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A REVIEW ON C.I ENGINE COMBUSTION CHAMBER GEOMETRY AND OPTIMIZATION

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Abstract

The fuel consumption in the world is increasing at alarming rate as well as fossil fuels prices are increasing day by day and they will deplete within few decades. Hence the use of biofuel is a key factor to enhance both food and bio-energy production. The piston bowl geometry, nozzle position and spray behavior plays a predominant role in the engine performance operated with biodiesel. The most important role of Compression Ignition (CI) engine combustion chamber is to enhance the fuel-air mixing rate (swirl) in short possible time. The turbulence can be guide by the shape of the combustion chamber hence there is a Necessity to study the combustion chamber geometry in detail. The engine design with re-entrant cavity with central pip Produces longer spray volumes, wider spray spreading and also introducing bottom comer radius helps to disperse the fuel. Re-entrant combustion chamber (TRCC) gives better fuel economy, lower hydrocarbons (HC),smoke, carbon monoxide (CO),greater brake thermal efficiency (BTE) and maximum cylinder pressure it I attributed to higher in turbulence, swirl, hotter surface of the re-entrant chamber and availability of oxygen with biodiesel. The double dish combustion Chamber and chamber with the bump ring increases the kinetic energy, air-fuel mixing rate than that of conventional combustion chamber.

1. INTRODUCTION

Due to increase in usage of diesel-fuelled vehicles has brought attention to environmental pollution, hence rapid depletion of fossil fuels, and increase in fuel demand and cost of the fuel. The biofuel technology is very important factor to enhance both food and bio-energy production and increase the output without bad effect on economic and environmental implications. One of the main goals of developing the biofuels sector is sustainability. The sustainability driver is based on the three pillars of economic, social and environmental sustainability. It is better for the environment because it is made from, renewable resources and has lower emissions compared to petroleum diesel. It is less toxic than table salt and biodegrades as fast as sugar. It can be made in India from renewable resources such as Jatropha and Pongamia. Its use decreases our dependence on foreign oil and contributes to our own economy. Dr. Rudolf diesel invented the diesel engine and he stated that “The diesel engine can be fed with vegetable oils and would help considerably in the development of agriculture of the countries which use it. “In 1912, Diesel said, “The use of vegetable oils for engine fuels may seem insignificant today. But such oils may become predominant in the future. His idea on agriculture and his invention provides the foundation for a society with clean, renewable and very economical to the country. The adoption of biodiesel (biodiesel +diesel) blends is very promising since proper blends can be used to have better combustion and lower emissions than diesel fuel alone. Due to better lubricity of biodiesel it can be used as a good lubricant. Biodiesel can be used as a direct substitute for diesel, or in a blend with diesel. Several technical improvements on both fuels and engines are still required, which might lead to slightly higher costs of operating a diesel engine with biodiesels but there is better improvement in engine performance and reduction in emissions .The fuel consumption and Petroleum prices in the world approaching record highs and they will deplete within few decades, it is noticed that utilization of domestic non-edible oils will enhance our energy security and create the self-employment. And biofuel technology will support the agriculture sector, tremendous employment opportunities in plantation and processing. Biodiesel can be mixed with petroleum based diesel in any proportion. Because Bio-diesel is the renewable energy, biodegradable, nontoxic, it’s potential to reduce exhaust emissions and energy efficient that can be directly used in any existing, unmodified diesel engine. It is fact that rather than importing other countries’ ancient natural resources, we can use our own living resources to power our development and we can reduce global warming. Instead of looking to the country’s petroleum products our own fuels from non-edible will save foreign exchange and reduce energy expenditures and allow developing countries to put more of their resources into health, education and other services

For their neediest citizens. Adopting this Bio-fuel technology will create new markets for agricultural products, by-products and helps for rural development because bio-fuels are generated from crops; they have enormous potential for farmers. Various investigations of spray and combustion technology have been conducted by many research scholars in order to decrease harmful emissions, such as unburnt hydrocarbons (UBHC), carbon monoxide (CO), nitrogen oxide (NO x) and particulate matter from diesel engines. Fuel injection strategies- spray angle, timing, multiple injections, and injector location, including engine modification of a diesel engine have a tremendous impact on the engine performance, combustion and emission characteristics. Therefore, many researchers have conducted experimental and numerical investigations of combustion and exhaust emission characteristics by altering the injection parameters and combustion chamber geometry. A lot of experimental investigations on the performance of biodiesel fuelled engine have been carried out without modification to the diesel engine. These studies have reported that the use of biodiesel blends and neat biodiesel in diesel engine decreases carbon monoxide, unburnt hydrocarbons However increases in NO x emission levels [13]. The idea behind this modification of combustion chamber geometry will provide a powerful squish along with the air movement, similar to that of the familiar smoke ring, within the toroid chamber. Due to powerful squish the mask needed on inlet valve is small and there is better utilization of oxygen.

2. MATERIALS AND METHODOLOGY

The role of air motion in diesel engines is well recognized for the purpose of fuel air mixing which is central to the engine combustion and emission characteristics. From the vast literature that exists in this area, the present discussion is studied that effect of different combustion chamber geometries on diesel engine operated with biodiesel.

2.1 Optimization of Combustion Chamber Geometry

2.1.1Optimization of combustion chamber geometry by using Simulation (Numerical) Technique

Arturo de Resi et al. (2003) [1] in their study, process of optimization of combustion chamber is done by Genetic Algorithm; five configurations were selected and compared with the baseline case. Configurations A, B and C improved the overall engine emission. Configurations C and D where found to reduce only NO x and Soot emissions, respectively. They have suggested that better result could be obtained by exploiting different injection strategies or changing other engine control parameters. On the other hand, by focusing the investigation on geometrical features only, one can put in evidence the influence of combustion chamber geometry on engine performance.

