International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 2, Issue 6, June 2014)

Effect of Nozzle Holes and Turbulent Injection on Diesel Engine Performance

Dr. Hiregoudar Yerrennagoudaru [1], Kullaya Swamy K B[2]

[1]*Professor and PG Co-ordinator (Thermal Power Engineering), Mechanical Engineering Department, RYMEC Bellary*
[2] *M.Tech (Thermal Power Engineering), Mechanical Engineering Department, RYMEC Bellary, Karnataka, India*

***Abstract* —In diesel engines the Analysis of fuel spray with various injection orientations has high influence on engine performance as well as exhaust gas emissions. The fuel injector orientation plays very important role in fuel air mixing. A single cylinder four stroke DI diesel engine with fuel injector having multi-hole nozzle injector is considered for the analysis. The geometry of the diesel fuel injection nozzle and fuel flow characteristics in the nozzle significantly affects the processes of fuel atomization, combustion and formation of pollutant emissions in a diesel engine. The objective of the research was to find the proper model to be used for fast analysis of existing nozzle geometry. Several models of the nozzle were made to increase further atomization and break down of fuel droplets into fine small molecules. The results were compared with the results of measurements at steady state conditions and fuel injection characteristics are required to deal effectively with major diesel engine design problem achieving sufficiently rapid fuel-air mixing rates to complete the fuel burning Process in the time available. In this experiment it has been investigated the effect of injector nozzle holes and models created such as fins for fuel spray on the performance of diesel engine such as fuel consumption and fuel in-engine cylinder the analysis of a swirl diesel engine research also reveals the effects of swirl in combustion chamber of a diesel engine depending on the shape, angle, and area of the jet passage, effects of the pressure, heat release HC, and CO concentrations.**

***Keywords*— Nozzle holes, Emission analysis, Swirl, Turbulence, HC and CO.**

I. Introduction

The use of Diesel engines today depends on lowering toxic components emission to the atmosphere, such as carbon monoxide (CO), nitric oxides (NO), hydrocarbons HC and particulate matter (PM) [1]. Considering the difficulties of proper control of the combustion process, some activities have been undertaken aiming at alleviating its effects that is purifying exhaust gases.

Often called 'The heart of the engine', the fuel injection system [2] is without any doubt one of the most important systems. It meters the fuel delivery according to engine requirements, it generates the high injection pressure required for fuel atomization, for air-fuel mixing and for combustion and it contributes to the fuel distribution [3] in the combustion system hence it significantly affects engine performance emissions and noise. The components of the fuel injection system require accurate design standards, proper selection of materials and high precision manufacturing processes. They lend themselves to mass production techniques and they become complex and costly. Along with the conventional pump-line nozzle [4] systems new concepts evolved such as distributor pumps, common-rail systems, accumulator systems, unit pumps, and unit injectors, etc. Combustion can be thus optimized for best performance, emissions [5], smooth operation etc., according to the needs of the application. The net result of this integration is an advanced diesel engine with high power density, very low emissions, low noise and superior drivability. Exhaust emission like HC, CO, NOx, soot are the most important, concern with the diesel engines, as a result of fuel distribution is non-uniform, and this causes the combustion mixture non-stoichiometric. Hence, the combustion process in the DI diesel engine [6] is heterogeneous in nature. It causes the increase the emissions air. Liquid fuel is injected through the nozzle by the fuel injection system into the cylinder through the end of compression stroke. The liquid jet leaving the nozzle becomes turbulent [7] and spreads out as it entrains and mixes with the in-cylinder air. The outer surface of the fuel jet breaks up into droplets. The initial mass of fuel will evaporates first thereby generating a fuel vapor-air mixture. Larger droplets provide a higher penetration but smaller droplets are requisite for quicker mixing and evaporation of the fuel. The sprayed fuel stream encounters the resistance from the dense in-cylinder fluids and breaks into a spray. Further they vaporize and mix with compressed high temperature and high pressure in-cylinder fluids. At this stage the in-cylinder fluids have above the self-ignition [8] temperature of the fuel.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online)) Volume 2, Issue 6, June 2014)

It causes the fuel to ignite spontaneously and initiate the combustion at various locations, where desired condition is prevailed. Accordingly spray interaction becomes an important phenomenon in high speed DI diesel engines. The spray impingement has a great influence on the distribution of fuel jet [9], evaporation. The fuel injection system of the diesel engine plays the dominant role on the fuel spray [10] formation, which affects the combustion and pollutant formation processes. It is well known that injector nozzle flow has a significant role on the spray, but it still not very well investigated. The major problem represents the dimension of the nozzle channel flow areas, which have a size of less then one millimeter and pressures which can exceed even 200 bars under this conditions measurements or other observations of the flow in the nozzle are very difficult. The measurements are more or less limited to the measurements of the nozzle flow coefficients at the steady state conditions or observations and measurements of the flow in the scaled-up transparent models [11].

