COLD FLOW ANALYSIS OF A SINGLE CYLINDER FOUR STROKE DIRECT INJECTION CI ENGINE AND ANALYSIS OF VOLUME FRACTION OF AIR USING CFD TECHNIQUE

Basanagouda C Biradar[1], Dr. S Kumarappa[2], Sarvanakumar Kandasamy[3]

[1] *Student, M.Tech Thermal Power , BIET, Karnataka, India*
[2] *Professor & PG coordinator, M.Tech Thermal Power, BIET, Karnataka, India*
[3]*Senior engineer, CFD Analyst, DHIO, KARNATAKA, India*

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Abstract - ***Internal combustion engines in nowadays is the best available reliable source of power for all domestic, large scale industrial and transportation applications. The major issue arises at the efficiency of these engines. Every attempt made to improve these engines tends to attain the maximum efficiency. The performances of the diesel engines are enhanced by proper design of inlet manifold, exhaust manifold, combustion chamber, piston etc. The study is about the effect of piston configurations on in- cylinder flow. Here a single cylinder direct injection diesel engine is used for study. Increase in swirl intensity results in better mixing of fuel and air. Swirl Velocities in the charge can be substantially increased during compression by suitable design of the piston. In the present work, a study on the effect of different piston configuration on air motion and turbulence inside the cylinder of a Direct Injection (DI) diesel engine is carried out using Computational Fluid Dynamics (CFD) code Flow vision. Three dimensional models of the manifolds, pistons and the cylinder are created in CATIA V5 and unigraphics.***

Key Words: *CFD, DI,CATIA V5*

1. INTRODUCTION

The rapid depletion of fossil fuels and environmental concerns make alternative fuels such as biodiesel more attractive. Biodiesel has properties comparable to ultra-low sulfur diesel (ULSD) however certain properties of biodiesel such as viscosity, calorific value, density and volatility differ from ULSD. These properties strongly affect injection, air-fuel mixing and thereby combustion and performance characteristics of biodiesel in a diesel engine. In order to realize the full potential of biodiesel use in diesel engine certain modifications to engine design and injection system are required. This experimental study aims to optimize the combination of injection timing, injection pressure and combustion chamber geometry to achieve higher performance and lower emissions from biodiesel fueled diesel engine. Hence for this proper analysis is required to justify the process.

1.1 TYPES OF COMBUSTION CHAMBERS

- Direct combustion chambers
- Indirect combustion chambers

Direct combustion chambers (DCC)

Presently the paper study is on direct combustion chamber. There are various types of DCC. They are differentiated on the location of injector and piston head geometry. Hence by considering three different shaped piston geometry the analysis is carried out. Flat shaped, Bowl shaped and Toroidal shaped pistons are considered. Instead of diesel as injection fuel, biodiesel is used for injection.

1.2 ENGINE AND COMPUTATIONAL DETAILS

The base engine is same for all three piston configurations CFD analysis. The detailed specification of the base engine selected for the simulation is given below. The engine selected is a single cylinder research DI diesel engine.

SPECIFICATIONS

- Cylinder Bore Diameter =70mm
- Clearance between Cylinder wall & piston surface =0.8mm
- Piston diameter =69.2mm
- Length of stroke =82mm
- Connecting rod length =63.07mm
- Crank radius =18.92mm
- Compression ration =17.6:1
- RPM =2000

2. METHODOLOGY

The methodology adopted for the present work is as follows. Flow through the intake manifold is simulated to

study the in cylinder flow field during non-reacting conditions,
The analysis is carried out through the solver called flow vision. This includes the following steps:
Initially with the specified geometry the 3d cad model of the objects are done using catia and unigraphics. The cylinder, intake manifold, piston with different head, valves are modeled. The piston head geometry measurements are done at GTTC Bangalore using CMMR machine. After modeling the objects are imported in to the solver, the cylinder is considered as static object and the piston and the valves are considered as moving objects. The steps involved in the solver part are ,

- Preprocessor
- Solver
- Postprocessor
- View port

Preprocessor

It's the first step in the flow vision solver part. It begins from importing the 3D cad model into the solver region. In the analysis part only the flow area of the region is considered. In this preprocessor there are several sub regions and hence it plays an imp role in the solver part. Loading the objects, assign the positions, importing the moving bodies, applying the boundary conditions and grid generations are the important steps in preprocessor.