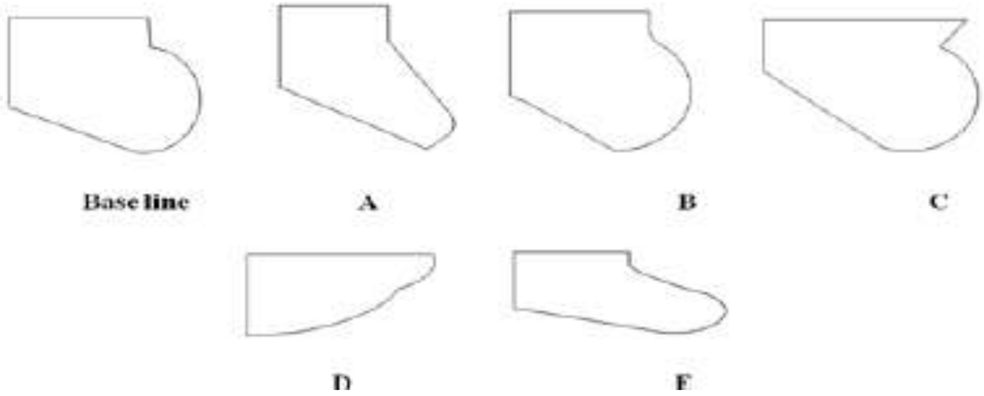

Fig.1. Combustion chamber geometries (Arturo de Resi et al. 2003).

F. Payri et al. (2004) [2] carried out study with five different piston bowls geometries and results are validated with CFD (Computational Fluid Dynamics). They determined that in cylindrical and re-entrant combustion chambers squish–swirl interaction generates two symmetric toroid vortices while in open bowl geometries; there is a clear non-symmetry of the flow field with only one non-cantered toroid vortex. It may be deduced from this that combustion chambers of large bowl diameter maintain some memory of the non-symmetrical flow generated by the intake. The bowl diameter plays an important role in the structure of the flow only around TDC. They suggested that the CFD represents an efficient design tool to develop less polluting and more efficient direct-injection Diesel engines.

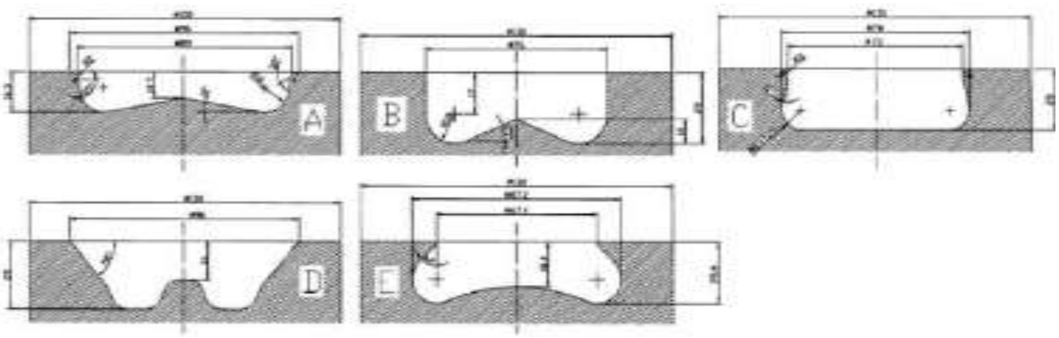

Fig .2. Geometry of the combustion chambers. (F. Payri et al. 2004).

Jinou Song et al. (2008) [3] determined the three-dimensional flow calculations of the in cylinder flow for a DI diesel engine with different combustion chambers. The study investigated the influences of the combustion chamber shape on the flow field near the TDC and CFD calculations of the compression stroke were performed for seven different piston bowl geometries. It is found that the squish and swirl flow plays a significant role in the turbulence generation process near the top dead centre (TDC) during compression. The coupling among the swirl, squish, bowl shape and turbulence is much more pronounced in the combustion chambers.

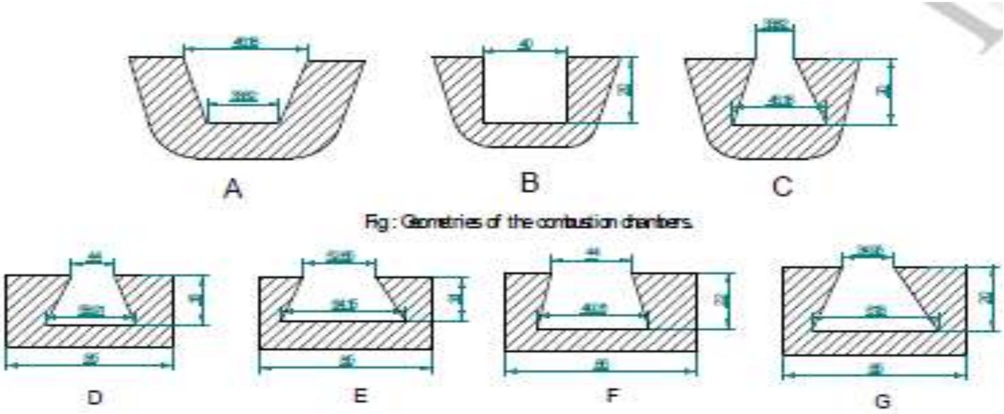

Fig.3. Geometries of the simplified combustion chambers (Jinou Song et al. 2008).

Mingfa Yao et al. (2009) [4] reported that in order to understand the underlying mechanism of emission reduction, STAR-CD code based on multidimensional combustion modelling study was carried out for a heavy-duty diesel engine with a BUMP combustion chamber and a conventional one without the bump ring. The chamber with bump ring shows high kinetic energy, high turbulence energy and enhancing mixing rate than that of conventional combustion chamber. The bowl with BUMP has a more homogeneous concentration. There is reduction in soot formation and shows optimal range of fuel/air equivalence ratio. It also shows the reduction of NOx.

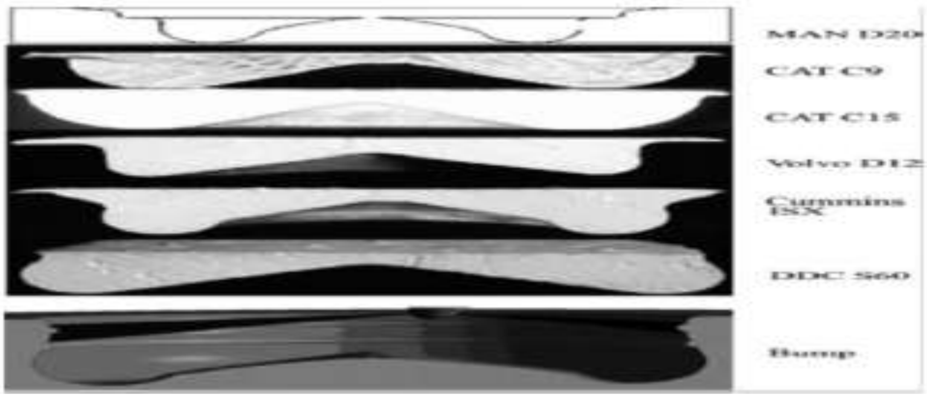

Fig.4. Combustion geometries used by advanced heavy-duty diesel engine in the World (Mingfa Yao etal. 2009).