This is why the main goal of research presented in this experiment was to find the proper simplified model of some existing multi-hole nozzle [12] that will be used for fast analysis of internal changes in order to create further atomization and turbulence in fuel spray which covers entire combustion space of diesel engine and reduce emissions [13]. Combustion and fluid flow modeling in an IC engine presents one of the most challenging problems. This is due to large density variations where, the fluid motion inside a cylinder is turbulent, unsteady, non-stationary both spatially and temporally [14]. The combustion characteristics were greatly influenced by the details of the fuel preparation and the fuel distribution in the engine cylinder, which was mainly controlled by the in-cylinder fluid dynamics. The fuel injection introduces additional complexities like two phase flows. Pollutant emissions were controlled by the turbulent fuel–air mixing and combustion processes [15].

II. Methodology

The experiment is done on existing fuel injector with minor modifications in design of nozzle. Firstly the dimensions of nozzle are measured. A model is created such that it covers the nozzle tip like a cap and provide as an obstacle for the fuel spray.

For this a hollow pipe of SS material of internal dia 6 mm and outer dia 7 mm with a thickness of 1 mm and length 26 mm and a step of 2 mm to the same model of 8 mm outer dia. 2 pieces of same dimensions are created where 1 model with 8 fins and other with 10 fins are cut up to 5 mm with a width of 0.5 mm.

The nozzles with 3, 4 and 5 holes are reduced in diameter from 8 mm to 5 mm with lathe machine and both the surfaces of nozzles and models are polished with fine emery paper and buffing for smooth finishing. Now the fuel injector is re-assembled with modified nozzle and model. The fuel pressure injecting is fixed to 210 bars and tested, the fuel injecting from nozzle is restricted by the model fins and help to reduce fuel droplets to further small particles. This helps for more proper mixing of fuel and air in combustion chamber because the particles of fuel are smaller than conventional nozzle spraying. This reduces delay in mixing of fuel and air with more turbulence because of its smaller size particles and readily burn with very less amount of unburnt fuel left to exhaust, thus this in-turn reduces the emissions caused due to incomplete combustion of diesel fuel. Varieties of nozzle and fin assemblies are tested to obtain the results.

Fig – 1. Shows Injectors with and without Fin Model.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online)) Volume 2, Issue 6, June 2014)

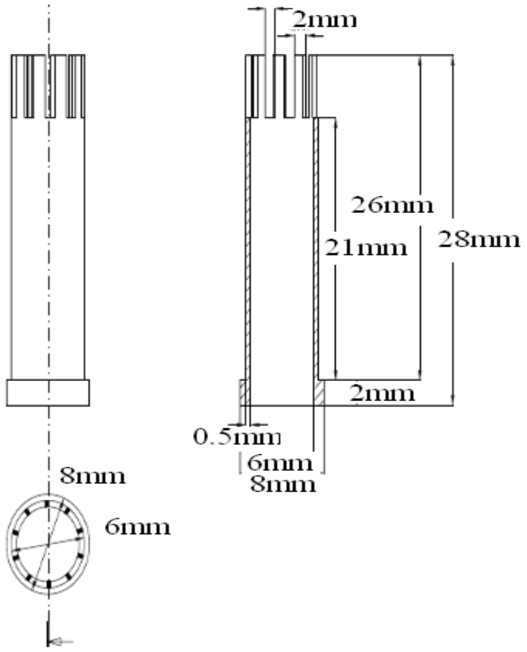

Fig - 2. Shows 2 – D Design of 8 Fins Model

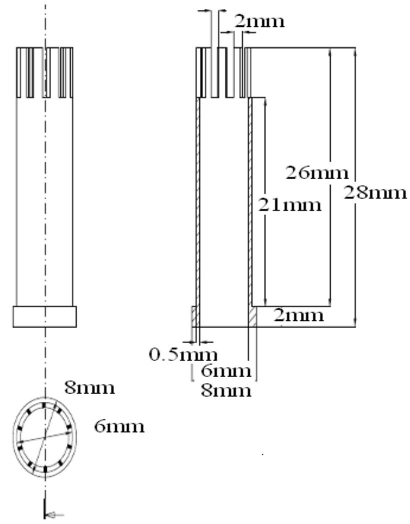

Fig - 3. Shows 2 - D Design of 10 Fins Model

Fig – 4. Shows 8 Fin Model

Fig - 5. Shows 10 fin model

III. EXPERIMENTAL SET UP

The test rig is built for loading mentioned below:

1. The equipment consists of KIRLOSKAR Diesel Engine 3.7kW capacity and is Water cooled.
2. Engine Speed and the load applied at various conditions are determined by a Digital RPM Indicator and spring balance reading.

