International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 04 | Apr-2018 www.irjet.net p-ISSN: 2395-0072

Numerically Analysing the Effect of EGR on Emissions of DI Diesel Engine Having Toroidal Combustion Chamber Geometry

Jibin Alex[1], Biju Cherian Abraham[2]

[1] Student, Dept. of Mechanical Engineering, M A College of Engineering, Kerala, India
[2] Assistant Professor, Dept. of Mechanical Engineering, M A College of Engineering, Kerala, India

---***---

Abstract – *Now a days diesel engines having a growing application because of their higher efficiency compared to petrol engines. Higher NOx emission , smoke emission and carbon monoxides are the major side effects of diesel engines. Introducing EGR is an effective method to reduce NOx emissions of diesel by decreasing oxygen concentration in charge. This will reduce the peak in-cylinder temperature and hence NOx emission.In the present work, it is proposed to analyse the emission of a diesel engine having toroidal combustion chamber (TCC)geometry using different percentage of EGR (10%,20%,30%.). STAR-CD is used for the simulation. It is concluded that NOx emission decreases with increasing percentage of EGR , CO emission and Soot emission are found tobe decreases with increasing percentage of EGR.*

***Key Words*: Analysis, Diesel Engine, EGR , NOx, STAR CD**

1. INTRODUCTION

In DI diesel engines the fuel is injected into the cylinder against the high pressure and temperature compressed air. In this process of combustion is heterogeneous, unsteady, and 3-Dimensional. Combustion is a chemical reaction where certain elements of hydrogen and carbon molecules are combining with oxygen and liberates heat energy[4]. Carbon monoxide, oxides of nitrogen oxides and soot are the main culprits responsible for deterioration of air quality[5].

The most effective method of reducing nitrogen oxides is introducing EGR. The use of EGR system is a trend for the upcoming diesel engines .EGR technology is highly effective in reducing the flame temperature and oxygen concentration of the working fluid inside the combustion chamber [3],so it is very effective to reduce the NOx levels. Hence in the present study, the effect of EGR on emission characteristics on direct injection diesel engine under three EGR rates of 10%, 20% and 30% was investigated. The results are then compared with baseline diesel operation, STAR-CD is used as the software tool for this analysis.

2. COMPUTATIONAL PROCEDURE

CFD simulation start with modelling the piston bowl geometry. Toroidal piston bowl geometry was done using SolidWorks 2010. The dimensions of the geometry is given in the fig: 1. The geometry is meshed by using ES_ICE (Expert Systems in IC Engine) prosurf software. Auto meshing is provided in the software for creating zero by selecting auto repair option of the CAD model. Meshed geometry is shown in fig:2.The meshing of the in-cylinder fluid domain is done using ES_ICE grid generation tool. 45º sector is taken for the analysis due to the symmetrical location of the eight-hole injector at the center of the combustion chamber. It is important to study the in-cylinder fluid dynamics during the later part of combustion and initial part of expansion strokes in DI diesel engines. Analysis is carried out from 40º before TDC (BTDC) to 80º after TDC (ATDC), as fuel injection , combustion and pollutant formations are taken place during this period[4].

The computational Grid when the piston is at Top Dead Center (TDC) is shown in fig: 3.A 3D sector mesh is modelled in ES_ICE to produce volume of combustion in the cylinder. Computational grids at 100 degree before TDC is given in fig: 4. After this, the sector grid is used as a part of STAR-CONTROLS. ECFM-3Z(Extended Coherent Flame Model-3Z)combustion model is used to characterize ignition and combustion. Also the analysis continued for applying initial conditions, boundary conditions like beginning temperature, initial pressure and cylinder crown temperature, wall temperature and so on.

