Influence of Swirl on the Performance of Honne Oil Methyl Ester in a DI Diesel Engine

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Abstract

Due to rapid depletion of fossil fuels, increased energy demand and environmental concerns alternative fuels such as biodiesel are gaining prominence for IC engine applications.In order to realize the full potential of biodiesel use in diesel engine certain modifications in combustion chamber design are required. In our study combustion chamber is modified by making number of grooves on the piston crown to enhance the swirl for better air fuel mixing operated with Honne Oil Methyl Ester hence the engine performance is increased and reduction in emissions. The test result showed that the grooves on piston crown have significant influence of air swirl. The Configuration 6-Groove Piston enhances the combustion rate which increases the brake thermal efficiency and lowers the CO, HC because of better air-fuel mixing among all 3-Groove, 9-Groove and normal piston.However the peak pressure for 6-grooves piston is higher than that for 3-grooves and normal piston.

Keywords*: Honne biodiesel, Swirl, Emissions, Diesel engine,brake specific fuel consumption.*

1. Introduction

The world is presently confronted with the twin crisis of fossil fuel depletion and environmental degradation. Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction in underground based carbon resources. The search for an alternative fuel, which promises a harmonious correlation with sustainable development, energy conservation, management, efficiency, and environmental preservation, has become highly pronounced in the present context. The inventor of the diesel engine, Rudolf diesel, in 1885, used vegetable oil (peanut oil) as a Diesel fuel for demonstration at the 1900 world exhibition in Paris.

Most important function of IC engine combustion chamber is to provide proper mixing of fuel and air in short possible time to produce high relative velocity between the fuel droplets and air is called swirl. The swirl will enhance the turbulence, thermal efficiency and helps to easier starting.

A lot of experimental investigations on the performance of biodiesel fuelled engine have been carried out without modification to the diesel engine.These studies have reported that the use of biodiesel blends and neat biodiesel in diesel engine decreases carbon monoxide,unburnt hydrocarbonsHowever increases in NOx emission levels[1].Mingfa Yao et al. (2009) [2] reported that bowl with bump ring has more kinetic energy, high turbulence energy, enhancing mixing rate and reducing soot compared to conventional combustion chamber.R.V Ravikrishna et al.(2011) [3] studied the effect of swirl induced by re-entrant piston bowl geometry by Computational Fluid Dynamics (CFD) simulations. This re-entrant chamber produced the highest in-cylinder swirl and turbulence kinetic energy. John. B Heywood (1988) [4]reported that an alternative design with a re-entrant bowl is used to promote rapid fuel-air mixing at the end of compression and maintain a high swirl levelfurther into the expansion stroke. Due to increase in swirl rate particulate, CO, HC and smoke will decreases whereas NO emissions increases due to more rapid fuel-air mixing. V.V Prathiba et al (2011) [5] investigated that by cutting grooves on the piston crown will affect the swirl for better mixing and hence reduction in brake specific fuel consumption (BSFC) and smoke.

2. Materials and Methodology

2.1 Biodiesel and its Properties

Calophylluminophyllum, commonly known as PenagaLaut in Malaysia, is a non-edible oilseed ornamental evergreen tree belonging to the Clusiaceae family. It grows along coastal areas and adjacent lowland forests, although it occasionally occurs inland at higher elevations. It is native of eastern Africa, southern coastal India, Southeast Asia, Australia and the South Pacific. Calophylluminophyllum is also often called as “Alexandrian Laurel” in English. Calophylluminophyllum is amedium and large-sized evergreen sub-maritime tree that averages 8–20 m (25–65 ft) in height with a broad spreading crown of irregular branches. It has elliptical, shiny and tough leaves. The flower is around 25mm wide and occurs in racemose or paniculate inflorescences consisting of 4–15 flowers. The fruit (ballnut) is a round, green drupe reaching 2–4 cm (0.8–1.6 in.) in diameter and having a single large seed Calophylluminophyllum kernels have very high oil content (75%) and the oil contains approximately 71% of unsaturated fatty acids The properties of Neat Honne Oil (H100), ND were determined as per the methods approved by Bureau of Indian Standards (BIS) [6].

