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Performance Analysis of C.I. Engine Using Different Shapes of Combustion Chamber

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Abstract-Nowadays, the number of vehicles are increasing due to the increasing population of the population. So, it needs to fulfill the fuel requirement for the country. A large number of vehicles use fossil- fuels which ultimately pollute the environment. To find a better solution to overcome this problem, research is going on all over the world to use renewable resources of energy more efficiently along with modifying the available resources which would be more efficient than previous, especially in the manufacturing & automobile sector. So in this paper, we analyze the combustion characteristics of a direct injection compression ignition (DICI) engine. Here we are going to use different piston geometries to compare the turbulent flow energy and eddy viscosity. So accordingly, a set of simulations were performed to examine the effect of the three different shapes of a piston crown on the performance behavior for comparison. These geometries are hemispherical surface, Toroidal surface, and shallow depth surface so that the engine combustion characteristics can be examined and the exhaust emissions can be reduced. Therefore, we can find through simulation that Shallow depth geometry has the highest turbulent kinetic energy (TKE) as we find in our result. We compared the velocity of the fuel and Eddy viscosity through different geometries. In these, we observed that the velocity in shallow depth surface is more as compared to other two shapes and the Eddy viscosity propagates more in case of shallow depth surface which will produce more turbulence inside the combustion chamber so that the air and fuel are mixed more thoroughly which will help in increased efficiency and reduce exhaust emissions.

Keywords:- Engine, Combustion chamber, velocity vector, and eddy viscosity vector etc.

I. INTRODUCTION

Over the years a great emphasis has been placed upon energy and atmospheric pollution related issues because the whole world is facing the global warming issue [1], especially by the automotive and manufacturing sector because of its high energy consumption (in terms of fossil fuels) and pollution So we tried to change the engine's piston structure to improve engine combustion and to mitigate the exhaust emissions like CO and SO2 ETC. Another method we could be try is by using alternative fuels to increase engine performance instead of using diesel and gasoline fuels, as if we used these fossil fuels which will pollute the environment and also as they are non- renewable resources so it will become extinct one day and now-a-days cost of these fuels are getting expensive.

So, we are considering different shapes of the engine piston surface and using Diesel liquid as a fuel. These shapes will improve the fuel-air mixing. In general, the mixture of the air-fuel is important for the engine, so in the paper, we will research the effect of the different shapes of the piston in the cylinder and do simulation to improve the efficiency of the engine and reduce exhaust emissions. By changing the shape of the piston crown, the better shape for the engine was found. The pre-mixture of the air fuel is important for the engine, so by making the air-fuel mixture better in the premixing process (induction stroke).

II. LITERATURE REVIEW

It is quite interesting to investigate the use of biodiesel in the diesel engine, and aims to increase the efficiency of operations and to reduce the emissions of pollutants. And the performance and emission characteristics of a CI (compression ignition) engine depend primarily on the combustion process.

The combustion of the fuel in the cylinder depends in turn on various factors such as fuel injection timing, fuel injection pressure, engine design such as combustion chamber shape and injector position, fuel properties, number and size of injection holes, fuel injection mode, air Whirlpool, fuel injection, etc. the researcher in order to improve the engine combustion to make good premix when the air and fuel injected into cylinder through changing the piston surface geometry for improving the combustion characteristics and promote the air- fuel mixture during the piston move down and compression stroke. The shape of the combustion chamber and the fluid dynamics inside the chamber are important in the diesel combustion process. As the piston moves to TDC, the gas pushed into the piston bowl gets compressed.

Piston bowl geometry is one of the important factors in the mixing of air-fuel mixture in engines. Various combinations of it with other parameters have been studied.

Jai chandar S et al. has studied the effect of injection timing and combustion chamber geometry fueled with biodiesel on diesel engines [5]. The geometry of the piston bowl can be designed to produce squish and swirling action which can improve the air/fuel mix turn formation before ignition takes place (premix). And when the piston moves down, due to the different shapes of the surface it can also affect the combustion of the air and biofuel. Context above the combustion and emission formation processes in diesel engines have a close relationship with the piston bowl geometry which can strongly affect the air fuel mixing before the combustion starts that is premixing.

In recent years, a few experimental studies on the effects of different bowl geometries of diesel engines fueled with biodiesel have been carried out.