Su Han Park et al. (2010) [5] carried out the study to analyse the exhaust emissions of DME fuel through experimental and numerical analyses of in-cylinder spray behavior. To investigate this behavior, spray characteristics such as the spray tip penetration, spray cone angle, and spray targeting point were studied in a re-entrant cylinder shape under real combustion chamber conditions. The combustion performance and exhaust emissions of the DME-fuelled diesel engine were calculated using KIVA-3V. The numerical results were validated with experimental results from a DME direct injection compression ignition engine with a single cylinder.

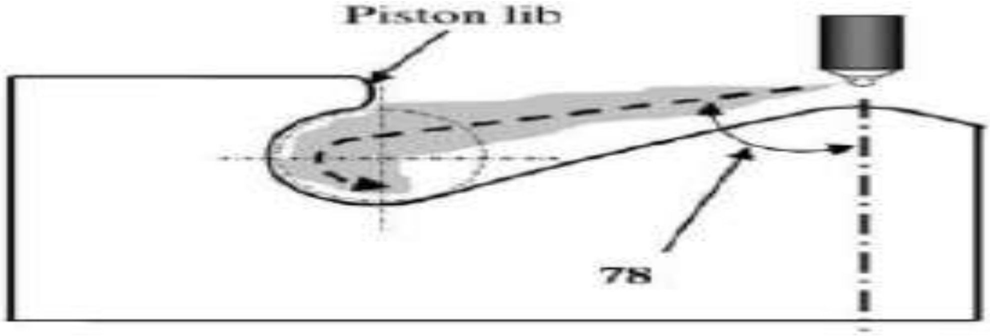

Fig.5. Piston shape of a re-entrant type (Su han Park et al. 2010).

Hyung Jun Kim et al. (2011) [6] the narrow spray angle and advanced injection timing for homogeneous charge compression ignition (HCCI) have significance in combustion of dimethyl ether (DME) fuelled diesel engine. The bowl shape of the piston head was modified to apply the narrow spray angle and advanced injection timing. The spray, combustion and emission characteristics in a DME HCCI engine were determined by using numerical KIVA-3 V code coupled with the detailed chemical kinetic model of DME oxidation. Model validation was conducted by a comparison of experimental results for the accurate prediction. The injection timing ranging from BTDC 80° to BTDC 10° and two fuel masses were selected to evaluate the combustion, emission and engine performance. The calculated results were in good accordance with the experimental results of the combustion and emissions of the engine.

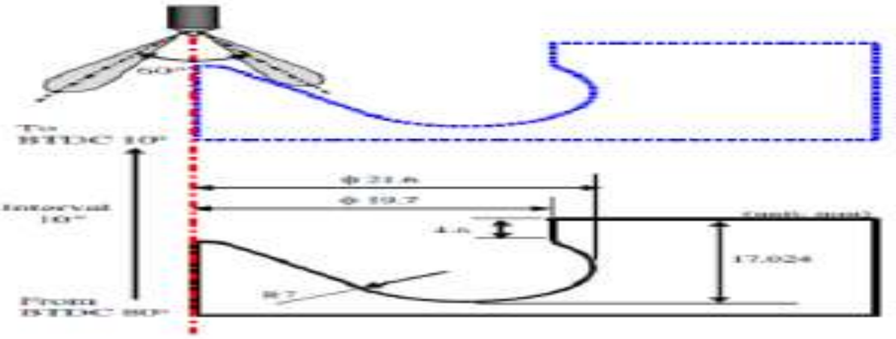

Fig.6. Specification of piston shape, injection angle and timing (Hyung Jun Kim et al.2011).

Seungmok Choi et al. (2011) [7] investigated the effects of in-cylinder EGR stratification on combustion and emission

Characteristics in a single cylinder direct injection diesel engine by using CFD. The EGR stratification pattern is improved using a 2-step bowl piston and an offset chamfer at the tangential intake port. When high EGR gas is supplied to the left (tangential) port, a high EGR region is formed at the central upper region of the combustion chamber. The EGR concentration of the high EGR region is increased in the 2-step piston by preventing a squish flow during the compression that mixes the upper gas of the higher EGR and the lower gas of the lower EGR.

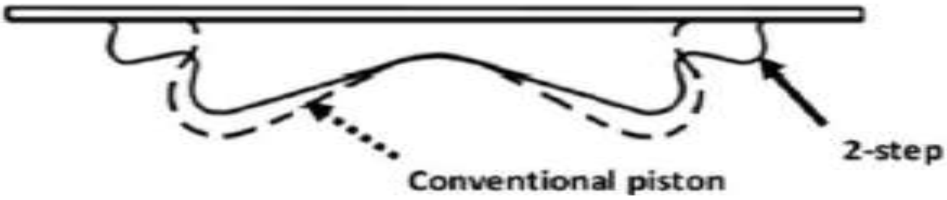

Fig.7. Enhancement of the degree of EGR stratification by a 2-step piston (Seungmok Choiet al.2011).

R.V. Ravi krishna et al. (2011) [8] studied the detailed three-dimensional CFD simulations involving flow and combustion chemistry are used to study the effect of swirl induced by re-entrant piston bowl geometries on pollutant emissions from a single-cylinder diesel engine. In-cylinder air motion was then studied in a number of combustion chamber geometries, and a geometry which produced the highest in-cylinder swirl and Turbulence Kinetic Energy (TKE) was identified. A no of simulations and emission predictions procedures are carried out and optimized that this reentrant piston bowl geometry has good combustion. Most studies in the literature concerning re-entrant chambers and injection characteristics have been conducted either on motored engines, or on large, fired engines. There are very few studies on the effect of combustion chamber geometry in medium and small engines.

