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Development of Combustion Chambers for Enhanced Performance of Biodiesel Fueled Compression Ignition Engine

[1] Abishek Hebballi [2] V.G. Patil [3] S. S, Upadhyaya [4] Rajesh Anawal [5] S. I. Akki [6] V.S. Yaliwal
[1][2][3][4][5][6] Department of Mechanical Engineering,
S.D.M. College of Engineering and Technology, Dharwad, 580 002, Karnataka, India

Abstract:- **Alternative fuels are renewable in nature and deal with mainly about socio-economic and environmental issues. In view of this background, causes of combustion chamber geometry on the performance, combustion and emission characteristics has been examined in a single cylinder, four stroke water cooled direct injection (DI) compression ignition (CI) engine operated on single fuel mode using Honge oil methyl ester (HOME). Results of examination on HOME operation showed 2-3% increased brake thermal efficiency with condensed emission levels. However, more study and progress of technology should be dedicated to this area to further investigate the performance and feasibility of these fuels for dual fuel operation and prospect exploitations.**

Keywords:-- **Honge oil methyl ester, injection pressure, combustion, emissions.**

I. INTRODUCTION

Energy is an important for social and economic development of any country. This is achieved by using Biofuels. Diesel engines are accepted worldwide due to their higher performance, power output, consistency, lower emissions and its robustness as well. In view of this, investigators have discovered many new aspects regarding its diesel engine operation and technology. Hence they are more efficient for transportation, agricultural and power generation applications. In the present energy scenario, fossil fuels are exhaustive in nature, while the demand for energy is grown up at a faster rate. Due to increasing penalty on the crude petroleum purchase and stringent government environmental legislations, use of renewable and alternative fuels in partial or complete replacement for diesel engine applications is the need of the hour. However, chief drawback of diesel engine is that, it releases high smoke and nitric oxide emissions. These pollutants can be overcome by using Biofuels with use of suitable fuel properties and engine design. However, a diesel engine using biodiesel such as Honge oil methyl ester (HOME) operating on single fuel mode results in a smoke and nitric oxide emissions.

Several investigators stated that the performance of a diesel engine is considerably affected by type of combustion chamber used. Use of combustion chamber may be different for different injected liquid fuels. Because, the combustion of fuels depend on the air/fuel mixing caused by the eddy developed inside the engine. Effective air and fuel mixing is significantly affected by nozzle, combustion chamber geometry and air stream inside the engine cylinder. Alteration of combustion chamber by suitable piston bowl can significantly influence the combustion characteristics i.e., it affects the profile and magnitude of the cylinder pressure and heat release rate, by affecting airflow volume and its disorderness, thus affecting air-fuel mixing rates. Efficient management and exploitation of the heat release rate is imperative to limit cylinder pressure, knocking and emission levels [1]. Good nozzle and combustion chamber geometry can results into better air-fuel mixing rates. This can lead to increased thermal efficiency with reduced engine discharge levels caused by the forcing air to the centre of the combustion chamber [2]. This causes turbulence even when the fuel is injected into the cylinder. Basic combustion chamber results into better engine performance. However, it may not be suitable for Biofuels including liquid and gaseous fuels; hence it is necessary to design different combustion chamber for alternative fuels [3-7].

In view of this effect of combustion chamber shape on the performance, combustion and emission characteristics have been investigated in a single cylinder, four stroke water cooled direct injection (DI) compression ignition (CI) engine operated on single fuel mode using Honge oil methyl ester (HOME) and results were compared with base line operation.

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2.0 Fuel properties

The properties of fuels can significantly affect the engine performance and emission levels and hence properties play important role during the combustion. In this context, fuel properties are measured at our college laboratory and are shown in Table 1.

3.0 Experimental set up

Experiments are conducted on a Kirloskar TV 1 type, four stroke, single cylinder, and water-cooled diesel engine test rig. Figure 1.0 shows the experimental set up. Rope brake dynamometer was used for loading the engine. The fuel flow rate is measured on the volumetric basis using a burette and stopwatch. The engine and dynamometer was coupled. The smoke and CO characteristic was measured by using AVL smoke meter. The tests were conducted with manufacturer settings. The specifications of the engine are given in Table 2. different combustion chambers used such as hemi-spherical (HCC), cylindrical (CCC), torroidal (TCC) and re-entrant combustion chamber (RCC) are shown in Figure 2.

