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PERFORMANCE AND COMBUSTION ANALYSIS OF OPTIMISED H_2 (AS INDUCTED FUEL) WITH NSGO IN REGULAR DIESEL ENGINE

Karthikayan. S , Sankaranarayanan. G and Karthikeyan. R

Research Scholar , Department of Mechanical Engineering , Sathyabama University , Chennai , India.
Professor & Dean -Research, Sree Sastha Institute of Engineering and Technology Chennai , India.
Professor, Sri Andal Alagar College of Engineering, Mamandur, India.

Abstract:-This paper investigates the use of Neat Simarouba Glauca Oil (NSGO) in a regular diesel engine with the help of combustion enhancer. The high calorific gaseous fuel hydrogen gas was used as a combustion enhancer and Inducted into the engine during the suction stroke. A vertical, four stroke, single cylinder regular diesel engine with modified engine operating variables was employed in the investigation. NSGO was admitted through regular fuel injection device of diesel engine and hydrogen was inducted through suction manifold. Inducted hydrogen gas was ignited by the intermediate compounds of neat SG oil. This process offers higher temperature combustion and leading to complete combustion of heavier molecules of NSGO within shorter duration. The results of the experiment disclose that the application of hydrogen has improved combustion behaviour of neat SG oil. The results of the experiments showed that a considerable improvement has obtained in performance and emission characteristics of neat SG oil. Also, this investigation successfully proved that the application of NSGO more than 80% is possible under a regular diesel engine with minimal engine modification and the combustion characteristics are discussed in this paper.

Keywords: Neat Simarouba Glauca oil, combustion enhancer, H2-Hydrogen, combustion & induction.

INTRODUCTION

Vegetable oil is one such alternate fuel which has an ability to run a regular diesel engine without engine modification. Many researchers proved that the neat vegetable is a good substitute for compression ignition engines [12] [13]. However, the neat oil application posed various engine problems such as smoky exhaust, severe carbon deposition and lube oil dilution [7] [9] [10]. Hence, the application quantity of neat oil was restrained upto 20% by volume [3] [12] [13]. The heavier molecular structure, higher viscosity and unsaturated molecular structure are the primary reasons for the poor performance of neat oil [1] [2]. The trans-esterification process is a very old process and converts the neat vegetable oil into biodiesel. Though the biodiesel is a perfect fuel for the CI engine it has not gained a wide spread application due to its few undesirable fuel properties [5] [14]. The main disadvantage of the biodiesel is a cumbersome chemical reaction and cost of production [6] [8]. Hence, many researchers have tried to apply vegetable oil in neat mode either in modified mode.

Plentiful methodologies have been tried to apply large varieties of neat vegetable oils in CI engine [11] [21]. Those methodologies have eliminated major disadvantages of biodiesel conversion and laid a problem free path for neat vegetable oil application in CI engine. Some of the suggested methodologies required engine modifications and some of them required fuel modifications [17] [18]. The most common engine modifications suggested by them are raising the compression ratio, using adiabatic combustion chamber, hot air induction and application of combustion enhancer [4] [19] [20].

Present investigation utilized one of the suggested methodologies along with a simple modification to apply NSGO in DI CI engine. The present work uses combustion enhancing method for applying NSGO in CI engine. Hydrogen gas was invoked as a combustion enhancer in the present work. The higher calorific value, higher flame speed and simpler molecular structure make the fuel to combust with elevated temperature. The production of high temperature during hydrogen combustion helps to enhance the combustion behaviour of neat SG oil. Hence, the NSGO combusts completely without leaving smoky exhaust. The results of the experiment show a considerable improvement in performance, combustion and

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Simarouba seeds can be easily refined, bleached, deodorised and fractionated. It is appropriate for edible and non-edible purposes. The oil is removed from the seeds in the existing oil mills and processed by adopting conventional methods. Each well-grown tree yields 15 to 30kg nut lets equivalent to 2.5-5kg oil. This amount to nearly 1000-2000 kg oil/hectare/year. The physical and chemical properties of neat Simarouba oil are given in Table 1.