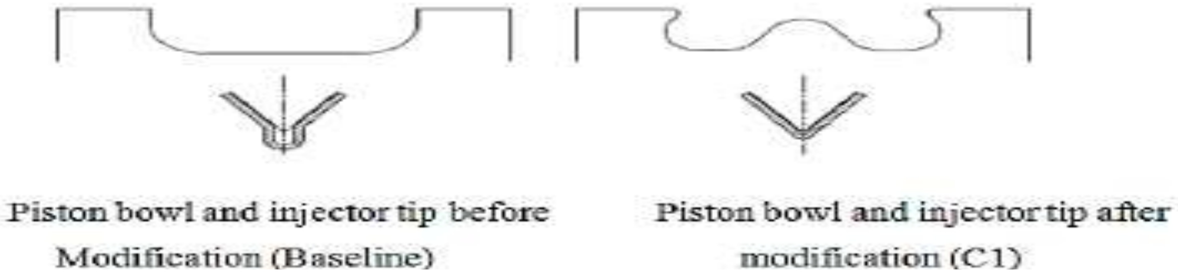

Fig.8. Modifications to the baseline engine (R. V. Ravikrisna et al. 2011).

Venkitachalam Ganesan et al. (2012) [9] determined that the piston configuration plays a very crucial role. Four configurations viz., flat, inclined, center bowl and inclined offset bowl pistons have been studied with numerical analysis by STAR-CD CFD software. Experimental results available in the literature for comparison are obtained by PIV measurements. The study concluded that a center bowl on flat piston is found to be the best from the point of view of tumble ratio, swirl, turbulent kinetic energy, turbulent intensity and turbulent length scale which play very important role in imparting proper air-fuel mixing and motion, thereby increasing the combustion efficiency of the engine, hence engine performance is increased.

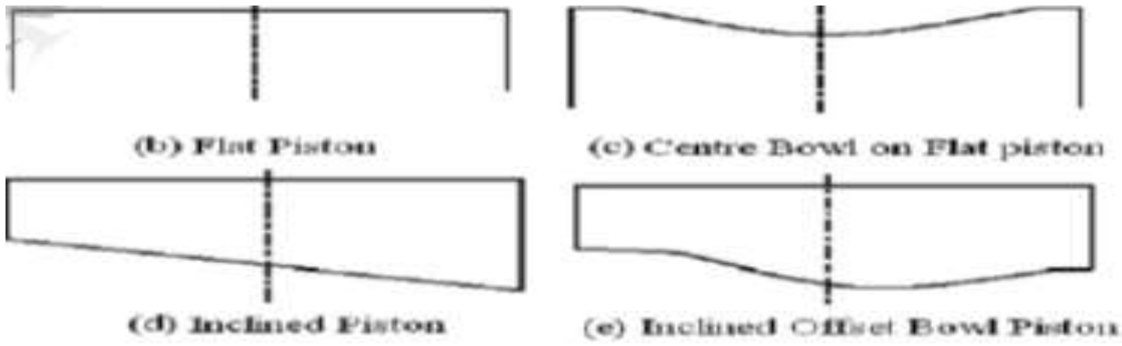

Fig.9.Various piston configurations (Venkitachalam Ganesan et al. 2012).

Sungwook Park (2012) [10] in his study, optimizations of engine operating conditions and combustion chamber geometry were performed on conventional diesel and DME engines using a micro-genetic algorithm. There were five optimization variables related to the combustion chamber geometry and six for engine operating conditions. Finally, the optimized design converges to design F, wherein simultaneous reductions of emissions, such as soot, NOx, CO, and HC, occurred with some sacrifice in fuel consumption. The optimized bowl shape of the DME engine had a deeper cup, compared to that of the optimized diesel engine. As a result of the optimization process for DME engines, NOx, CO, and HC emissions were reduced dramatically without sacrificing fuel consumption.

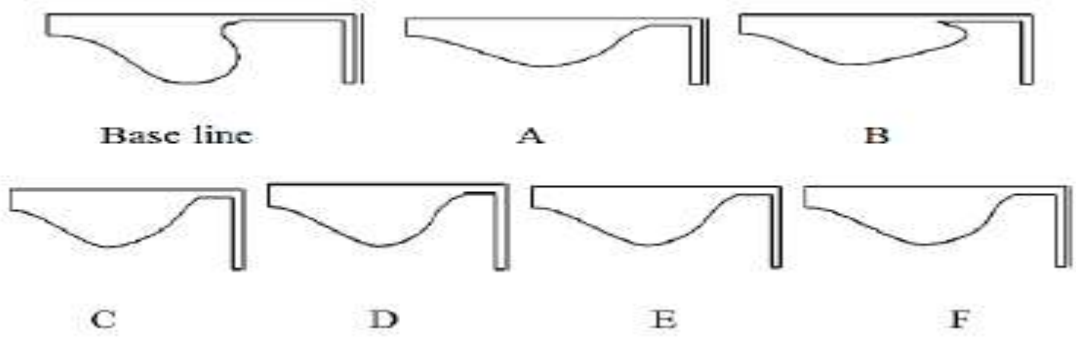

Fig.10. Designs for diesel engines combustion chamber geometries (Sungwook Park 2012).

2.1.2. Optimization of Combustion Chamber Geometry by Using Experimental Method

John .B Heywood (1988) [11] reported that swirl is usually defined as organized rotation of the charge about the cylinder axis. In engine designs with bowl-in-piston combustion chambers, the rotational motion sets up during intake is substantially modified during compression. Use of a bowl-in-piston combustion chamber (Fig. 11) results in substantial swirl amplification at the end of the compression process.

