shows the variation of brake specific energy consumption with the brake power Exhaust

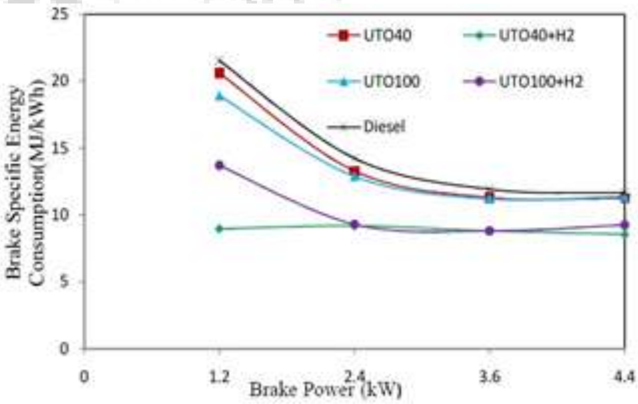


Figure 5: Variation of brake specific energy consumption with brake power

4.1.3 Gas Temperature

The variation of exhaust gas temperature with brake power is shown in Fig 6. The exhaust gas temperature of UTO40 with hydrogen is 365^{0}C at full load while that of UTO40 is 325^{0}C and that of diesel is 269.54^{0}C while the exhaust gas temperature of UTO100 with hydrogen is 375^{0}C at full load while that of UTO100 is 360^{0}C. The exhaust gas temperature of UTO100 with hydrogen is more compared to UTO40 with and without hydrogen and also with baseline diesel. The reason is may be due to high auto ignition temperature of

Paper ID: ART20183745 DOI: 10.21275/ART20183745

hydrogen. It requires high temperature to ignite. Therefore the residence time is more for the hydrogen.

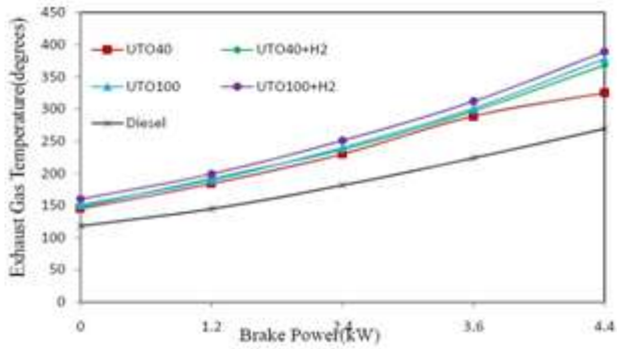


Fig 6. Variation of exhaust gas temperature with brake power

4.1.4 Volumetric Efficiency

The variation of volumetric efficiency of fuels is shown in the Fig 7. The volumetric efficiency of the engine is found to be less when hydrogen is inducted with the main fuels. The reason for low volumetric efficiency is because of the high velocity of hydrogen tends to displace the air. The volumetric efficiency is calculated as the ratio of actual volume of air passed into the engine to the swept volume. The UTO40 and UTO100 with hydrogen shows lower volumetric efficiency of 10.94 and 11.38% respectively while UTO40 and UTO100 without hydrogen shows more volumetric efficiency. The diesel fuel possesses the volumetric efficiency of 12.81% at full load, intermediate of UTO40 and UTO100 with and without hydrogen.

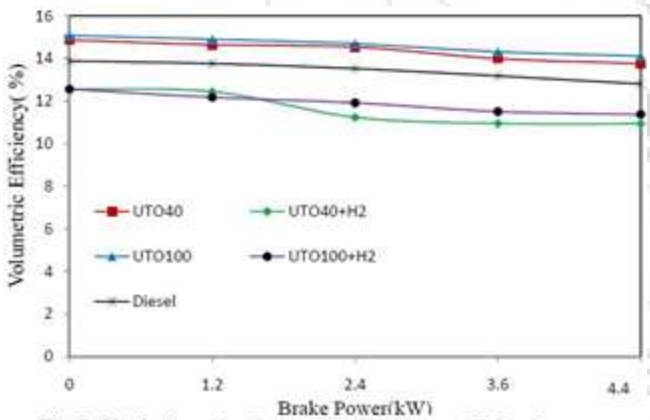


Fig 7. Variation of volumetric efficiency with brake power

5. Conclusion

A single cylinder, four stoke, air cooled direct injection compression ignition engine was operated successfully using hydrogen gas, supplying at a flow rate of 4 LPM and inducting at a distance of 40 cm from the intake manifold. The performance, emission and combustion parameters of the engine using UTO40 and UTO100 as a main fuel, with and without hydrogen induction were obtained in the investigation are compared with the diesel fuel. The following conclusions are drawn:

