Experimental Analysis on Diesiel Engine

Dr. Shaik Abdul Siddique[1], Raffi Mohammed[2], SK Abdul Azeez[3]
[1]*Faculty of Mechanical Engineering, King Khalid University, Saudi Arabia*
[2,3]*Faculty of Mechanical Engineering, Ramachandra College of Engineering Eluru, A.P*

Abstract- **In the present work, an investigation has been carried out on, in-cylinder flow for non-reacting as well as firing condition with different types of combustion chamber geometries. The multi-dimensional CFD code Diesel-RK is used for the simulation of air motion inside the cylinder and combustion process. Three-dimensional computational domains constituted the intake ports, combustion chambers, and the exhaust ports, which were capable of simulating complete engine cycles and can work on any operating conditions. The investigation has been carried out to study the effect of combustion chamber geometries.**

1. INTRODUCTION

The experiments are conducted on 5.2kw single cylinder, four stroke direct ignition diesel engine. The experiments are conducted by varying the load at constant speed of 1500rpm. This system is having a hemi spherical shaped combustion chamber with single injector having three 0.3mm nozzles. In order to verify the reliability of CFD simulation, the values obtained for the simulation are compared with the experimental results. The results showed good agreement with the experimental results. From the results, it reveals that the Diesel-RK software can be one of the reliable CFD software for modelling and simulating combustion of diesel engines.

The results showed that the combustion chamber geometry has negligible impact on the flow characteristics during the suction stroke and first phase of the compression stroke. It has significant influence when piston approached TDC position where the fuel air mixing and combustion process start. The reentrant with central projection combustion showed higher Swirl ratio and turbulent kinetic energy when piston at TDC than other two chambers. Further combustion studies have been carried out on reentrant with central projection combustion chamber, which gives better air motion during motoring conditions.

II.EXPERIMENTAL SETUP

In the present research work, water-cooled single cylinder diesel engine which is very well-suited for agriculture has been used. Experiments are conducted for different load conditions. The full experimental setup is arranged in the JNTUHCEH mechanical engineering department engines laboratory. Engine performance and exhaust emissions are plotted with respect to the engine load. The features of the experimental setup, fuel sample properties and systematic description about the test procedure is mentioned.

III. EXPERIMENTAL APPARATUS

A single cylinder, Direct Injection (DI), and four-stroke cycle diesel engine is used for the experimentation. The detailed specification of the test engine is presented in Table 3.1. The experimental apparatus consists of compression ignition single cylinder four stroke water cooled diesel engine, dynamometer, exhaust gas analyzer system, fuel supply system, etc,. For measuring various parameters, this setup has standalone air box, fuel tank, manometer, fuel measuring unit, digital indicators and transmitters. It is also inbuilt with necessary sensing elements. All these signals are interfaced to PC through signal conditioner and signal converter. The specification of the experimental test set up is mentioned in Table No 3.1.

S. No.	Details	Specifications
1.	Engine Power	5.2 kW
2.	Engine Max. Speed	1500 rpm
3.	Cylinder Bore	87.5 mm
4.	Stroke Length	110 mm
5.	Connecting rod length	234 mm

6.	Compression Ratio	16.5
7.	Stroke type	Four
8.	No. of Cylinders	One
9.	Speed Type	Constant
10.	Cooling Type	Water
11.	Dynamometer Type	Eddy Current
12.	Indicator Used Type	Cylinder Pressure

