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Experimental Investigation of Different Pistons Like Standard, Toroidal, And Modified Toroidal Piston Dish Type Combustion Chamber (Piston Top) Geometry for Four Stroke Single Cylinder DI Diesel Engine Fueled with Diesel

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ABSTRACT

The automotive industry is growing, thanks to recent advancements in gasoline and diesel vehicle versions, but there is a need to optimize emissions that create significant air pollution. Modifications in piston design are constantly needed, and old fuels like diesel have emission concerns that may affect thermal efficiency. We chose a customized toroidal piston having grooves just on the piston surface for our purpose to avoid the issue of diesel engine emissions. Toroidal pistons produce a greater fuel-to-air mixture, which leads to a much more realistic mixture burning. This little modification to the piston might improve the squish of the mixture of air, leading to higher thermal efficiency and fewer exhaust emissions. The present research investigates how to adapt, produce, and evaluate a toroidal piston bowl shape with grooves on the top of the cylinder for use in a hemispherical combustor diesel engine. Diesel will also be utilized to study performance, combustion, and emissions.

KEYWORDS:single cylinder DI engine, toroidal piston, modified toroidal piston grooves, hemispherical, semi spherical bowl (combustion chamber), diesel, performance, and emissions

1. INTRODUCTION

Combustion engines have supplied a relatively affordable and reliable source of power for uses ranging from residential to large-scale transportation and industrial applications throughout the twentieth century. Because DI Diesel engines have better thermal efficiency than every other engine, they have been employed in both light and heavy-duty vehicles. In-cylinder fluid motion is one of the most important factors influencing the complete combustion in internal combustion engines. In diesel engines, it regulates the mixture of fuel and air, as well as the rate of combustion. The fluid flow ignition in combustion engines is created during the induction phase and developed throughout the compression stroke. Therefore, understanding fluid motion during the induction process is critical for developing engine designs that have optimal operational and emission characteristics. In simple diesel engines, the amount of fuel that is injected into the combustion chamber needs to be spread out in a way that improves combustion and reduces emissions. The fuel spray must be adjusted to the combustor geometry to make the best use of the gas. To put it another way, combining the combustion chamber geometry, fuel injectors, and gas fluxes is the most important factor in attaining enhanced combustion. By accelerating the amount of fuel-air mixing, Swirl may minimize the burning duration for re-entrant chambers in DI diesel engines with delayed injection timings. In the combustion bowl, swirl contact with compression-induced squished flow increases turbulence, which aids mixing. So, because flow inside the combustion chamber starts to develop from the interaction of intake flow with the goal of this study is to categorize the position of the combustor geometrical on in-cylinder flow and thus the fuel-air mixing, combustion, as well as pollutant formation processes. The influence of geometry on flow during the intake stroke and the early portion of the compression stage is negligible. When the piston approaches Top Dead Centre (TDC), the bowl shape has a significant impact on airflow, leading to increased alienation, mixing, and combustion. The swirl number in the re-entrant chamber having sharp edges and also no center projection is higher than in the other chamber [8]. In the current scenario, various types of techniques will be used to improve performance, such as pre-combustion, post-combustion, and piston bowl modifications (i.e., the piston crown will be changed to different shapes). In the current investigation into piston bowl modification, i.e., the toroidal piston on the surface with grooves, various types of techniques will be used to improve performance, such as pre-combustion, post-combustion, and piston bowl modifications (i.e., piston crown is changed to different shapes). Both standard and modified pistons are tested on diesel fuel using physically overloaded Kirloskar combustion engine test rig equipment. In the face of an approaching energy crisis, vegetable oils have emerged as a promising source of motor fuel. They're getting a lot of attention because of their vast availability, renewable nature, and greater performance than diesel engines. There have been a lot of tests of compression ignition engines with a lot of different vegetable oils, either by changing the fuel or the engine.

2.MEATERIAL&METHODS

The typical piston has a spherical combustor piston geometry bowel form. To convert a hemispherical bowl to a spherical bowl, utilize the hemispherical bowl piston (i.e., the cavity divides the hemispherical piston into two neighboring lunes). This geometric bowl shape is used to fill the aluminum welding limitations on a hemispherical bowl. The piston was then delivered to a CNC to be carved into the toroidal form we needed, with a bowl capacity of 34,727 cu mm. After that, the piston's surface was machined to create No. 8 circular grooves, and the piston was completed. The toroidal piston is known as a modified toroidal piston. Only diesel fuel is used throughout the procedure. The following are the characteristics of diesel fuel.

