Influence of injection timing on the performance of DI engine by Tangential Grooves on Piston Crown

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Abstract—**Automobile sector is a growing field where there evolves a new technology every day. The recent trend in the automobile sector is to improve the efficiency and reduce the amount of pollutants. Increased pollution awareness and the consequent introduction of stringent emission norms throughout the world are forcing engine manufacturers to continue to investigate for strategies for reducing emissions which contributes to the study of air motion. The air motion plays a very important role in fuel-air mixing, combustion and emission formation. When the in-cylinder air motion is unsteady the efficiency of the engine gets reduced and emissions are increased. In the present work experiments are conducted on D.I. Diesel engine to investigate the influence of the injection timing on the performance and exhaust emissions characteristics of tangentially grooved piston direct injection diesel engine fueled with dual fuel like neat diesel and B20 (20% WVOME + 80% diesel). it is found that 200 bar is the optimum injection pressure with 20BD blend of COME, which has resulted in better performance and emission characteristics among the biodiesel blends. Based on the results it is concluded that the base line engine with tangential grooved piston configuration gives maximum performance in all aspects and reduces emissions. 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.**

keywords—**D.I. Diesel engine, waste vegetable methyl ester biodiesel, Tangential Grooved Pistons, Blended fuel, Brake thermal efficiency, Injection Timing, Emissions.**

I. INTRODUCTION

An engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work. Engines normally convert thermal energy into mechanical work and, therefore, they are called heat engines. When fuel burns in the presence of atmospheric air, a tremendous amount of heat energy is released. The products of combustion attain a very high temperature. A heat engine converts the released heat energy into useful work with the help of a working fluid.

(a) External Combustion Engines (EC Engines)

(b) Internal Combustion Engines (IC Engines)

In external combustion engines, the combustion of the fuel in presence of air takes place outside the engine cylinder. The heat energy released from the fuel is utilized to raise the high- pressure steam in a boiler from water. Steam is a working fluid, which enters into the cylinder of a steam engine to perform mechanical work. Here, the products of combustion of fuel do not enter into the engine cylinder and hence they do not form the working fluid.

I.I COMBUSTION IN COMPRESSION IGNITION ENGINES:

The diesel engine is a compression ignition (Cl) engine and the typical compression ratios are in the range of 14:1 to 22:1. In order to achieve spontaneous ignition, the compression stroke must raise the air to a much higher temperature than that in the SI engine, and this requires a high compression ratio. Diesel engines have considerable advantages in commercial applications, for example, for Continuous heavy duty operation such as that required in locomotives, heavy road transport and marine engines, and where robustness is at a premium as in tractors and earth moving vehicles. These engines are also used for stationary industrial applications, such as in pumping sets, small and medium electric power generators, etc.

The thermal efficiency of the CI engine is higher than that of the SI engine because of the higher compression ratio. The CL engine fuels (diesel or crude oil) are less expensive than the ST engine fuels (petrol or gasoline). Moreover, the CI engine fuels have higher specific gravity than that of petrol and since the fuel is sold on volume basis, more kilograms of fuel per liter are obtained in purchasing CI engine fuels. Most of the time engines are run at part toad and the supply of fuel through the fuel injectors can be controlled in CI engines, thus reducing the fuel/air ratio at part load. In SI engines, the fuel/air ratio prepared in the carburetor remains almost constant at all loads, These factors reduce the running cost of CI engines. However, the CI engines are not favored in passenger cars, where the use is limited, because of certain drawbacks compared to SI engines, such as heavier weight for the same power output. It is because of the fact that heterogeneous mixture is used in CI engines, and the compression ratio is high as well It increases the initial cost of the engine. The C' engines produce more noise and vibrations because of heavier pans. The exhaust emissions from CI engines with heterogeneous mixture are unburned hydrocarbons. oxides of nitrogen, aldehydes, carbon monoxide, smoke particulates and the odour constituents. The major pollutants from SI engines are unburned hydrocarbons, oxides of nitrogen and carbon, monoxide. Smoke and odour are the most noticeable emissions of diesel engines.