TABLE I. PHYSICAL AND CHEMICAL PROPERTIES OF SG OIL

Sl. No.	Physical and Chemical Properties of SG oil		
	Properties	***SG oil***	***Diesel***
1	Molecular Weight	436	200
2	Density kg/m3 @ 20ºC	905	820
3	Specific Gravity @ 20ºC	0.91	0.82
4	Boiling Point ºC	250-260	180-340
5	Viscosity cSt @ 20ºC	17.3	3-4
6	Latent Heat of Vaporization kJ/kg	-	230
7	Lower Heating Value kJ/kg	38,100	42,700
8	Flash Point ºC	225	74
9	Auto Ignition Temperature ºC	<250	250
10	Flammability limit % Volume	1.0 – 5.2	1.0 – 6.0
11	Cetane Number	45-48	45-50

B.Literature review

M.Senthil Kumar et al. [17] conducted a detailed engine experiment to evaluate the performance of a compression ignition engine primarily fuelled with Jatropha oil and a small quantity of hydrogen. Results showed that an increase in the brake thermal efficiency was obtained with 7% of hydrogen mass share at maximum power output. Smoke was reduced to a large extent at the best efficiency point. There was a large reduction in HC and CO emissions were obtained at maximum power output. Hydrogen induction raised combustion rates. The results of the experiment concluded that the induction of small quantities of hydrogen significantly enhanced the performance of a vegetable.

N. Saravanan, G. Nagarajan [16] conducted an experiment to reduce the common problem with the use of neat vegetable oils in diesel engines. It was found that the problem has been alleviated very much by inducting gaseous fuel through the intake manifold along with air. In this investigation, hydrogen was invoked as the inducted fuel and rubber seed oil mixed diesel fuel was used as main fuel. This investigation found that the induction of hydrogen increases brake thermal efficiency reduces smoke, reduces CO and HC emissions.

G. Sankaranarayanan et al. [15] conducted an engine experiment using mahua oil and hydrogen induction in a single cylinder regular diesel engine. The experiment proved that the hydrogen enriched air improved the brake thermal efficiency and reduced smoke density. Also, hydrogen enrichment increased the combustion rate of mahua oil and increased NO emission. N. Saravanan et al. investigated the combustion analysis of dual fuel engine using hydrogen as a primary fuel and diethyl ether and diesel as an ignition source. Hydrogen and diethyl ether was injected through the intake manifold and diesel was injected directly inside the combustion chamber. It was found that hydrogen admission increased the BTE, NOx and reduced smoke emission compared to diesel.

