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Research paper

Performance and Emission characteristics of IC engine using modified coated Piston Head

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Abstract

Internal combustion engines have been a relatively inexpensive and reliable source of power for applications ranging from domestic use to large scale industrial and transportation applications for most of the twentieth century. DI Diesel engines, having the evident benefit of a higher thermal efficiency than all other engines, have served for both light- duty and heavy-duty vehicles. In DI diesel engines, swirl can increase the rate of fuel-air mixing. Swirl interaction with compression induced squish flow increases turbulence levels in the combustion bowl, promoting mixing. It is evident that the effect of geometry has a negligible effect on the airflow during the intake stroke and early part of the compression stroke. But when the piston moves towards Top Dead Centre (TDC), the bowl geometry has a significant effect on air flow thereby resulting in better atomization, better mixing and better combustion. In CI engine piston shapes on crown is flat and concave combustion chamber, with this geometry we have been running the engine. But here air fuel ratio mixture cannot mix properly. To avoid this we make piston geometry changes. The main object of this project is to investigate the performance technique to enhance the air swirl to achieve betterment in engine performance and emission in a direct injection (DI) single cylinder diesel engine. In order to achieve the swirl intensities in the cylinder, changes on the piston crown has been selected. To increase the swirl, series of experiments were conducted like 2 toroidal grooves piston, 4 toroidal grooves piston, 6 toroidal grooves piston on piston crown and compare the results with normal piston values

Keywords: *Engine performance, Biodiesel, grooves on piston, coating*

1. Introduction

The consumption of petroleum has been increased tremendously in both industries and transport sector. For economic development of any country these two sectors are very important. It is learnt that day by day the increase in demand of fossil fuels leads to exhaust of petroleum products in near future. So the time has come to identify alternative fuels for diesel such that they may serve as fossil fuels, which are depleting at much faster rate than expected. And also the rising prices of petroleum products and environmental concern led to intensive studies on use of alternative fuels. There is lack of sufficient oil reserves in India. Because of growing demand of petroleum products our government spending billions of dollars for their imports. Though diesel engines play a vital and indispensable role in today‟s modern life, it contributes to pollution substantially. An intensive search is being carried in developing diesel engine fuels and lubricants based on vegetable oils. Therefore it is the right time to search for alternative fuels. The vegetable oils are renewable and are produced easily in rural areas. Its usage has been studied even since the advent of the internal combustion engine. However it is only recent years focused much on usage of vegetable oils. Since they have properties comparable to diesel fuel, they may be used in compression ignition engine. In this connection several researchers Biodiesel is a clean burning fuel, which means that it does not give off harmful emissions that cause environmental effects. Since bio-diesel is oxygenated, diesel engines have more complete combustion with bio-diesel than with petroleum. Biodiesel is safer to use than petroleum diesel. The use of biodiesel in a conventional diesel engine results substantial reduction of unburnt hydrocarbons, carbon monoxide, and particulate matter had been working continuouslyusing different vegetable oils with slight modifications on engine and also with varied fuel properties. The problems associated with vegetable oils like high viscosity, filter clogging, flame propagation has led to more alternative by researchers. There is limited reserve of the fossil fuels and the world has already faced the energy crisis of seventies concerning uncertainties in their supply. Fossil fuels are currently the dominant global source of CO_2 emissions and their combustion is stronger threat to clean Tiffany McKerahan environment. Increasing industrialization, growing energy demand, limited reserve of fossil fuels and increasing environmental pollution have jointly necessitating in exploring some alternative to conventional liquid fuels. Internal combustion engines particularly of the compression ignition (CI) type are playing a major role in transportation, industrial power generation and in the agricultural sector. There is a need to search in using alternative fuels. These fuels are to be renewable and emit low levels of gaseous and particulate pollutants in internal combustion engines. In the case of agricultural applications, fuels that can be produced in rural areas in a decentralized manner, near the consumption points will be favored. The permissible emission levels can also be different in rural areas as compared to urban areas on account of the large differences in the number density of engines. Fuels like vegetable oils, biodiesel (transesterified vegetable oils- methyl esters of vegetable oils), alcohols, natural gas, biogas, hydrogen, liquefied petroleum gas (LPG), etc. are being investigated by researchers for engine applications. Ceramic coatings are used in diesel engine combustion chambers are aimed to reduce heat transfer to the cooling water. Engine cooling systems are planned to be removed from internal combustion engines by the development of advanced technology. One can expect that engine power can be increased and engine weight and cost can be decreased by removing cooling system elements (coolant pump, ventilator, water jackets and radiators etc.). More silent engine operation can be obtained considering less detonation and noise causing from uncontrolled combustion. Another important topic from the view point of internal combustion engines is exhaust emissions. Increased combustion chamber temperature of ceramic coated internal combustion engines causes a decrease in soot and carbon monoxide emissions.When increased exhaust gases temperatures so volumetric efficiency decrease.