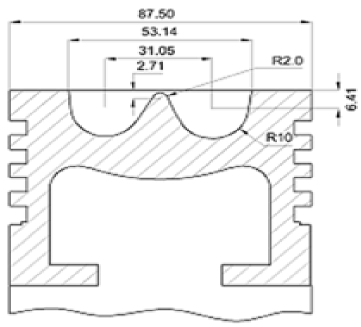

Fig -1.Dimensions of the TCC geometry

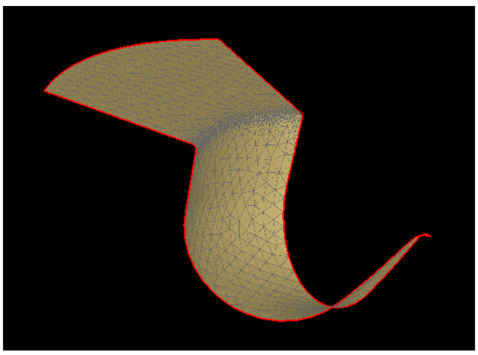

Fig -2: Surface geometry meshed in prosurf

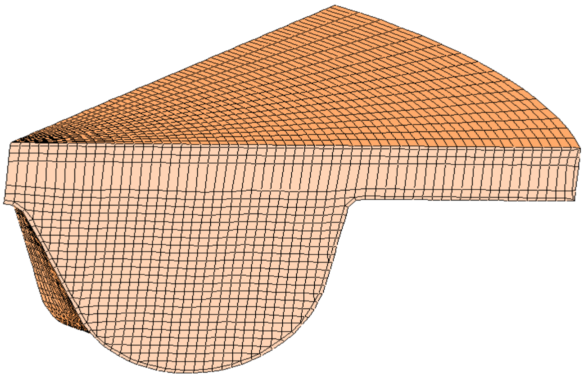

Fig -3: Computational grids at TDC

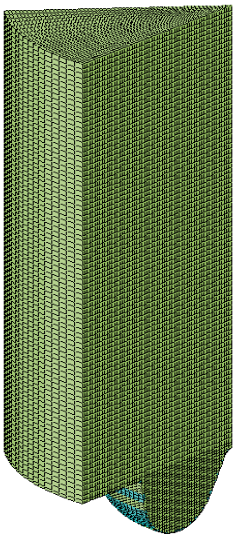

Fig -4: Computational grids at 100º before TDC

After that the analysis is further carried out in PRO-STAR for applying the atomisation model ,fuel properties and injection parameters like injection temperature, nozzle hole diameter mass flow rate of fuel etc. Simulation was started in solver after completion of PRO-STAR. After the results were obtained in ES_ICE, the analysis if repeated with different percentage of EGR ie 10%,20%,30%.

3. ENGINE PARAMETERS & DETAILS

Table -1: Engine Specifications

Engine	Kirloskar TV1
Type	Vertical diesel engine, 4 stroke, water cooled, single cylinder
Displacement	661 cc
Bore	87.5 mm
Stroke	110 mm
Compression Ratio	17.5 : 1
Connecting rod length	174 mm
Squish Clearance	5 mm
Start of injection	714.75 ºCA
End of injection	722.65 ºCA
Rate of injection	.0075Kg/Sec
Injector hole diameter	.00017m
Number of holes	8
Combustion chamber shape	Toroidal

5. RESULTS AND DISCUSSIONS

5.1 VALIDATION

A comparison between experiments and numerical simulation is presented, in order to measure the accuracy of the subsequent predictions. Fig : 5 shows the pressure Vs crank angle graph of experimental and numerical results. The numerical and experimental in-cylinder pressure are 85.5x10^5 Pa and 81.6x10^5 Pa. The peak pressure difference between experimental and computation are 4.56%.The pattern anticipated by the model is sensibly near trial comes about, in spite of the fact that there are still a few contrasts.

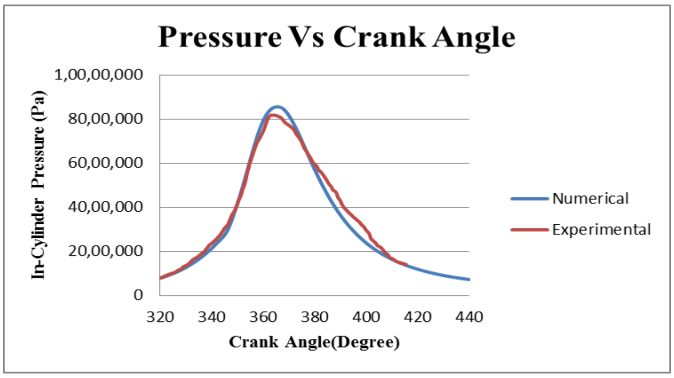

Fig.5. Validation between numerical and experimental graphs

5.2 PRESSURE

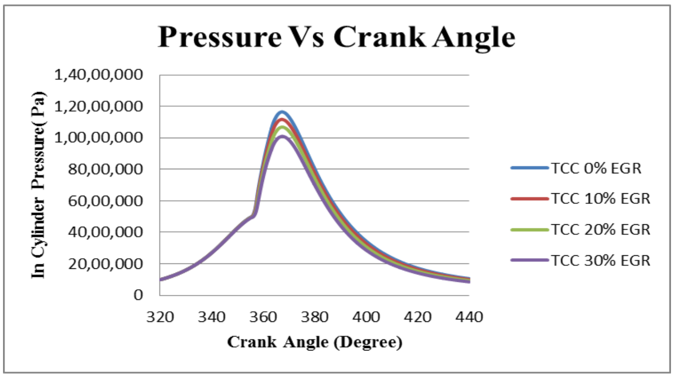

Fig.6. Cylinder pressure with respect to crank angle at different percentage of EGR