I.II AIR MOTION IN CI ENGINES

In open chamber CI engines the fuel is injected in the bulk of the air, so the turbulence of air in the combustion chamber at the time of fuel injection and during the combustion process is very important. The air velocity in the combustion chamber has two components: (a) air swirl (spiral flow) and (b) air radial flow (squish). Air swirl is created during the intake stroke by inducing the air into the cylinder through a shaped intake port which is tangential to the piston. the induced swirl can be increased during compression by transferring the air to the recess in the piston or in the cylinder head. As the piston approaches TDC, the air flows radially inwards, i.e. cowards the combustion chamber recess. It is shown in Figure 7.2. The radial streams coming from the opposite sides meet and get deflected upwards into the chamber. After reaching the end of the chamber, the air flows radially outwards, i.e. towards the outer walls, then downwards, i.e. towards the open end. Here the air is met by air flowing radially inwards from between the cylinder and piston, and is carried around again, producing a toroidal movement within the combustion chamber. The effect of the squish component on the spray formation is very small compared to the similar effect of the swirl component.

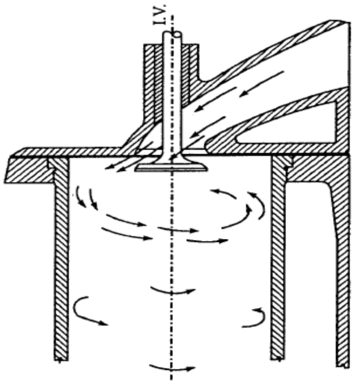

Figure 1.1 Induction induced swirl.

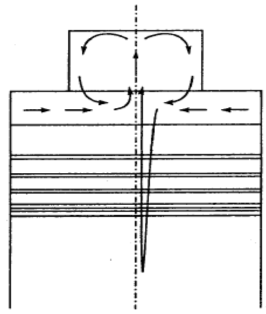

Figure 1.2 Air radial flow (squish).

II. TRANSESTERIFICATION OF NON-EDIBLE AND EDIBLE OIL

Transesterification is the general term used to describe the important class of organic reactions, where an ester is transformed into another ester though interchange of alkyl groups and is also called as alcoholysis. Transesterification is an equilibrium reaction and the transformation occurs by mixing the reactants. However, the presence of a catalyst accelerates considerably the adjustment of the equilibrium. The general equation for transesterification reaction is given below.

RCOOR' + R" OH ↔ RCOOR" + R' OH ---------------- Eq. (1)

The basic constituent of vegetable oils is triglyceride. Vegetable oils comprise of 90-98 percent triglycerides and small amounts of mono-glyceride, diglyceride and free fatty acids. In the transesterification of vegetable oils, a triglyceride reacts with an alcohol in the presence of a strong acid or base, producing a mixture of fatty acid alkyl esters and glycerol. The overall process is a sequence of thee consecutive and reversible reactions in Which diglyceride and mono-glycerides are formed as intermediates.

The stoichiometric reaction requires one mole of triglyceride and thee moles of alcohol. However, an excess of alcohol is used to increase the yield of alkyl esters and to allow phase separation from the glycerol formed. Several aspects including the type of catalyst (base or acid), alcohol/vegetable oil molar ratio, temperature, purity of the reactants (mainly water content in alcohol) and free fatty acid content have influence on the course of transesterification. So in this work, the reactants of high purity have been used (methyl alcohol with 99.95% purity). In the base-catalyzed process, the transesterification of vegetable oils proceeds faster than the acid-catalyzed reaction. Also the alkaline catalysts are less corrosive than acidic compounds. The mechanism of the base-catalyzed transesterification reaction of vegetable oil is shown in the Figure is the reaction of the base with the alcohol, producing an alkoxide and the protonated catalyst. The nucleophilic attack of the alkoxide at the carbonyl group of the triglyceride generates a tetrahedral intermediate, from which an alkyl ester and the diglyceride are formed. The latter deprotonates the catalyst, regenerates the active species, and enables it to react with a second molecule of the alcohol thus starting another catalytic cycle. Diglycerides and monoglycerides are converted by the same mechanism to a mixture of alkyl esters and glycerol. Alkaline metal alkoxides (such as CH3ONa for the methanolysis) are the most active catalysts since they give high yields in short reaction times even if they are applied at lower molar concentrations. However, they require the absence of water which makes them inappropriate for typical industrial process. Alkali metal hydroxides (KOH and NaOH) are cheaper than metal alkoxide, but less active. Nevertheless, they are good alternatives since they can give the same high conversions of vegetable oils just by increasing the catalyst concentration by 1 or 2 folds.

