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Effect of Tangential Grooves on Piston Crown Of D.I. Diesel Engine with Retarded Injection Timing

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Abstract:- Direct injection diesel engines are in service for both heavy duty vehicles, light duty vehicles not only in the fields of agriculture and transport sectors, but also stationary engines consume maximum percentage of petroleum based fuels and have the evident benefit of a higher thermal efficiency than all other engines. However, the D. I. Diesel engine emits significant amount of pollutants such as CO, UHC, NOx, smoke etc, which are harmful to the environment. In the present experimental attempt is made to study the influence of injection timing on the performance, emission characteristics of a single cylinder, direct injection diesel engine (base line engine) and tangential grooved piston engine (TGPE) has been experimentally investigated. The tests are performed at three fuel injection timings of 23^0,20^0 and 17^0 before TDC. When compared with the standard injection timing of 23^0, the retarded injection timing from 23^0 to 17^0 decreases the emissions of oxides of nitrogen, carbon monoxide and increases thermal efficiency under all test conditions. From the experimental investigations, it is concluded that the base line engine with tangential grooves on piston (TGPE) with retardation injection timing gives better performance in all aspects and reduces emissions.

Keywords:- D.I. Diesel Engine, TGPE, Standard injection timing, Retarded injection timing, Emissions.

I. INTRODUCTION

It is well known that in DI diesel engines swirl motion is needed for proper mixing of fuel and air. Moreover, the efficiency of diesel engines can be improved by increasing the burn rate of fuel air mixture [1]. This can be achieved in two ways; one by designing the combustion chamber in order to reduce contact between the flame and the chamber surface, and two by providing the intake system so as to impart a swirl motion to the incoming air [1,2]. The swirl ratio and resulting fluid motion can have a significant effect on air-fuel mixing, combustion, heat transfer, and emissions. During compression stroke, swirl ratio decreases with the decrease of angular momentum. When the piston moves close to the top dead centre [TDC], the variation of swirl ratio depends on the shape of the combustion chamber [5]. For combustion chamber bowl-in piston, the gases are squished in to the piston bowl when the piston moves close to TDC. The momentum of inertia of gases decreases abruptly, leading to the increase of swirl ratio [Belair et al.,1983]. This increase in large scale flow speed contributes to the fuel spray being spread out which accelerates the processes of the fuel-air mixing and rate of combustion in diesel engines. The effect of swirl on combustion and emissions of heavy duty-diesel engines has been investigated by Benajes et al [8].and suggested that optimum level of air swirl that minimizes soot depends on engine running conditions. Timothy [7] has recognized that over-swirling causes centrifugal action which directs the fresh air away from the fuel, resulting incomplete combustion and there by soot formation. The interaction between the swirl motion and the squish flow induced by compression increases the turbulence levels in the combustion bowl, promoting mixing and evaporation of fuel. In diesel engine, fuel is injected at the end of compression stroke, followed by the entry of compressed air tangentially into the injected fuel spray and then it mixes with air. It is possible to predict to some extent the engine performance based on injection characteristics. The most injection characteristics a reinjection pressure, injection duration and injection timing [12]. The injection and injection duration influences the harmful NOx and smoke emissions.

II. 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 of different widths of 5.5mm, 6.5mm and 7.5 mm on three pistons of same diameter and maintaining constant depth of 2 mm in each piston. The experiments are conducted with these three different tangential grooved pistons and their performance and emissions are compared with base line piston of diesel engine (BLE). It is observed that the piston with tangential grooves of width 6.5 mm is found to give better results than those grooves of widths 5.5 mm, 6.5 mm, 7.5 mm and 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.

Fig 1a: Tangential Grooved Piston

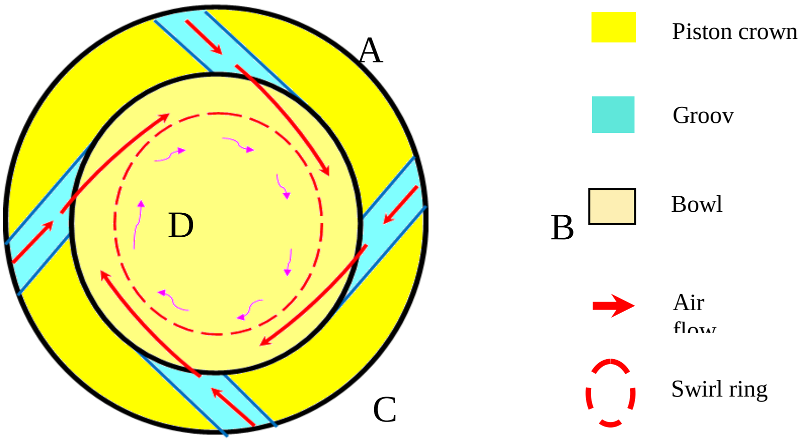

Fig 1b: Swirl Motion in Tangential Grooves

Table I: 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, CO2 and NOx
Crank angle Encoder	Crank angle