Solver

- Time step:
  Method: via CFL number
  Conventional CFL: 7
  Max step: 0.001

- Data auto save: Here in this section auto save of images and readings can be done at required amount.
- Stopping conditions: Here the stopping conditions of the solver can be adopted.

Postprocessor

- Objectives: Here the colour contour variations in any prescribed plane can be done. Characteristics curve also one of the imp factors in this section. Vectors the motions of particles can be identified in the arrow flow form. Final result analysis can be done here.

View port

The clip lighting , clip solver area and the solver status can be viewed in the process.

3. Result and Discussion

3.1 Variation of swirl generation in Flat, Bowl, and Toroidal shaped piston.

3.1.1 Flat shaped piston.

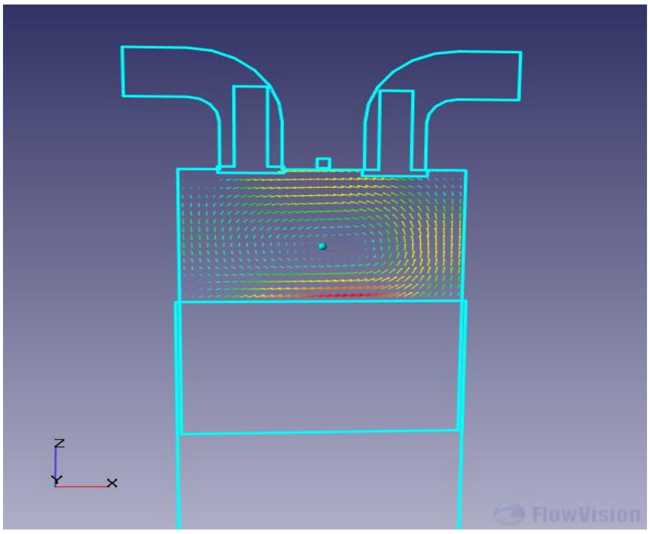

Fig.1 : swirl pattern in flat shaped piston

3.1.2 Bowl shaped piston

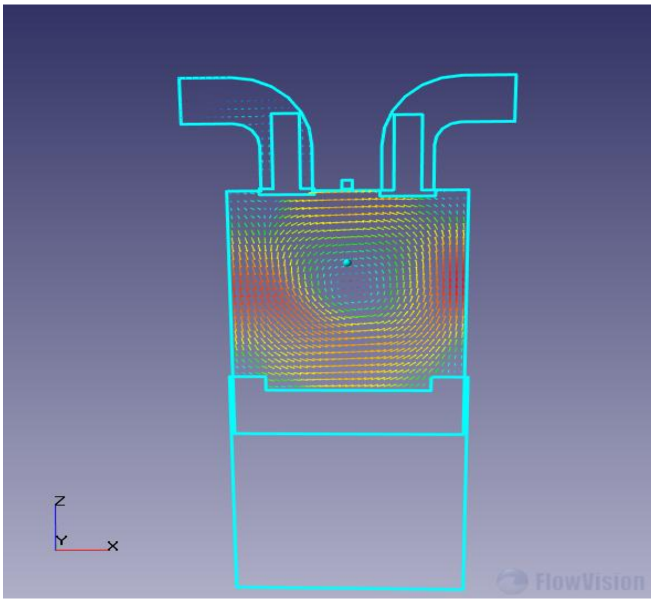

Fig.2: swirl pattern in bowl shaped piston

3.1.3 Toroidal shaped piston