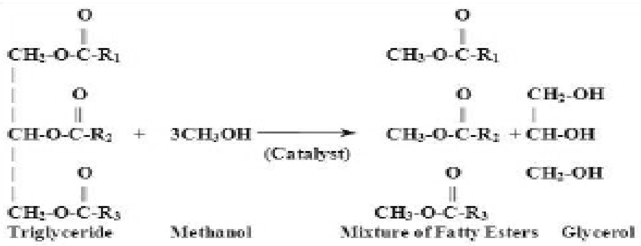

Figure 1.3 Mechanism of the base-Catalyzed Transesterification Process

III. EXPERIMENTAL SET UP

The engine tests were conducted on a four stroke, compression ignition, water cooled, single cylinder, constant speed diesel engine. The block diagram of the test setup is given in fig. The engine specifications are given in Table-1. An eddy current dynamometer is used to load the engine. An air box was fitted to the engine for air flow measurement. A pressure transducer with a charge amplifier and a computer are used to measure the cylinder pressure. The pressure pickup is mounted on the cylinder head. An encoder at TDC is used to detect the engine crank angle. An Exhaust gas Analyzer is used to measure emissions of CO, UHC, NOX in the exhaust. All the tests are conducted by the engine with diesel only. The engine and the dynamometer are interfaced to a control panel, which is connected to computer for automatic recording the experimental observations such as fuel flow rate, temperatures, air flow rate, loads, water flow rate, etc., are measured.

Experiments are conducted on D.I. diesel engine with three configurations. Emissions and performance characteristics of baseline engine and tangential grooved piston engine with standard injection timing are compared with that of retarded injection timings.

- Base line engine with standard injection timing
- Base line engine with tangential grooved piston (TGPE) with standard injection timing
- Base line engine with tangential grooved piston (TGPE), retarded injection timing
- The steady state engine performance testing is carried out with diesel at 200 bar injection pressure

III.I EXPERIMENTAL WORK:

In the present experimental work, the piston crown of 80 mm diameter of base line engine is modified by producing four tangential grooves widths of 5.5mm, diameter and maintaining constant depth of 2 mm in piston. The experiments are conducted with this tangential grooved pistons and their performance and emissions are compared with base line piston of diesel engine (BLE). the effect of the geometry of the grooves shown in Fig1a and Fig1b on combustion performance is analyzed in the study.

The combustion efficiency in the combustion chamber depends on the formation of homogeneous mixture of fuel with air. The formation of homogenous mixture depends on the amount of turbulence created in the combustion chamber. During the suction stroke, the atmospheric air is drawn through helical grooved manifold and enters the engine cylinder with swirl motion. As the piston approaches the TDC, the part of compressed air enters the bowl at points A, B, C & D through the tangential grooves and forms a swirl ring in the combustion bowl and increase mixing of fuel with air resulting increase in combustion efficiency. The effect of the geometry of tangential grooves on piston with retarding injection timings on combustion performance is analyzed in the study.

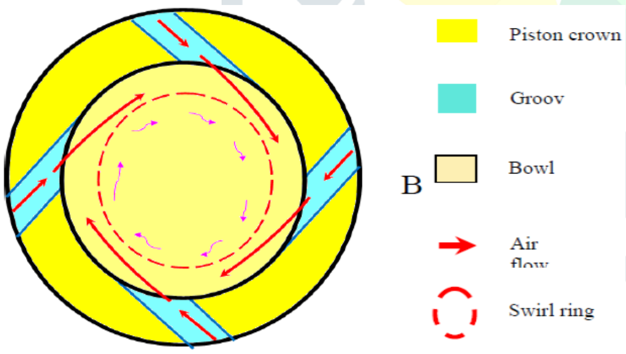

Figure 1.4 Swirl Motion in Tangential Grooves

Figure 1.5 Tangential Grooved Piston

Table 1.1 Engine Specifications.