3. A separate air box with orifice assembly is provided for regularizing and measuring the flow rate of air. The pressure difference at the orifice is measured by means of Manometer.
4. A volumetric flask with a fuel distributor is provided for measurement and directing the fuel to the engine respectively.

Further the pattern of fuel spray is recorded externally by using water jet pump and recorded by varying 3, 4 and 5 holes nozzles with 8 and 10 fins models.

Fig – 6. Shows Diesel Engine Experimental Set Up

IV. Results And Discussion

a. HC Comparisons:-

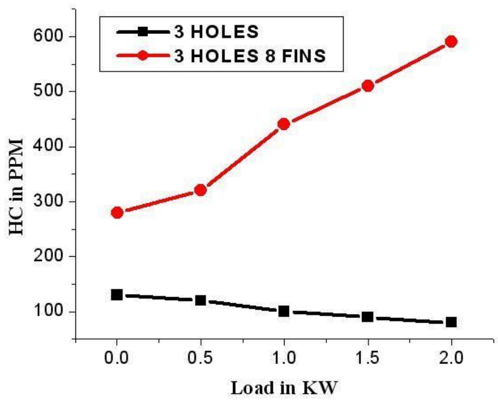

Fig -7. Shows HC Comparison for 3 Holes verses 3 Holes with 8 Fins

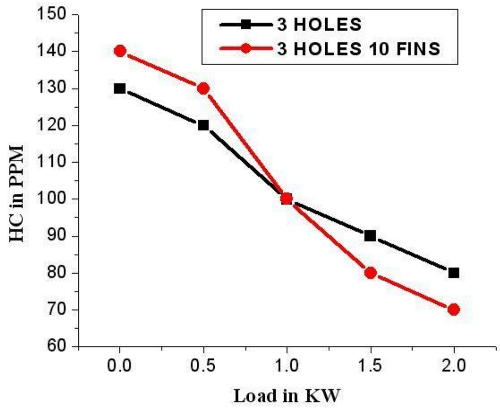

Fig – 8. Shows HC Comparison for 3 Holes verses 3 Holes with 10 Fins

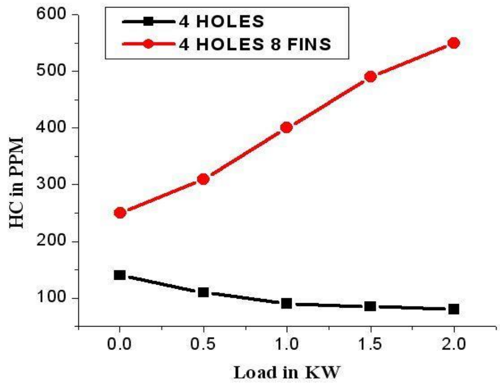

Fig - 9. Shows HC Comparison for 4 Holes verses 4 Holes with 8 Fins

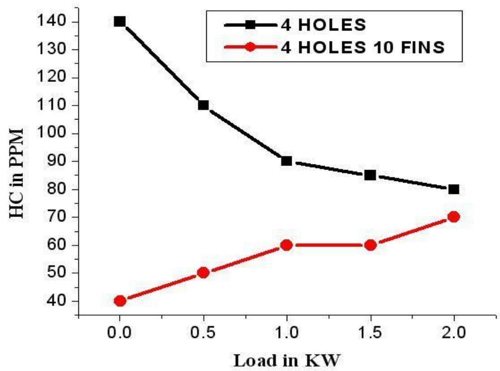

Fig – 10. Shows HC Comparison for 4 Holes verses 4 Holes with 10 Fins

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online)) Volume 2, Issue 6, June 2014)