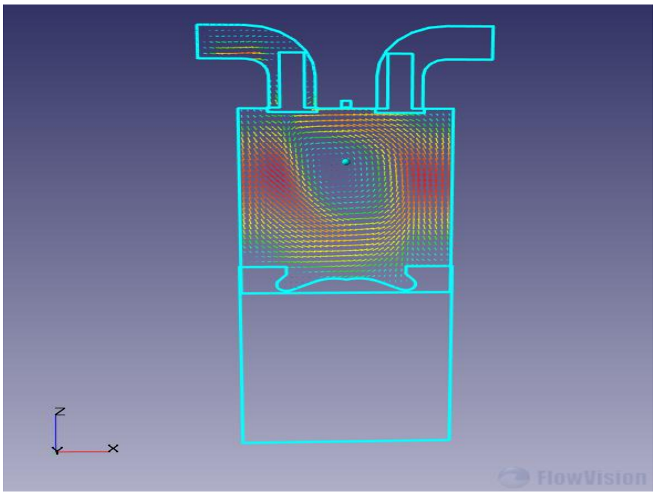

Fig3.: swirl pattern in toroidal shaped piston

Fig 1, fig 2 and fig 3 show the swirl generation pattern for flat, bowl and toroidal shaped piston. For flat shaped piston swirl generation will be only at the valves and volume fraction of air will be less and hence mixing of air and fuel will be less when compared to bowl shaped piston. In Toroidal shaped piston the generation of swirl is better and hence better mixing of air fuel mixture. And efficiency of the system increases. Hence when compared through analysis part the swirl generation is better in Toroidal shaped piston then bowl and flat shaped piston.

3.2 Temperature and Pressure variation in Flat, Bowl, and Toroidal shaped piston.

3.2.1 FLAT PISTON

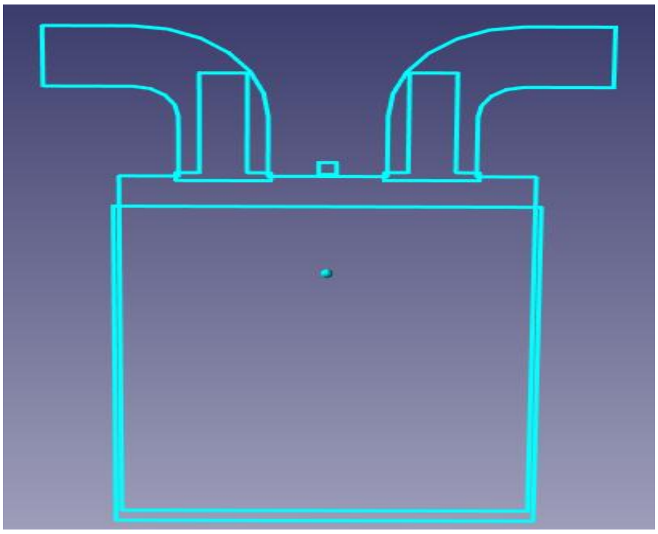

Fig4.: CAD models of flat shaped piston

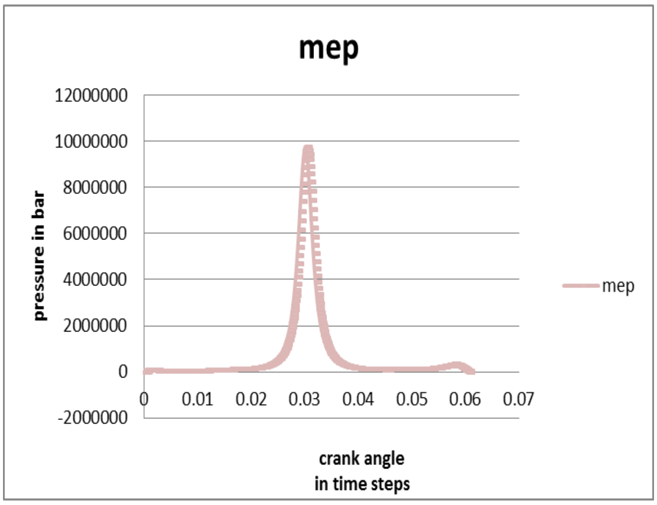

Fig5. MEP for flat shaped piston

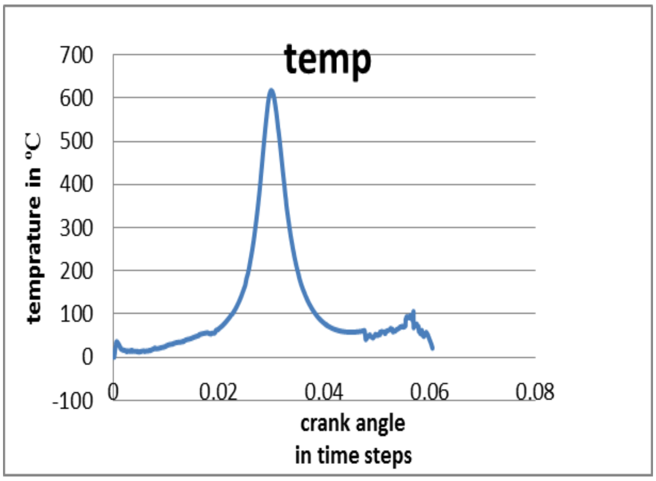

Fig6. variation of temp with respect to crank angle for flat shaped piston.