Engine	4-Stroke, Single cylinder, constant speed, water cooled, D.I. diesel engine
BHP	5
Speed	1500 rpm
Broke x Stroke	80 x 110
C R	16.5:1
Dynamometer	Eddy Current dynamometer
Water flow measurement	Roto meter
Interfacing with computer	ADC cord
Emission measurement	5 gas analyzer and MRO make
Piezo Electric tranducer	Cylinder Pressure
Smoke Meter Crypton Computerised Emission analyser	Smoke Intensity and Emissions (HC, CO, CO_2 and NOx
Crank angle Encoder	Crank angle

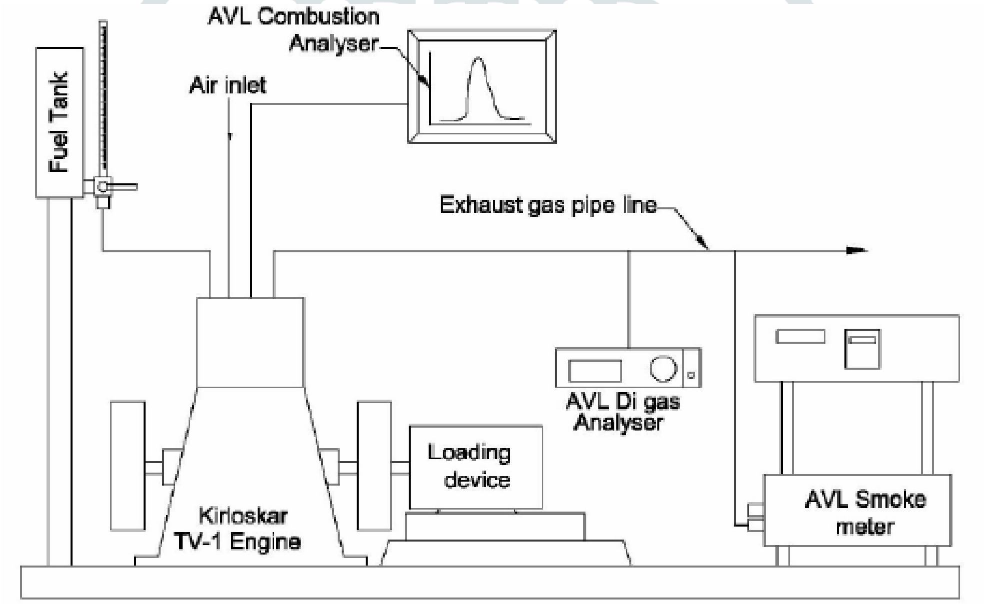

Figure 1.5 Block Diagram of Experimental Setup

IV. RESULTS AND DISCUSSION

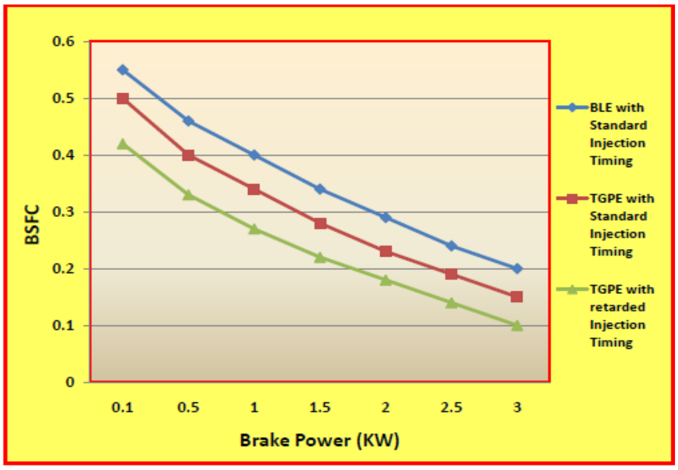

Figure 1.6 BSFC vs Brake power

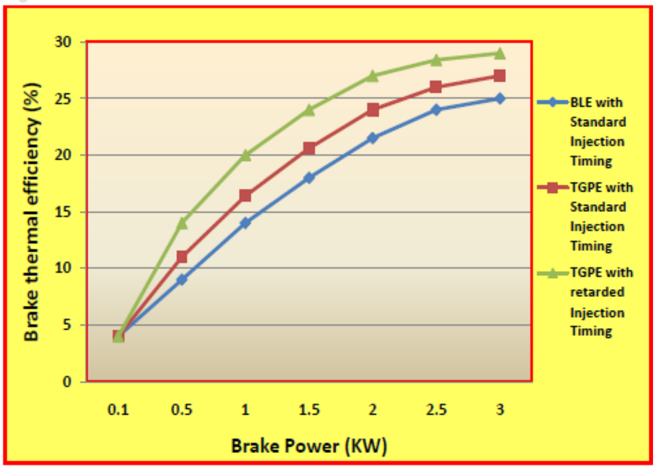

Figure 1.7 Brake thermal efficiency vs Brake power

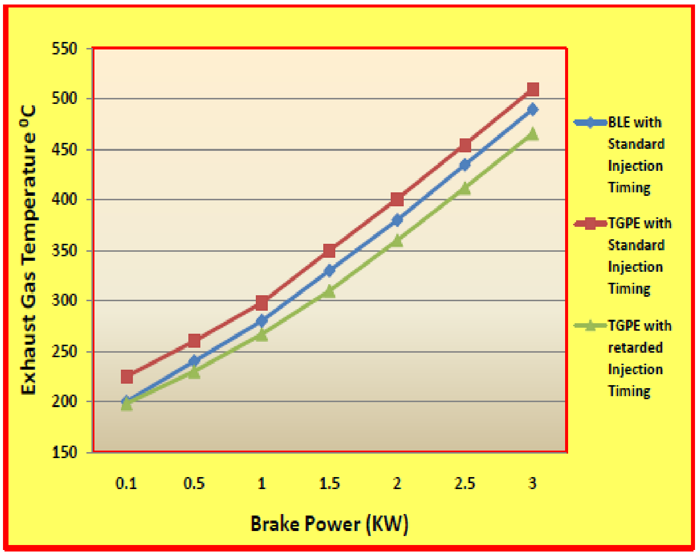

Figure 1.8 Exhaust Gas Temperature vs Brake power

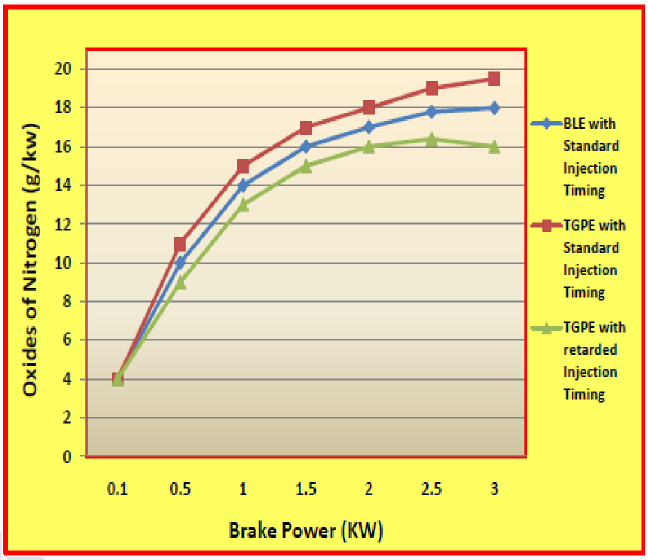

Figure 1.9 Oxides of Nitrogen vs Brake power

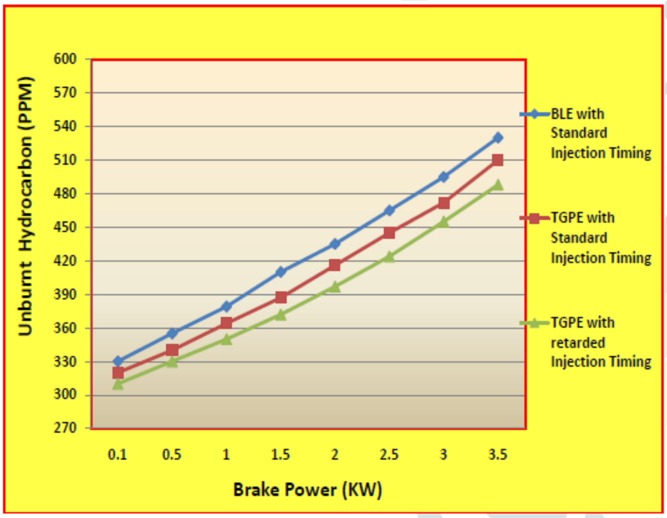

Figure 1.10 Carbon Monoxide vs Brake power

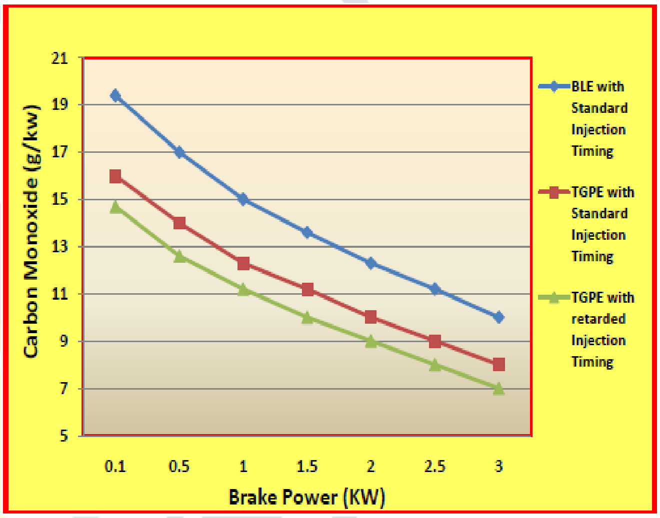

Figure 1.11 Unburnt hydrocarbon vs Brake power

- In Figure 1.6 the brake specific fuel consumption varies from 0.62 kg/kWh at low load to 0.327 kg/kWh at full load for base line engine and 0.594 kg/kWh at low load to 0.275k g/kWh at full load for tangential grooved piston engine with standard injection timing and it varies from 0.534 kg/kWh at low load to 0.242 at full load for retarded injection timing. The reduction in specific fuel consumption is 13.2% by retardation injection at full load compared with standard injection timing.