Fig: 1. Filling with welding Aluminum metal

Fig:2. Machining Process

Fig: 3. Final Modified Toroidal Piston (8 grooves)

3. OBJECTIVES

The purpose of this research is to see how effectively diesel can be used as a fuel in diesel engines to reduce emissions. 1. To investigate the parameters of diesel engines and the performance implications of changing the shape of the toroidal piston bowl.2. The piston crown's round shape and grooves are employed to increase turbulence and fuel mixture quality. 3. To see how a grooved piston reacts to a different combustion chamber and surface in a single-cylinder diesel engine operating on diesel fuel, when utilizing diesel fuel, compare emissions from standard pistons, toroidal pistons, and modified toroidal pistons. 5. Use swirl and squish with the help of a modified crown to cut down on NOx and HC emissions.

4. EXPERMENTAL SETUP:

4.1 Engine Set Up

This research looked at the performance of a ci-engine DI diesel engine running on diesel fuel and using conventional, toroidal, or modified toroidal pistons. Kirloskar's gasoline engine, direct injection, and four-stroke cycle diesel engine were used in the experiments. Table 4.1 lists the specifications of the Kirloskar engine. A normally aspirated liquid eddy current dynamometer was employed in this experiment. A Piezo cylinder pressure sensor, magnetic pick-up, thermos couplings for detecting the temperature of outlets including liquid, airflow, and gas, a given below, for measuring the flow rate of water, and a multimeter for measuring airflow or fuel rates were all included in the engine. To assess the density of smoke, the smoke meter, and gas analyzer are positioned. In this investigation, the smoke density was assessed with a Bosch smoke meter. In this project, the milling of the piston on the piston head of an aluminum alloyed piston is attempted. Figure 4.2 depicts the toroidal bowl form of the piston head. The efficiency of the donut-shaped cylinder dish-style combustion chamber was contrasted to that of a standard piston engine in experiments conducted on a single-cylinder diesel engine with varied loads (loads ranging from 0 to 18 kg delivered gradually).

4.2 Test Procedure:

The analysis of the performance of a ci engine DI diesel engine is divided into three parts. The first step of the test performed is conducted using a conventional piston fueled

with diesel to establish baseline data to compare to the changed piston results. In the second step, a toroidal piston powered by diesel is used to conduct performance testing experiments. Finally, an experimental assessment of performance monitoring is carried out using the modified toroidal piston (i.e., 8 grooves on the piston surface). Inspect the engine's lubrication system and gas tank level and enable water to drain into the engine before performing these operations. In this experiment, several sorts of instruments were used to measure the different engine parameters. Then, using a flux dynamometer, apply a load to the engine and record all the relevant engine measurements, such as engine speed, the time it takes for 10cc of fuel usage, and brake force applied to the engine. Go through the same procedure for various fuel loads. Finally, shut off the fuel supply and reduce the load to switch off the engine.

