[1.] P. Jaya PRAKASH, [2.] S. Sunil Kumar REDDY

STUDY ON DI DIESEL ENGINE SUBSTITUTED WITH GROOVED PISTON AND POWERED USING NANO ADDITIVE BIODIESEL

[1-2.]Department of Mechanical. Engineering, Siddharth Institute of Engineering & Technology, Puttur, AP, INDIA

Abstract: Economic and social transformation of people is leading to urbanization of a country. It becomes necessary to have good transportation facilities for a better life of the people in urban areas. Majority of transport vehicles in the transportation sector are equipped with the diesel engines due to their high efficiency. Dependency and utilization of these vehicles is increasing, as such the demand for petroleum products is also on high. On the other side because of high emissions from the diesel engines, strict regulations are laid by the governments to the engine manufactures to reduce emissions and save the environment from the pollution. Researchers are always in the processes of finding a suitable alternate fuel such as biofuels produced from Jatropha oil, Pongamia oil, Rice bran oil, Corn oil, Neem oil etc. Jatropha biodiesel properties are near similar to that of diesel fuel. With or without minor changes in the diesel engine, Jatropha biodiesel can be used as an alternate fuel in existing diesel engine. One of the major drawbacks of Jatropha biodiesel is its flow characteristics, to overcome this problem nano additive (Aluminum oxide) is added to the Jatropha biodiesel to enhance the flow properties of the biodiesel. In the present work, the performance and emissions of diesel engine are investigated with biodiesel 20% by volume (B20) added with the Nano additive in quantities of 50 ppm, 100 ppm and 150 ppm. B20 biodiesel blend with 100 ppm nano additive showed better performance compared to diesel. Performance of the diesel engines depends upon the formation of homogeneous mixture and turbulence inside the combustion chamber. To investigate on this, engine is fitted with piston consisting of grooves that are created on its crown to enhance turbulence of biodiesel fuel in the combustion chamber. Diesel engine showed better performance fitted with rhombus grooved piston (RGP) fuelled with B20 blend biodiesel added with 100 ppm aluminum oxide Nano additive.
Keywords: Rhombus grooved piston (RGP), Jatropha biodiesel, Al_2O_3 Nano additive, Brake thermal efficiency, Emissions

INTRODUCTION

Diesel engines have been utilized as work horses for the industry from over a long period. This is due to their high torque output, durability, exceptional fuel economy and ability to provide power under a wide range of conditions. The consumption and demand of petroleum products are increasing day by day with increase in number of vehicles due to urbanization, the immediate effect of this change is leading to higher emissions of pollutants into the environment. To address this problem it becomes necessary to decrease the consumption and emissions of petroleum products. For this one solution is to substitute the petroleum products with the alternative fuels. The alternative fuels can be produced as per the demand and are environmental friendly. Current world energy dependency on fossil fuels is taking a gradual change and the situation is such where entire focus is on alternate methods of energy sources, one such source where more and more that is explored is on the usage of alternate fuels. On the other side which is hindering its dependability is lower heating value of alternative fuels so it is tried upon to overcome this by adding metal oxide Nano particles. With this biodiesel enhances the engine performance as well reduce the harmful gases from engine exhaust. Many researches had tried on Jatropha oil as a suitable substitute for diesel and confirmed that a slight increase in diesel engine efficiency with minor changes in diesel engine. Other issues like high viscosity of Jatropha oil affecting the flow capacity of oil is addressed by adopting blending process with diesel. It is also reported that adding aluminum oxide Nano particles to Jatropha biodiesel could enhance the ignition properties of biodiesel due to the heat buildup with in the fuel of sensitive nature of aluminum Oxide Nanoparticles. Size of Nano particles may also affect the parameters like combustion process, ignition delay and burning rates of fuel.

LITERATURE REVIEW

Considerable quantity and quality of research work has been done on diesel engines fuelled with biodiesels with minor engine modifications. Some of them are referred and their analysis and inference of their works are presented below.