2. Literature Review

AydinHuseyin [1]examined the combined effects of thermal barrier coating and blending with diesel fuel on usability of vegetable oils in diesel engines. The possibility of using pure vegetable oils in a thermally insulated diesel engine has been experimentally investigated. Initially, the standard diesel fuel was tested in the engine, as base experiment for comparison. Then the engine was thermally insulated by coating some parts of it, such as piston, exhaust and intake valves surfaces with zirconium oxide (ZrO_2). The main purpose of engine coating was to reduce heat rejection from the walls of combustion chamber and to increase thermal efficiency and thus to increase performance of the engine that using vegetable oil blends. Pure inedible cottonseed oil and sunflower oil were blended with diesel fuel. Blends and diesel fuel were then tested in the coated diesel engine. Experimental results proved that the main purpose of this study was achieved as the engine performance parameters such as power and torque were increased with simultaneous decrease in fuel consumption. Furthermore, exhaust emission parameters such as CO, HC, and Smoke opacity were decreased. Also, sunflower oil blends presented better performance and emission parameters than cottonseed oil blends.

Helmisyah A.J., Ghazali M.J [2] has studied the high temperature and pressure produced in an engine that uses compressed natural gas with direct injection system (CNGDI) which may lead to high thermal stresses. The piston crown fails to operate effectively with insufficient heat transfer. In this study, partially stabilized zirconia (PSZ) ceramic thermal barrier coatings were plasma sprayed on CNGDI piston crowns (AC8A aluminum alloys) to reduce thermal stresses. Several samples were deposited with NiCrAl bonding layers prior to the coating of PSZ for comparison purposes. Detailed analyses of microstructure, hardness, surface roughness, and interface bonding on the deposited coating were conducted to ensure its quality. High stresses were mainly concentrated above the pinhole and edge areas of the piston. In short, the PSZ/ NiCrAl coated alloys demonstrated lesser thermal stresses than the uncoated piston crowns despite a rough surface. Extra protection is thus given during combustion operation H. Hazar, U. Ozturk [3]studied the effect of Al_2O_3-TiO_2 coating in a diesel engine on performance and emission of corn oil methyl ester, the piston, cylinder head, exhaust and inlet valves of a diesel engine were coated with the ceramic material Al_2O_3-TiO_2 by the plasma spray method. Thus, a thermal barrier was provided for the parts of the combustion chamber with these coatings. The effects of corn oil methyl ester that produced by the transesterification method and ASTM No. D2 fuels performance and exhaust emissions" rates were studied by using equal in every respect coated and uncoated engines. Tests were performed on the uncoated engine, and then repeated on the coated engine and the results were compared. A decrease in engine power and specific fuel consumption, as well as significant improvements in exhaust gas emissions (except NOx), were observed for all test fuels used in the coated engine compared with that of the uncoated engine.

3. Transesterification Reaction

The transesterification reaction is the reaction of a fat or oil with an alcohol to form esters and glycerol. This reaction is also called alcohol. The overall chemical reaction is shown in Fig.5.1. A catalyst is generally used to improve reaction speed and performance. Because the reaction is reversible, the excess of alcohol is used to change the balance next to the products. The alcohols that can be used in the process of transesterification are methanol, ethanol, propanol, butanol and amyl alcohol. Methanol and ethanol are used more frequently, especially methanol because of its low cost and its physical and chemical advantages (methanol is polar and is the shortest chain alcohol). It can react quickly with triglycerides and sodium hydroxide (NaOH) used because the catalyst dissolves easily in it. To complete a stoichiometric transesterification, a 3: 1 molar ratio of triglycerides is required. In practice, the ratio must be greater to bring the balance sheet to a maximum yield of foreign. The reaction can be catalyzed by alkalis, acids or enzymes. The alkalis include sodium hydroxide (NaOH), potassium hydroxide (KOH), carbonates and the corresponding sodium and potassium alkoxides such as sodium methoxide, sodium ethoxide, sodium peroxide and sodium, but the oxide. Sulphonic acids of sulfuric acid (H_2SO_4) and hydrochloric acid (HCI) are commonly used as acid catalysts. Lipases can also be used as biocatalysts.

