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Recital Exploration of Enclosure of Hydrogen to Compression Ignition Diesel Engine with Biodiesel Mingles

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Abstract: The objective of reducing the discharge of Nitrogen Oxide (NOx) in CI engine through mingled bio fuel is a operative unconventional fuel for fossil fuels in provisions of contamination decrease in discharge and effectiveness augmented in engine. The performance and discharge features of a CI engine and the updraft efficacy amplified by influence of hydrogen through bio fuel are deliberate in this exploration. The stability of ignition by accumulation of hydrogen and the effectiveness of NOx decrease correspondingly engaged by means of HGBD as an fuel.

Key words: CI engine, thermal efficiency, emission, Hydrogen and Bio Diesel blends (HGBD), performance, India

INTRODUCTION

An internal combustion engine is an obligatory and critical part of everyday life. Though, diesel engines produce conspicuous such as impulsive and recurrent noises which are unpleasant (Alt *et al*., 2005). Combustion blare possibly will be reformed by using another type of fuel. Hydrogen is the largest part of potential fuels because it has dirt free burning characteristics and healthier performance matched up to other fuels. Though, hydrogen cannot be used as the solitary fuel in a CI engine because the compression temperature is not enough to kick off combustion due to its elevated self-ignition temperature (Maxwell, 1892). The observed recompenses of this are largely reduced CO discharges, HC and PM then through eventually amplified NOx discharges associated to fossil diesel fuels. That's why an ignition source is obligatory whilst using it in a CI engine.

The easiest method of utilizing hydrogen in a CI engine is to run in the dual fuel mode in the company of diesel fuel that be capable of perform as an explosion cause for hydrogen. Various inquiries already defined on the co-ignition of hydrogen-diesel combustible mixtures (Das, 2002). Miyamoto *et al.* (2011) investigated the production features of the diesel engine with hydrogen added to the absorption air at deferred inoculation timings. That has inspected the retort of diesel-fuel inoculation scheduling on the extreme ratio of in-chamber compression increase aimed at a diesel engine through accumulation of hydrogen to the absorption air (Jacobs, 1963). The outcome validated in the event of a diesel-fuel inoculation consequently TDC through accumulation of 11 vol% hydrogen to the absorption air, the elevated percentage of in-chamber density increase was reasonably lesser than that without hydrogen accumulation at higher heaps for a unsurprisingly trailed diesel engine. Hydrogen is essentially the finest swearing alternative fuels. Hydrogen combustion essentially not produces CO_2 and smoke, meanwhile that designated as a carbon-free fuel. Eason *et al.* (1995) showing that hydrogen fueled CI engine with fuel outflow from the injector could sustenance combustion of the hydrogen fuel. While burned in IC engines, hydrogen has been acknowledged as an on-spot carbon free energy carter with admirable ignition features. Delectable ignition possession such as a profligate flame proliferation speed and extensive slender effective variety make H_2 an eminent fuel for SI engines (Furuhama, 1983). By blending H_2possessed by the ingestion mingle, hydrogen be capable of flamed in CI engines. The compressed H_2-air mingle is kindled by an experimental diesel sprig as the compression stroke finished. An effectual and consistent methodology to tingle numerous sparkling fuels such as H_2 in CI engines, dual fuel process has been endorsed (Gopal *et al*., 1982). Numerous investigates narrated the pros and penalties accompanying with the change-over of environment diesel by H_2. These encompass the augmentation to the BTE, NOx discharge augment, impeding the jerk of combustion, refining the heat

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discharge practice and currently the on-spot discharge diminution of Carbon dioxide (CO_2). The formerly finished investigation procedure on H_2-diesel mingled dual fuel engines was accomplished through diffident single cylinder diesel engines such as the experimentation specified by Varde and Frame (1983).

A cram on the properties of hydrogen addition to precise biodiesel was initiated by Bika *et al.* (2008). In recent times, diverse investigators founded the possessions of H_2 accumulation on the recital as well as the ignition uniqueness of multi-cylinder; fewer purpose diesel engines (Karim, 2003a, b). The addition of H_2 to these less function diesel engines was considered to augment significantly the discharges of NO_2 convoyed with a lessening in NO discharges. For instance, Shirk *et al.* (2008) examined the possessions of H_2 accumulation on the exhaustion discharges of a 1.3 L, turbocharged, light-duty diesel engine. The accumulation of H_2 somewhat abridged the discharges of NOx whereas its significance on the BTE was discreetly small. The dissever must generate these modules; reintegrating the applicable criteria that follow. Hydrogen has been injected to CI engine. Meanwhile, hydrogen has injected to dual-fuel category diesel engines in which diesel-fuel combustion is burning basis for hydrogen (McWilliam *et al.*, 2008). This investigates concentrated hydrogen to absorption air while the diesel fuel was ingested straightly hooked on the chamber.