S.Chiranjeeva Rao, et al. [1] examined the effect of diesel, M20 (20% Mahua Methyl Ester + 80% Diesel), M50 (50% Mahua Methyl Ester + 50% Diesel), M20+50CeO_2 (20% Mahua Methyl Ester + 80% Diesel+50 ppm of Cerium Oxide Nano additive) and M20+100CeO_2 (20% Mahua Methyl Ester + 80% Diesel+100 ppm of Cerium Oxide Nano additive). A single cylinder, four stroke, water cooled DI diesel engine is used for this experiment. The experiments are conducted at a constant speed of 1500 rpm by varying loads. From his findings it is noted that M20+50CeO_2 shows a better performance compared to diesel. The Brake thermal efficiency is increased up to 9% and SFC decreased compared to diesel at 12 Kg load. The emission NO_x is increased and other emissions (HC, CO and Smoke) are decreased at full load condition (12 Kg). V.Karthickeyan, et al. [2] studied the influence of Diesel, B10 (10% Waste Cooking Palm oil+ 90% Diesel) and B20 (20% Waste Cooking Palm oil+ 80% Diesel) in single cylinder, four stroke, water cooled DI diesel engine. A thermal barrier with PSZ (partially stabilized zirconia) is coated in combustion chamber on piston crown, piston head, inlet valve and exhaust valve by using plasma spray coating technique. The experiment is carried at constant speed of 1500 rpm by varying loads. At full load condition results show that brake thermal efficiency increased by 0.4% with B20 compared to diesel in coated engine. The Brake specific fuel consumption is increased in both the engines with B20 compared to diesel. The CO emissions are lower by 0.05% volume in coated engine with B20 compared to diesel. The HC emissions are lower by 8ppm with B20 compared to diesel in coated engine. The NO_x emissions are higher in coated engine for diesel, B10 and B20 compared to uncoated engine. B.Dhinesh, et al. [3], Investigated the effect of diesel, B100 (100% Cymbopogon flexuous), B20(20% Cymbopogon flexuous + 80% Diesel), B20+10ppm (20% Cymbopogon flexuous + 80% Diesel +10ppm of Cerium Oxide), B20 + 20ppm (20% Cymbopogon flexuous + 80% Diesel + 20ppm of Cerium Oxide) and B20 + 30ppm (20% Cymbopogon flexuous + 80% Diesel+30ppm of Cerium Oxide).

A single cylinder, four stroke, water cooled DI diesel engine is used for his investigation. The Investigation is carried at constant speed of 1500rpm by varying loads. From his findings at full load conditions it is noted that the Brake thermal efficiency is increased by 4.76% with B20+20ppm compared to B20. The Brake specific fuel consumption is lowered with B20+20ppm compared to B20. The CO and HC emissions are lower by 12.5% volume and 4ppm with B20+20ppm compared to B20.The NO_x and smoke are reduced by 3% and 6.6% with B20+20ppm compared to B20. A.Prabhu, et al. [4], examined the effect of diesel, B20(20% Jatropha + 80% Diesel), B20+10A+10C (20% Jatropha + 80% Diesel +10ppm of Aluminum Oxide + 10ppm of Cerium oxide), B20+30A+30C (20% Jatropha + 80% Diesel +30ppm of Aluminum Oxide + 30ppm of Cerium oxide) and B20+60A+60C (20% Jatropha + 80% Diesel +60ppm of Aluminum Oxide + 60ppm of Cerium oxide). A single cylinder, four stroke, water cooled DI diesel engine is used for this experiment.

The experiments are conducted at a constant speed of 1500 rpm by varying loads. From his findings at full load conditions it is noted that the Brake thermal efficiency is nearer with B20+30A+30C compared to diesel. The Brake specific fuel consumption is lowered with B20+30A+30C compared to diesel. The CO, HC, NO_x and smoke are reduced by 6%, 3.3%, 1.3% and 3.2% with B20+30A+30C compared to B20. Bhupendra Singh chauhan, et al. [5], observed the effect of diesel, B5 (5% Jatropha + 95% Diesel), B10 (10% Jatropha + 90% Diesel), B20 (20% Jatropha + 80% Diesel), B30 (30% Jatropha + 70% Diesel) and B100 (100% Jatropha). A single cylinder, four stroke, air cooled DI diesel engine is used for his experiment.