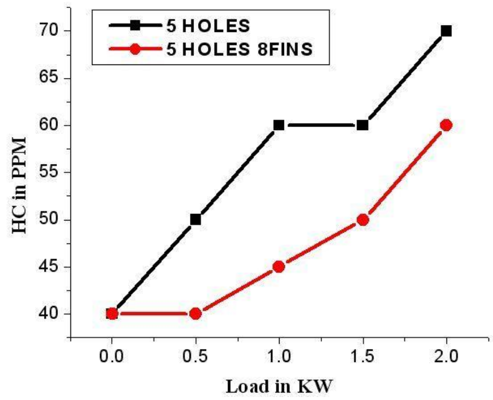

Fig – 11. Shows HC Comparison for 5 Holes verses 5 Holes with 8 Fins

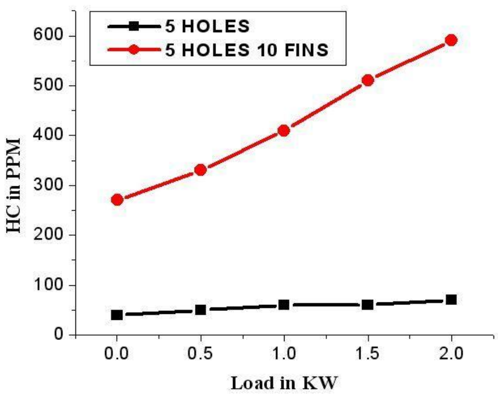

Fig -12. Shows HC Comparison for 5 Holes verses 5 Holes with 10 Fins

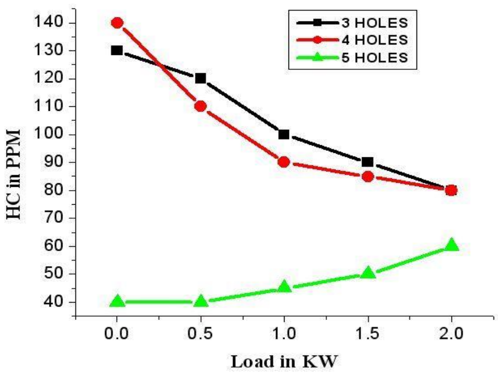

Fig - 13. Shows HC Comparison for 3, 4 & 5 Holes

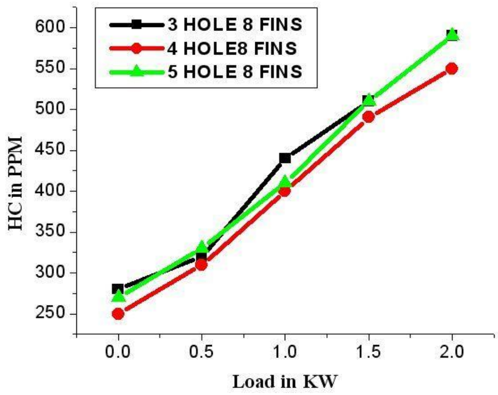

Fig – 14. Shows HC Comparison for 3, 4 and 5 Holes with 8 Fins

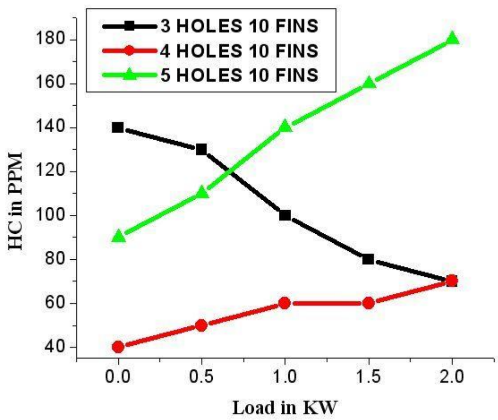

Fig – 15. Shows HC Comparison for 3, 4 and 5 Holes with 10 Fins

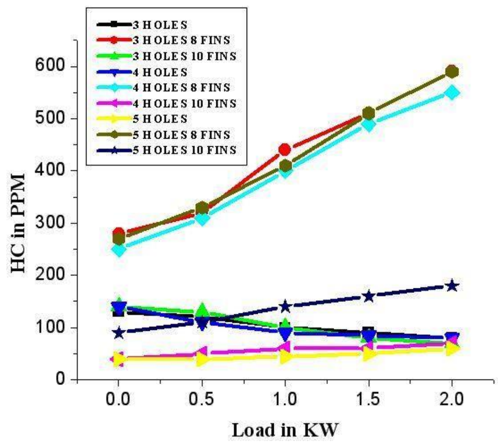

Fig – 16. Shows HC Comparison in all type models

b. CO Comparison :-

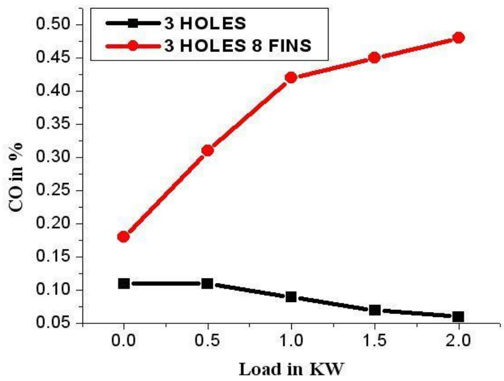