Jaichandar and Annamalai studied the influence of bowl geometry on the engine performance in a diesel engine fueled with biodiesel [6]. And in their study, four bowl geometries, namely HCC (Hemispherical Combustion Chamber), FCC (Flat Combustion Chamber) and DHCC (Double Hemispherical Combustion Chamber), IBCC (Inclined Bottom Combustion Chamber) were investigated.

Dolak and Reitz optimized the bowl geometry of a light-duty diesel engine using a two spray angle nozzle by considering variables such as the start of injection, the fractional amount of fuel per injection and the swirl ratio [7].

Raj et al. conducted a study concerning energy efficient piston configuration for effective air motion, wherein four configurations namely flat, inclined, center bowl, and inclined offset bowl pistons were investigated [8].So the paper's main goals desired from the design of chamber geometry are to optimize the mixing of the fuel and air before ignition and to improve the flow of the exhaust products once combustion is complete.

Some researchers have changed the cylinder volume or changed the geometry of the piston surface, or added some components to change the airflow direction. As experimental work requires a lot of money and human power, researchers turned their attention towards the theoretical prediction for the optimization techniques.

Researchers such as **Mobasheri and Peng[9]** studied the effect of Re-entrant combustion

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geometry in Computational Fluid Dynamics (CFD) in a high speed diesel engine(HSDI)and they reported that combustion bowl parameters had a huge effect on the emission and performance characteristics, among which lowering the bowl depth resulted in higher NOX emission.

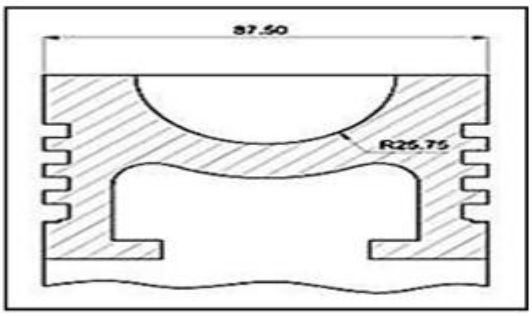
And other research workers such as **Raj et al.[10]** reported the air motion for four different geometries for a single cylinder diesel engine, reasoned out that combustion bowl profile played a key role in cylinder air fuel mixing.

Another researcher **Subramanian et al. [11]** optimized the combustion chamber using CFD for a diesel engine with a mono cylinder. The researchers concluded that turbulent kinetic energy and swirl ratio profile had a huge impact on the combustion bowl profiles.

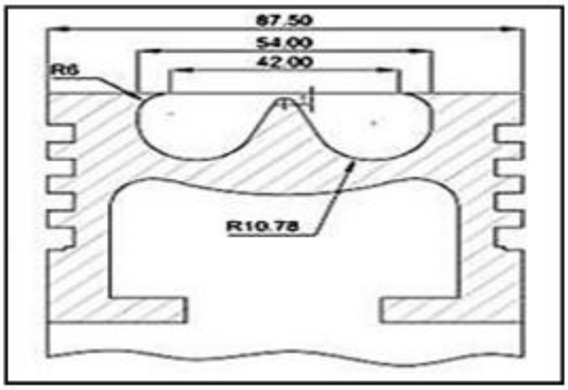
With these results, we can find that increase of the toroidal radius, and with this effect get better combustion efficiency and higher reduction of soot emission. The re-entrant combustion geometry was preferable to direct injection diesel engine owing to its higher cylinder pressure and better soot reduction process and reported by other researchers. A lot of researchers investigated the field of optimization of the combustion bowl, mainly on the re-entrant design with respect to the fuel, load, and speed conditions. Using this re-entrant bowl, the engine can reduce the emission and soot in particular.

III. STRUCTURE MODELS

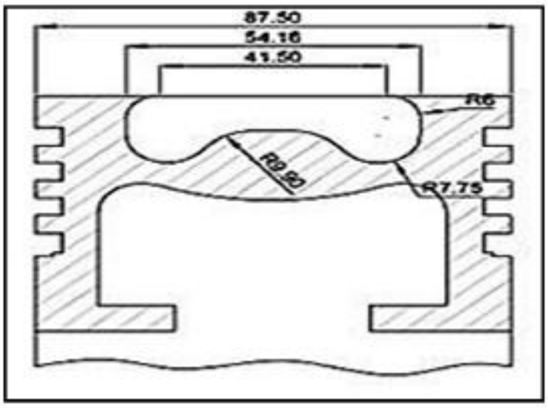
1. Diagram:



(a) Hemispherical Shape.



(b) Toroidal Shape.