The experiments are conducted at a constant speed of 1500 rpm by varying loads. From his findings at full load conditions it is noted that the Brake thermal efficiency is lower in Jatropha biodiesel blends compared to diesel. The Brake specific fuel consumption is higher with Jatropha biodiesel blends compared to diesel. The CO, HC and Smoke emissions are lower with Jatropha biodiesel blends compared to diesel. The NOx emissions are increased with Jatropha biodiesel blends compared to diesel. R.Vallinayagam, et al. [6], investigated the effect of diesel and Pine oil in characteristics study of pine oil in a single cylinder, four strokes, and water cooled DI diesel engine. The investigations are carried out at constant speed of 1500rpm by varying loads. From the results at full load conditions, they observed that HC, CO and Smoke emissions are reduced by 30%, 65% and 70%. M.J. kao, et al. [7], studied the effect of the diesel and addition of Aluminum nanoparticle to diesel along with 3-6% volume of water.

A single cylinder, four stroke, water cooled DI diesel engine is used for his experiment. The experiments are conducted at a constant speed of 1500 rpm by varying loads. From his findings at full load conditions it is noted that there is significant improvement in brake thermal efficiency and also reduction in smoke and nitrous oxide. Arockiasamy, et al. [8], conducted an experimental analysis using diesel, alumina nanoparticle with jatropha biodiesel in single cylinder, four strokes, water cooled DI diesel engine. The experiments are conducted at a constant speed of 1500 rpm by varying loads. From his analysis at full load conditions it is noted the HC, CO, NO_x and smoke are reduced.

PRODUCTION OF JATROPHA OIL

The Jatropha plant is known for its adaptability to different climatic conditions and the oil productivity of the Jatropha seeds. Preparation of Jatropha oil is shown with the flow chart diagram in Figure 1 below.

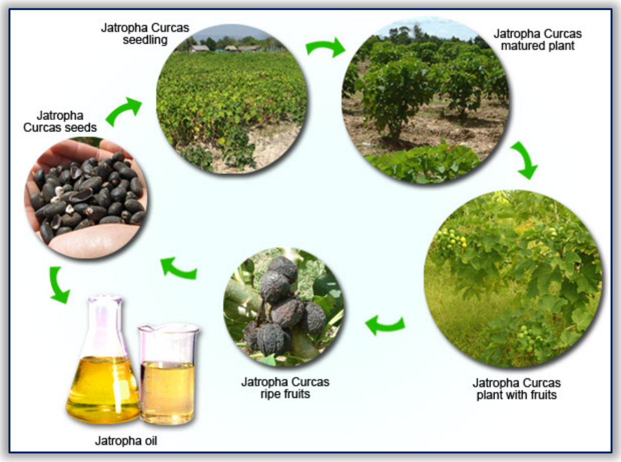

Figure 1. Flow chart for production of Jatropha oil

EXPERIMENTAL WORK

In the present experimental work, four stroke single vertical cylinder type, water cooled, constant speed diesel engine is equipped with AVL flue gas analyzer system and smoke meter is used. Aluminum oxide nano particle powder is the additive mixed in Jatropha blended biodiesel. Engine operated at a constant speed of 1520 rpm, fuel injected at 23.4° before TDC (Top Dead Centre), and a continuous load tests were carried out for different loads. To measure its output, belt type brake dynamometer is fitted to engine. Data was collected under steady state conditions and results were evaluated for analyzing performance and emission characteristics of the diesel engine with modified piston fuelled with biodiesel mixed with additive. The investigation setup for experimental tests is shown in below Figure 2. The specifications of the engine and properties of fuel and Nano additive is shown in the below Tables 1,2& 3.