Fig 5 shows the mean effective pressure graph for the flat shaped piston. In flat shaped piston the swirl generation is less when compared to bowl and toroidal shaped piston. Since there is no clearance volume in the piston head and the complete volume of air in the cylinder is compressed to max extent and hence the peak pressure rise is much in this case.

Fig6. shows the temperature variation for flat shaped piston. Corresponding to the pressure the temperature rise is also max in this case when compared to bowl and toroidal shaped piston. For the prescribed specifications for flat shaped piston the mean effective pressure is around 98bar and temperature is around 620ºc.

3.2.2 BOWL PISTON

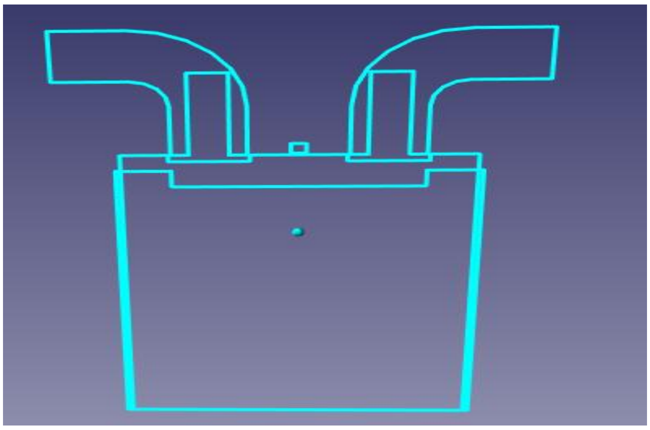

Fig7.: CAD models of bowl shaped piston

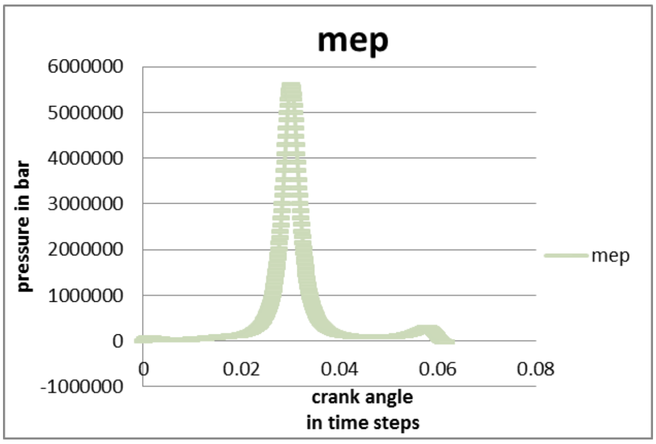

Fig8. MEP for bowl shaped piston

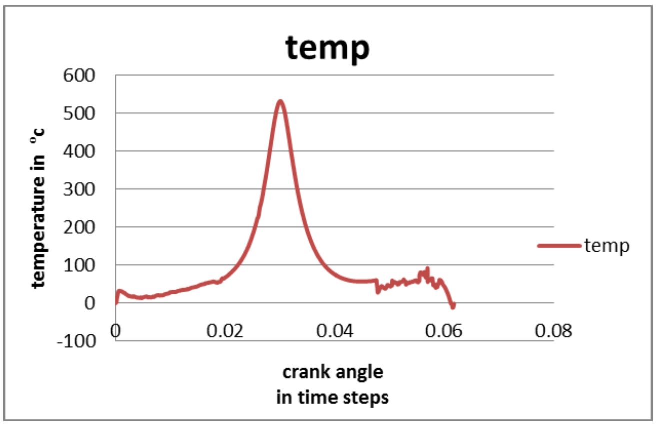

Fig9. variation of temp with respect to crank angle for bowl shaped piston

Fig 8 shows the mean effective pressure graph for the bowl shaped piston. In bowl shaped piston the swirl generation is better when compared to flat shaped piston. Since there is a bit of clearance volume in the piston head and the peak pressure rise depends on the depth of the piston bowl.