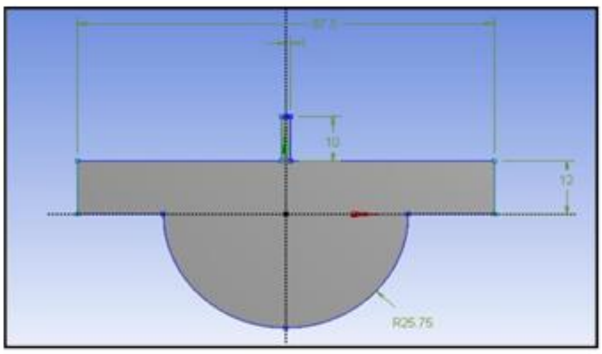


(c) Shallow Depth Shape.

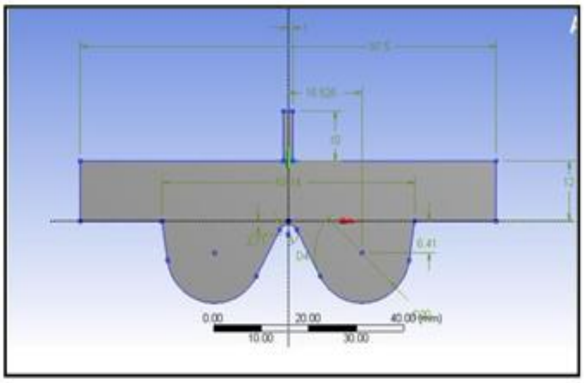
Fig 1. Schematic Diagrams of the engine pistons with different shapes.

As shown in Fig.1 we used dimensions for the three shapes of the piston surface, and created the design as per that dimensions (i.e., cylinder bore is 87.5 mm), then analyzed it on the Ansys software. In the analysis we considered the diameter of the injector as 1 mm. The inlet pressure used is 145 psi that is constant for all shapes. Diesel is used as a fuel. Then observed the velocity vector and Eddy viscosity vector.

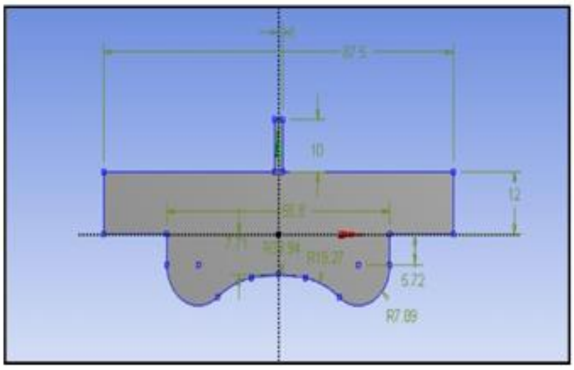
2. Design:



(a) Hemispherical shape (HCC).

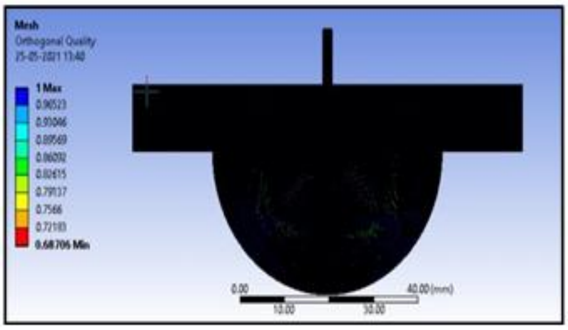


(b) Toroidal shape (TCC).

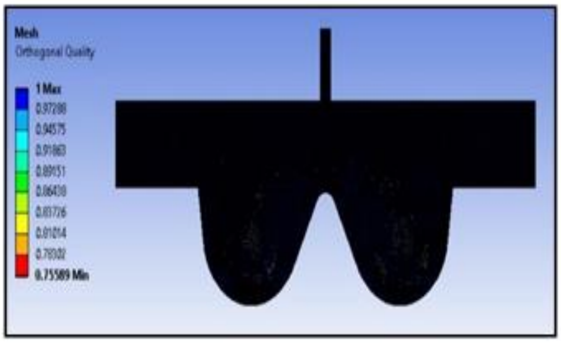


(c) Shallow Depth shape (SCC).
Fig 2. Design of the engine pistons with different shapes.