Fig – 17. Shows CO Comparison for 3 Holes verses 3 Holes with 8 Fins

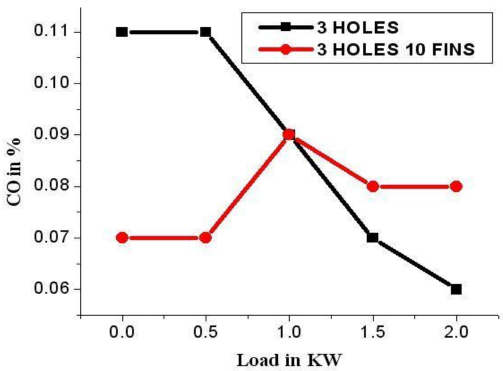

Fig – 18. CO Comparison for 3 Holes verses 3 Holes with 10 Fins

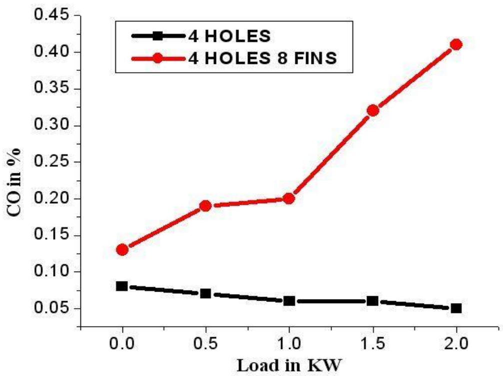

Fig -19. CO Comparison for 4 Holes verses 4 Holes with 8 Fins

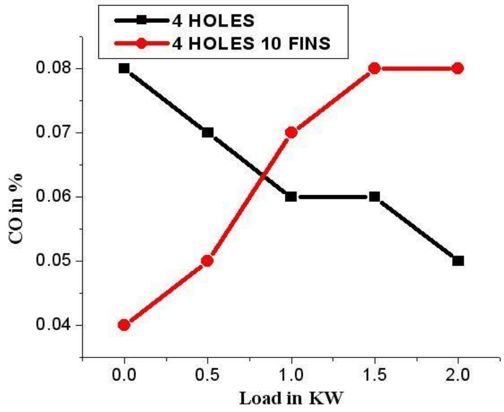

Fig – 20. CO Comparison for 4 Holes verses 4 Holes with 10 Fins

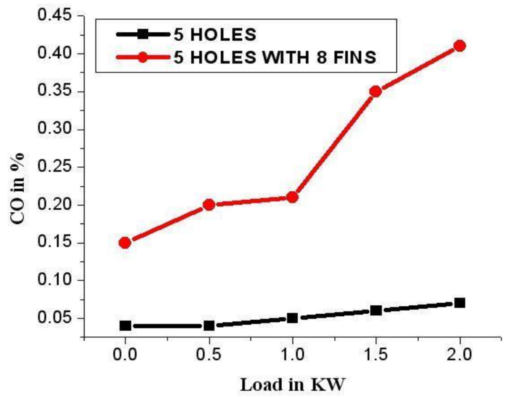

Fig – 21. CO Comparison for 5 Holes verses 5 Holes with 8 Fins

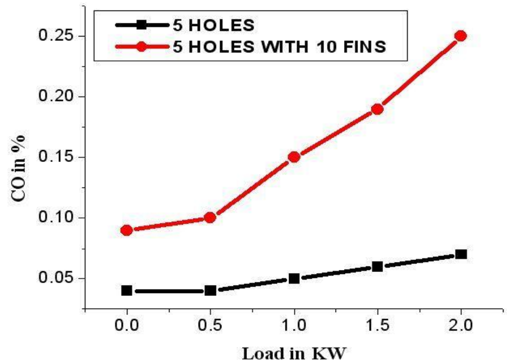

Fig – 22. CO Comparison for 5 Holes verses 5 Holes with 10 Fins

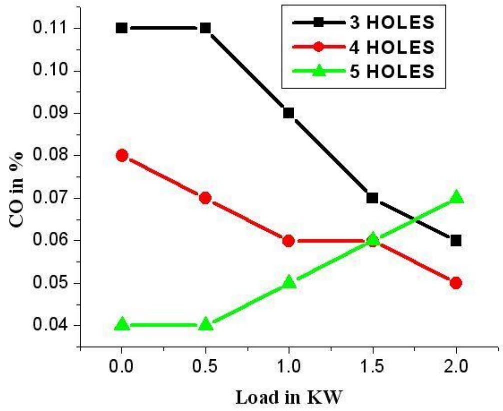

Fig – 23. CO Comparison for 3, 4 and 5 Holes