Table No. 3.1: Specifications of the experimental setup

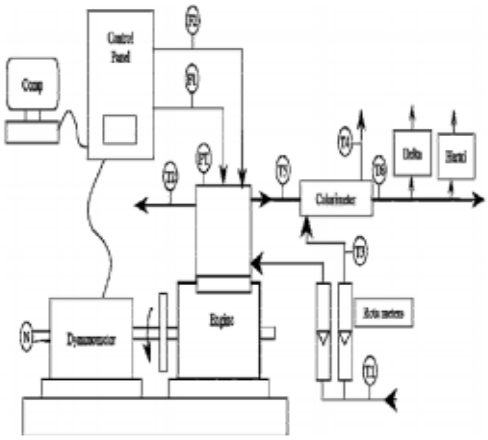

Fig 3.1: Schematic of the experimental setup

3.1.1 Test Engine:

A four stroke, single cylinder, naturally aspirated, direct injection and water cooled diesel engine with a displacement volume of 562 cc, compression ratio of 16.5:1 and rated power output of 5.2 kW at 1500 rpm is used for conducting experiments. The engine is run at its rated constant speed of 1500 rev/min. Engine is coupled with a dynamometer. The engine and the dynamometer are connected to a control panel and is coupled to a digital computer. The test parameters are measured with the help of manufacturer supplied software. Fuel rate, temperatures, air flow rate, load, brake power etc are measured for the experiment. From the data, the engine performance characteristics such as brake thermal efficiency, brake specific fuel consumption, volumetric efficiency and mechanical efficiency are calculated. The calorific value and the density of the diesel fuel which is used for test are given as input to the computer software. Eddy current type of dynamometer is used for this experimentation. Fuel injection pump (MICO BOSCH make) is used in the experimental set up. This Pump is having plunger which is operated with the help of cam shaft.

3.2. Data Acquisition System:

Data acquisition system is used to study the processes inside the cylinder. This system is used to analyze the measured cylinder pressure data and to quantify the combustion parameter with crank angle variation. The various elements of this system are pressure pick up, charge amplifier, TDC position sensor, A/D card and PC. By using this system, various parameters such as, start of combustion, fuel injunction pressure, peak cylinder pressure, occurrence of peak pressure shall be calculated. The data is to be analyzed to get required parameters from experimentation. Data processing is an important process in the experimental investigation. During experimentation, large data is collected and processed systematically.

From the results, it is observed that, the cylinder pressure and crank angle values are varied from cycle to cycle. Minimum 100 cycles data is used to get accurate measurements in quantitative analysis. The average number of cycles required for stable measurement is depending upon the repeatability of pressure data. The calibration factor is calculated and applied for conversion of the pressure in voltages in conventional unit.

3.3 Measuring instrumentation:

During experimentations different engine parameters are monitored with the help of built - in sensing elements and analyzers. All the sensors are calibrated and the validity is within due date. Before starting the experimentation, all the sensing elements are powered on and checked for functionality. The following are the measuring systems available in the test apparatus to get the engine parameters.

3.3.1 Injection Pressure:

This instrument is used with cam type mechanism inside the injection pump rocker arm. The fuel injection pump rocker arm is oscillated between the fuel injection timing cam in the cam shaft and fuel injection pump plunger and is hinged on cylindrical shaft at its centre. Shims are required in the set up, to change fuel injection timing. This instrument is varied the fuel injection timing from 23^0 b TDC to 28, 32, 36^0 b TDC. Eccentric shaft is placed in place of cylindrical shaft and it is connected to a worm wheel gear assembly with a reduction ratio of 30:1.

3.3.2 Fuel Supply:
A 3.5 Lts fuel tank is mounted on a cantilever type load cell and also it helps in measuring the fuel consumption. The loss in weight of the fuel is converted to the flow rate in kg/hr and is directly indicated on the digital fuel indicator. Burette is also connected in parallel as a stand by option to cross check the measurement.

3.3.3 Air Consumption:
An air tank is mounted below the control panel and is connected to the manometer across an orifice of 20 mm diameter. The pressure tapings are connected to a differential pressure transducer. The manometer difference is correlated to the actual volume in m^3/hr and the same is directly indicated on the air rate indicator.

3.3.4 Speed and Crank Angle:
The proximity sensors are positioned below the coupling with a reference for measuring the speed and the crank angle. Speed sensor is connected to the speed indicator. The crank angle sensor is connected to a signal conditioner.

3.3.5 Temperature:
Multi-channel temperature indicators are used for sensing the temperatures. PT-100 type temperature sensor is used for measuring low temperatures. The other temperature indicator, k-type thermocouple, is used for sensing high temperature of the exhaust gas. Other supporting instrumentation a wide variety of instruments are used during experimentation.

3.3.6 Indicated Work:
From the pressure volume diagram, indicated work of each cycle is estimated. Indicator diagram is obtained from a dynamic piezo electric pressure sensor which is fitted in the cylinder head to sense the combustion pressure. For crank angle signal, a rotary encoder is fitted on the engine shaft. Both the signals are scanned simultaneously by electronic unit (engine indicator) and it is communicated to the computer. The software in computer draws the pressure - cranks angle plot and computes the indicated power of the engine.