Due to increasing the IOP with H100 from the rated injector opening pressure (200 bars) increase in the brake thermal efficiency and reduction in CO, HC and smoke opacity emissions. However, NOx emission was increased. With H100, ignition delay decreased as injector opening pressure increased. Improved premixed heat release rate was observed with H100 when the injector opening pressure is advanced. The best IOP is 240 bars with H100 based on brake thermal efficiency [7].

Table .1 Properties of Honne biodiesel.

Properties	Units	Neat Diesel	Calophyllum inophyllum biodiesel (Honne)	ASTM D6751-06 standard
Den sity at 15 °C	Kg/m^3	830	869	860-900
Flash point	°C	56	140	130 min
Kinematic viscosity at 40 °C	mm^2/s	3.12	4.0	1.9-6.0
Cetane number	-	40-50	57	47 min
Cloud point	^{0}C	-15 to 5	13.2	-3 t0 12
Pour point	^{0}C	-35 to -15	4.3	-15 to 10
Calorific value	KJ/kg	42990	41397	-
Distillation 90%	^{0}C		356	360 max
Water content	Wt%		0.005	0.030 max
Ash content	Wt%		-	0.020 max
Carbon residue	Wt%		-	-
Acid value	mgKOH/g		1.62	0.8 max

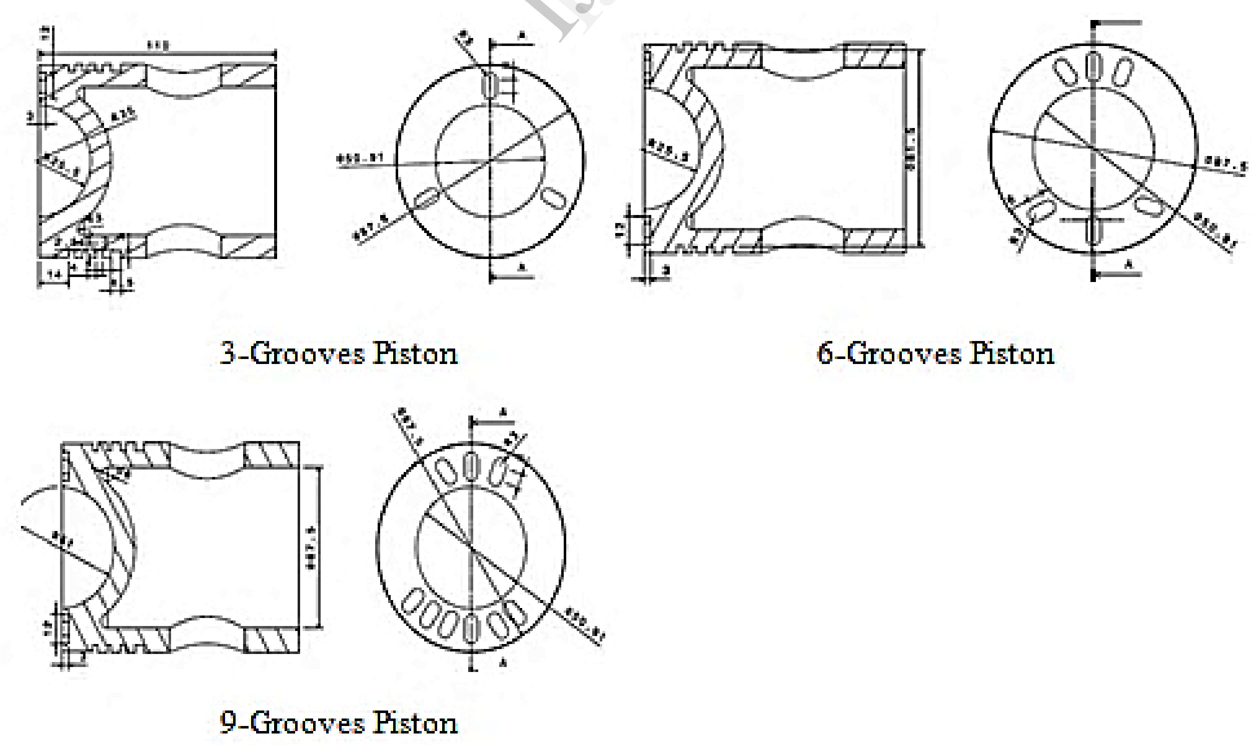


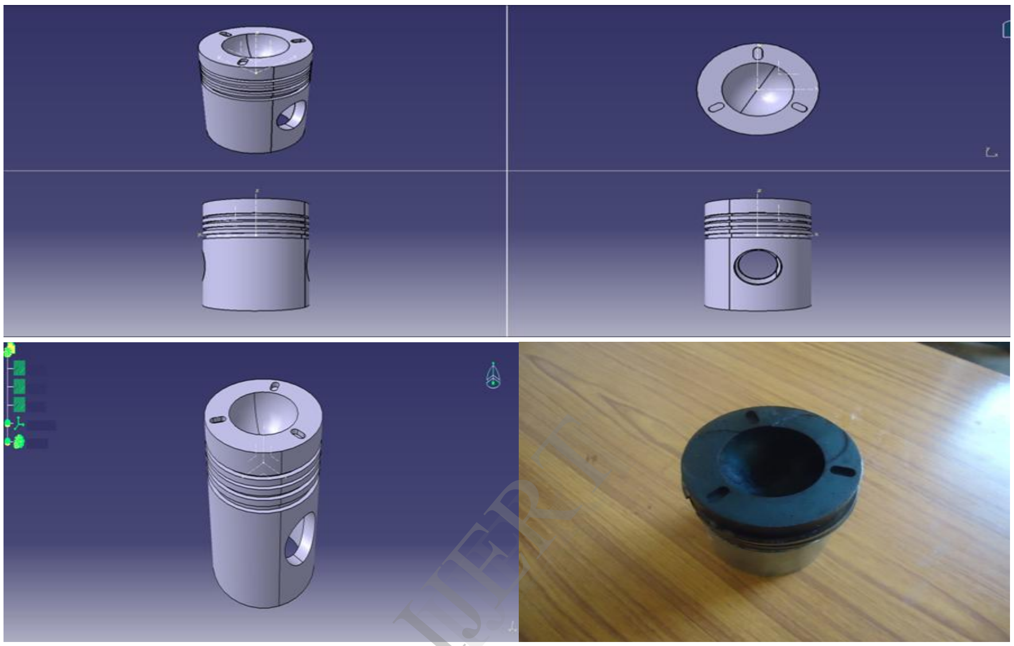
Fig.1. Schematic diagrams of grooves made on piston surface.

2.2 Engine Modifications

In the present investigation, to investigate the effects of combustion chamber geometry on performance and emission characteristics Honne oil methyl ester fuelled direct injection diesel engine is used. The baseline hemisphericalcombustion chamber (HCC) bowl geometry has modified to enhance the swirl effect by cutting grooves on the piston crown such as 3-Groove, 6-Groove and 9-Grooves.