Fig 9 shows the temperature variation with crank angle for bowl shaped piston. Corresponding to the pressure the temperature rise is also noticeably varied. For the prescribed specifications for bowl shaped piston the mean effective pressure is around 55bar and temperature is around 520 ºc.

3.2.3 TOROIDAL PISTON

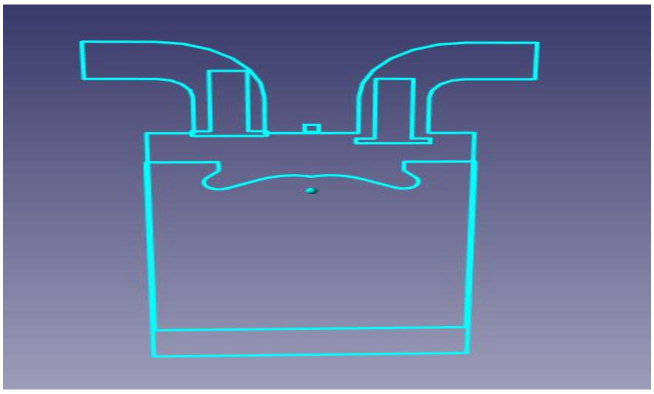

Fig10: CAD models of torodial shaped piston.

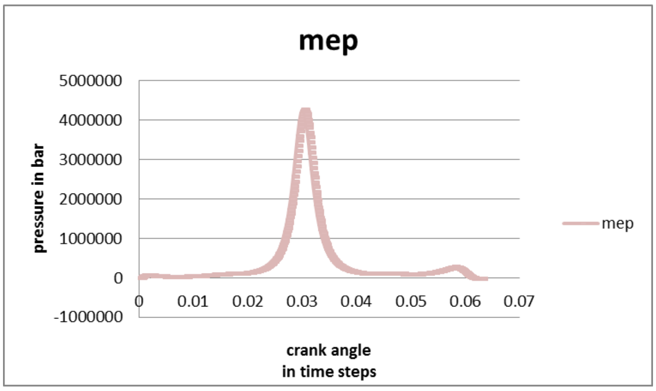

Fig11. MEP for bowl shaped piston.

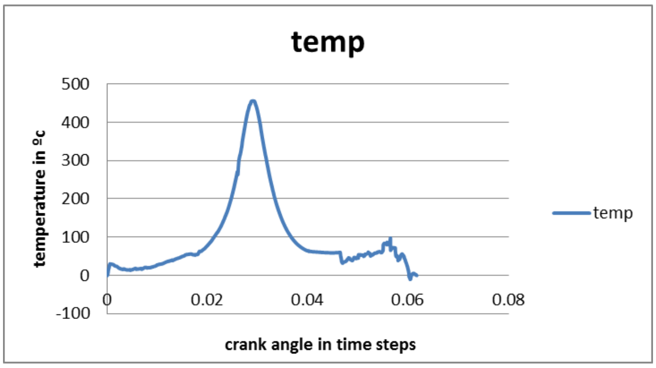

Fig12. variation of temp with respect to crank angle for bowl shaped piston

Fig 11 shows the mean effective pressure graph for the toroidal shaped piston. In toroidal shaped piston the generation of swirl is optimum and hence gets better mixing of air and fuel. And hence after combustion will get better output result when compared to flat and bowl shaped piston.

Fig 12 shows the temperature variation with crank angle for toroidal shaped piston. Corresponding to the pressure the temp rise is also noticeably varied. For the prescribed specifications for bowl shaped piston the mean effective pressure is around 43bar and temperature is around 450 ºc.