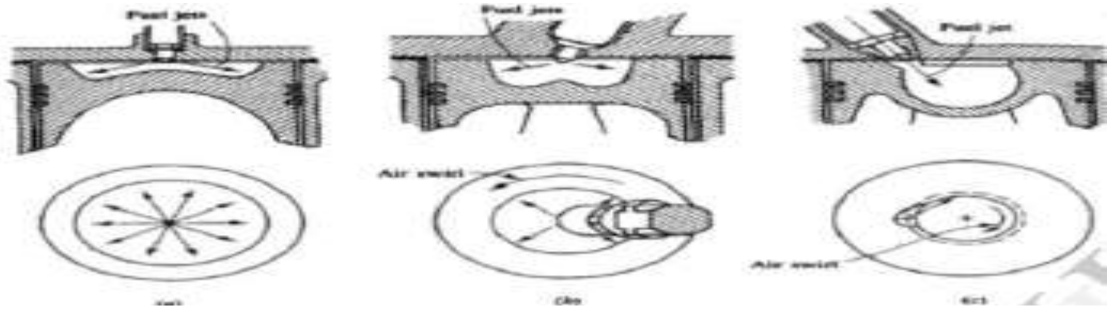

Fig.11. Common types of direct-injection compression ignition or diesel engine combustion systems (John-B Heywood, 1988)
a) Quiescent chamber with multi hole nozzle typical of larger engines
b) Bowl-in-piston chamber with swirl and multi hole nozzle
c) Bowl-in-piston chamber with swirl and single hole nozzle

Since air swirl is used to increase the fuel air mixing rate, one would expect the overall duration of the combustion process to shorten as swirl increases and emissions that depend on the local fuel/air equivalence ratio to be dependent on swirl level. Particulate and CO emissions decrease as swirl increases due to more rapid fuel-air mixing. NO, emissions increase with increasing swirl. Various types of bowl in- piston design for multi hole fuel nozzle DI engines are shown in Fig.12.

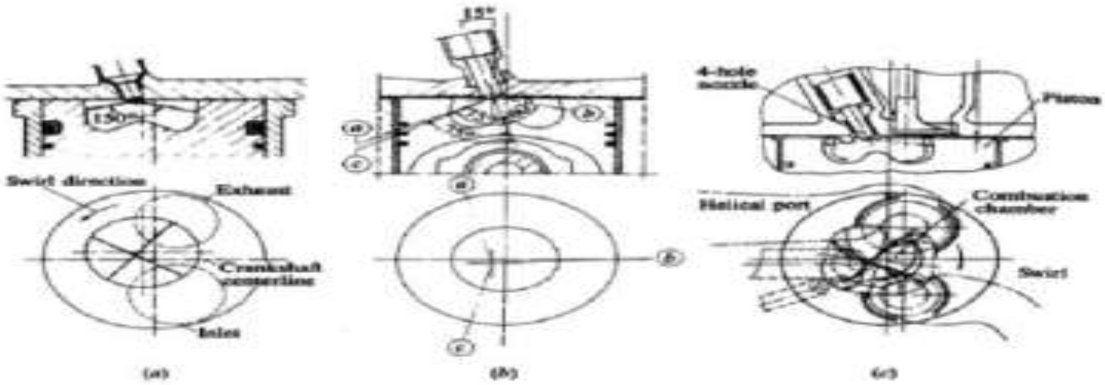

Fig.12.Various bowl-in-piston chamber designs for DI diesel engines with swirl:
(a) Conventional straight sided bowl: 7
(b) re-entrantbowlp5
(c) Square re-entrant bowl. (John .B Heywood 1988).

An alternative design with a re-entrant bowl (Fig. 12) is sometimes used to promote more rapid fuel air mixing within the bowl. The squish-swirl interaction with highly re-entrant bowl designs differs markedly from the interaction in non-reentrant bowls. Re-entrant chambers generally produce higher swirl at the end of compression, and maintain a high swirl level further into the expansion stroke. Re-entrant chambers usually achieve lower HC and smoke emissions and slightly lower bsfc. Especially at retarded injection timings.Hiromi Kondoh et al. (1994) [12] investigated the combustion characteristics of engines for marine use, tests conducted on various combinations of fuel nozzles and piston bowls using single-cylinder diesel engine with a cylinder bore of 165 mm. The effect of individual factors on NOx and Smoke were confirmed by changing engine speed and brake torque. It provided information on the difference in combustion characteristics depending on the piston bowl shape.

Fig.13. Comparison of combustion chamber shapes (Hiromi Kondohet al.1994).

Table.1. shows number of holes and diameter of the nozzle.

Name	A	B	C	D	E
Nozzle diameter in mm	0.36	0.34	0.34	0.32	0.30
Number of nozzle holes	6	6	8	8	8

The combustion chambers SD l, SD2, and SD3 are of a shallow dish type and the R is of a re-entrant type. Combustion characteristics such as NOx and smoke density have been evaluated combining five kinds of fuel nozzles from A through E shown in Table 1 and four kinds of combustion chambers. It has been recognized anew that the retardation of fuel injection timing is particularly effective for reducing NOx 13 sharply.

S. Jaichandar et al. (2012) [13] carried out the Experiments using a blend of 20% Pongamia Oil Methyl Ester (POME) by volume in ULSD (B20), in a single cylinder Direct Injection (DI) diesel engine equipped with pistons having Hemispherical and Toroidal Re-entrant Combustion Chamber (TRCC) geometries. The test result showed an improvement in BTE, a reduction in BSFC for TRCC compared to baseline engine operated with ULSD mainly due to better charge mixing. There is significant reduction in CO, UBHC and smoke intensity in modified engine. Increased swirl and squish of modified engine improves air fuel mixing which results in proper combustion and increases the combustion efficiency. The improved air motion and better mixing in re-entrant combustion chambers further decreases ignition delay and higher in exhaust gas temperature when compared to open combustion chambers. TRRC with B20 has shown maximum peak pressure, wall temperature and maximum heat release rate compared to baseline engine.

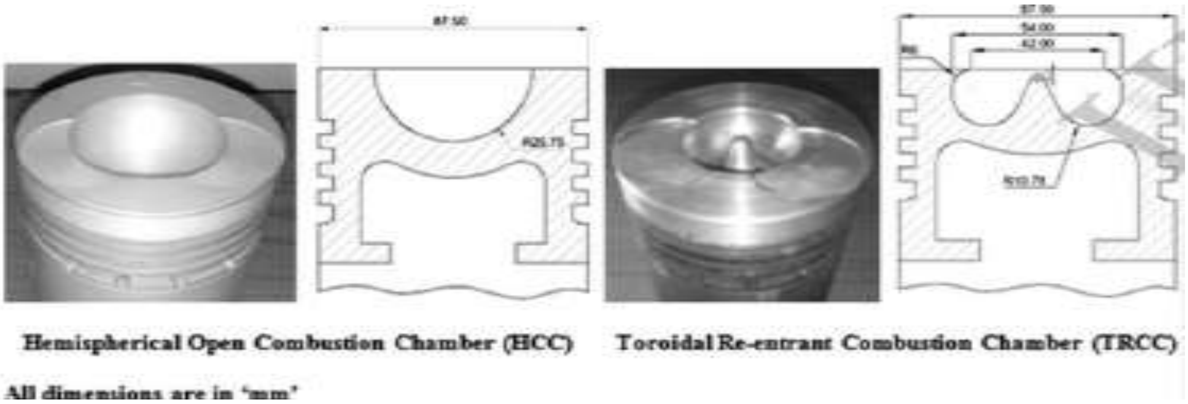

Fig.14. Photographic and sectional view of different combustion chambers employed (S.Jaichandaret al.2012).