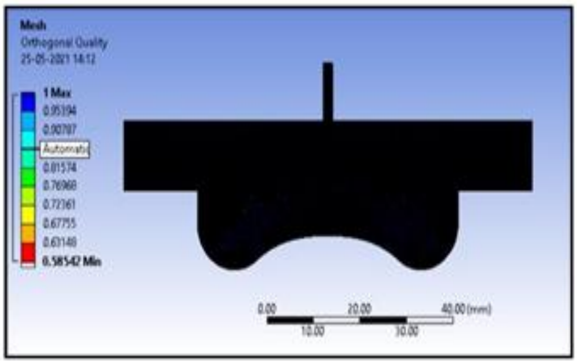
3. Meshing:



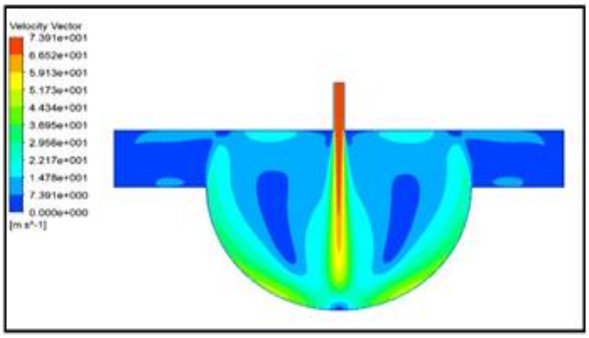
(a) Meshing of Hemispherical shape.



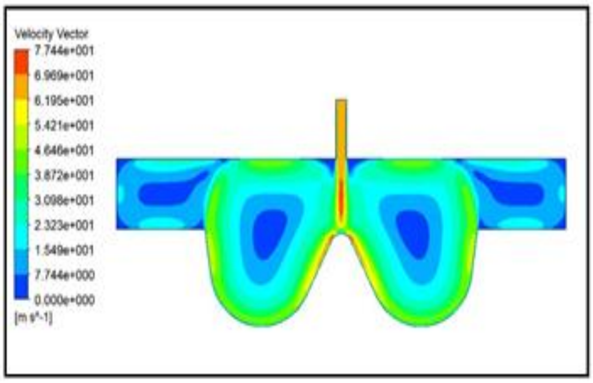
(b) Meshing of Toroidal shape.



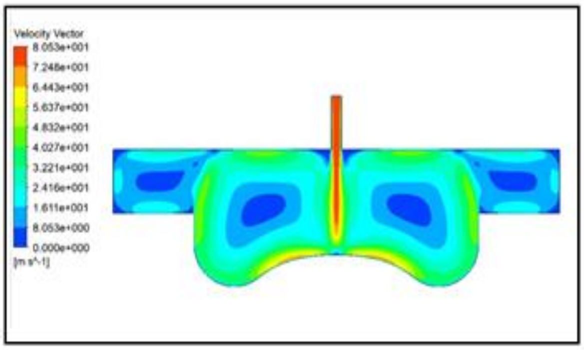
(c) Meshing of Shallow Depth shape.
Fig 3. Meshing of the engine pistons with different shapes.



(a) Velocity of Hemispherical shape.



(b) Velocity of Toroidal shape.



(c) Velocity of Shallow depth shape.
Fig 4. Velocity of different piston shapes.

IV. MODEL ANALYSIS

In this study, we have set up pistons of different shapes (three shapes). When air and fuel flow into the chamber during this process, the engine with a constant engine speed compares PIV (particle image velocimetry) with different shapes.

Finally, we set a constant value setting simulation process and compared the performance of the engine by simulation. So, for different shapes, we can observe the different piston shapes producing different levels of TKE (turbulent kinetic energy).

As shown in the phenomenon in below figures. And when during compression stroke, the piston upward TDC (top dead center) due to the high pressure the injector makes the fuel inject into the piston surface as tiny droplets with high pressure, with the higher pressure inside of the cylinder cause air-fuel mixed combustion.

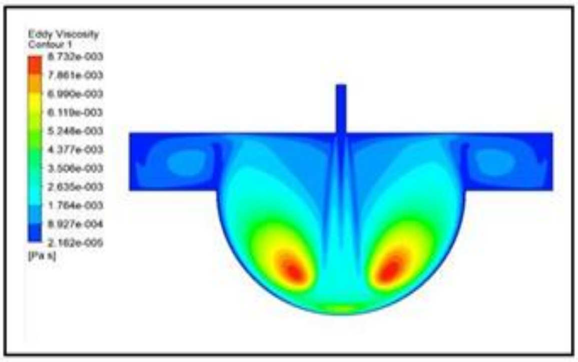
In this step, we compare the differentshapes of the piston surface's effects, because in this step, the geometry of the surface plays an important role to affect the air-fuel mixture.