3.3.7 Exhaust Gas Analyzer:
MARS 6 Quintox Kane International exhaust gas analyzer is used for the engine exhaust gas pollution measurement. The exhaust gas pollutants, such as, CO, CO_2 and NO_X are measured by continuous online monitoring mode for all performance trials.

3.4. Experimental Procedure:
Experiments are carried out at constant speed of 1500 rpm at different load conditions. Readings are taken after the engine attained stability of operation. Exhaust gas analyzers are switched on and allowed to stabilize before taking measurements. Experiments are conducted using diesel and hemispherical piston combustion chamber at the full speed at varied load conditions. Speed, Load, fuel flow rate, air flow rate, exhaust gas temperature, exhaust emissions of unburnt hydrocarbon ,carbon monoxide, carbon dioxide, and oxides of nitrogen are observed. Cylinder pressure and top dead center (TDC) position signals are measured for analysis of the data to get combustion parameters.

Fig 3.2: Experimental set up

3.5. Experimental Results:

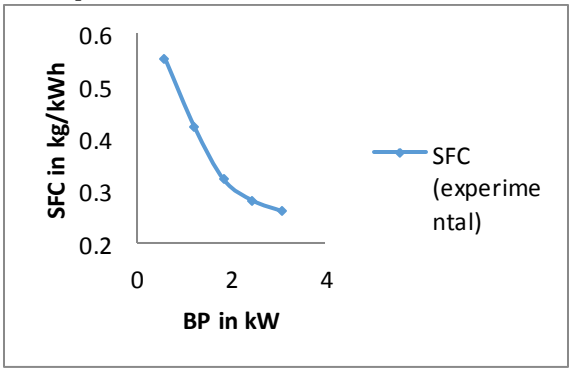

Fig 3.3: Variation of SFC w.r.t BP

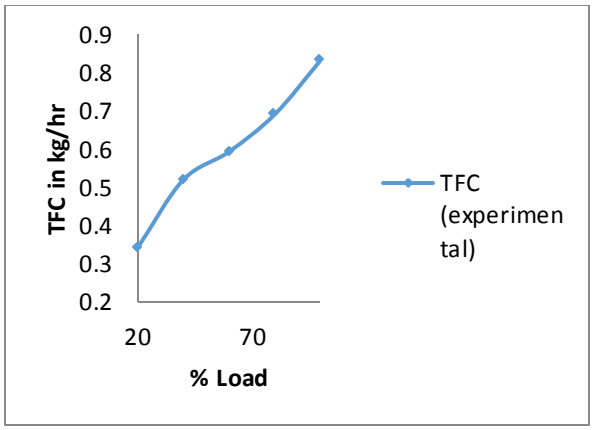

Fig 3.4: Variation of TFC w.r.t % Load

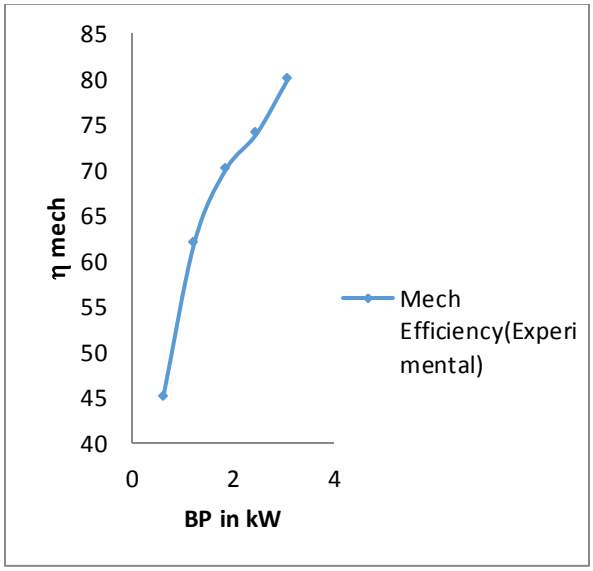

Fig 3.5: Variation of Mechanical Efficiency w.r.t BP

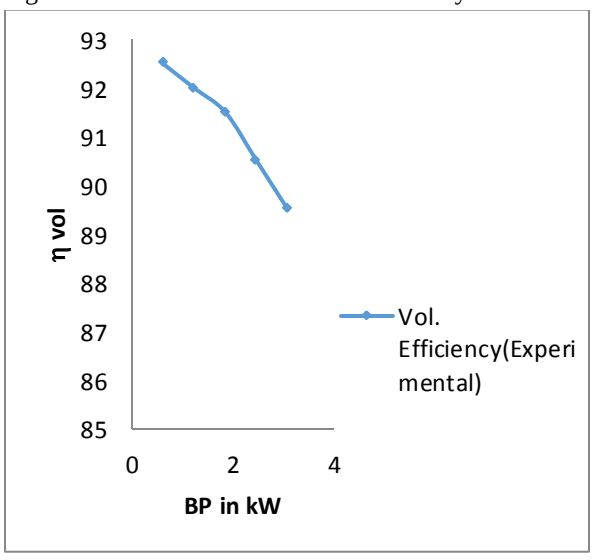

Fig 3.6: Variation of Volumetric Efficiency w.r.t BP

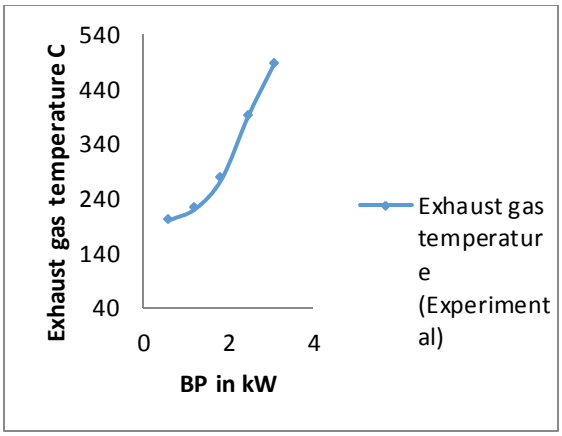

Fig 3.7: Variation of Exhaust Gas Temperature w.r.t bp

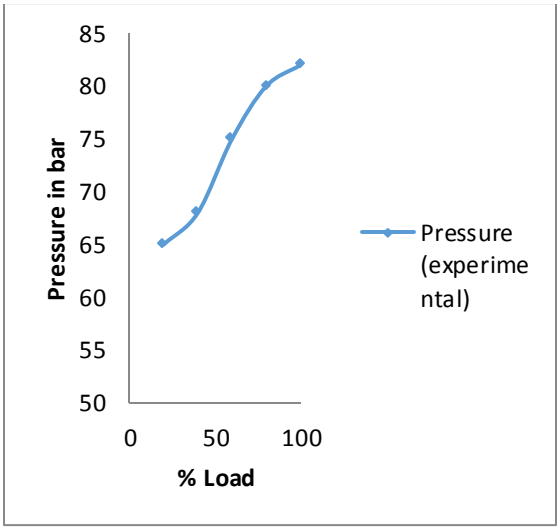

Fig 3.8: Variation of Pressure w.r.t % load

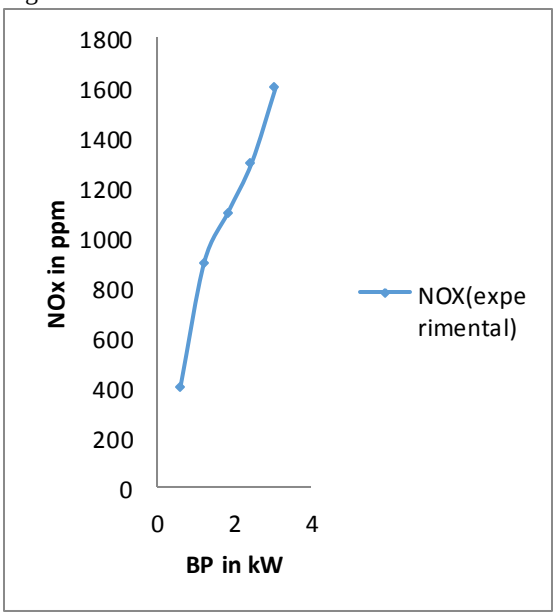

Fig 3.9: Variation of NOx w.r.t Break Power

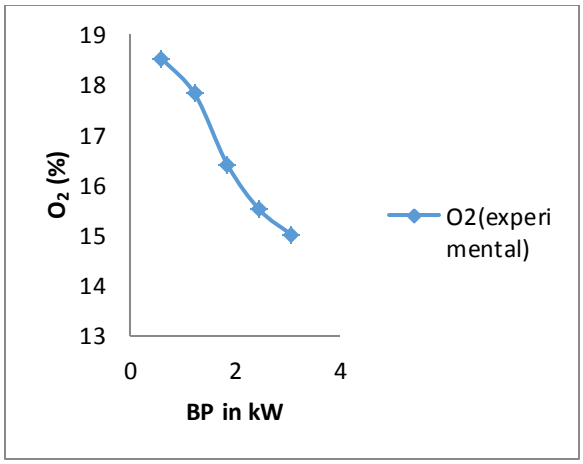