Fig. 1 Separating Funnel

3.1 The Modfied And Coared Piston Heads:

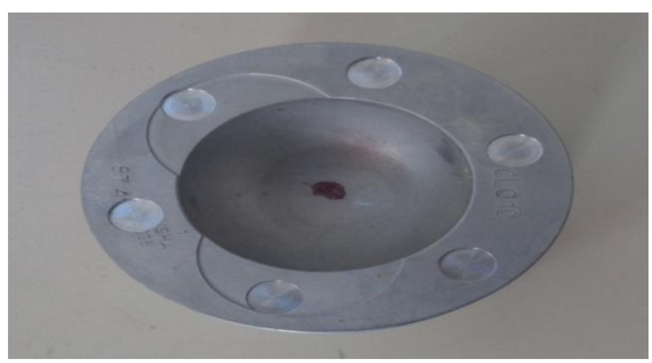

Fig. 2 Modified Piston Head

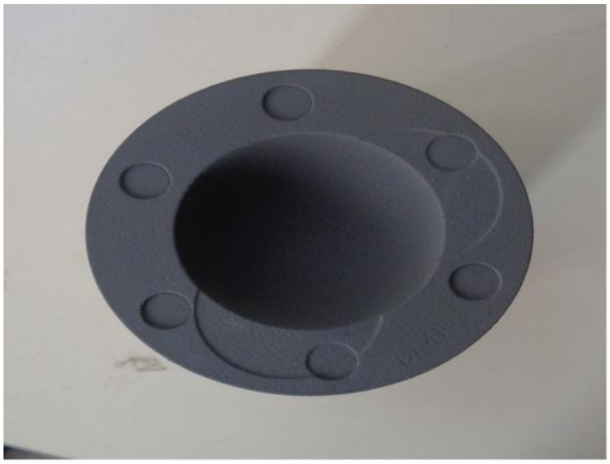

Fig. 3. Modified coated piston head

The geometry of the piston bowl has a major influence on combustion, performance and emission characteristics in diesel engines. Due to the high velocities inside the combustion chamber, the flow has been termed turbulence. Due to this turbulence, the mixture of heat exchange air and the combustion rate increase. This turbulence inside the combustion chamber has been classified as squish, swirl and tumble. The rotary movement of the fluid mass inside the cylinder is called a vortex. It can be generated by a suitable design of intake manifolds, valves and piston faces.

3.2 Coating material silicon carbide

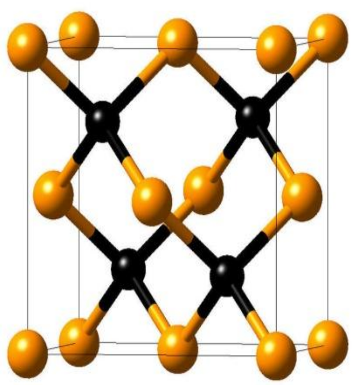

Fig. 4. silicon carbide

Ceramic materials are non-metallic inorganic materials made of metal and non-metallic compounds. The ceramic materials can be crystalline or partially crystalline. Ceramic materials have excellent thermal properties. They have a very low thermal conductivity. Therefore, providing a ceramic coating would provide thermal insulation to the engines. The increase in temperature may suddenly cause the isolation of grain boundaries in some semiconducting ceramic materials, silicon carbide.

4. Vertical milling center:

Milling is the machining process of using rotary cutters to remove material from a work piece advancing in a direction at an angle with the axis of the tool. It covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most commonly used processes in industry and machine shops today for machining parts to precise sizes and shapes.