- In Figure 1.7 It can be observed from the Fig. that the brake thermal efficiency of tangential grooved piston engine (TGPE) with standard and retarded injection timing are 26% and 28.1% at full load compared with base line engine with standard injection timing, it is 24.9%. It is clear that the base line engine with tangential grooves piston operation with retarded injection timing gives higher brake thermal efficiency.
- In Figure 1.8 the exhaust gas temperature is found to be less with retarded injection timing of 170 before TDC, which is an indication of control combustion. The decrease in exhaust gas temperature with retarded injection timing of tangential grooved engine operation is due to less heat transfer as evident from high brake thermal efficiency.
- In Figure 1.9 the emission of NOx for retarded injection timing is significantly lower at all load conditions. NO_X varies from 16.35g/kWh at no load to 8.9 g/kWh at full load for standard injection timing whereas for retarded injection timing it varies from 14.63 g/kWh at no load to 8, 56 g/kWh at full load. Diesel engines are always run at lean condition and emit high amounts of NO_X due to high temperature.
- In Figure 1.**10** the emission of CO was lower for retarded injection timing compared to standard injection timing. This may be due to higher heat release leading to complete combustion.
- In Figure 1.11 Its seem from the graph TGPE with retarded injection timing has lower unburnt hydrocarbon then other parameter and base line engine has highest unburnt carbon ratio, unburnt hydrocarbon causes incomplete combustion in diesel engine, here the TGPE has lower result of hydrocarbon. With increases brake power the hydrocarbon increases.

V. CONCLUSIONS AND FUTURE SCOPE

- The reduction in specific fuel consumption is 13.2% by retardation injection at full load compared with standard injection timing.
- The work output is better for retarded injection timing and therefore the brake thermal efficiency increases at full load compared with part load as the injection timing is retarded. This complete combustion results in higher thermal efficiency.
- The exhaust gas temperature is found to be less with retarded injection timing of 170 before TDC, which is an indication of control combustion.
- The emission of NOx for retarded injection timing is significantly lower at all load conditions. Lower peak pressure results in lower peak temperatures. So the NOx emission tends to be less.
- The TGPE has lower result of hydrocarbon. With increases brake power the hydrocarbon increases.

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