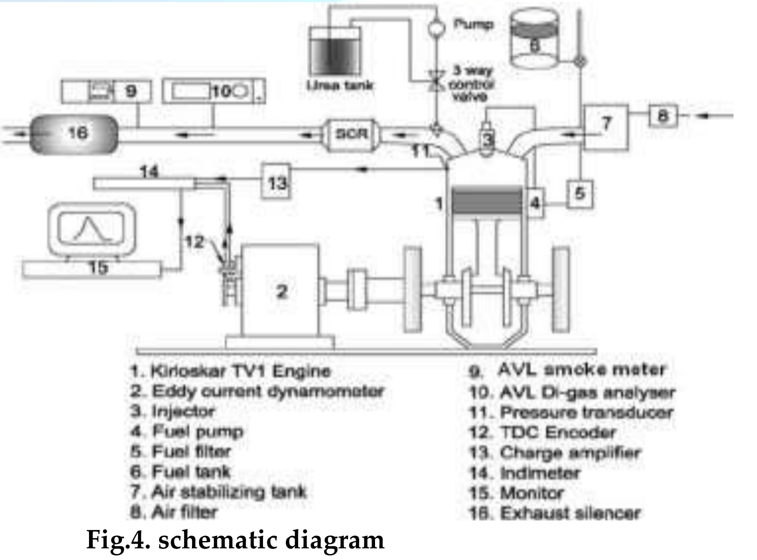

Fig.4. schematic diagram

4.3 Engine Modifications :

To assess the effectiveness, combustion, and exhaust emissions of a CI engine, a diesel engine, the piston crown of a standard engine is changed in this research. The conventional semispherical (toroidal) combustion chamber was designed for cylinder DI diesel engines; however, it must be adjusted for diesel fuel (and biofuel) applications to assess the engine's characteristics and performance. The mixture production of diesel with air particles is crystalline, resulting in full combustion, which increases BTE and decreases SFC owing to the significantly increased fluid velocity in the combustion process due to its shape. With the concocted altered toroidal combustion chamber nozzle and schematic depiction of the piston shown in figs. 4 and 5, squish and swirl augmentation by spherical steps are supplied on the cylinder top to improve the effectiveness of diesel air atom mixing by improving the velocity of the swirling motion of the mixture. During the suction stroke, outside air entering the engine barrel was condensed to a higher weight and temperature, which was inadequate to mix with the fuel injector, and some of the fuel particles were not ingested in this procedure and were released into the air during the exhaust stroke, likely resulting in fuel loss and delivering less power than required. The piston is made up of the heads, bore, piston pin, piston skirt, piston rings, and lands. The piston head is the upper portion (closest to the cylinder head) of the cylinder that is exposed to greater loads and heat during ordinary engine operation. It was updated to verify the efficiency of the revised toroidal piston. When the system is fully loaded, the main advantage of this new design is that it enhances thermal efficiency. Squish and swirl will be effectively created by the piston head's newly designed toroidal combustion chamber, resulting in a rich fuel mix formula and a high compression ratio. To achieve an appropriate air-to-fuel ratio, the cylinder's modified toroidal combustion chamber piston is employed to induce turbulence. In earlier DI diesel engines, this was still the main problem. The fluid motion within a single-cylinder diesel engine cylinder is critical, and the mixture has a significant influence on the quality of fuel combustion (diesel).

Fig:6. Different geometric Bowl shapes

5. RESULTS AND DISCUSSIONS

a. Performance Analysis:

1. LOAD vs BSFC:

Figure 7 shows how specific fuel consumption varies with load. The graph demonstrates that as the load rises, the brakes' specific fuel usage decreases. At full load, the BSFC for the conventional piston was 0.43 kg/kW-hr, 0.29 kg/kW-hr for the toroidal piston, and 0.22 kg/kW-h for this modified toroidal piston. The BSFC was determined to be lower in comparison to other pistons.

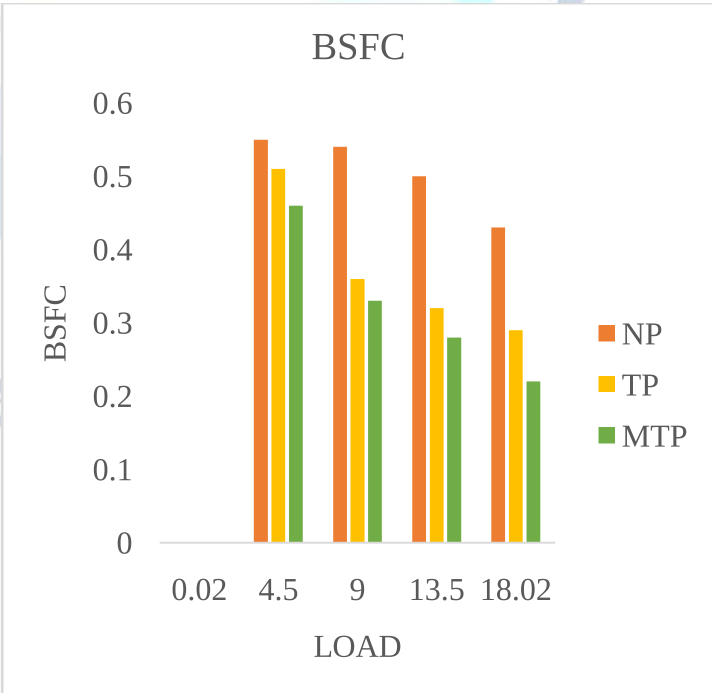

Fig:7. LOAD VS BSFC

2. LOAD VS BTE :

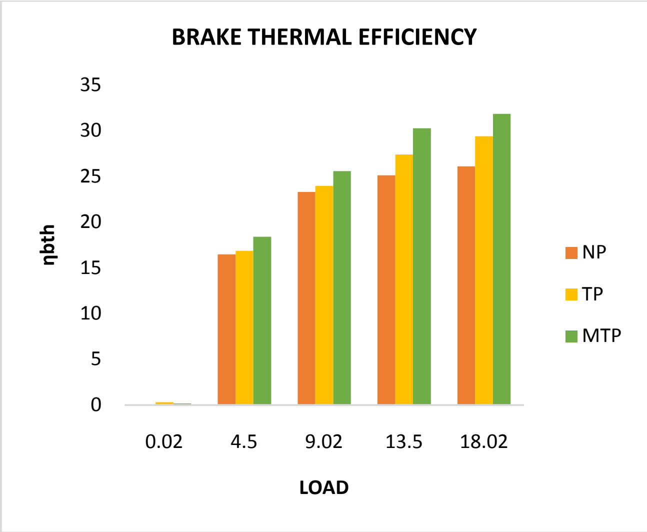

Fig:8.LOAD VS BTE

The variation in brake thermal efficiency under load is seen in Figure 8. The graph indicates that the thermodynamic efficiency of the brakes rose as the load increased. Normal pistons had a BTE of 26.11 percent at full load, toroidal pistons had a BTE of 29.40 percent, and modified toroidal pistons had a BTE of 31.86 percent at full load. was determined to be somewhat greater compared to other pistons.