NOx emission mechanism

Impression of hydrogen accumulation on ignition: The NOx emissions of combustion devices burning fuels that are Nitrogen (N) free can be designed through the underneath contrivances) NOx updraft contrivance conquered by the native hotness of the burning yields) the rapid NOx contrivance detected primarily at fuel amusing blend and unburned fuel-air assortment preceding to the influx of the fore-flame and) the N_2O intermediate mechanism occurring mainly at trifling heap procedure of diesel engines and gas turbines (Miller and Bowman, 1989). When operated under medium to high load, the local combustion temperature of a diesel engine is usually higher than the threshold temperature for the development of NOx through NOx thermal mechanism. Comparatively, the N_2O transitional contrivance persuaded to subsidize suggestively to NOx development in diesel engines and gas turbines at lesser heap maneuver where the engine-out NO_2/NOx ratio is known to exceed 10% (Sahoo *et al.*, 2009).

Among these, the contribution of the prompt mechanism to the development of NOx in diesel fuelled engines is moderately trivial. The development contrivance of NO_2 has been researched by various researchers (Saravanan and Nagarajan, 2008). It was noticed that the Nitrogen oxide molded in the blaze section could be rehabilitated to NO_2 through responses such as:

$$NO+HO_2 \Leftrightarrow NO_2+OH$$

Past research reported the salient role of HO_2 in potentiating the alteration of NO to NO_2. The HO_2 portion of a particle can be designed by another reaction:

$$H+O_2+M \Leftrightarrow HO_2+M$$

Procedures devouring the impeding to noticeably increase the deliberation of HO_2 were expected to encompass the development of NO_2. For example, the HO_2 portion of a particle systematized in the moderately less warmth unburned blend area preceding to the fore flame. The HO_2 enrich mingle reacts with the NO particles conveyed through high temperature ignition areas and augments the development of NO_2. When available at a appropriate heat, the unburned fuels contusing hydrogen could oxidize in the occurrence of O_2 and outline HO_2 which might augment the progress of NO_2. This might help to describe the significant enhancing property on the development of NO_2 when H_2 was blended into the ingestion mixture of diesel engines as reported in the literature (Sellerbeck *et al.*, 2007; Varde and Frame, 1983) investigated a processing of decreased diesel matter in the exhaust by articulating less quantities of gaseous hydrogen in the ingestion of a diesel engine. The outcome demonstrates that smoke reduced with the prolonged hydrogen accumulation. However, NOx and ignition disturbance augmented since fine ignition happened as an outcome of elevated combustion enhance of hydrogen.

Lilik *et al.* (2010) uttered that dual-mingle fuel procedure of rubber seed oil and its mingle through hydrogen. The consequences describe that NOx discharge augmented with the prolonged hydrogen energy fraction for RSO and RSOME. Turns (2000) suggested a double fuelled engine with hydrogen and diesel-fuel under the PPCI (Premixed Power Compression Ignition) circumstance. Hydrogen was provided to the absorption port and diesel fuel was conveyed directly into the combustion cylinder. The diesel-fuel was assorted systematically with hydrogen-air mingle and combustion turn into mild as preeminent diesel fuel inoculation effectiveness was sustained.

EGR is effective in diminishing NOx and evading colliding, though the smoke discharge augments along EGR in traditional diesel engines. Therefore, EGR is controlled to a very trivial EGR rate. Smoke-less and NOx-less combustion was made successful by this method and it is termed as low temperature combustion method (Kumar *et al*., 2003). Smoke formation depends on combustion high temperature and correspondence ratio.