Fig 3.10: Variation of O_2 w.r.t BP

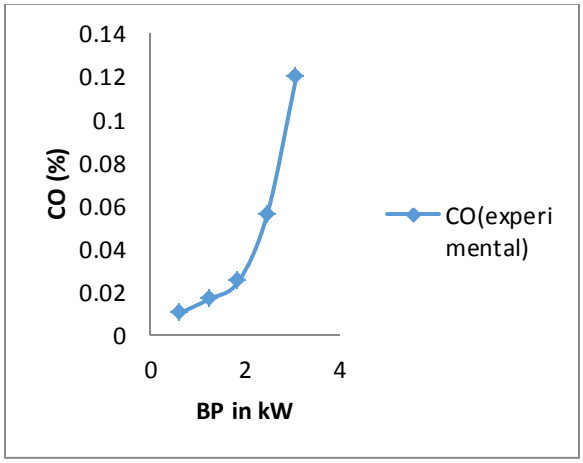

Fig 3.11: Variation of CO w.r.t BP

IV.RESULTS AND DISCUSSIONS

In this investigation, four pistons of different configurations suitable to 5.2kw single cylinder four stroke DI diesel engine are considered. The hemispherical shaped geometry is taken as base engine combustion chamber geometry. In the present work, simulations are conducted to investigate the performance, emission and combustion characteristics using diesel fuel alone at different loads by using DIESEL -RK. The following graphs shows the results of different efficiencies, exhaust emissions, specific fuel consumptions and cylinder pressures for all combustion chamber geometries.

V.CONCLUSION

In view of the petroleum reserves deficit critical environmental concerns and huge usage demand an attempt is made in to investigations on the combustion chambers geometry of diesel engine. It is learnt that a suitable modification in the piston bowl which enhances the air fuel mixture turbulence in the cylinder is provided superior quality of combustion parameters and emissions hence in this research work a set of four configurations of combustion chamber geometries have been used to enhance afore said parameters. In this connection the performance emission and combustion characteristics are calculated by using a validated Diesel RK CFD technique. In this work the following significant observation are made and are presented as conclusions of the investigations related to the Diesel engine available in Department of mechanical engineering (J.N.T.U.H) collage of engineering.