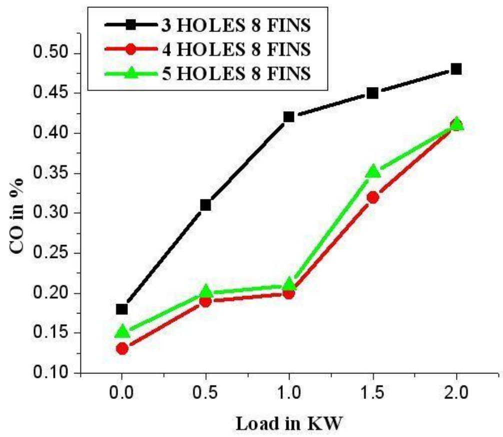

Fig – 24. CO Comparisons for 3, 4 & 5 Holes with 8 Fins

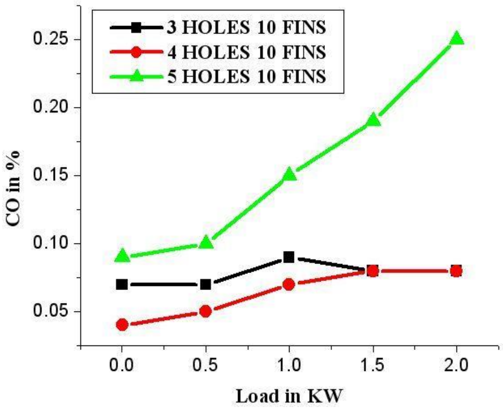

Fig – 25. CO Comparison for 3, 4 and 5 Holes with 10 Fins

c. Break Specific fuel verses Break Mean Effective Pressure

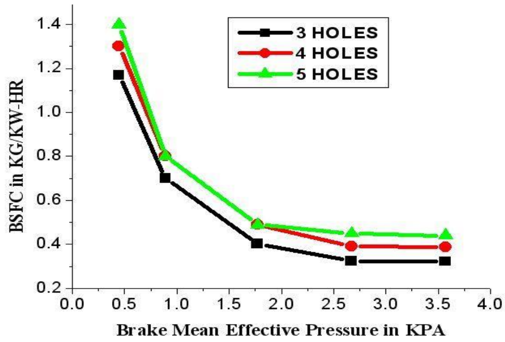

Fig – 26. BSFC verses BMEP Comparison 3, 4 and 5 Holes

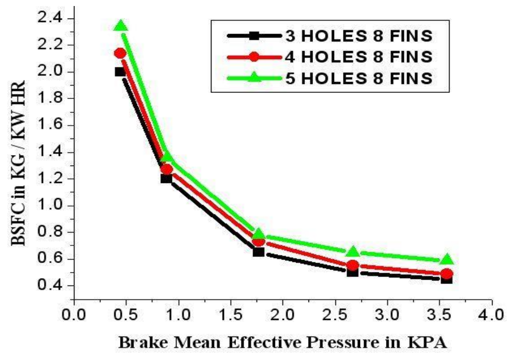

Fig – 27. BSFC verses BMEP Comparison 3, 4 and 5 Holes with 8 Fins

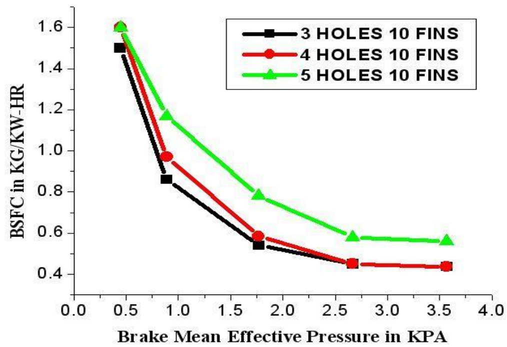

Fig – 28. BSFC verses BMEP Comparison for 3, 4 and 5 Holes with 10 Fins

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online)) Volume 2, Issue 6, June 2014)