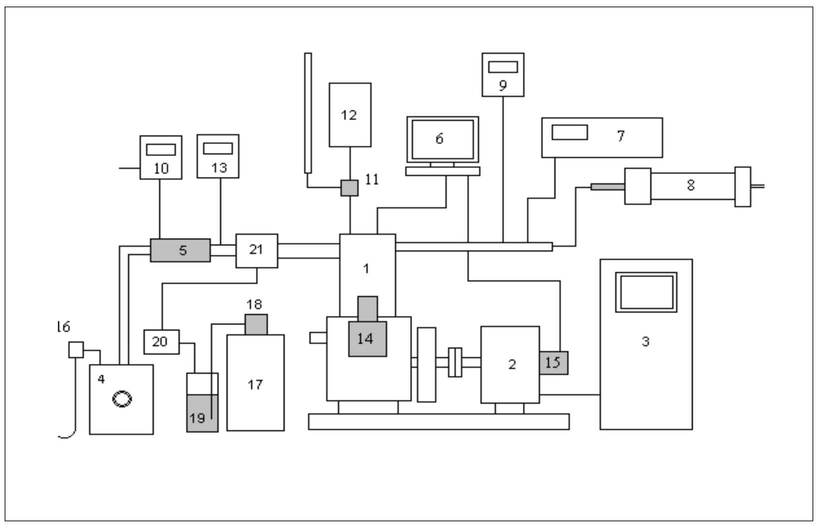


Fig. 1. Engine experimental setup

1. Diesel engine, 2. Eddy-current dynamometer(loading device), 3. Loading device control, 4. Anti-pulsating drum, 5. Air pre heater setup, 6. PC with Digital Data Acquisition System, 7. Exhaust gas analyser instrument, 8. Smoke tester, 9. EGT indicator, 10. Electrical energy meter, 11. 2-way valve, 12. Diesel fuel, 13. Inlet air temperature display, 14. Pump for fuel injection, 15. Encoder for crank angle, 16. U-tube Manometer, 17. Hydrogen gas cylinder, 18. gas regulator, 19. Flame arrester, 20. Gas flow meter, 21. Gas admission manifold.

A single cylinder four stroke vertical air cooled direct injection diesel engine capable of developing 4.4 kW has been used for this experiment. The engine is coupled with an eddy current dynamometer to vary the engine output power. The suction side of the engine has anti pulsating drum, orifice meter, air inlet temperature measuring probe, air heater and air temperature measuring probe. The exhaust side of the engine has exhaust gas temperature measuring probe, gas analyzer and smoke sampling pump. The fuel flow rate is measured by regular fuel flow measuring device. Piezoelectric pressure pick-up and a crank angle encoder is mounted in engine head and on the main shaft of the engine respectively to acquire cylinder pressure data with respect to crank angle (in degrees)

National Instruments LABVIEW based software is used to calculate performance and combustion parameters using the acquired cylinder pressure data. Air in-flow rate is measured by an orifice meter and manometer. Air temperatures before and after the air heater and exhaust temperature are measured by Cr-Al thermocouples. The air intake temperature is varied using electric air heater. A wattmeter of 3000W capacity has been deployed in the test setup to measure the power input for the air heater. This setup also consists of hydrogen supply system to admit hydrogen through suction manifold. The hydrogen gas is supplied through flow meter and flame arrester. The pictorial view of the experimental setup is shown in Figure 1 and the engine specification is shown in Table 2.

TABLE II. ENGINE SPECIFICATIONS

Sl. No.	Engine specifications	
	Specifications	***Parameters***
1	Make and Model	Kirloskar, TAF1
2	General details	4-S, DICI, constant speed, vertical, air-cooled
3	Number of cylinders	One
4	Bore and Stroke	87.5 mm and 110 mm
5	Cubic capacity	661 cc
6	Compression ratio	17.5:1
7	Rated output and speed	4.4 kW @ 1500 rpm
8	Diesel injector opening pressure and timing	180 bar @ 23º bTDC
9	Number of nozzle hole and diameter	3 and 0.23 mm

EXPERIMENTAL METHOD

The primary objective of the work is to apply NSGO in DI CI engine using hydrogen gas as combustion enhancer. To accomplish this regular diesel engine has been modified in such a way to apply NSGO through diesel injector and hydrogen gas through the suction manifold. Since, hydrogen gas has higher flame speed a flame arrester was connected in-between hydrogen cylinder and manifold. The flow rate of hydrogen is needed to be measured using a gas flow meter and varied using a gas regulator. The present work studies the effect of hydrogen gas over NSGO combustion at various hydrogen quantities. The supply of hydrogen was measured in terms of hydrogen energy share using the relation given below.

A.Experimental Procedure

Engine was started with diesel fuel and then switched over to the NSGO operation.
Hydrogen gas of the required quantity was admitted into the engine through the suction manifold.
Engine performance parameters were observed in various loads at various hydrogen energy shares.

B.Engine Modifications

The following engine modifications were achieved in the test engine before the experimentation.

1.The engine operating parameters were relocated as per the optimum values indicated in Table 3.
2.The suction side of the engine was equipped with gaseous fuel admission device.
3.The suction side of the engine was further fitted with an air pre-heater to preheat the incoming air.
4.The regular piston of the test engine was substituted for a newer one to increase the compression ratio of the engine.