1) Experimental results shows UTO40 as the optimum blending compared to all other blending proportion with diesel. The performance, emission and combustion characteristics of UTO40 can be improved further by hydrogen induction along with air. Also with UTO100, the engine was able to run but engine gives high vibration. So by inducting hydrogen on UTO100, the engine was able to run smoother.
2) The brake thermal efficiency for both the main fuel inducted with hydrogen was found to be high, UTO40 with hydrogen is 42.14% and UTO100 with hydrogen addition was 38.91%, because of proper combustion and high burning velocity.
3) The brake specific energy consumption of UTO40 and UTO100 with hydrogen induction was found to be lower 8.5411MJ/kWh and 9.2498 MJ /kWh respectively compared to11.2443 MJ/kWh for UTO40 without hydrogen and 11.3803 MJ/kWh for UTO100 without hydrogen at full load.
4) The exhaust gas temperature of UTO40 with hydrogen is 365^{0}C at full load while that of UTO40 is 325^{0}C and that of diesel is 269.54^{0}C while the exhaust gas temperature of UTO100 with hydrogen is 375^{0}C at full load while that of UTO100 is 361^{0}C.
5) The carbon monoxide and hydrocarbon emission of UTO40 and UTO100 with hydrogen induction was lower compared to diesel and UTO40 and UTO100 without hydrogen due to the absence of carbon atoms present in the hydrogen structure. But the carbon dioxide emission increases for UTO40 and UTO100 with hydrogen induction with the increase in load but the concentration is very less compared UTO40 and UTO100 without hydrogen induction.
6) The NO_x emission of UTO100 and UTO40 with hydrogen is found to be higher compared to UTO100 and UTO40 without hydrogen and also diesel because of high temperature achieved during combustion when hydrogen was admitted. The UTO100 with hydrogen shows more NO emission of 490 ppm at full load while UTO40 with hydrogen is found to be 465 ppm. The diesel shows lower NO emission of about 318 ppm. The NO emission of UTO40 and UTO100 without hydrogen was found to be 380 ppm and 430 ppm respectively at full load.
7) The smoke level was found to be low at all loads for hydrogen enriched fuels because of proper mixing of hydrogen and air and proper combustion. At full load the smoke emission for UTO100 and UTO40 was found to be 25.5% and 18.1% respectively which gets reduced after hydrogen induction to 15.1% for UTO40 and 15.7% for UTO100 at full load.
8) The UTO100 with hydrogen exhibits a higher ignition delay of 12.1231^{O}C at full load followed by 12.0101^{0}C for UTO40 with hydrogen while that of UTO40, UTO100 without hydrogen shows lower ignition delay of 11.0112^{0}C and 11.7889^{0}C respectively. The higher ignition delay for hydrogen inducted fuel is due to high self ignition temperature of hydrogen and more residence time.
9) Due to high self ignition temperature of hydrogen fuel, and more charge accumulation inside the combustion chamber, hydrogen inducted fuel possess higher peak pressure and high rate of heat release. Due to the high viscosity of UTO100, less quantity of the fuel gets actually admitted results lower heat release rate and also maximum cylinder pressure. More study is required to

evaluate the combustion behaviour of the engine inducted withhydrogen.

6. Scope for Future Work

Hydrogen seems to be the future fuel for the automobile but more works are needed on the field of its production, storage and transportation. Also the safety of hydrogen fuelled engine is also an important matter of concern. As fare as the emission is concerned; only NOx emission is found to be high. The excessive work is required to reduce the NOx emission from the engine. Also at higher flow rate of hydrogen, the engine starts vibrating, so still scope is there to implement new techniques, so that the engine could perform even better at a higher flow rate, A detailed research on Used Transformer Oil is also required. Especially the neat used transformer oil (UTO100) needs a high attention of researchers. The unexpected combustion behaviour of UTO100 and UTO100 with hydrogen still needs to be evaluated deeply.