Figure2. Experimental Setup

Table 1. Technical Specifications of the Engine

Make	Kirloskar
Type	Four-stroke, Single cylinder diesel engine (Water cooled)
Rated power output	5HP,1500 RPM
Bore & Stroke	80mm x 110mm
Compression Ratio	16.5:1
Dynamometer	Belt brake
Emissions	AVL Gas analyzer

Table 2. Properties of Diesel and Jatropha biodiesel

Sl.No	Properties	B20	Jatropha	Diesel
1	Density (Kg/m^3)	856	880	850
2	Viscosity (mm^2/s)	3.0	4.8	2.6
3	Flash Point (ºC)	73.4	127	60
4	Fire Point (ºC)	77.4	131	64
5	Calorific Value (MJ/Kg)	41.5	39.2	43

Table 3. Properties of Al_2O_3 powder

S. No.	Properties	Aluminum oxide
1	Density (Kg/m^3)	3900
2	Molecular Weight (g/mol)	101.96
3	Appearance	White solid
4	Melting Point (ºC)	2000

Biodiesel is a mixture of Jatropha oil mixed with diesel in different proportions. Magnetic stirrer is used for uniform mixing of both the oils.

Next step in this process is addition of Nano additive to the biodiesel. For this Ultrasonication process is employed. Ultrasonicator is a device known for fast agitation and homogeneous mixing of particles with help of sound waves. Ultrasonicator is set to a frequency of 40 kHz and 120W and operated for a period of 60 minutes so that Aluminum oxide nano powder is thoroughly mixed with Jatropha biodiesel to form very small clusters in a selected sample. This process is utilized to prepare different B20 blends of biodiesel with mass fractions of 50 ppm, 100 ppm and 150 ppm of Aluminum oxide nano particles. Finally engine fuel is a B20blend (80% diesel+20% Jatropha biodiesel) added with aluminum oxide nano powder in the quantity fraction of 50 ppm, 100 ppm and 150 ppm. Performance and emission characteristics of diesel engine fueled with these fuels are compared with diesel. B20 blend with 100ppm proved with better a result which was further investigated with modified piston.

— Replacement of Piston in the Engine

In-cylinder air motion in internal combustion engines has its own significance which shows its influence on the combustion process. It governs the fuel-air mixing and burning rates in diesel engines. To obtain a better combustion with lesser emissions in diesel engines, it is necessary to reach a good longitudinal distribution of the injected fuel throughout the full space of chamber. This requires matching of the fuel sprays with combustion chamber geometry. In other words, the combustion chamber geometry, fuel injection and gas flows are the most critical factors for getting a better combustion.

In DI diesel engines compression induced squeeze flow increases turbulence which in turn increases the rate of fuel-air mixing ultimately reducing the combustion spell. Since the flow in the combustion chamber develops from interaction of the intake flow with the in-cylinder geometry, the goal of this work is to characterize the role of combustion chamber geometry on in-cylinder flow, fuel-air mixing and combustion processes. For this six rhombus grooves were created on the crown of the piston to vary the air turbulence in the engine cylinder.

Performance parameters such as brake power, specific fuel consumption and thermal efficiency are calculated based on experimental results.

— Rhombus Grooved Piston (RGP):

Dimensions of rhombus groove machined on the piston crown are given below and modified piston is shown in the Figure 3 below:

- Length of the diagonal 1 = 10mm
- Length of the diagonal 2 = 5mm
- Depth of the groove = 2mm
- Number of grooves to be made = 6 No's
- Angle between consecutive grooves = 60^0

Figure 3.Top view of the Rhombus Grove Piston Crown

RESULTS AND DISCUSSIONS

— Performance Characteristics

Performance and emissions data of the diesel engine fitted with normal aluminum piston and RGP of aluminum material fuelled with both diesel and B20 blend biodiesel added with 100ppm aluminum oxide nano powder are collected and compared. Based on data at full load conditions, graphs are plotted for analysis.

» Brake Thermal Efficiency

The variation of brake thermal efficiency with brake power is given in figure 4. The brake thermal efficiency of the diesel engine fitted with RGP increased by 1.72% compared to normal piston when fuelled with diesel. In the other case brake thermal efficiency of the diesel engine fitted with RGP increased by 3.7% compared to normal piston when fuelled with B20 blend Jatropha biodiesel with 100ppm Al_2O_3 nano additive.