The variation of mass of exhaust gas at 100% load are 0.0075g/sec, 0.008g/sec, 0.0084g/sec, 0.0087g/sec for shallow depth, Re-entrant, Double wedge shallow and Torriodal geometries respectively whereas 0.006g/sec for Hemispherical geometry.

The indicated mean effective pressure are 7.35 bar, 7.45 bar,7.54 bar and 7.58 bar for Torroidal, shallow depth, Re-entrant ,and Double wedge shallow combustion chamber geometries. A maximum pressure is observed with double wedge shallow geometry compared to other pistons. For different load conditions the pressure obtained is minimum for Torroidal shape combustion chamber. After ignition the cylinder pressure rapidly increases when there is a slight increase in combustion pressure caused by injection later then the TDC.

The mechanical efficiency obtained at rated load is 76%, 77%, 78.2% and 79% for Torroidal, Re-entrant, Double wedge, and Shallow depth geometries respectively. The mechanical efficiency obtained is maximum with Shallow depth chamber comparatively other configurations. This is due to the impingement of fuel on the piston walls lead to minimum. This is almost equal to hemispherical geometry. This is because of reduced heat losses in the engine.

It is observed that the volumetric efficiency is gradually decreased with increase in engine output however the maximum volumetric efficiency of 96% is observed with shallow depth combustion chamber geometry. This is because of systematic controlled enhancement of swirl during suction stroke which lead in controlling volumetric efficiency also. The minimum volumetric efficiency is observed for

Torriodal shape piston geometry. This is because of heat loss to incoming air.

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