Impact of hydrogen on biodiesel blends: Biodiesel is the popular utilized reusable fuel in CI engines. The better component of the researches accepts that PM, THC and carbon monoxide discharge from biodiesel are lesser to normal diesel fuel (White *et al*., 2006). The oxygen content of biodiesel that stimulates an added whole and cleaner combustion process is the main factor (Yorozu *et al*., 1987). The biodiesel usage could lead to more effective THC, CO and particulate matter oxidation and increased NOx emissions, depending on the engine technology employed, combustion characteristics and other physical and chemical properties of the biodiesel comparatively with nature diesel. The additional feature which justifies the PM reduction with revere to diesel is the nonexistence of pungent compounds in biodiesel (Das, 1990). The present study attempted to resolve the tradeoff between NOx and smoke under high load conditions without scarifying indicated thermal efficiency by LTC with hydrogen mixed to the ingestion mixture for the delayed diesel-fuel injection timing in a high-pressure direct injection diesel engine. This study offers two approaches to LTC (Young, 1989). Study, the injection timing of diesel-fuel was deferred drastically until 2° ATDC or high to reduce combustion temperature for hydrogen concentration in ingestion mixture within the flammability choice. Subsequently, amplified EGR rate is done almost upto stoichiometric condition with little amount of hydrogen to decrease combustion temperature considerably.

MATERIALS AND METHODS

The experimental apparatus was lay down as detailed in Fig. 1. The engine was a single cylinder, naturally diligence research engine and engaged a pump-line-nozzle direct injection system as described in Table 1. To load the engine an eddy current dynamometer has been utilized. The Kistler pressure transducer was escalated at the cylinder head through charge amplifier to a data acquisition board to the in-cylinder pressure traces. The digital shaft encoder has been used to measure crank shaft position. Alternate engine test assemble instrumentation was used to observe ingestion air, exhaust gas recirculation, temperatures (oil, air, inlet manifold and exhaust) and pressures. Data acquirement and combustion investigation were conceded out using a personalized lab view based code. A Horiba Mex an analyzer was engaged to determine the concentrations of gaseous emissions.

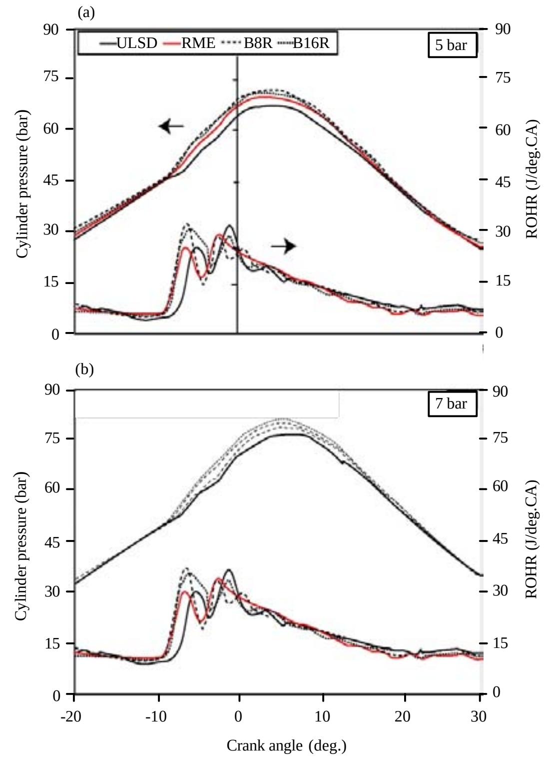

Fig. 1: In cylinder pressure and rate of heat release for the tested liquid fuels: a) 5 bar and b) 7 bar

Table 1: Engine specification

Engine specification	Values
Number of cylinders	1
Bore (mm)	98.4
Stroke (mm)	101.6
Connecting rod length (mm)	165
Displacement volume (cm^3)	773
Maximum torque (Nm)@1800 rpm	39.2
Maximum power (kW)@2500 rpm	836
Compression ratio	15.5:1
Injection timing (obTDC)	22
Maximum injection pressure (bar)	180
Injection system	Three holes pump-line-nozzle
Engine piston	Bowl-in-piston

A non-dispersive infrared, flame ionization detector and chemiluminescence method were employed to determine CO, THC and NOx correspondingly. To revise extent distribution of particulate matter emitted from the engine, a SMPS, fitted with thermo diluter was fitted. Experiments were carried out at a constant engine speed of 1500 rpm and changeable engine loads of 7 and 9 bar indicated mean effective pressure, representing 40% low and 70% high of ultimate load, respectively. The tests were processed out initially using diesel and biodiesel fuels as a instance. B8R and B16R blends were prepared and tested under the same conditions for comparison. Hydrogen mixed with the air before the ingestion manifold valve.