Fig :6 shows variation of in-cylinder pressure with crank angle at different percentage of EGR. The maximum pressure is obtained for 0% EGR . That is 117x10^5 Pa. There is a reduction of 14.5 % pressure for 30% EGR compared to pressure without EGR. The in-cylinder pressure decreases with increasing percentage of EGR. This is due to increase in amount exhaust gas along with air intake.

5.2 TEMPERATURE

Fig.7. shows In-cylinder temperature variations versus crank angle at different percentage of EGR. As the EGR percentage increases from 0% to 30% the in-cylinder temperature decreases. This is because of decreasing oxygen concentration in intake air. From the graph it is shows that maximum temperature is 14.3% greater than the temperature at 30% EGR.

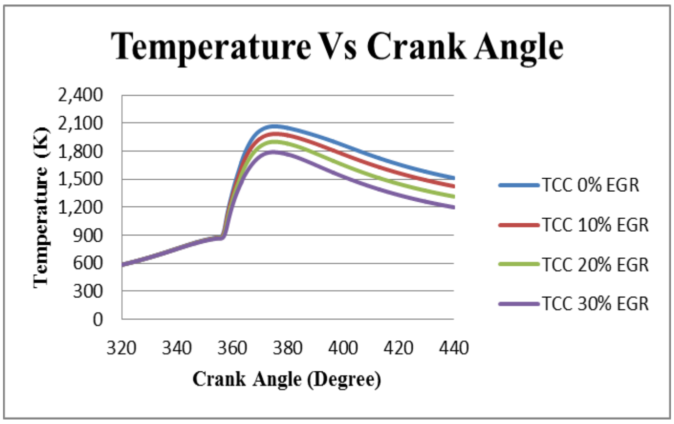

Fig.7. Cylinder temperatures with respect to crank angle at different percentage of EGR