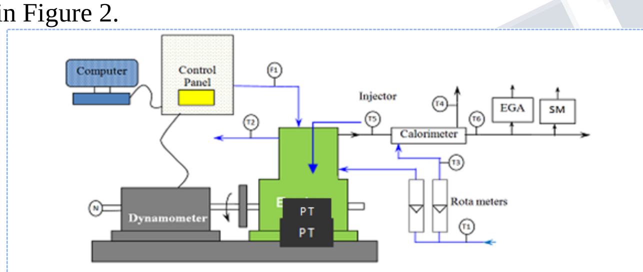

Fig. 1 Schematic view of the experimental set up

T1,T3-Water inlet Temperature	T6- EGT after calorimeter
T2-Engine water jacket outlet Temperature	F1-Fuel flow DP(differential pressure) unit
T4-Calorimeter outlet Temperature	PT-Pressure transducer
T5-Exhaust gas temperature(EGT) before calorimeter	N- RPM encoder
	EGA-Exhaust gas analyzer
	SM- Smoke meter

Table 1 Properties of Diesel and HOME

Property	Unit	Diesel	HOME
Viscosity (40^{o} C)	cSt	3.7-4.2	5.6
Acid Value	mg/KOH	0.26	0.92
Calorific Value	kJ/kg	44500	39500
Specific Gravity at 20^{o}	-	0.854	0.930
Density (15^{o})	Kg.m^{3}	840	930
Iodine Value	gI$_2$/100g	97-100	---
Cetane Number	-	53-56	44
Flash Point	^{o}C	53	170
Pour Point	^{o}C	35-15	---
Cloud Point	^{o}C	3-7	---
Copper strip Corrosion	-	less	Wax deposition

Table 2. Specification of CI Engine

Particulars	Specification
Make	Kirloskar
Type	Single cylinder, 4stroke CI
Brake power	3.6775 KW
Bore (D)	80 mm
Stroke (L)	110 mm
Compression ratio	16:1
Effective brake drum radius	162 mm

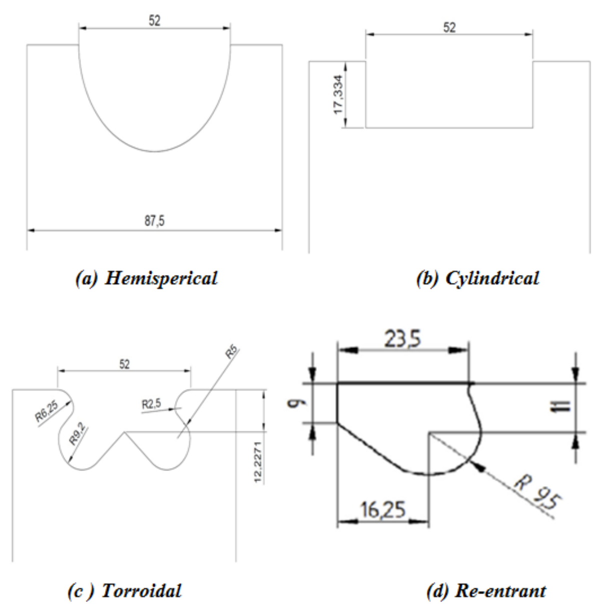

Fig. 2 Combustion chambers used in the present work

4.0 Results and discussions

In this section, combustion chamber geometry effect on the performance and emission characteristics of diesel engine operated on Honge oil methyl ester (HOME) has been investigated. In this present work, experimentation was conducted at variable engine load conditions. During the single fueled engine operation, compression ratio, injection pressure, injection timing was kept constant at 17.5, 230 bar and 23 ^{0}bTDC respectively. In this context, a brief overview of preliminary engine testing is summarized in the following sections.

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6.4.1 Performance attributes

Effect of combustion chamber geometry on the brake thermal efficiency (BTE) is presented in Figure 3. Enhanced BTE has been noticed for base fuel (diesel) operation compared to HOME at the identical working conditions. This might be because of dissimilarities in the fuel properties. Trial examination on various combustion chamber profiles on HOME operation with reentrant ignition chamber (RCC) demonstrated higher performance compared to other combustion chamber profiles. It is observed that with RCC, BTE was expanded by 3.1%, 2.4% and 1.2% for HCC, CCC and TCC individually. This might be brought about by the way that with HOME and RCC operation, the flame from scattering over to the squish region leading to improved air- HOME fusion growth. Likewise RCC can coordinate the stream field inside the sub volume at all loads and expands flame spreading and prompting better combustion [2, 3, 8]. Diesel engine working on HOME with other combustion chamber profiles, increases heat release during dispersal or later stages compared to premixed combustion. As a result, other burning chamber profiles may prompt increased ignition delay that lead to lessening in BTE. In this way it can be inferred that utilization of RCC for the burning of HOME, may come into better ignition. The BTE got for HOME with a HCC, CCC, TCC and RCC were observed to be 18.02% and 19.1% individually contrasted with 21.45% for diesel operation with RCC.

6.4.2 Emission characteristics

Figure 4 shows the variety of smoke levels with brake power. Results demonstrated that HOME operation brought about higher smoke levels compared to base fuel operation. It could be credited to dishonorable mixing rates and decreased oxidation and improper ignition of HOME. However diminished oxidation rates, higher unsaturated fats in HOME and lower air-fuel ratio might be the reason for such observed pattern. But, smoke levels can be diminished by utilizing appropriate combustion chambers. In perspective of this, HOME operation with RCC brings the smoke levels lower compared to other combustion chamber profiles. Utilization of RCC enhances air –fuel blending and superior oxidation brings the improved disordered air movement (turbulence) in the ignition chamber. This variable prompts lower soot particles in the fumes. Expanded disordered air movement is active due to use of RCC contrasted with the operation with other ignition chambers. The smoke levels acquired for HOME with a HCC, CCC, TCC and RCC were observed to be 18.02% and 19.1% separately contrasted with 21.45% for diesel operation with RCC.