Table 2: Specification of tested fuels

Properties	ULSD	RME	Butanol	Hydrogen	B8R	B16R
Chemical formula	$C_{14}H_{26.09}$	$C_{18.96}H_{35.29}O_2$	C_4H_9OH	H_2	$C_{15.36}H_{29.2}O_{1.76}$	$C_{12.83}H_{24.92}O_{1.59}$
Cetane number	53.9	54.7	17	-	-	-
Density at 15°C (kg/m^3)	827.1	883.7	809.5	0.08	878.3	870.5
Kinematic viscosity at 40°C (cSt)	2.70	4.53	2.23	-	3.95	3.78
Lower heating value (MJ/kg)	43.11	37.80	33.12	120	37.12	36.91
Latent heat of vaporistion (kJ/kg)	243	216	585	-	-	-
Bulk modulus (MPa)	1410	1553	1500	-	-	-
Lubricity at 60°C (μm)	312	205	620	-	257	293
Stoicmetric A/F mass ratio	14.53	12.49	11.14	34.07	12.39	12.29
Sulphur (mg/kg)	46	5	-	-	-	-
Total aromatics (wt.%)	24.4	-	-	-	-	-
C (wt.%)	86.44	77.09	64.78	0	76.18	75.26
H (wt.%)	13.56	12.07	13.63	100	12.19	12.30
O (wt.%)	0	10.84	21.59	0	11.63	12.44

Abbreviations: Volumetric make-up (%); ULSD: 100 Ultra Low Sulphur Diesel; RME: 100 Rapeseed Methyl Ester; B8R: 8 Butanol+92 RME; B16R: 16 Butanol+84 RME

The property of hydrogen concentration (1, 1.5 and 2% of volumetric air flow rate) was estimated with the aim of resolving the optimal hydrogen concentration. Hence, the varied conditions of reticent EGR rate (5, 15 and 18%) were assessed to overcome the NOx penalty. The basic properties of tested fuels are given in Table 2.

RESULTS AND DISCUSSION

To achieve improved efficiency and emissions using lean burn combustion, it is essential to protected combustion stability in the lean operation condition such that the stable lean burn range is extended. Wobbly slant operation will source deterioration in competence and an augment of unburned hydrocarbon emissions. The NOx reduction, also is in adequate through the slender flammability edge. As noticed in preceding research and in this revise, there as on of accretion of hydrogen to a natural gas engine is to take benefit of the wider lean burn uniqueness of hydrogen. In this explore, the slant burn characteristics were processed according to the hydrogen addition ratio as the hydrogen addition was assorted from 10-40 vol.%.

The covalence values in Fig. 1 explain changes in combustion constancy with the hydrogen count proportion in the fuel at the MBT spark timing of each operation condition. If the covalence value is set as 2% as the typical for an operable stable combustion, it is pragmatic that the flammability edge is absolute by the hydrogen addition. Figure 2 demonstrates the thermal effectiveness against excess air ratio as hydrogen was supplemented. As the leanness was augmented, the thermal effectiveness enlarged, however, when the excess air ratio exceeded a certain level of leanness, the degree of efficiency decreased due to the degradation in combustion stability.

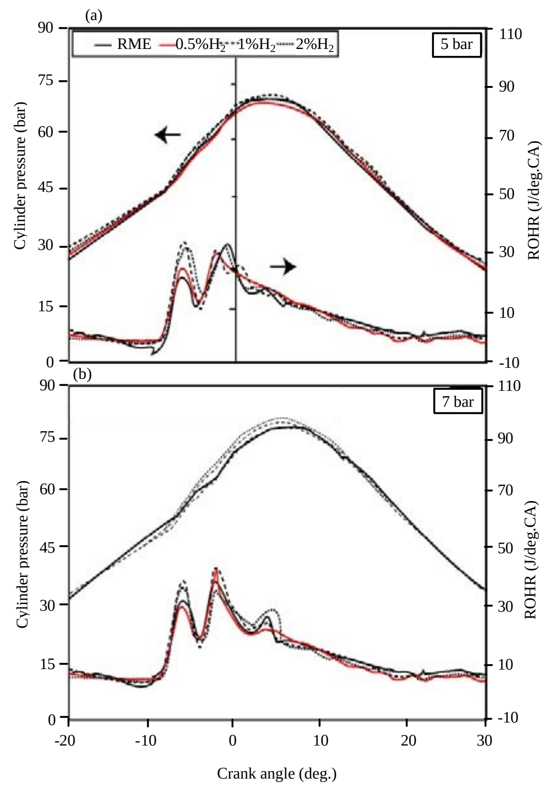

Fig. 2: The effect of hydrogen on the combustion characteristics of RME: a) 5 bar and b) 7 bar