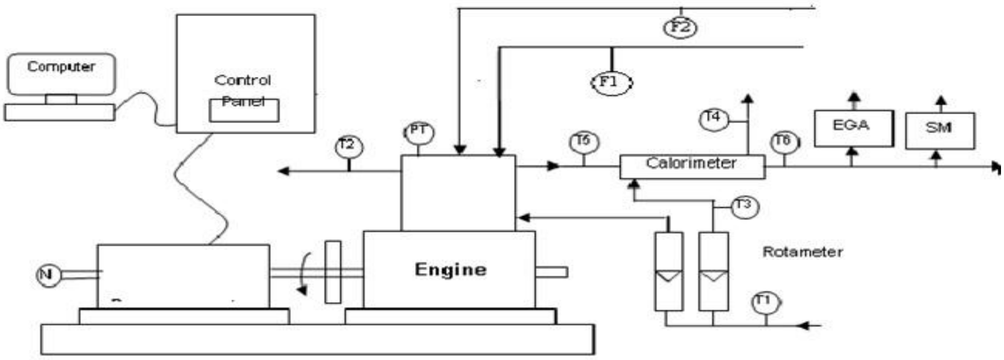

Fig 2: Block Diagram of Experimental Setup

T_1, T_3=Inlet Water Temperature. T_2 = Outlet Engine Jacket Water Temperature. T_4 = Outlet Calorimeter Water Temp. T_5 = Exhaust Gas Temp. Inlet to Calorimeter. T_6 = Exhaust Gas Temp. Outlet to Calorimeter F_1 = Fuel Flow Measuring unit. F_2= Air Intake DP unit PT = Pressure Transducer EGA = Exhaust Gas Analyzer SM= Smoke Meter

III. EXPERIMENTAL SETUP

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 base line 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.

IV. RESULTS AND DISCUSSION

The output results from D.I. diesel engine can reduce the pollutant emissions with some modifications and test runs are first carried out under standard injection timing (230 BTDC) to establish the baseline readings. The test results showed that standard injection timing of diesel engine with tangential grooved piston (TGP) enhances the turbulence and produces higher NOX than the base line diesel engine (BLE). To counteract this, the fuel injection timings are retarded from 230 to 170 before TDC and the effects of retarded injection timings on the combustion, performance and exhaust emission are investigated on single cylinder constant speed D.I. diesel engine. The discussion is presented in the following

A. Brake specific fuel consumption

The brake specific fuel consumption measures how efficiently an engine is using the fuel supplied to produce work. The fig.3 shows the comparison of the brake specific fuel consumption between standard and retarded injection timings. 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 o.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.

B. Brake thermal efficiency

The brake thermal efficiency of tangential grooved piston engine with standard and standard injection retarded injection timing is shown in Fig.4. It can be observed from the Fig.4 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. The tangential grooves on piston crown produces swirl motion of air in the bowl of piston and increase the evaporation rate of fuel. The TGPE with Retardation of injection timing leads to fast start of combustion and combustion continues in the expansion stroke (power stroke) also. This results increase in effective pressure on piston to increase effective work. Consequently 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.

C. Exhaust gas temperature

Fig.5 compares the exhaust gas temperature of engine with standard and retarded injection timing. It is observed that the exhaust gas temperature varies from 2300C at low load to 4500C at full load of base line engine without modification and 2400C to 4740C for base line engine with tangential grooves for standard injection timing and for retarded injection timing, it various from 2250C at no load to 4230C at full load. 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.

D. Ignition Delay Period

From fig.6, it can be observed that the ignition delay period with standard injection timing in the case of tangential grooved piston engine configuration is longer than that of retarded injection timing. The longer delay period with standard injection timing, results in a rise cylinder pressure. The delay period of TGPE with retard injection timing is lower that base line engine with standard injection timing due to better mixing and evaporation fuel.

E. Rate of pressure rise

The comparison of rate pressure rise with crank angle for the standard and retarded injection timing at full load is shown in fig7. When the injection timing is retarded, the rate of pressure rise is marginally higher than that of standard injection timing. The increase in rate of pressure rise of tangential grooved piston engine with retarded injection timing is slightly higher than of the same configuration engine with standard injection timing. After reaching the maximum pressure, it drops progressively to a lower value during the expansion stroke with retarded injection timing.