Figure 5 and 6 demonstrates the variety of hydrocarbon (HC) and carbon monoxide (CO) engine discharge levels for diesel and HOME operation at all loads. It is watched that, HC and CO emission levels were produced to lower levels for diesel compared to HOME operation. It could be because of inadequate combustion of the HOME due to lessened air use and reduced burning rates. In addition, inferior oxidation rate, linked with lower calorific value of HOME and lower air-fuel ratio and lower mean compelling weight are responsible for higher HC and CO emanation levels. From the Figures 5 and 6, it was seen that RCC spread out lower HC and CO levels compared to the operation with other combustion chambers (HCC and CCC). This is because of better ignition of HOME and enhanced air-fuel combining rates brought out by the increased whirl and squish movement of mixture is possible with RCC. Legitimate usage of oxygen present in the HOME may be better exploited with RCC leading to increased BTE. But the other burning chamber profiles may not result in best possible mixing rate and prompting inadequate combustion. It might be because of imprisonment in the average part of the dish by the vortex created with other ignition chamber setups. The HC levels got for HOME with a HCC, CCC, TCC and RCC were observed to be 18.02% and 19.1% individually contrasted with 21.45% for diesel operation with RCC. So also, the CO levels acquired for HOME with a HCC, CCC, TCC and RCC were observed to be 18.02% and 19.1% individually contrasted with 21.45% for diesel operation with RCC.

For the same combustion chamber arrangements, it is noticed that diesel operations convey higher NOx levels in the fumes when weighed against HOME operation (Figure 7). It could be because of better usage of air leading to enhanced combustion temperature. Additionally higher rate of energy discharge is accountable for this result pattern. However, higher NOx levels have been noticed for HOME operation when the engine was employed with RCC compared to other combustion chambers. This might be because of better burning of the fuel to higher degree taking place inside the combustion chamber caused by the homogeneous mixing and enhanced air utilization and better squish and swirl, and better combustion occurs just near to the top dead centre. Presence of oxygen in HOME is used towards better ignition. The NOx levels acquired for HOME with a HCC, CCC, TCC and RCC were observed to be 18.02% and 19.1% separately contrasted with 21.45% for diesel operation with RCC.

5.0 Conclusions

The application to a HOME fueled engine showed that combustion process is strongly influenced by the

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combustion chamber type. However, the procedure is successful in defining the best combustion chamber configuration with perfectly existing nozzle geometry in order to achieve the goals of the conversion process and a reduction of emissions.

- From the experimental investigations, for high viscous fuel HOME operation, it is observed that HOME operation resulted in improved performance with RCC.
- The use of RCC, could lead to efficient mixture preparation resulting in lower emissions. Significant improvements in power output and the trade-off between smoke and NOx emissions can be obtained for HOME fuel operation if mentioned nozzle geometry is used.

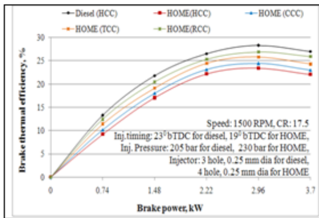

Fig. 3 Variation of BTE with brake power

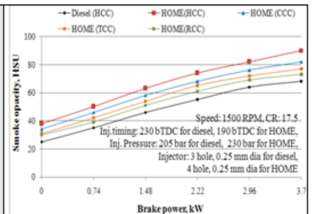

Fig. 4 Variation of smoke with brake power

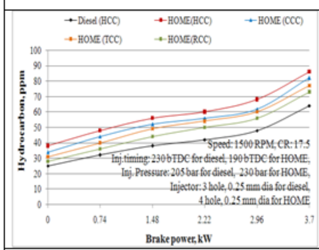

Fig. 5 Variation of HC with brake power

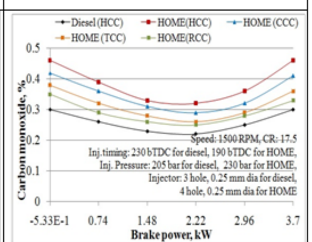

Fig. 6 Variation of CO with brake power

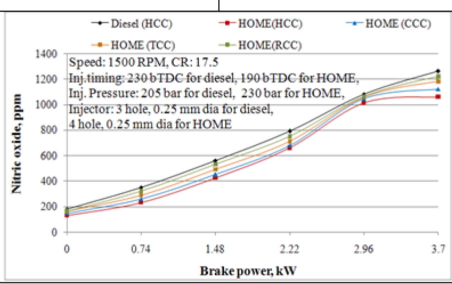

Fig. 7 Variation of NOx with brake power

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