3. LOAD VS BMEP :

Figure 9 depicts the fluctuation of brake mean effective pressure with the load. The brake is activated. As the load increases, the mean effective pressure rises, as seen in the graph. At full load, the BMEP of a normal piston was 3.49 bar, the Toroidal piston was 6.21 bar, and the Modified Toroidal Piston was 6.49 bar. When compared to other pistons, BTE was discovered to have the greatest BTE.

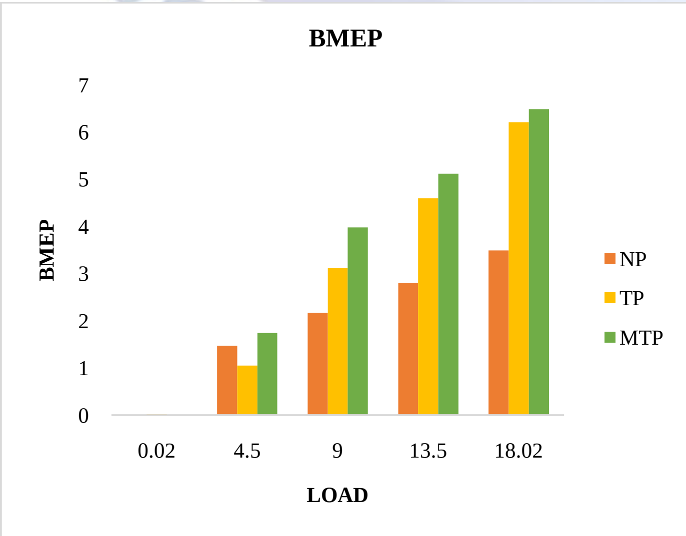

FIG:9. Load Vs BMEP

4. LOAD VS ME :

The variation in efficiency as just a result of the load is seen in Figure 5.4. Mechanical efficiency increased as the load increased, as seen in the graph. At maximum load, the ME was 62.02 percent for the standard piston, 74.53 percent for the toroidal piston, and 75.23 percent for the modified toroidal piston. was discovered to be the most powerful piston as compared to other pistons.

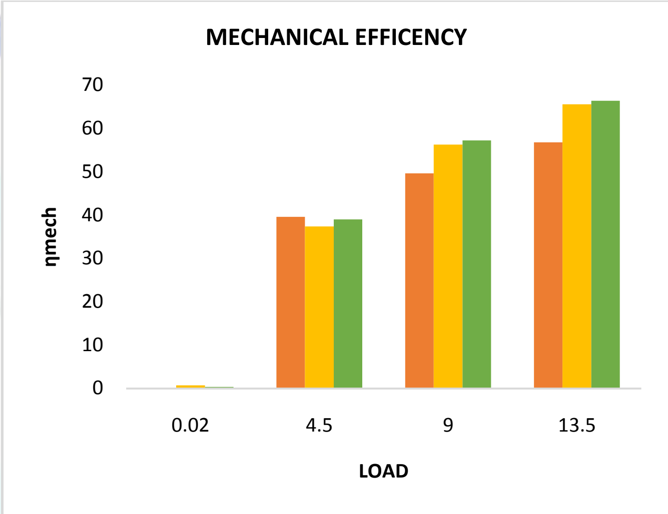

Fig:10. LOAD vs ME

5. LOAD VS NOX :

The graph below depicts the change in NOx as a function of load. The graph shows that as the load increases, N0x rises with it. When using diesel, the quantity of NOx produced by the engine is rather minimal (at the standard piston, toroidal piston, and modified toroidal piston). The conventional piston for diesel fuel is 601 parts per million, the toroidal piston is 570 parts per million, and the modified toroidal piston is 615 parts per million. The NOx for diesel MTP was lowered when compared to fuel MTP at full load.