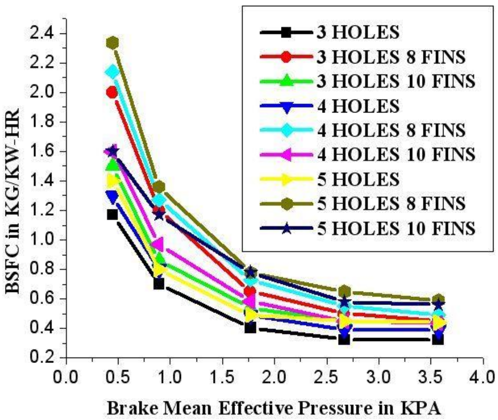

Fig – 29. Shows BSFC Comparison in all Models

d. Brake Thermal Efficiency verses Break Mean Effective Pressure:-

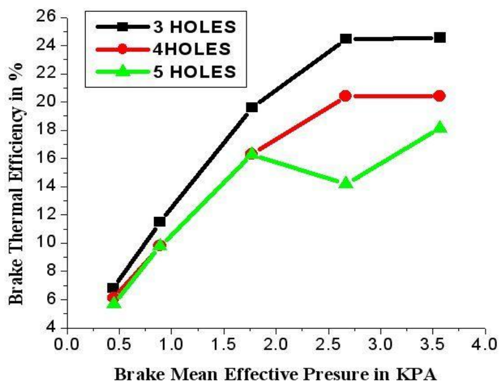

Fig – 30. Brake Thermal Efficiency verses BMEP Comparison 3, 4 & 5 Holes

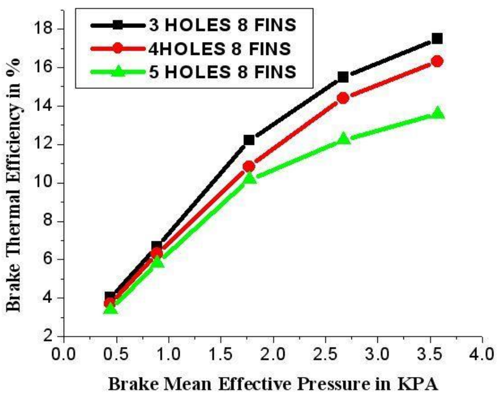

Fig – 31. Brake Thermal Efficiency verses BMEP Comparison 3, 4 & 5 Holes with 8 Fins

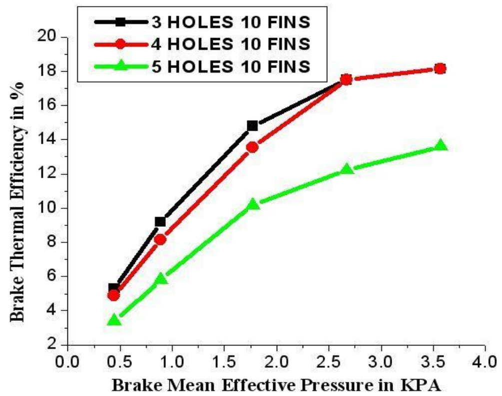

Fig -32. Brake Thermal Efficiency verses BMEP Comparison 3, 4 and 5 Holes with 10 Fins

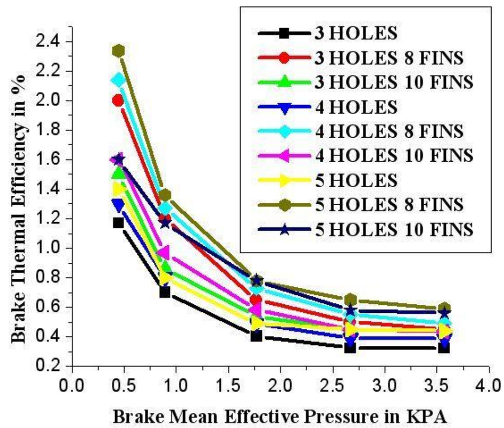

Fig – 33. Shows Brake Thermal Efficiency Comparison in all Models

- All the nozzles have examined and the results shown that in 3, 4 and 5 holed nozzles the 5 holes nozzle gives the reduced HC emissions when compared to 3 and 4 holes nozzles.
- In 3, 4 and 5 holes nozzles with 10 fins 4 holes with 10 fins gives the best reduced HC emissions. Also BSFC and Brake Thermal Efficiency are good.
- In 3, 4 and 5 holes nozzles with 8 fins it was found that the emissions are high when compared to conventional nozzle. It has been seen that the fins created for fuel spray in 10 fin model has given good result when compared with 8 fins. When seen externally.
- This is because the fuel sprayed through nozzle hole is falling on the fins such that it makes the fuel droplets collide and join to form bigger droplets
- Further it is noted in 10 fins that the fuel droplets collide with fin and escape between the gaps of fin to fin area.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online)) Volume 2, Issue 6, June 2014)