Sole used transformer oil after filtering is utilized on compression ignition engine. Scope is there to work on distilled used transformer oil (i.e. used transformer oil after distillation). It is expected that after distillation, the viscosity of the used transformer oil will get reduce and that may enhance the performance of the engine. The above experimental investigation was carried out at a fixed injection timing and injection pressure. The scope is there to find out the optimized injection timing by adding or removing the shim neare fuel pump and also to optimize the nozzle injection pressure. After optimizing all those parameters, hydrogen at different flow rate is need to be supply and to obtain the optimize flow rate of hydrogen. This work is under the progress.

More attention is required to understand the unexpected combustion behaviour of UTO with and without hydrogen induction. Used transformer oil also needs special attention, because UTO has all desirable properties to be treated as fuel.

References

[1] V.M. Domkundwar," A course in internal combustion engines" Dhanpat Rai publication, ISBN 81-7700-003-0, pp 22.22-22.32.
[2] G.D. Rai,"Non conventional energy sources" Khanna publishers, ISBN 81-7409-073- 8, pp 315-615.
[3] R.B. Gupta,"Hydrogen fuel-Production, storage and transportation" CRC Press publication Taylor and Francis group, ISBN 978-1-4200-4575-8, pp 1- 12.
[4] V.Ganeshan," A textbook on Internal Combustion Engines" 2nd edition, ISBN 0-07- 049457-6, pp 220-223.
[5] L.E. Reid, D.A. Gudelis, Low Pour Point Transformer Oils from Paraffinic Crudes, US Patent 4, 018, 666, and 1977
[6] Tulstare products, inc. material safety data sheet Transformer Oil, Type II, and TS-3487.
[7] P.Behera, S.Murugan," combustion, performance, and emission parameters of used transformer oil and its diesel blends in a DI diesel engine" Fuel manuscript no: JFUE-D- 11-00382,2011.
[8] L.M. Das,"Fuel induction techniques for a hydrogen operated engine" Int. J. Hydrogen Energy, Vol. 15, pp 833-842,1990.
[9] N.Saravanan, G.Nagarajan, S. Narayanswamy,"An experimental investigation of DI diesel engine with hydrogen fuel", Renewable Energy 33, pp 415-421, 2008.
[10] N.Saravanan, G.Nagarajan, K.M.Kalaiselvan, C.Dhanasekaran,"An experimental investigation on hydrogen as a dual fuel for engine system with exhaust gas recirculation technique" Renewable Energy 33, pp 422-427, 2008.
[11] N. Saravanan, G. Nagarajan, "Performance and emission studies on port injection of hydrogen with varied flow rates with diesel as an ignition source" Applied Energy, Vol.87, pp 2218-2229, 2010.
[12] N. Saravanan, G. Nagarajan, G. Sanjay, C. Dhanasekaran, K.M. Kalaiselvan, "Combustio n analysis on a DI diesel engine with hydrogen in dual fuel mode", Fuel 87,pp 3591-3599, 2008.
[13] Li Jing-Ding, Lu Ying-Qing and Du Tian-Shen, "Improvement on the combustion of a hydrogen fuelled engine" Int. J. Hydrogen Energy, Vol 11.No.10,pp 661-668, 1986.
[14] J.M.Gomes Antunes, R. Mikalsen, A.P. Roskilly, "An experimental study of a direct injection compression ignition hydrogen engine" Int. J. Hydrogen Energy Vol 34,pp 6516- 6522,2009.
[15] L.M. Das, "Hydrogen engines: A view of the past and a look into the future" Int. J. Hydrogen Energy, Vol 15, pp 425-443, 1990.
[16] L.M. Das, "Safety aspects of a hydrogen fuelled engine system development" Int. J. Hydrogen Energy, Vol 16, pp 619-624,1991.