S. Jaichandar et al. (2012) [14] investigated the influences of the pistons such as Toroidal Reentrant Combustion Chamber (TRCC) and Shallow Depth Re-entrant Combustion Chamber(SRCC) having the same volume as that of the baseline Hemispherical open Combustion Chamber were tested in a four stroke, single cylinder, DI diesel engine. The test results showed that substantially BTE and lower IN BSFC for TRCC compared to standard engine fuelled with 20% POME. There is reduction in particulates; CO and UBHC were observed for TRCC compared to the other two chambers due to improved air motion in TRCC. TRCC gives maximum in cylinder pressure compared to SRCC and TRCC

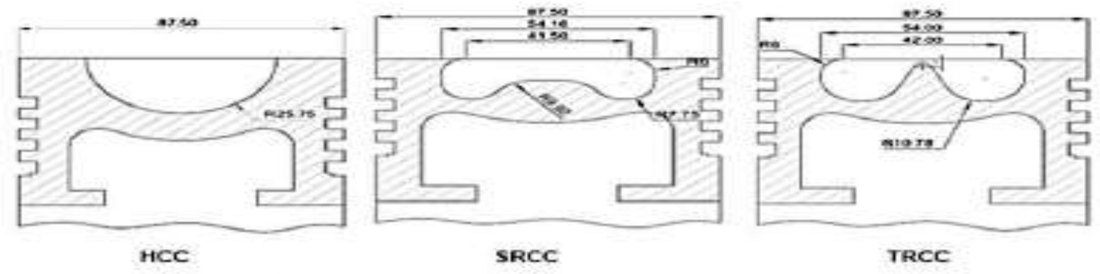

Fig.15. Schematic diagram of different open combustion chambers employed (S. Jaichandar et al. 2012).

S. Jaichandar et al. (2012) [15] investigated the effect of varying the combustion chamber structure on the performance of a DI diesel engine using biodiesel in terms of brake specific fuel consumption, brake thermal efficiency, exhaust emissions characteristics using various types of combustion chambers namely Hemispherical combustion chamber (HCC), Toroid combustion chamber (TCC) and Shallow depth combustion chamber (SCC) without altering the compression ratio of the engine. The test results reveal that brake thermal efficiency for toroid combustion chambers higher than for the other two types of combustion chambers. There is improvement reduction in particulates, carbon monoxide and unburnt hydrocarbons is observed for toroid combustion chamber compared to the other two chambers, but increase in the brake thermal efficiency and lowers the specific fuel consumption compared to SCC and HCC.

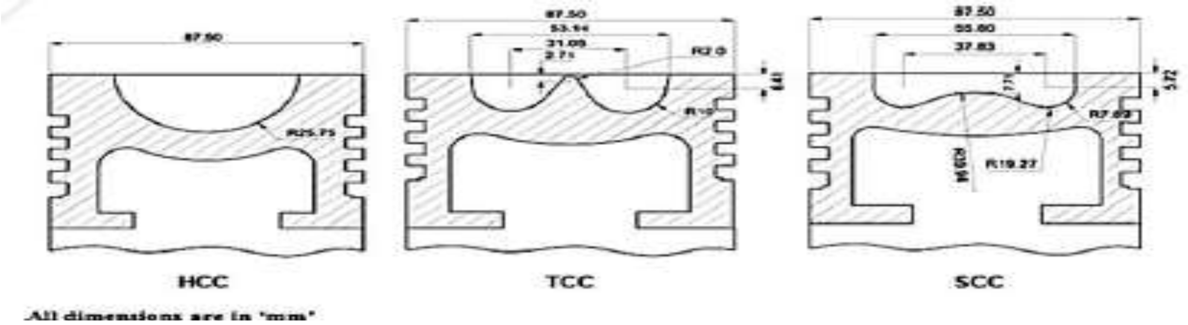

Fig.16. Schematic diagram of different open combustion chambers employed (S. Jaichandar et al. 2012).

3. RESULTS AND DISCUSSIONS

In this we reviewed the effect of swirl on engine performance combustion and emission characteristics of various combustion chambers by experimental and numerical method. The combustion chambers namely hemispherical (HCC), shallow depth (SRRC), cylindrical (CCC), trapezoidal (TCC), and toroid re-entrant combustion chamber (TRCC) shapes, double combustion system (DCS), chamber bump ring different bowl structures .**Arturo de Resi et al:** Configurations A, B and E improved the overall engine emissions for all the tested modes. Configurations C and D where found to reduce only NOX and soot emissions, respectively. To reduce NO x emissions the combustion chamber should be narrow and deep with a shallow re-entrance and a low protuberance on the cylinder axis while the spray should be oriented towards the bowl entrance. For re-entrant piston E has more turbulence and high squish.

Jino song: For piston C cross section averaged swirl ratios versus dist. Z increases due to the reduction of cross section diameter of bowl. The cross section-averaged swirl ratio piston B is not constant although it has constant diameter of cross section. During the compression process, the gas moves to the bottom of the bowl from the entry, so the gas in the downstream section has lower angular momentum than in the upstream section. This leads to a slight reduction of the cross section-averaged swirl ratio from the entry to the bottom of the bowl piston B. similarly to pistons C and B, the axial distributions of the swirl ratio for piston A is highly dependent on the diameters of cross sections and the gas angular momentum at the cross sections. This is more evident for piston C which has a stronger squish and therefore stronger toroid vortices due to the re-entrant geometry of the bowl. The squish, swirl, bowl shape and turbulence are much more pronounced in the combustion chambers.