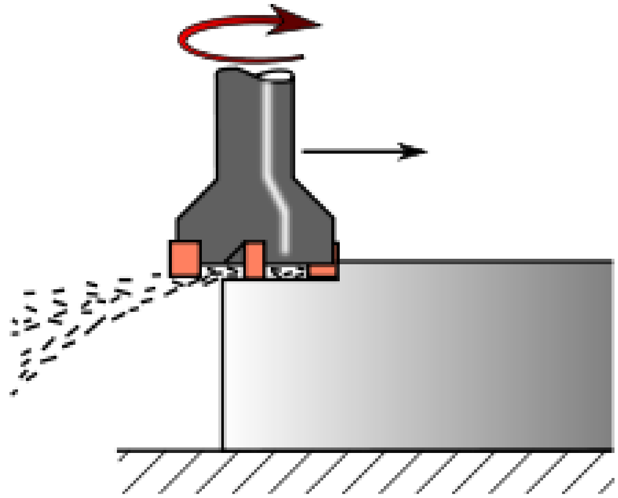

Fig.5 Milling cutting process

5. Engine Test Rig

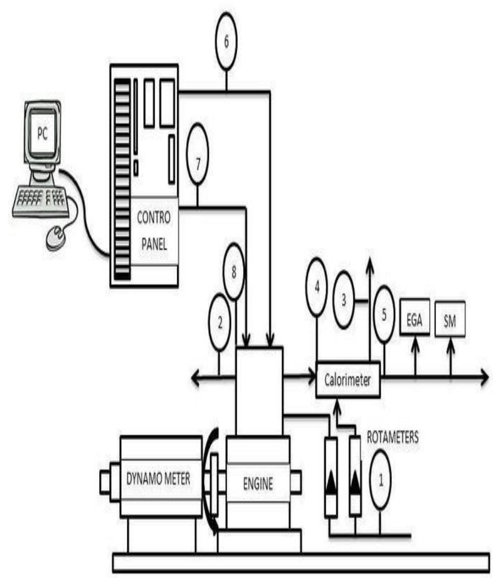

Fig. 6. Engine Test Rig

1.Water inlet to the calorimeter and engine, 2. Water outlet from the engine gasket, 3.Water outlet from the calorimeter, 4.Exhaust gas inlet to the calorimeter, 5.Exhaust gas outlet from the calorimeter, 6.Atmospheric air temperature, 7.Fuel flow. 8.Pressure transducer The experimental set up consists of engine, an alternator, hydraulic load system, fuel tank, exhaust gas measuring digital device and manometer.

Table 1 engine specifications

Sl.No.	Parameters	Descriptions
1	Engine type	4 stroke C.I engine
2	No. of cylinders	1
3	Bore	102mm
4	Stroke	110mm
5	Compression ratio	17.5:1
6	Injection pressure	200 bar
7	Type of cooling	Water cooling
8	Type of loading	Eddy current dynamometer
9	BHP	5.2kw

6. Results and Discussion(Performance of engine by using Modified piston head)

6.1 Break thermal energy

The graph below shows the variation of Brake Thermal efficiency for various blends under different loads for a diesel engine having a CR=17.5 and IP=200bar.

In the graph below it is observed that Brake Thermal efficiency for diesel has the highest value and B20 has the least value compared to other blends.

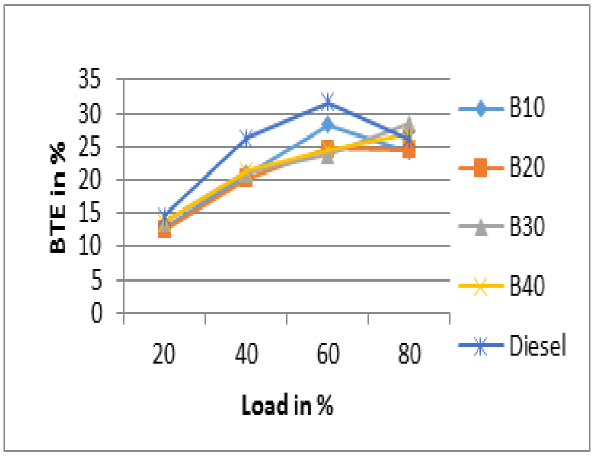

Fig. 7 shows the graph for BTE vs Load for various blends

6.2 Break specific energy consumption

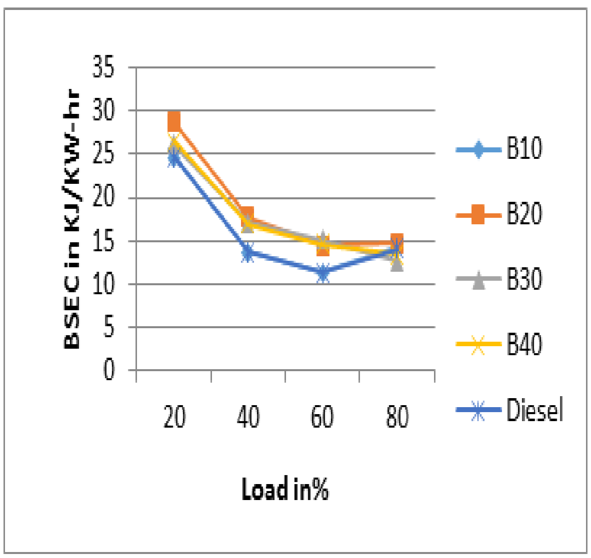

Fig. 8 shows the graph for BSEC vs Load for various blends

The graph below shows the variation of Brake Specific Energy Consumption for various blends under different loads for a diesel engine having a CR=17.5 and IP=200bar.