3.3 Variations in the geometry of Toroidal piston

3.3.1 24degree angle and radius of curvature 4mm

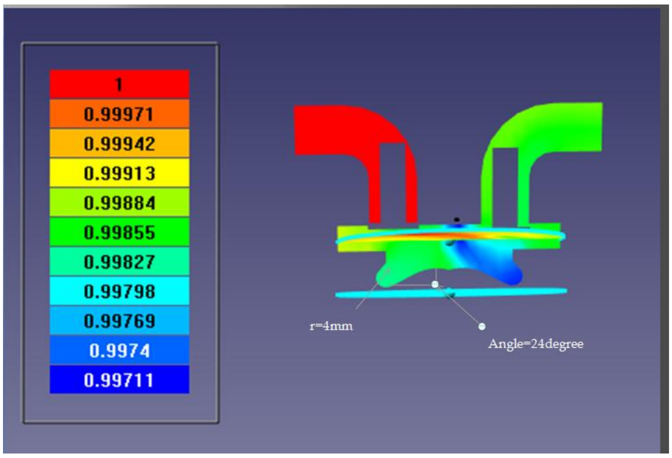

Fig. 13: 24degree angle and radius of curvature 4mm

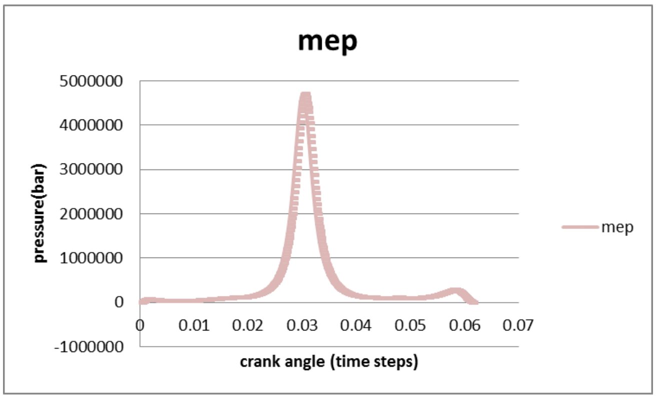

Fig. 14 MEP vs Crank angle graph

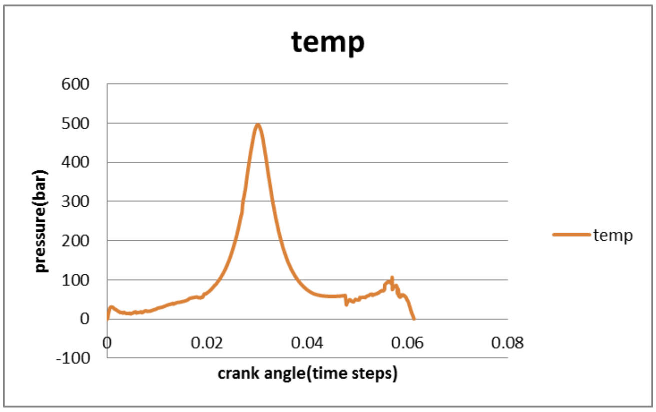

Fig. 15 temp vs crank angle graph.

Fig 14 shows the mean effective pressure graph for the modified toroidal shaped piston. With decreasing radius of curvature and angle of actual piston geometry, the pressure and temperature increases with actual geometry. In toroidal shaped piston the generation of swirl is optimum and hence gets better mixing of air and fuel. And hence after combustion will get better output result when compared to flat and bowl shaped piston.

Fig 15 shows the temperature variation with crank angle for modified toroidal shaped piston. Corresponding to the pressure the temp rise is also noticeably varied. For the prescribed specifications for bowl shaped piston the mean effective pressure is around 48bar and temperature is around 490 ºc.

3.3.2 30degree angle and radius of curvature 5mm:

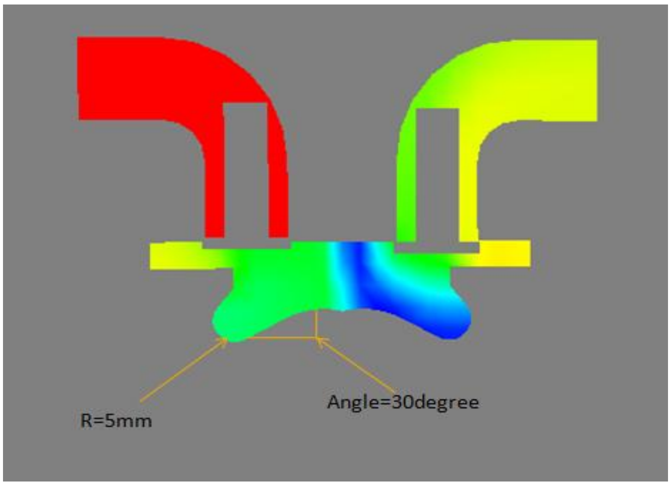

Fig 16: 30degree angle and radius of curvature 5mm

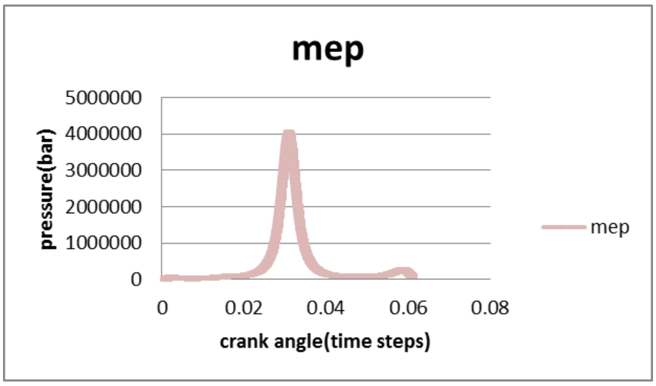

Fig. 17 MEP vs Crank angle graph

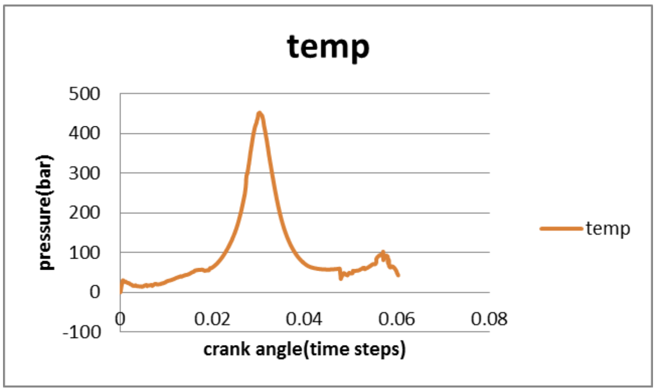

Fig. 18 temp vs crank angle graph

Fig 17 shows the mean effective pressure graph for the modified toroidal shaped piston. With increasing radius of curvature and angle of actual piston geometry, the pressure and temperature decreases with actual geometry.

Fig 18 shows the temperature variation with crank angle for modified toroidal shaped piston. Corresponding to the pressure the temp also noticeably varied. For the prescribed specifications for bowl shaped piston the mean effective pressure is around 41bar and temperature is around 445 ºc

4. CONCLUSIONS

Improvement of any internal combustion engine is determined primarily by fuel efficiency and emission necessities. This requires modification of the in-cylinder flow, mixture configuration and combustion processes. With proper modification of the intake/exhaust port, valves and piston bowl geometry the above requirements can be achieved. The use of Computational Fluid Dynamics (CFD) can to shorten the design optimization cycle time. Conventional approach of experiments using flow bench testing is very costly as well as time consuming. Were as CFD allows to analyse the process in short time and economically compared to conventional technique. Using CFD technique optimization of the system can be determined .In this project work, the internal flow characteristic in the combustion chamber of a diesel engine is investigated computationally for the different piston configurations. The overall flow field inside the combustion chamber and various quantities, such as pressure, temperature, mixing pattern for different injection pressures and swirl ratio were examined for all three types of pistons.

The summary of the comparison is as follows:

- Generation of pressure and temperature is more in flat shaped piston at the end of compression stroke when compared to bowl and Toroidal shaped piston.
- But swirl generation is better in Toroidal and bowl shaped piston when compared to flat shaped piston.
- Better swirl generation implies better mixing of air fuel ratio and hence better efficiency of engine.
- Modification in the Toroidal shaped piston, with increasing the cone angle and radius of curvature, generation of pressure and temperature is less and reduced swirl generation when compared to actual piston.
- Modification in the Toroidal shaped piston, with reducing the cone angle and radius of curvature generation of pressure and temperature is better with better swirl generation.

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