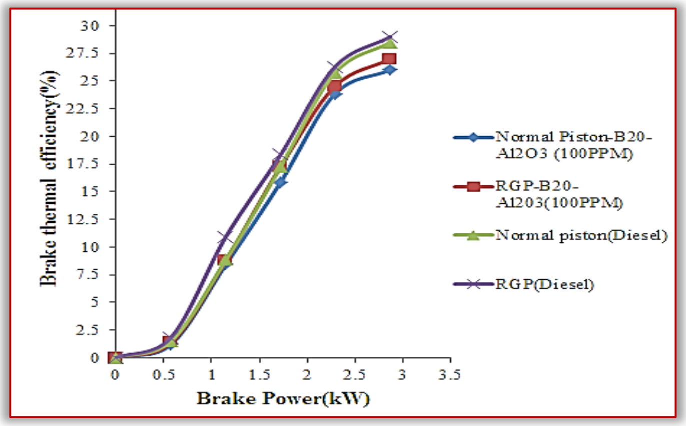

Figure 4. Variation of Brake thermal efficiency with B.P

Turbulence characteristics improved with the RGP due to presence of grooves on piston crown that enhances the combustion with the formation of homogeneous mixture and oxygen content in biodiesel compared to normal piston.

» Specific Fuel Consumption

The variation of Specific fuel consumption with brake power is given in figure 5. The Specific fuel consumption of the diesel engine fitted with RGP decreased by 1% compared to normal piston when fuelled with diesel. In the other case Specific fuel consumption of the diesel engine fitted with RGP decreased by 3.2% compared to normal piston when fuelled with B20 blend Jatropha biodiesel diesel with 100ppm Al_2O_3 Nano additive. Grooved piston enhances fuel combustion releasing more power that is less fuel more power so this reduces specific fuel consumption. Additionally with the grooved piston the weight of the piston is reduced which adds to decrease in the specific fuel consumption.

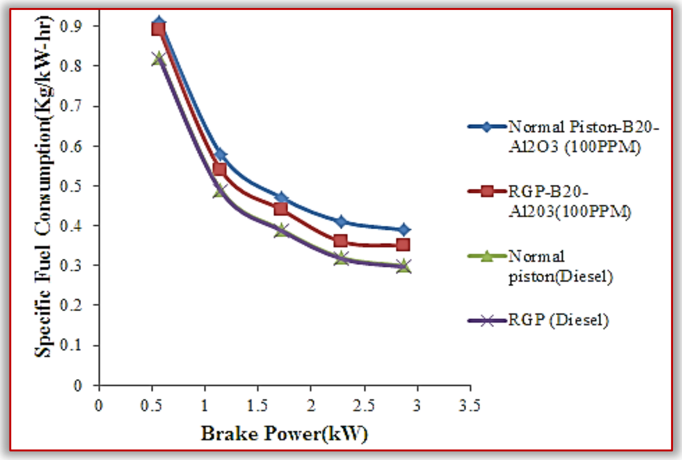

Figure 5. Variation of Specific fuel consumption with B.P

» HC Emissions

The variation of HC emissions with brake power is shown in figure 6.

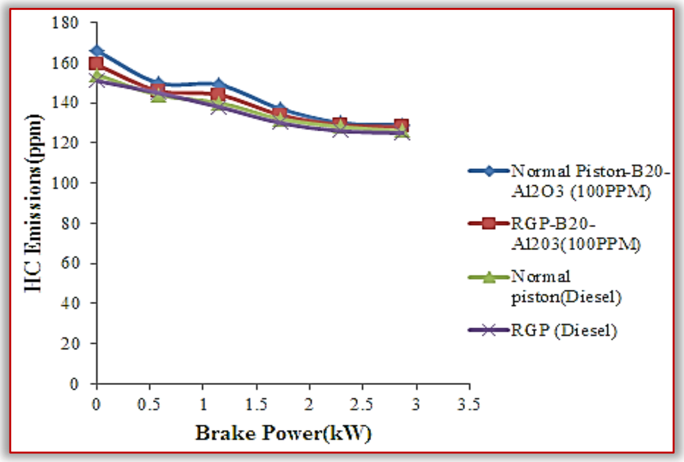

Figure 6. Variation of HC Emissions with B.P

The creation of HC emissions is due to the wall quenching, inappropriate mixing and incomplete combustion. With the turbulence in the combustion chamber standardized mixture forms which leads for the complete combustion and higher temperatures in the chamber.