F. Oxides of Nitrogen

The variation of Oxides of nitrogen (NO_x) emission with brake power for both standard and retarded injection timing of engine operation is shown in fig.8. The emission of NO_x for retarded injection timing is significantly lower at all load conditions. NOX 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 NOX due to high temperature. When the injection timing is retarded, a decrease in the NOX emission at all the loads is observed. When the injection timing is retarded, the crank angle at which the cylinder peak pressure occurs is delayed due to the late combustion of fuel. At the time of start of combustion, the accumulated fuel is less when injection timing is retarded and therefore premixed combustion stage (initial combustion) is less intense leading to lower rate of heat release. Lower peak pressure results in lower peak temperatures. So the NOX emission tends to be less.

G. Carbon Monoxide

Carbon monoxide (CO) emission production relates to the fuel-air ratio and it is a measure of the combustion efficiency. Fig.9 compares the CO emission characteristics of tangential grooved piston engine operation with standard injection timing and retarded injection timing. The CO concentration varies from 17.69 g/kWh at no load to 1.59 g/kWh at full load for standard injection timing and it varies from 14.49 g/kWh at no load to 7.15 g/kWh at full load for retarded injection timing. 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.

Conclusion

The experimental investigation of the TGPE on the influence of injection timing on the combustion, performance and exhaust emission of D.I. diesel engine has been experimentally investigated with retarded injection timing and standard injection timing. When the injection timing is operated from 230 to 170 before TDC, the following observations are made:

- The base line engine with Tangential Grooved Piston Engine (TGPE) is able to run when the injection timing was retarded.
- Cylinder peak pressure is found to be marginally lower due to decrease in delay period
- Ignition delay period is decreased with retardation injection timing due to high swirl ring, formed in bowl by tangential grooves on piston crown
- Brake thermal efficiency of the engine fueled with TGP with retarded injection timing is found to be higher.
- NOX is found to decrease at all load conditions of the TGPE
- CO emission decreased by 25% in retarded injection timing of waste plastic oil operation compared to standard injection timing.
- Unburnt hydrocarbon emission is decreased dramatically by about 30%