- Also the arrangement of holes in a nozzle should be equally spaced and orientation should be properly placed to increase the efficiency and reduce emissions.
- If we look in 5 holed nozzles it is observed that the alignment of holes is not uniform, as a result of this the spray of fuel is restricted more so that the fuel droplets formed and sprayed in combustion chamber is confined to a smaller area. Due to this the emissions are slightly more than 4 holes nozzle with 10 fins.

e. Water Testing photos:-

Fig – 34. 3 Holes

Fig – 35. 3 Holes with 8 Fins

Fig – 36. 3 Holes with 10 Fins

Fig – 37. 4 Holes

Fig – 38. 4 Holes with 8 Fins

Fig -39. 4 Holes with 10 Fins

Fig -40. 5 Holes

Fig – 41. 5 Holes with 8 Fins

Fig – 42. 5 Holes with 10 Fins

V. CONCLUSION

- It is observed that 4 holes 10 fins nozzle design is given good result when compared to other designs in emission reduction, Better BSFC and Brake Thermal Efficiency and even fine spray can be seen in photo.
- It may be suggested that by increasing the number of fins we may achieve better results than 10 fins, as the break down of fuel to fine droplets is more with increased fins and easy escape due to reduced width of fin to fin gap.

REFERENCES

[1] Kato, M., Kano, H., Date, K., Oya, T. and Niizuma, K. (1997). Flow Analysis in Nozzle Hole in Consideration of Cavitation. *SAE* Paper 970052.

[2] Heseding, M. and Daskalopoulos, P. (2006). Exhaust Emission Legislation-Diesel- and Gas Engines, VDMA, Frankfurt am Main.

[3] J.B. Heywood, “Internal Combustion Engine Fundamentals”,McGraw-Hill Book Co, pp 493-494, 1988.

[4] D. Ing. H. Tschöke, “Diesel distributor fuel-injection pumps”, Robert Bosch GmbH, pp 12-53, 1999.

[5] B. Challen R. Baranescu, “Diesel Engine Reference Book” Reed Educational and Professional Publishing Ltd., Second Edition, pp.260-301, 1999.

[6] M. Volmajer, B. Kegl, “Experimental and numerical analysis of fuel flow in the diesel engine injection nozzle" , Journal of Kones. Combustion Engines, Vol. 8, No. 1-2, 2001.

[7] Z. Li, M. Kokkolaras, D. Jung, Panos Y. Papalambros and D. N. Assanis, “An Optimization Study of Manufacturing Variation Effects on Diesel Injector Design with Emphasis on Emissions”, SAE International, 2004.

[8] A.J.Von Wielligh, “Influence of fuel quality on diesel injector failures”, Fifth International Colloquium Fuels, Germany, 2005.

[9] R.D Reitz,. and F.V Bracco,. (1979): “On the dependence of Spray Angle and Other Spray Parameters on Nozzle Design and Operating Conditions”, SAE paper 790494,.

[10] T. Yoda, T. Tsuda, Inflence of Injection Nozzle Improvement on DI Diesel Engine, SAE paper 970356

[11] Y.Oishi et.al., A computational Study into the Effect of the Injection Nozzle Inclintion Angle on the Flow Characteristics in Nozzle Holes, SAE paper920580

[12] Arcoumanis C. et al., Investigation of Cavitation in a Vertical Multi-Hole Injector, SP-1415, p.181-198, SAE, Warrendale, 1999

[13] C.Arcoumanis et. al., Analysis of the Flow in the Nozzle of a Vertical Multi Hole Diesel Engine Injector, SAE paper 980811

[14] M.Kato et al., Flow Analysis in Nozzle Hole in Consideration of Cavitation, SAE 970052

[15] K.Melcher, I.Komaroff, Experimentelle Utersuchung der Stroemung durch Dieseleinspritzduesen in stationaer betriebenen Grossmodel, Bosch Techn. Berichte 5 (1976)