As more oxygen content is available with the diesel in RGP, the HC emissions are decreased by 0.79% in grooved piston compared to normal piston with diesel.

» CO Emissions

CO emissions with brake power are detailed in figure 7. The formation of CO emissions is due to the incomplete combustion and lack of sufficient oxygen content with the fuel. With the higher inherent oxygen content in the diesel, the carbon monoxide emissions formed will be oxidized and converts into carbon dioxide gas. Hence the CO emissions are decreased by 6.7% with grooved piston compared to normal piston with diesel. In grooved piston the air fuel ratio is equal to the stoichiometry air fuel ratio and also due to presence of grooves on piston crown the air gets turbulence throughout the combustion chamber, the complete combustion takes place in the combustion chamber. So the CO emissions are decreased in RGP compared to normal piston.

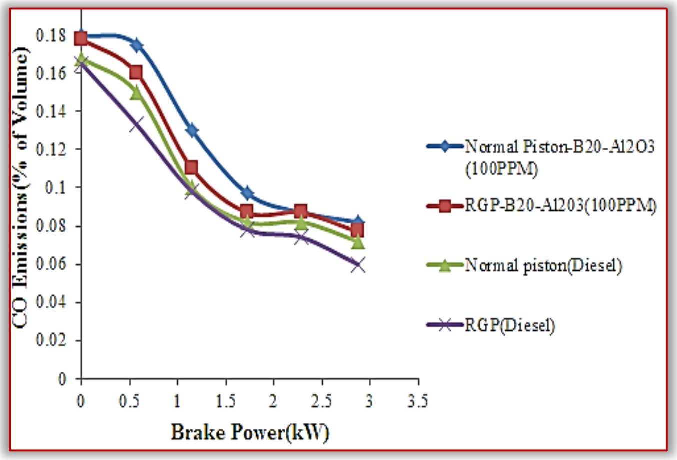

Figure 7. Variation of CO Emissions with B.P

— NO_x Emissions

NO_x emissions with brake power are shown in figure 8.

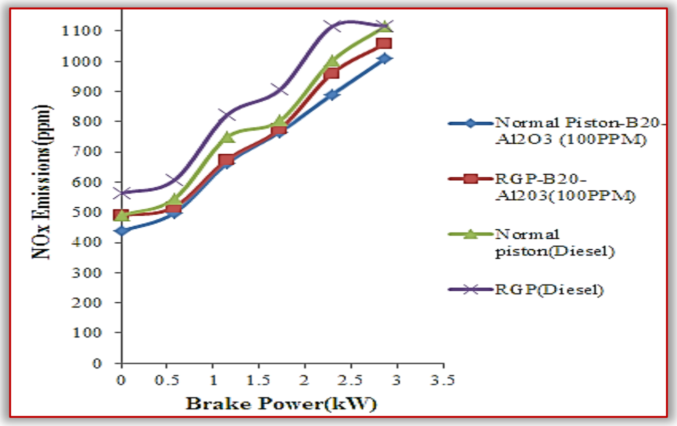

Figure 8. Variation of NO_x Emissions with B.P

At lower temperatures nitrogen acts as an inert gas and will be active at higher temperatures. With the grooved piston, there is good turbulence and homogeneous mixture formation in the combustion chamber. Hence the heat produced is more and with the higher oxygen content the NO_x emissions are increased by 0.13% in grooved piston compared to normal piston with diesel.

CONCLUSIONS

The performance and emission characteristics of diesel engine with normal piston fuelled with diesel and also with B20 blend Jatropha biodiesel added with Al_2O_3 Nano additive are investigated in the first phase. Later similar procedure is adopted with rhombus grooved piston (RGP) and further investigations are carried out. The conclusions are as follows.

— Brake thermal efficiency of diesel engine fitted with RGP is more because of complete combustion in the chamber compared to normal piston.
— The Specific fuel consumption of diesel engine fitted with RGP decreased compared to normal piston.
— HC emissions of diesel engine fitted with RGP decreased compared to normal.
— CO emissions also decreased when normal piston is replaced by RGP.

With the higher temperature in chamber, the NO_x emissions increased in case of RGP compare to normal piston.

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