5.3 NOx EMISSION

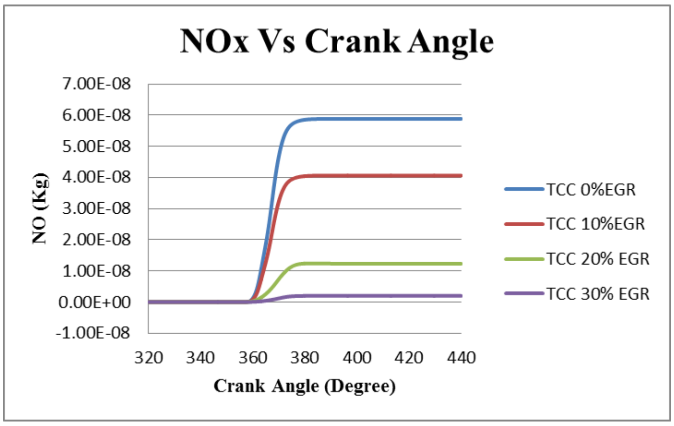

Fig.8.NOx emissions with respect to crank angle at different percentage of EGR

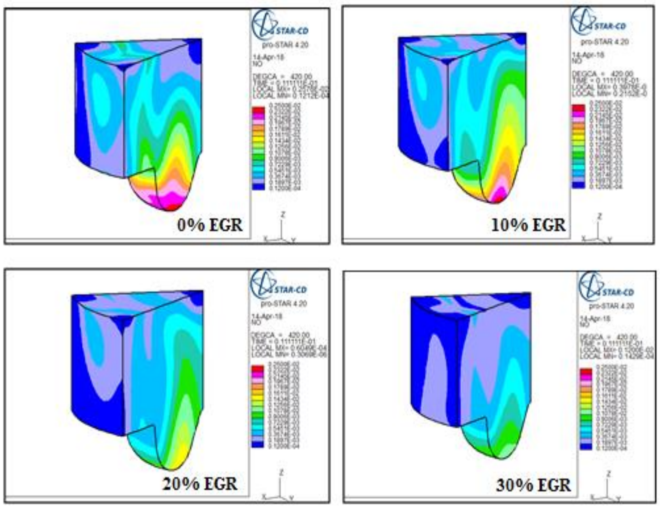

Fig.9. NOx contour at 420 degree crank angle at different percentage of EGR

NOx is formed by chain reactions involving nitrogen and oxygen in the air. These reactions are highly temperature dependent. Since diesel engines always operate with excess air, NOx emissions are mainly a function of gas temperature and residence time.[6].Introducing EGR is the most effective method to reduce NOx level. Fig:8 shows the variation of NOx with Crank Angle. It is clear that the addition of EGR along with the intake air decreases the NOx emission. Nitrogen oxides are developed at higher temperature . Increasing percentage of EGR decreases the in-cylinder temperature. There by NOx level decreases.

The level of NOx emission without EGR is about 5.88x10^{-8}. There is a reduction of about 70% NOx emission for 20% EGR and 30% of reduction for 10% EGR compared to NOx emission without EGR. It shows that there is a large variation of NOx emission while introducing EGR with the intake air and slight decrease in in-cylinder pressure. Fig : 9 shows NOx emission contour at 420 degree crank angle at different percentage of EGR. From the figure it can be see that NOx emission decreases with increasing percentage of EGR.

5.4 SOOT EMISSION

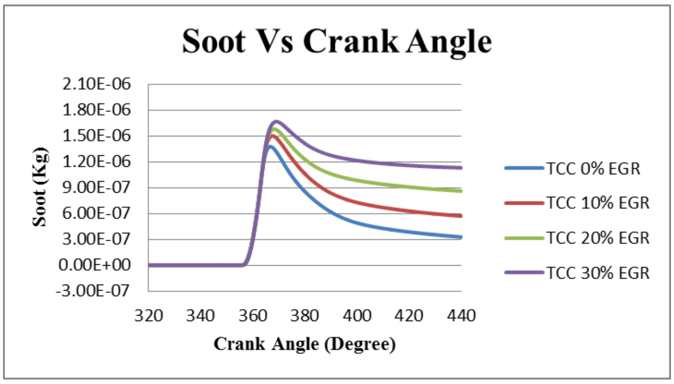

Fig.10. soot emissions at different percentage of EGR

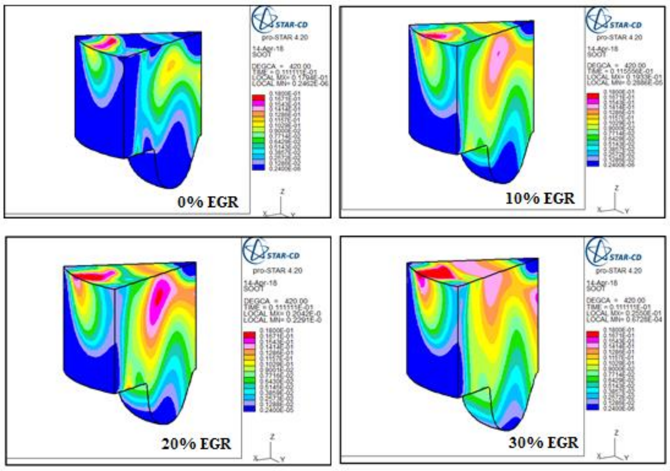

Fig.11. soot emission contour at 420 degrees for different percentage of EGR

Soot is the result of combination of soot generation and soot oxidization. And it mainly generates in local high temperature and over rich fuel zones. The formation of soot emissions can be greatly reduced by avoiding the appearance of the local high temperature zones, when local fuel over rich zones is generated due to the deteriorated combustion[2]. Variation of soot with crank angle and its contour are shown in the fig 10 and Fig : 11.. From the graph, it shows that the soot emission is increases with increasing percentage of EGR. This is because of exhaust gas consist of certain amount of soot particles, it reduces the in-cylinder temperature. The minimum soot emission is found to be 1.35×10^{-6} Kg for 0% EGR. The contour shows soot is concentrated at the top of the piston bowl geometry, because fuel concentration is high at this region.