The optimum values of engine operating parameters used in the present work that are, injection pressure-275 bar, injection timing-27°bTDC, compression ratio-19.5 and inlet air temperature 65º C.

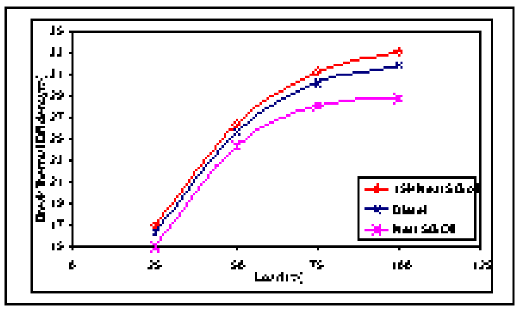
RESULTS AND DISCUSSION

The experimental results of the modified engine fuelled with NSGO and hydrogen gas are provided in this section to study the effect of hydrogen over NSGO combustion. The engine operating parameters were relocated using the optimum values arrived in the previous experiment. The engine was operated as per the procedure mentioned above and its performance and combustion parameters were observed in various loads at various hydrogen energy shares.

A.Comparison of Hydrogen assisted NSGO operation with diesel fuel and NSGO operation.

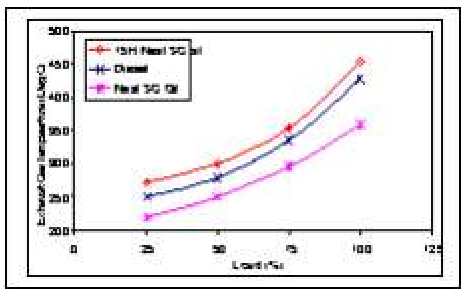
In this work compares the combustion enhanced (hydrogen assisted) neat oil operation with diesel fuel operation. In this section, neat oil with 15% of hydrogen energy share has been considered for comparison with diesel fuel operation as this fraction of hydrogen has offered maximum performance at all loads. This section also is used to know the performance, combustion and emission behaviour of combustion enhanced neat oil.

1)Brake Thermal Efficiency: Fig. 2 compares Brake Thermal Efficiency (BTE) of 15H neat SG oil (15% hydrogen mixed neat SG oil) with diesel and neat SG oil. From the figure, it is seen that the highest BTE is obtained with 15H NSGO than that of diesel and neat oil. The addition of hydrogen improves combustion by offering higher combustion temperature. The higher combustion temperature increases the rate of production of intermediate compounds and initiates combustion little later than neat oil. This delay in combustion sufficiently accumulates oil vapour before combustion. Hence, this fuel offers higher in-cylinder pressure than that of other fuels used in the same engine setup. The higher heating value and higher flame speed of hydrogen is another reason for the combustion improvement and higher BTE.



)Exhaust Gas Temperature: Fig. 3 compares EGT of 15H neat SG oil with diesel and neat SG oil. From the figure, it is seen that the highest EGT is obtained with 15H NSGO than that of diesel and neat oil. The addition of hydrogen increases combustion temperature and combusts heavy fuel molecules in a shorter duration. This particular incident offers higher combustion temperature and hence, it offers the highest EGT than that of diesel fuel and neat oil combustion.

The highest EGT produced by 15H NSGO is 454 °C. This is 6 % higher than diesel fuel and 21 % higher than neat SG oil. The addition of Hydrogen increases EGT of NSGO performance from 360°C to 454 °C.



3)In-Cylinder Pressure: Fig. 4 compares in-cylinder pressure of 15H + neat SG oil with diesel and neat SG oil. From the figure, it is seen that the highest in-cylinder pressure is obtained with 15H NSGO than that of diesel and neat oil. The co-combustion of hydrogen rises the cylinder gas temperature extremely high and hence it offers higher in-cylinder pressure. Moreover, the higher combustion temperature of hydrogen stimulates the neat oil to release more breakdown products at a rapid rate. This is the main cause for the production of higher in-cylinder pressure for this fuel. The higher calorific value of hydrogen and its higher flame speed are also other causes for the development of higher in-cylinder pressure.