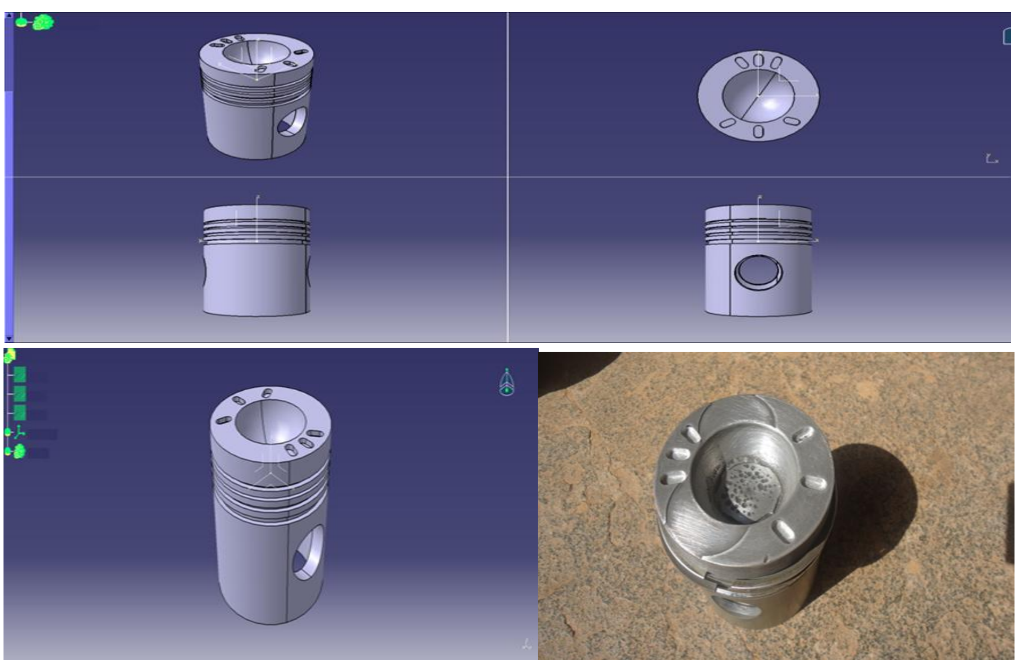
2.2a 3-D modelling of different grooved Combustion Chambers:

A) 3-Grooved Combustion Chamber:



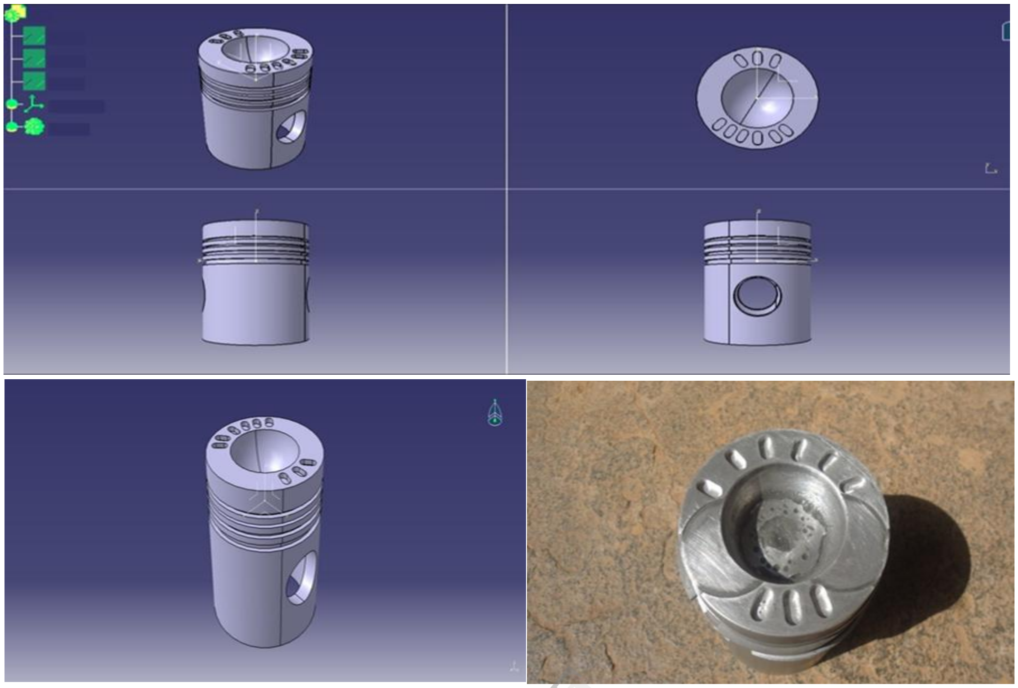
3-D Modelling **Photographic View**

B) 6-Grooved Combustion chamber:



3-D Modelling **Photographic View**

C)9-Grovved Combustion Chamber:



3-D Modelling **Photographic View**

Fig.2 3-D Modelling of various grooves made on piston surface.