5.5 CO EMISSION

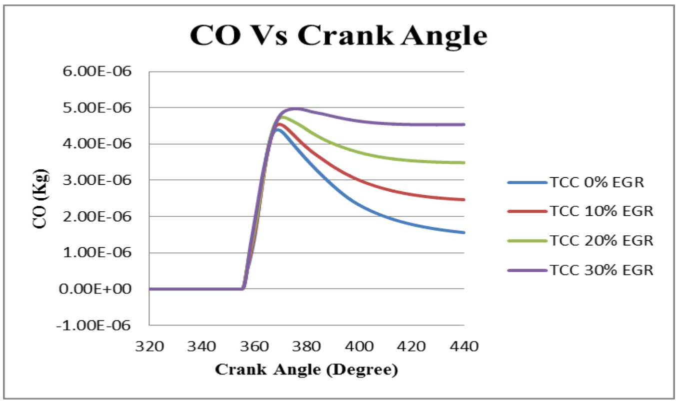

Fig.12. CO emissions at different percentage of EGR

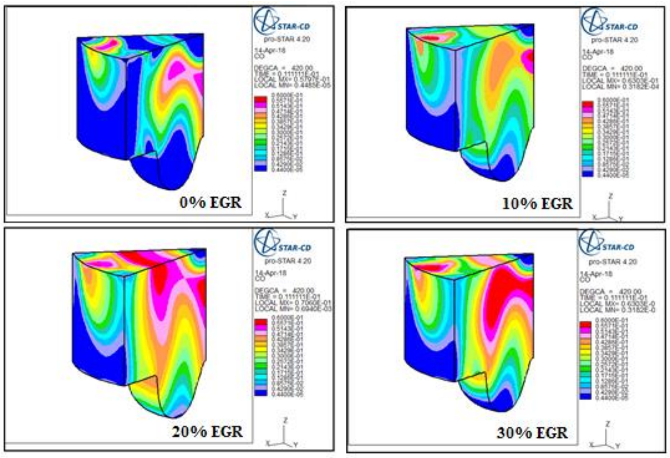

Fig.13. CO contour at 420 degrees for different percentage of EGR

Carbon monoxide results from the incomplete combustion of mixture inside the combustion chamber geometry where the oxidation process does not occur completely. Fig 12 shows the variation of carbon monoxide emission with crank angle. By increasing percentage of EGR the carbon monoxide emission increases. This is due to the lower concentration of oxygen in intake air. There is an increase of 15% of CO emission for 30% of EGR compared to CO emission without EGR. Fig: 13 shows the CO emission contours oat 420 degree crank angle.

6. CONCLUSIONS

- Analysis of emission on diesel engine having toroidal combustion chamber geometry for different percentage of EGR was completed using STAR-CD and results were obtained.
- Higher injection pressure because of improved combustion due to better air-fuel mixing in toroidal combustion chamber geometry.
- Nitrogen Oxides emission decreases with increase in percentage of EGR.
- Carbon monoxide and soot are found to be increasing with increasing concentration of EGR.

REFERENCES

[1] S. Jaichandar , K. Annamalai (2013),"Combined impact of injection pressure and combustion chamber geometry on the performance of a biodiesel fueled diesel engine"Energy.

[2] Xiaochen Shi, Bolan Liu, Zhang Chao, Hu Jingchao, Qiangqiang Zeng (2017),"A study on combined effect of high EGR rate and biodiesel on combustion and emission performance of a diesel engine" Applied Thermal Engineering.

[3] Pandian m, Sivapirakasam sp, Udayakumar m. (2010), "Investigations on emission Characteristics of the pongamia biodiesel–diesel blend fuelled twin cylinder Compression ignition direct injection engine using exhaust gas recirculation Methodology and dimethyl carbonate as additive." Journal of Renewable and Sustainable Energy.

[4] Dr.p.Manoj kumar. ,Prof .V.Pandurangadu, Dr.S.L.V.Prasad, Dr.M.Srinivasa Reddy. (2013), "Effect of injection orientation on mass-averaged temperature in a di diesel engine: through cfd simulation" International Journal of Application or Innovation in Engineering & Management.

[5] Chetan s bawankar1, rajesh gupta, (2017) " Effects of piston bowl geometry on combustion and Emission characteristics on diesel engine: a cfd case Study" Iinternational Journal of Research in Engineering and Technology.

[6] S. Prasanna RajYadav, C.G.Saravanan, M.Kannan , (2015)"Influence of injection timing on DI diesel engine characteristics fueled with waste transformer oil" Alexandria Engineering Journal.

[7] Chen, Z., Wu, Z., Liu, J., Lee, C. (2014). "Combustion and emissions characteristics of high n-butanol/diesel ratio blend in a heavy-duty diesel engine and EGR impact". Energy Conversion and Management.

[8] Lin, L, Shulin, D, Jin, X.(2000) ."Effects of combustion chamber geometry on in-cylinder air motion and performance in DI diesel engine". SAE paper 2000-01-0510.