In the graph below it is observed that Brake Specific Energy Consumption is very less for diesel and B20 has the highest value.

6.3 Carbon monoxide Emission

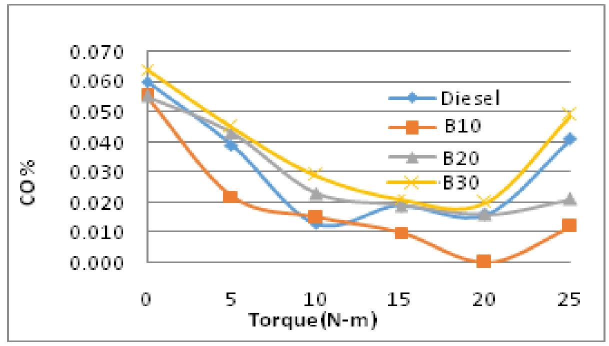

Fig. 9 shows the graph for CO% vs Load for various blends

Fig shows the variation of % CO with Torque for base and modified piston for Diesel, B10, B20 and B30 for CR = 17.5 and IP = 200 bar. It is observed that the emission of CO is very low for B10 at 20 N-m. And the emission of CO is high on B30. This shows that, as the blends increases the emission percentage also increases.

6.4 HC Emissions

Fig shows the variation of HC Emissions with Brake power for Diesel, B10, B20 and B30 for CR = 17.5, IP200 bar. It is observed from the graph that the HC emissions for B30 blend is maximum at peak load in both pistons and HC emission for B20 blend is very less.

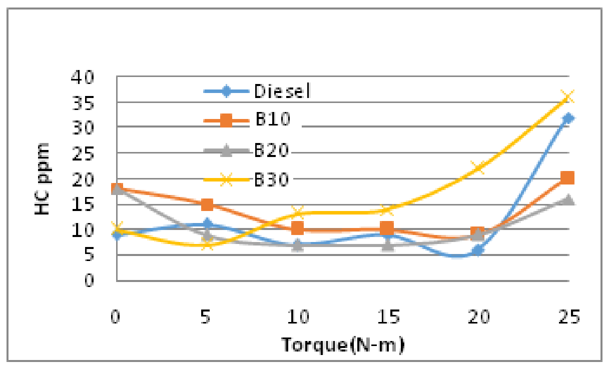

Fig. 10 shows the graph for CO% vs Load for various blends

6.5 NOx Emission

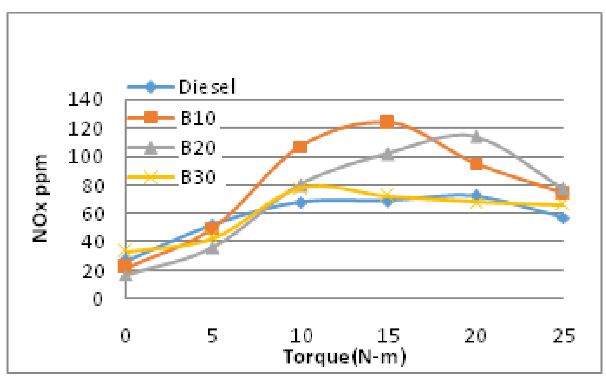

Fig. 11 shows the graph for NOx vs Load for various blends

Fig shows the variation of NO_X with Brake power of Diesel, B10, B20 and B30 for modified and base piston for CR = 17.5. It is observed from the graph that the emission of NO_x is increasing as a load up to 15Nm load increases as a result of high oxygen consumption. In general high temperature in cylinder results in higher level or NO_X. In base piston it is observed that NO_x is more for B10 till 15N-m and for diesel the NO_x emission is very less in base piston compare to others. Where as in the modified piston B20 is showing very less NO_x emission characteristics compare to 20N-m.

7. Conclusion

The better results for modified coated piston head, because of grooves, the swirling action of fluids in combustion increases the rate of combustion. Coating of silicon carbide makes the heat availability in the combustion chamber more. So better performance parameters and reduced emissions

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