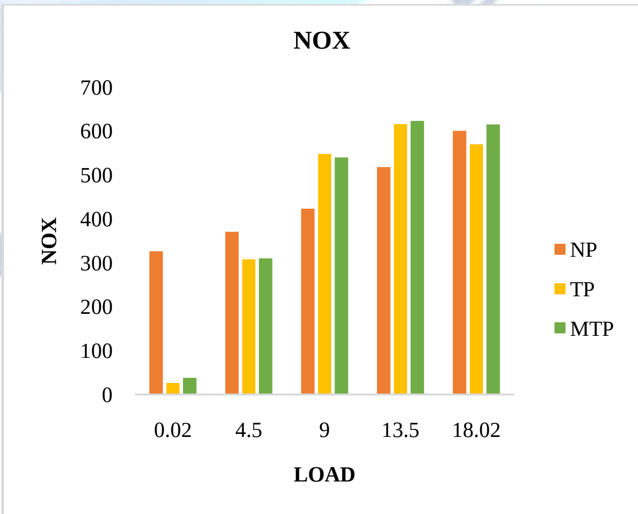

Fig:11. LOAD VS NOx

6. LOAD VS CO2 :

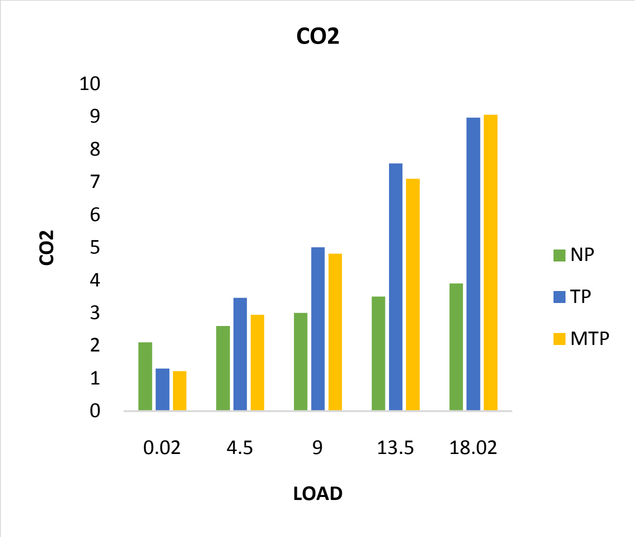

Fig:12. Load vs CO2

The graph above depicts the CO2 fluctuation as a function of load. The plot lines show that CO2 levels grow as the load increases. According to the statistics, the redesigned toroidal piston without grooves produces more CO2 than the normal piston at all load levels. The carbon dioxide content of the exhaust gas is 3.9 percent for a regular piston and 8.67 percent, 9.06 percent, and 9.06 percent, respectively, for TP and MTP pistons. The higher the carbon dioxide measurement, the more efficient the engine is in general.

6. CONCLUSION :

The following findings are based on the results of operating a single-cylinder water-cooled diesel engine with both conventional and modified grooved pistons to get experimental results. In all diesel engine architectures, the Modified Toroidal Piston arrangement enhances the turbulence, resulting in a superior air-fuel mixing process. Therefore, the system's thermal efficiency has increased, and emissions have dropped. The best of the two different layouts was determined to be the modified toroidal piston. When the three pistons are compared, the modified toroidal piston with grooves outperforms the ordinary piston.

The following conclusions are drawn based on the present investigation.

When compared to a conventional piston, the greatest gain in brake thermal efficiency for MTP and TP was determined to be 31.80 percent, 29.40 percent, and 26.11 percent, respectively. As a result, MTP and TP brake specific fuel consumption were determined to be 0.29 kg/kWh for TP and 0.22 kg/kWh with MTP, respectively, when compared to the standard piston of 0.43 kg/kWh. When compared to a conventional piston, the maximum improvement in indicated thermal efficiency for MTP and TP was determined to be and, respectively. The greatest increases in volumetric efficiency for MTP and TP, when compared to the regular piston, were 65.34 percent for the regular piston, 81.21 percent for TP, and 86.61 percent for MTP. For normal piston (NP), 6.21 bar for TP, and 6.49 bar for MTP, the maximum increase in brake means an effective pressure of 3.49 bar, 6.21 bar, and 6.49 bar, respectively. The greatest increase in indicated mean effective pressure for normal piston (NP), 5.62 bar for TP, and 8.26 bar for MTP was 4.4 bar for NP, 5.62 bar for TP, and 8.26 bar for MTP. Carbon monoxide emissions from TP and MTP are 0.05 percent by volume, 0.033 percent by volume, and 0.021 percent by volume, respectively. The nitrogen oxide emissions for a conventional piston are 570 ppm, whereas the TP 617 ppm and MTP 601 ppm emissions are 617 ppm and 601 ppm, respectively.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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