2.3 Experimental Setup

Kirloskar Company made single cylinder, 4 stroke, and water cooled diesel engine of 3.7 kW is used to conduct the experimental work. The test engine is directly coupled to an electric dynamometer. Five-gas analyser is used for emission testing.

Table.2 Specifications of the engine.

SL.NO	Parameters	Specifications
1	Machine supplier	Apex Innovations Pvt. Ltd. Sangali Maharastra State ,India.
2	Type	TV1 (Kirlosker made)
3	Software used	Engine soft
5	Nozzle opening pressure	200-225 bar
Governor type		
6	No.of cylinders	Single cylinder
7	No of strokes	foure stroke
8	Fuel	H.S Diesel
9	Rated Power	5.2 kw (7HP) at 1500 RPM
10	Cylinder diameter (Bore)	87.5 mm
11	Stroke length	110 mm
12	Compression Ratio	17.5:1
Air measurement manometer		
13	Made	MX 201
14	Type	U-Type
15	Range	100-0-100 mm
Eddy current Dynamometr		
16	Model	AG-10
17	Type	Eddy current
18	Maximum	1500-3000 RPM

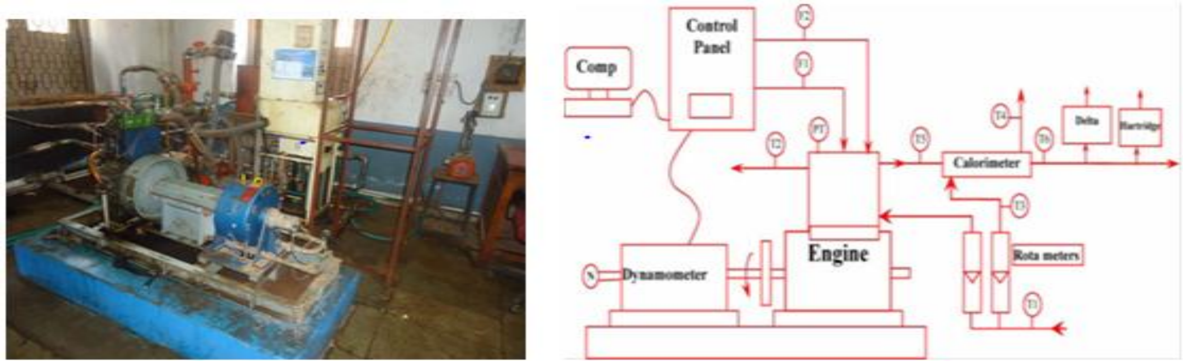


Fig.3 Engine setup.

3. Results and Discussions

In this study experimental work is carried out to investigate the effect of swirl by cutting grooves on the piston surface. In this work different configuration of piston such as 3-grooves,6-grooves and 9-grooves are used and their effects on the performance and emissions are recorded with Honne Oil Methyl Ester.

3.1 Performance Analysis

3.1.1 Brake Thermal Analysis

The brake thermal efficiency with brake power for different configurations are compared with the normal engine configuration and is shown in Fig.4The brake thermal efficiency for normal piston at full load is 24.45 %. It can be observed that the engine with 3-grooves and 6-grooves give thermal efficiencies of 17.47 % and 25.67 %, respectively, at full load. It is observed that 9-Grooves piston operation stops the engine due to large change in compression ratio. The thermal efficiencies of 3-grooves and normal piston (HCC) are lower compared to 6-grooves. From Fig.4it was inferred that the brake thermal efficiencies were increasing with an increase in brake power for configurations that were under consideration. These configurations were found to offer better thermal efficiencies than the normal engine. This might be due to the enhanced mixing rate in the case of 6-grooves carried by turbulence in the combustion chamber.

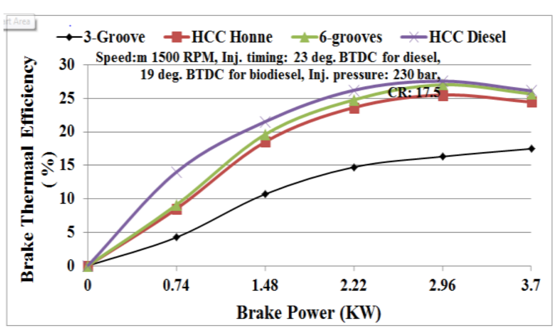


Fig.4 Comparison of BTE for 3-Grooves, 6-Grooves and 9-Grooves.