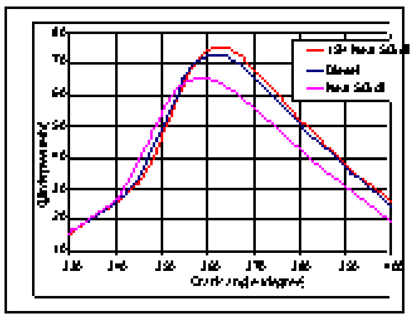


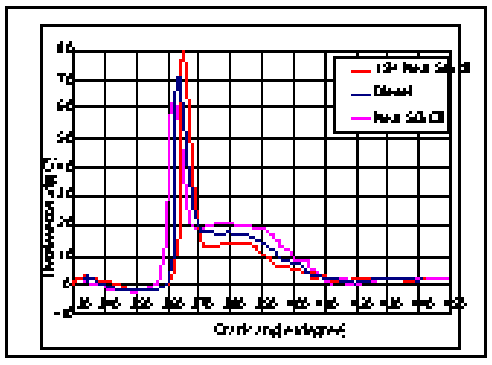
Fig. 4 Effect of hydrogen energy share on In-Cylinder pressure

The highest in-cylinder pressure produced by 15H NSGO is 76bar. This is 5bar higher than diesel fuel and 11bar higher than neat SG oil. The addition of hydrogen increases cylinder pressure of NSGO from 65bar to 76bar.

4)Heat Release Rate: Fig. 5 compares HRR of 15H+neat SG oil with diesel and neat SG oil. From the figure, it is seen that the highest HRR is obtained with 15H NSGO than that of diesel and neat oil. Since, hydrogen has poor self ignition property the ignition of the mixture was initiated by the breakdown products of neat oil. Usually, neat oils have sizeable amount of unsaturations in it. They weaken and break the fatty acids chain of neat oil due to the high temperature and pressure inside the cylinder. This intermediate compounds initiates combustion in the mixture of fuel inside the cylinder.

Generally, neat oils produce intermediate compounds immediately after the injection and then helps to initiate combustion comparatively earlier than other fuels. In the present work, the application of hydrogen changes the phenomena and combusts the neat oil with sufficient ignition delay.

This delay accumulates fuel vapour and starts combustion little later than neat oil combustion. This is the main reason for the higher heat release rate in the first phase of combustion of this fuel. The extreme high temperature offered by hydrogen reduces the length of combustion. Hence, the second phase of combustion of 15H NSGO is shorter than diesel and neat oil duration of combustion.



The highest heat release rate produced by 15H NSGO is 80 J/deg CA. This is 12.5% higher than diesel fuel and 20 % higher than NSGO. The addition of hydrogen increases heat release rate ofNSGO from 64 J/deg CA to 80 J/deg CA.

CONCLUSION

The results of the experiments expose that the performance of NSGO was improved sufficiently with hydrogen combustion enhancer. The inherent properties of hydrogen such as higher calorific value, higher flame speed and gaseous nature helps to combust NSGO with higher performance and lower emission. The application of 15 percent hydrogen+NSGO performance compared with diesel fuel, and the results are 5% higher brake thermal efficiency and 6 % higher EGT than that of diesel fuel operation.

The improvement achieved by optimum quandity of 15 percent hydrogen combustion enhancer with NSGO is 15 % in BTE, 17 % in cylinder pressure and 25 % in heat release rate than that of NSGO operation (with out enhancer). The overall result of the experiment reveal that the neat oil combustion performance has been improved satisfactorily by the inducted fuel H2 combustion enhancer.

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Karthikayan. S
Research Scholar , Department of Mechanical Engineering , Sathyabama University , Chennai , India