Mingfa Yao: Design of combustion chamber geometry and utilization of energy of spray wall impingement has more significant on the engine performance. STAR-CD code [229] based on multi-dimensional combustion modelling study was carried out for a heavy-duty diesel engine with a BUMP combustion chamber and a conventional one without the bump ring [228]. The numerical results reveals that the chamber with the bump ring the air motion induced by fuel injection impinges on the wall and then is partially bent over, forming a vortex, under the disturbance of the bump ring. With the other air stream sweeping along the chamber wall, the two air flows stir the combustion chamber with different scales, increasing the turbulence kinetic energy, enhancing mixing rate and increases the wall temperature. In addition, the results also indicate that the high kinetic energy zone in the combustion chamber with the bump ring occupies a larger space and possesses a higher level of turbulence energy than that of conventional combustion chambers, due to wider space with strong mixing rate. Which implies that the bowl with a bump has a more homogeneous concentration distribution and vortex is formed hence it reduces soot formation and reduction in NOx for the bumped bowl.

Su Han Park: In the re-entrained piston shape, the spray targeting point affected the DME spray behavior in the combustion chamber. The results indicate that an increased equivalence ratio reduced NOx emissions due to the low combustion temperature which resulted from insufficient oxygen content, but caused a small increase in CO and HC emissions. However, with re-entrant shape of piston will reduce HC and CO emissions by controlling the injection timing to between BTDC 20° and BTDC 30°. Therefore, considering the spray targeting and high equivalence ratio, exhaust emissions such as NOx, soot, HC, and CO were simultaneously.

Seungmok Choi: A 2-step piston and an offset chamfer at the tangential port were adapted to the single cylinder engine to enhance the degree of EGR stratification and to improve the distribution of EGR stratification. When a high EGR gas is supplied to the tangential port (LS-EGR), a high EGR region is formed at the central upper area of the combustion chamber. Consequently, combustion is initiated in the low EGR region, and NO x tends to increase slightly while PM is reduced by 30%. Therefore, combustion is initiated in the high EGR region, and NO x is reduced by 6 % while PM increases slightly. Proper in-cylinder swirl with RSEGR maximized the effect of the stratified EGR and had positive effects on NO x, PM, CO and THC emissions, achieving simultaneous reductions in NO x (7%) and PM (23%).

R.V.Ravikrisna: they studied the detailed three-dimensional CFD simulations involving flow and combustion chemistry are used to study the effect of swirl induced by re-entrant piston bowl geometries on pollutant emissions from a single cylinder diesel engine. In-cylinder air motion was then studied in a number of combustion chamber geometries, and a geometry which produced the highest in-cylinder swirl and Turbulence Kinetic Energy (TKE) around the top dead center (TDC). The optimal nature of this re-entrant piston bowl geometry is confirmed by detailed combustion simulations and emission predictions. Increased surface area, presence of a large central projection and insufficient re-reentrancy were identified as the reasons for the modified geometry yielding poor results. Combustion simulations revealed that the reduction in emissions observed during experiments is mainly due to the change in the injector rather than change in the piston bowl geometry, thus indicating scope for optimization of bowl geometry. A highly re-entrant piston bowl and without a central projection was found to be the best for swirl and TKE intensification around TDC.

Sungwook Park: studied the, optimizations of engine operating conditions and combustion chamber geometries were performed for conventional diesel and DME engines using a micro-genetic algorithm. There were five optimization variables related to the combustion chamber geometry and six for engine operating conditions. The optimized bowl shape of the DME engine had a deeper cup, compared to that of the optimized diesel engine. As a result of the optimization process for DME engines, NO x, CO, and HC emissions were reduced dramatically without sacrificing fuel consumption.

3.1. Optimization of Combustion Chamber Geometry by Using Experimental Method

John .B Heywood: reported that use of a bowlin- piston combustion chamber results in substantial swirl amplification at the end of the compression process. Since air swirl is used to increase the fuel air mixing rate, one would expect the overall duration of the combustion process to shorten as swirl increases. Particulate and CO emissions decrease as swirl increases due to more rapid fuel air mixing. NO, emissions increase with increasing swirl. An alternative design with a re-entrant bowl is sometimes used to promote more rapid fuel-air mixing within the bowl. The squish-swirl interaction with highly re-entrant bowl designs differs markedly from the interaction in non-re-entrant bowls. Reentrant chambers generally produce higher swirl at the end of compression, and maintain a high swirl level further into the expansion stroke. Re-entrant chambers usually achieve lower HC and smoke emissions and slightly lower BSFC, especially at retarded injection timings.

Hiromi Kondoh: Shallow dish type combustion chambers have also shown characteristics equal to those of the combustion Chamber R when they have been combined with appropriate fuel nozzles. It has been recognized anew that the retardation of fuel injection timing is particularly effective for reducing NOx 13 sharply. The effect of individual factors on NOx and Smoke were confirmed by changing engine speed and brake torque. It provided information on the difference in combustion characteristics depending on the piston bowl shape.

S. Jaichandar: However better results were obtained from engine having re-entrant combustion chambers mainly due to better air movement and charge mixing. It was also observed that there is a significant reduction in CO, UBHC and smoke intensity, ignition delay in modified engine due to better mixture formation and combustion. However CO, UBHC and smoke intensity in modified engine marginally increases with retarded injection timing due to poor initial phase of combustion. The increased swirl and squish of modified engine improves charge mixing which results in better combustion and increases the combustion chamber temperature. This further increases NOx emission of modified engine. However TRCC with B20 has shown maximum peak pressure and maximum heat release rate compared to baseline engine operated with TRCC. Biodiesel B20 obtained from Pongamia oil is quite suitable as an alternative to modified engine, particularly the engine with Toroidal reentrant type combustion chamber operated with marginally retarded injection timing (21 bTDC) improves the performance, combustion and emission characteristics due to better mixing and improved combustion.

S. Jaichandar: The improved air motion in TRCC due to its geometry improves the mixture formation which increases brake thermal efficiency substantially and lowers the specific fuel consumption compared to SRCC and HCC. Due to higher oxygen content in the POME and better combustion as a result of improved mixture formation, the emissions of CO, UBHC and smoke were lower for TRCC than other types of combustion chamber. Due to higher combustion chamber wall temperature, availability of oxygen with POME and improved mixture formation due to better air motion, the ignition delay for TRCC is found to be lesser compared to SRCC and HCC. Better combustion due to better air fuel mixing in TRCC gives maximum in cylinder pressure compared to SRCC and TRCC.