3.1.2 BSFC

Fig.5 shows the variations of BSFC with different configurations having different number of grooves on the piston crown operated with Honne Oil Methyl Ester. It observed that the BSFC for 6-grooved piston is lower compared to other two configurations of the piston. The higher specific fuel consumption for 3-grooves and normal piston (HCC) may be attributed to poor air fuel mixing which lead to poor combustion comparing to the 6-grooves piston.

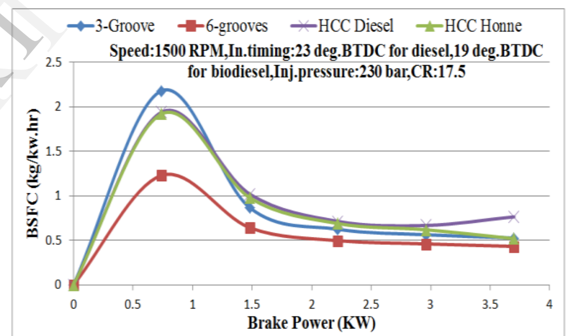


Fig.5 Comparison of BSFC (kg/Kw.hr) for 3-Grooves,6-Grooves and 9-Grooves.

3.1.3Peak Pressure

The variation of peak pressures with respect to brake power for 3-grooves, 6-grooves and 9-grooves when operated with Honne Oil Methyl Ester is shown in Fig.6. It can be seen that the peak pressure for 6-grooves is greater when compared to 3-grooves and normal piston (HCC). This may be attributed to improper mixing Honne Oil Methyl Ester with air due to higher viscosity and lower calorific value for Honne OilMethyl Ester. However the peak pressure for 6-grooves piston is higher than that for 3-grooves and normal piston but slightly lower than the baseline engine operated withdiesel. This may be due to better combustion due to better air fuel mixing in 6-grooves piston as a result of improved air motion. It is observed that 9-Grooves piston operation stops the engine due to large change in compression ratio.

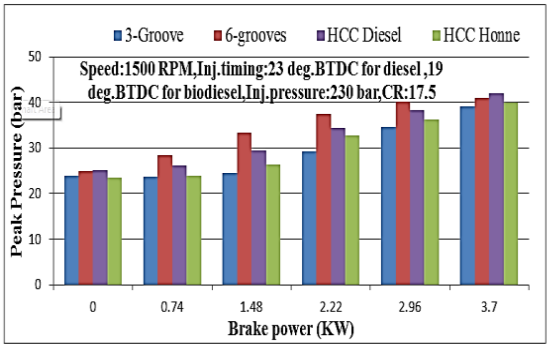


Fig.6Variations of peak pressure (bar).

3.2 Emission Analysis

3.2.1 UBHC (ppm)

The comparison of Hydrocarbon emission in the exhaust is shown in Fig 7. Unburnt hydrocarbon emission is the direct result of incomplete combustion. It is apparent that the hydrocarbon emission is decreasing with the increase in the turbulence which results in complete combustion. At the rated load with 6-grooves piston a maximum reduction of hydrocarbon emission level is observed and compared to normal engine. It is also observed that with 6-grooves results the reductions in hydrocarbon levels compare to the 3-grooves and normal piston (HCC).

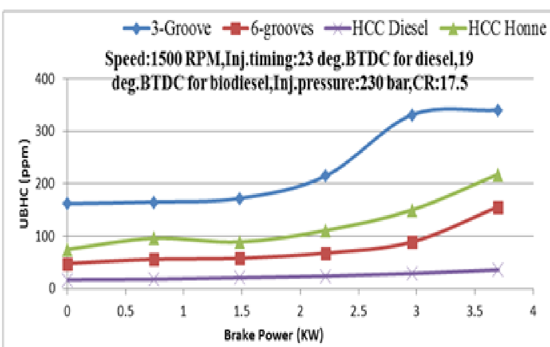


Fig. 7 Variations of UBHC (ppm) emissions.