The additional air ratio of maximum efficiency for each hydrogen addition proportion also denotes a leaner condition with the increase of the hydrogen addition proportion. It is prominent that the thermal effectiveness of 35 vol.% hydrogen addition was immensely less by 1.5%, than that of the natural gas.

The justification behind hydrogen addition at specific excess air proportions was reliable in amending thermal effectiveness is the efficient augmented work in order to

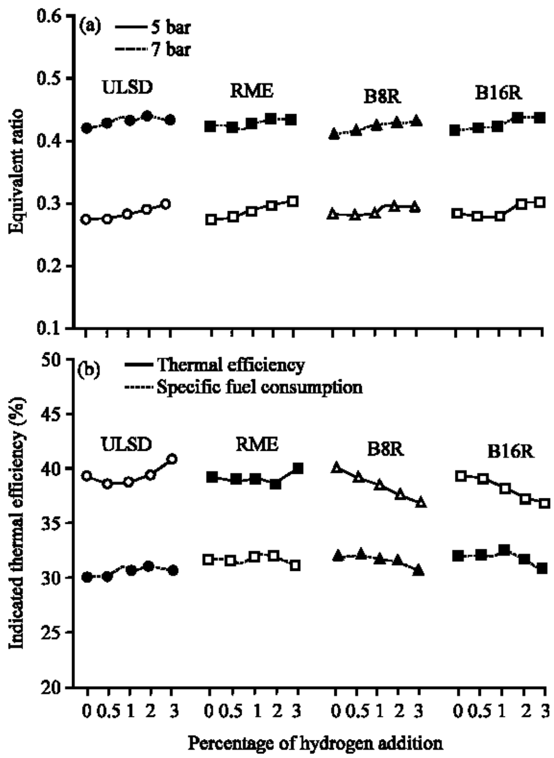

Fig. 3: Engine performance: a) Equivalence ratio and b) Indicated fuel consumption and indicated thermal efficiency

the increased laminar flame speed of the mixture as concluded in Fig. 3 which presents the MBT spark advance timing at each operating condition. An expansionof thermal effectiveness is presumed with an increase of the hydrogen addition proportion due to the anti-knocking characteristics of hydrogen are advantageous to form a increased compression proportion possible as higher hydrogen is mixed (Lilik *et al*., 2010; McWilliam *et al*., 2008; Miller and Bowman, 1989). Figure 3 shows the results of the dangerous emissions NOx, CO_2 and CO, respectively as a measure of changes in the excess air proportion under the same operating condition as in Fig. 3.

As shown in Fig. 3 enlarged ratio for enhanced elucidate assessment, beneath certain surplus air quantity circumstances, the intensity of NOx greater than before as hydrogen was assorted. This is due to promoted NOx generation as the high adiabatic flame temperature of hydrogen extends the temperature of the combustion gas. Also, considering the best efficiency illustrated in Fig. 3, NOx emissions are possibly to decrease because of possible stable operation of hydrogen addition with higher excess air proportion conditions.

A comparison of NOx emissions with standard gas with the conditions of finest efficiency indicated as 64% reduction of the NOx with the addition of 35 vol.% hydrogen and 78% NOx reduction with 35 vol.% hydrogen. The characteristics of CO emissions are actually slight different from that of NOx emissions as shown in Fig. 3. CO emissions decreased with hydrogen addition at certain excess air proportion conditions, CO emissions are matching or higher at the operating condition of finest efficiency.

CONCLUSION

An analysis to attain NOx reduction was achieved in a heavy duty natural gas engine with the addition of hydrogen to biodiesel blend fuel. As such to endorse the suitability of hydrogen-blended fuel, the thermal effectiveness and emission characteristics were reviewed. Therefore, recital and incineration aspect of a CI engine and the thermal competence augmented by persuade of hydrogen through bio fuel is scrutinized in this study. The reliability of ignition by accumulation of hydrogen and the competence of NOx lessening as well unremitting by means of hydrogen gas mingled diesel as a fuel.

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