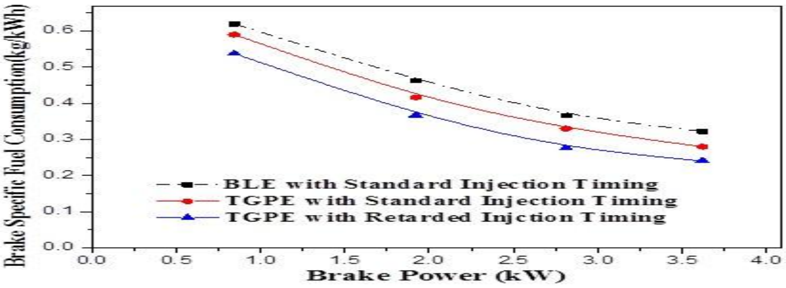

Fig 3: Variation of BSFC with Brake Power

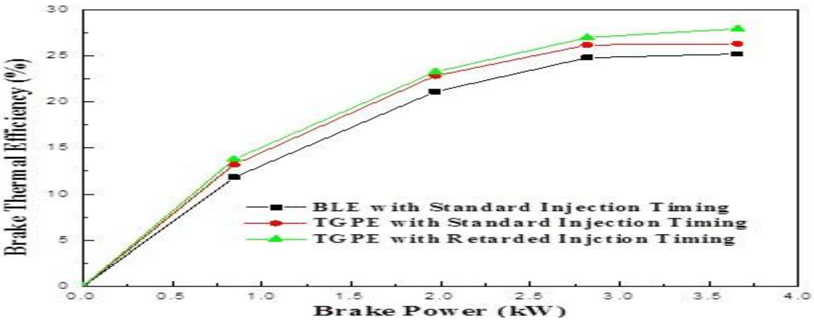

Fig 4: Variation of BTE with Brake Power

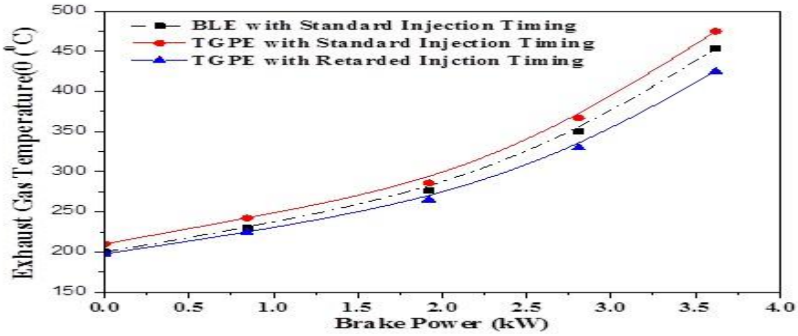

Fig 5: Variation of Exhaust gas Temperature with Brake Power

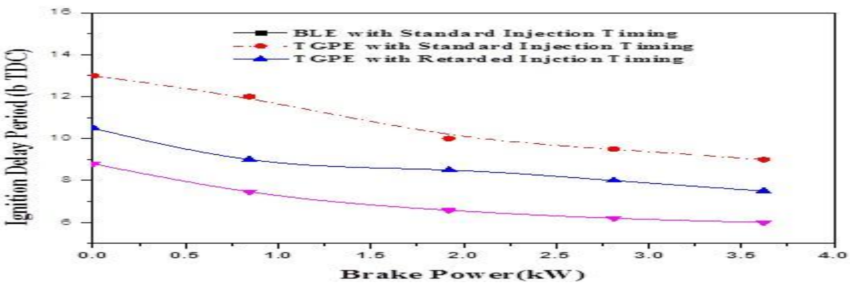

Fig 6: Variation of Ignition Delay Period with Brake Power

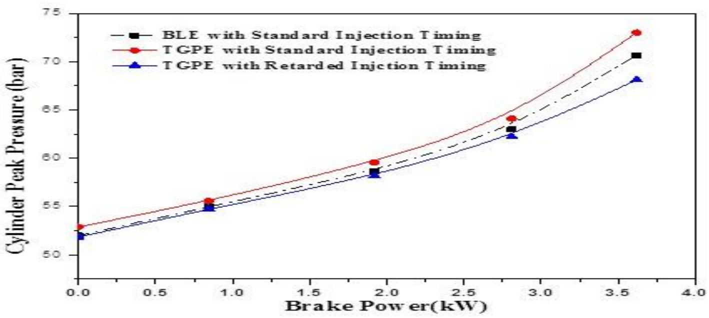

Fig 7: Variation of Cylinder Peak Pressure (bar)with Brake Power

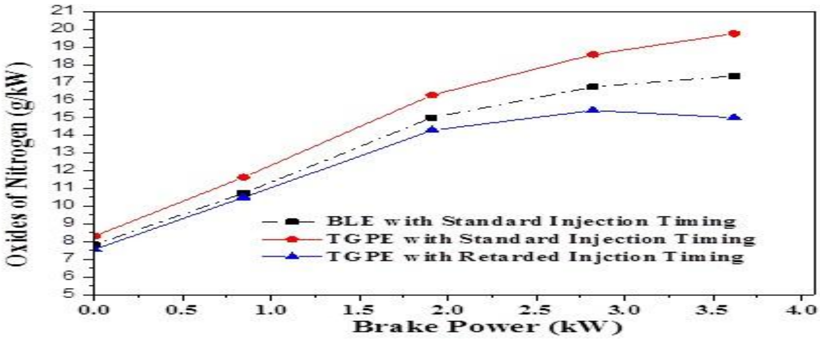

Fig 8: Variation of Oxides of Nitrogen (g/kW)

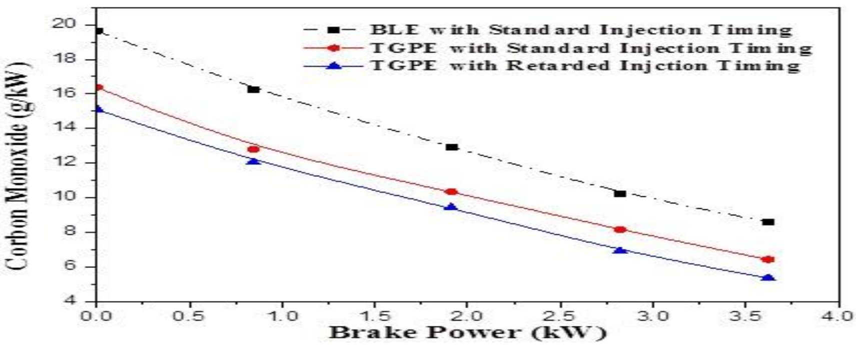

Fig 9: Variation of Carbon Monoxide with Brake Power

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