3.2.2 CO (%)

Fig.8 shows the comparison of Carbon monoxide emission with brake power. Generally, C.I engines operate with lean mixtures and hence the CO emission would be low. With the higher turbulence and temperatures in the combustion chamber the oxidation of carbon monoxide is improved and which reduces the CO emissions. The lowest carbon monoxide emission is occurred with 6-grooved piston configuration compared to other two configurations.

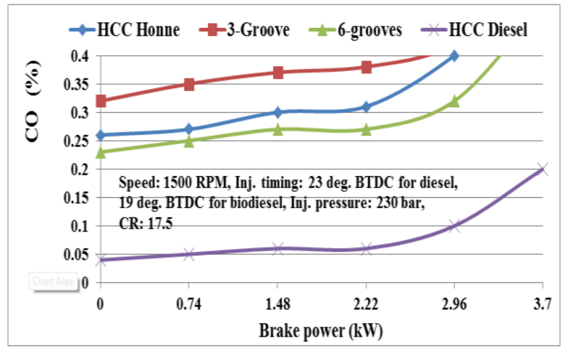


Fig. 8 Variations of CO (%) emissions.

3.2.3NOx (ppm)

NOx is formed by chain reactions involving nitrogen and oxygen in the air. These reactions are highly temperature dependent. Since diesel engines always operate with excess air, NOx emissions are mainly a function of gas temperature and residence time. Fig.9 shows the variations of oxides of nitrogen emissions for standard engine and modified engine withHonne Oil Methyl Ester. The NOx emissions were higher for 3-Grooves piston. The reason for the increase in NOx may be attributed to higher combustion temperatures arising from improved combustion due to better mixture formation in 3-Grooves piston and availability of oxygen in Honne Oil Methyl Ester. However NOx can be controlled by adopting Exhaust Gas Recirculation (EGR) and by employing suitable catalytic converters. At full load with Honne Oil Methyl Ester for the 6-grooves, the NOx emission was 902 ppm compared to 935 ppm for 3-groove piston. There is anincrease of about 4% NOx emissions for 3-grooves piston.

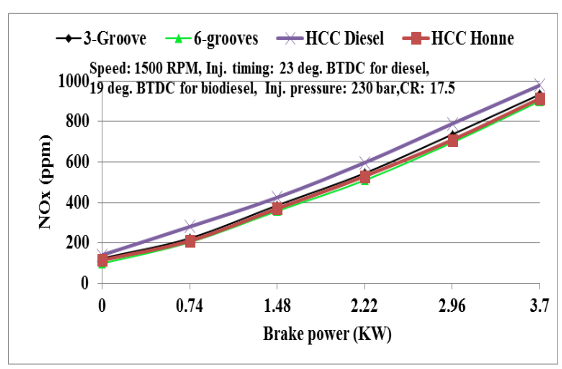


Fig.9 Variations of NOx emission.

4. Conclusion

In this present work a study about influence of the air swirl in the cylinder upon the performance and emission of a single cylinder diesel direct injection engine is presented. In this work three different configurations of piston i.e. in the order of number of grooves 3, 6, 9 are used operated with Honnebiodiesl.

1) The Configuration 6-Groove Piston enhances the turbulence and hence results in better air-fuel mixing among all three configurations of diesel engine which increases the brake thermal efficiency.

2) Due to high content of oxygen in the Honne biodiesel and better air swirl the emissions CO, HC are reduced in 6-Groove Piston compared to baseline combustion chamber operated with Honne oil methyl ester.

3) There is better fuel economy hence BSFC is lower for although the Nox emission is increased owing to better mixing and a faster combustion process in 6-Groove Piston.

4) However the peak pressure for 6-grooves piston is higher than that for 3-grooves and normal piston but slightly lower than the baseline engine operated with diesel. This may be due to better combustion due to better air fuel mixing in 6-grooves piston as a result of improved air motion.

5) It is observed that 9-Grooves piston operation stops the engine due to large change in compression ratio.

5. References

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