S. Jaichandar: The improved air motion in TCC due to its geometry improves the mixture formation of 20% POME with air hence increases BTE and lowers the BSFC compared to SCC and HCC. Due to higher oxygen content in the POME and better combustion as a result of improved charge mixture formation, there is reduction in emissions of CO, UBHC and smoke for TCC than other types of combustion chamber. Due to higher combustion chamber wall temperature, availability of oxygen with POME and improved mixture formation due to better air motion, the ignition delay for TCC was found to be lesser compared to SCC and HCC which attributed to better combustion due to better air fuel mixing in TCC, gives maximum peak pressure compared to SCC and HCC with 20% POME. The study reveals that performance, emission and combustion characteristics of biodiesel from Pongamia oil can be improved by suitably designing the combustion chamber. However, it should be noted that the obtained results are valid for the tested engine for different piston bowl shapes equipped Pongamia biodiesel.

4. CONCLUSION

- Better results could be obtained by exploiting different injection strategies and combustion chamber geometry on the engine performance.
- The swirl, squish, bowl structure and turbulence are pronouncing more effect on the flow fields in the combustion.
- The piston bowl geometry, piston and spray characteristics play a predominant role in the combustion process and which have significant effect on engine performance, combustion and emission characteristics operated with biodiesel.
- A highly re-entrant piston bowl is the best for swirl and the turbulent kinetic energy (TKE) intensification at the compression stroke.
- The improved air motion in TRCC cause proper air-fuel mixing hence increases the brake thermal efficiency and reduction in the specific fuel consumption compare to SRRC and conventional pistons.
- TRCC operated with biodiesel will give better performance and lower in emissions but NOX slightly increased due to higher combustion chamber wall temperature and availability of oxygen with biodiesel.
- Re-entrant piston has higher peak pressure and lesser ignition delay, reduction in HC, CO, soot which is attributed to improved air mixing, higher temperature in chamber, and minimum heat losses on operating with methyl ester.
- The chamber with bump ring the air stream sweeping along the chamber wall hence increasing the turbulence, kinetic energy and enhancing charge mixing rate than baseline combustion chamber.
- There is improvement in air motion in Toroidal combustion chamber (TCC) cause the increase in BTE and reduction in brake specific fuel consumption (BSFC) compare to shallow depth (SCC) and hemispherical (HCC).
- Double swirl combustion system (DSCS) is made of two dish smaller in the middle of the bigger one. It forms double swirl this is attributed to the collision of fuel jets on the ridges of the DSCS hence increases the combustion rate and combustion efficiency.
- Overall, optimization of combustion chamber geometry and spray parameters is the key factor for better fuel economy, better performance and reduced pollutant emissions operated with biodiesel.
- Improving overall efficiency improvement and better lower emissions.

REFERENCES

1. Arturo de Risi, Teresa Donate0 and DomenicoLaforgia. “Optimization of the combustion chamber of direct injection diesel engines”, Society of Automotive Engineers, 2003-01-1064.
2. F. Payri , J. Benajes, X. Margot, A. Gil, “CFD modeling of the in-cylinder flow in direct injection Diesel engines”, Computers & Fluids 33 (2004) 995–1021.
3. Jinou Song, Chunde Yao, Yike Liu and Jiang, “investigation on flow field in simplified piston bowls for Di Diesel engine”, Engineering Applications of Computational Fluid Mechanics Vol.2,No.3,pp.354-365(2008).

4. Mingfa Yao, ZhaoleiZheng, Haifeng Liu, "Progress and recent trends in homogeneous charge compression ignition (HCCI) engines", Progress in Energy and Combustion Science 35 (2009) 398–437.
5. Su Han Park a, Hyung Jun Kim a, Chang Sik Lee b, "Effects of dimethyl-ether (DME) spray behavior in the cylinder on the combustion and exhaust emissions characteristics of a high speed diesel engine", Fuel Processing Technology 91 (2010) 504–513.
6. Hyung Jun Kim a, Kwan Soo Lee b, Chang Sik Lee, "A study on the reduction of exhaust emissions through HCCI combustion by using a narrow spray angle and advanced injection timing in a DME engine", Fuel Processing Technology 92 (2011) 1756–1763.
7. SeungmokChoia, Wonah Parka, SangyulLeea, Kyoungdoug Mina, HoimyungChoib, "Methods for in-cylinder EGR stratification and its effects on combustion and emission characteristics in a diesel engine", Energy 36 (2011) 6948e6959.
8. B.V.V.S.U. Prasad, C.S. Sharma, T.N.C. Anand, R.V. Ravi krishna, "High swirl-inducing piston bowls in small diesel engines for emission reduction", Applied Energy 88 (2011) 2355–2367.
9. Antony Raj Gnana Sagaya Raj, Jawali Maharudrappa Mallikarjuna, Venkitachalam Ganesan, "Energy efficient piston configuration for effective air motion – A CFD study", Applied Energy xxx (2012) xxx– xxx.
10. Sungwook Park, "Optimization of combustion chamber geometry and engine operating conditions for compression ignition engines fueled with dimethyl ether", Fuel 97 (2012) 61– 71.
11. John B.LHeywood, "Internal Combustion Engine Fundamentals", McGraw-Hill Series in Mechanical Engineering, 198
12. Hiromi Kondoh, Yutaka Inui Takahide Kawano, TomoakiYumiba, "Reduction of NOx in Single-Cylinder Diesel Engine - Effect of Combustion Chamber Shape on NOx Under- Wide Range Operation Condition", Bulletin of the M.E.S.J., Vo1.23, No.2.
13. S. Jaichandar a, P. Senthil Kumar , K. Annamalai, "Combined effect of injection timing and combustion chamber geometry on the performance of a biodiesel fueled diesel engine, Energy 47 (2012) 388-394.
14. S. Jaichandar, K. Annamalai, "Influences of reentrant combustion chamber geometry on the performance of Pongamia biodiesel in a DI diesel engine", Energy 44 (2012) 633-640.
15. S. Jaichandar , K. Annamalai , "Effects of open combustion chamber geometries on the performance of Pongamia biodiesel in a DI diesel engine", Fuel 98 (2012) 272–279.
16. M. N Channappagoudra 1*,Sunil Thaned 2, K. Ramesh 3, G. Manavendra Optimization of Combustion Chamber Geometry for a Direct Injection Diesel Engine: A Review , IJERT 2013.