By the flow rate of the fluid produced by the vertical cutting shown in Fig 3, it can be found that different shapes of piston surfaces can generate different flow rates. Because of the different shapes, it also plays a role in the mixing of air and fuel. Because of the difference in flow velocity, eddy currents can be formed. In space, eddy currents play an important role in the mixing of air and fuel.

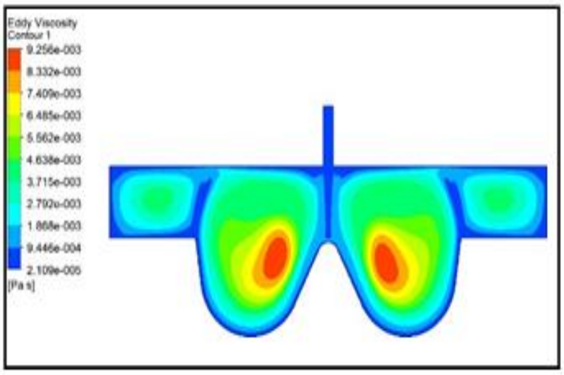
As shown in the figure, under the influence of eddy currents, the pre-combustion air under compression is compressed. It promoted mixing with fuel and provided great help for burning. This can be called premixing here. As the phenomenon can be seen in Figure 3, the shallow depth surface is more suitable for use.

Figure 3 shows the different flow velocities and vortices generated by the piston surface of different shapes under cross-sectional conditions.

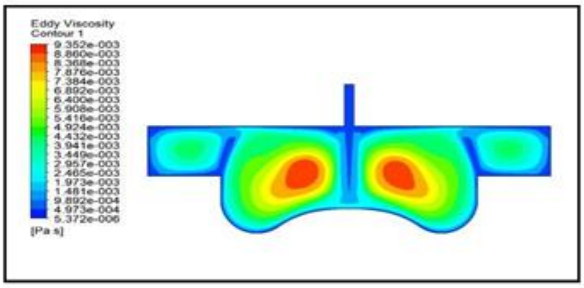
It can be fully seen from this graph that the area of the vortex generated by the Shallow depth surface is larger than that produced by the single toroidal and hemispherical surfaces, however, there is also the area covered by the Eddy viscosity slightly greater than the hemispherical and toroidal surfaces. Because of a large number of eddy currents, it has a good influence on the mixing of air and fuel, and it directly affects the combustion of the engine and the emission of exhaust gas.



(a) Eddy Viscosity of Hemispherical shape.



(b) Eddy Viscosity of Toroidal shape.



(c) Eddy Viscosity of Shallow depth shape.

Fig 5. Eddy viscosity showed through different shapes.

In the combustion process, a large amount of turbulence is required to promote the mixing of air and fuel, thereby the geometry can provide complete combustion.

In determining the formation of eddycurrents, we can determine the intensity of eddy currents based on the magnitude of the eddy viscosity. The mutual influence between two eddy currents is called eddy viscosity. In general, eddy currents are generated along with squish and pressure flow.

The generation of these phenomena promotes combustion and reduces emissions of harmful substances. As shown in Figure 4, we can easily find that the shallow depth surface is more viscous than the toroidal and even more turbulent than the hemispherical surface. It can be found in the red part of the figure.

V. RESULTS

Table 1. Results of the various shapes.

SN	Name of the shape	Velocity Vector(m/s)	Eddy Viscosity Vector(Pa-s)
1	Hemispherical	7.391e+0001	8.732e-003
2	Toroidal	7.744e+001	9.256e-003
3	ShallowDepth	8.053e+001	9.352e-003

VI. CONCLUSION

This paper briefly describes the pre-combustion process, the impact of different piston surfaces on the combustion, so as to find the piston shape suitable for engine combustion.

By comparing flow velocities, eddy viscosities, etc., found their respective effects. In the comparison of the flow velocity, it was found that the shape of the shallow depth surface was greater than that of toroidal and hemispherical shapes. It can better promote the mixing of air and fuel, thereby reducing exhaust emissions. The Eddy viscosity is more in case of shallow depth surface which results in enhanced turbulence subsequently mixing of air and fuel thoroughly. During the combustion process, we can find that the shape of the shallow depth surface is more effective than the other shapes in promoting the mixing of air and fuel.

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