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Research paper

Research on the Effect of Engine Intake System and Cylinders with Different Surface Shapes on the Engine

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Abstract

In the present, the automobile is the popular tool in every family. In the DI diesel engine, about the intake system that this system can affect properties of the engine, such as change the air flow velocity and pressure into cylinders, and among the air through the pump or throttle body(throttle valve), the throttle body can make air to produce eddies and change the air flow pressure, because when air into cylinder, the air pressure is an important parameter, so the time of the throttle valve opening in very important(also say the angle of opening), we know the surface of the cylinder can affect the air and fuel mixing rate, so we have investigated the effect of different surface shape. Found the different surface can improve the engine combustion properties. In this article, we will combine the throttle valve and the different surface shapes of the cylinder, make a survey what find the effect of this combination at the constant revolutions per minute(RPM). We will set the velocity at 1000rpm by tentative and investigate the position of the piston at the same location(inhale status) when premix air and fuel into the cylinder.

Keywords: *Di Diesel Engine; Throttle Body; Cylinder; Mixing Rate; Combustion Properties.*

1. Introduction

In the present, the automobile is popular traffic tool in every family, and every driver wants to use the least cost for the cars, so let the more and more researchers investigate the automobile. In recent years, governments, all over the world, have voiced their deep concern about fast depletion of fossil fuel and higher pollution levels which have forced them to implement stringent emission norms [4]. And to reduce the severity of the frightening situation and to mitigate the impact of the fuel problem the researchers are working on various techniques such as pre-combustion, post-combustion and engine design modification to enhance their performance and reduce their emission magnitudes[10]. The in-cylinder air motion, fuel injection timing, pressure and bowl dimensions are some of the important parameters that govern the performance and emission characteristics and the consequence of the combustion in the internal combustion engines[11]. Such as how to make the noise least come out the car, and how to make drivers in the car feel comfortable. On the other hand, the researchers investigate the throttle body that in this intake system the effect of the throttle valve for mixing of air and fuel, show us when the valve is opened suitable can get the optimum mixing rate into cylinder, in these research can set the engine constant speed to found effect of throttle body position, angle of opening(0°, 30°, 45°, 60°, 90°), and found the shape of throttle valve effect. In addition, on the location of the throttle body, some researchers also research the method of reducing noise, such as making the volume to bigger, or add a resonator on the pump ect. a number of methods to reduce noise.

On the other hands, many researchers have investigated the piston shapes in cylinders, and combustion bowl's design plays a crucial role in monitoring the air and fuel mixture which has a direct impact on the performance and emission characteristics. how to design the surface of the piston shapes, like half round, double-half round, flat base, ect., in these models found the effect of the piston surface about combustion of air and fuel into cylinder, because the air and fuel flow into cylinder needs to premix, if the air-fuel mix good at this step, the engine can make fuel complete combust during compression stroke, make the fuel consumption at least with high torque. If in premix step, the air and fuel get the complete mixture, not only make the fuel consumption at least but also can make the emission reduction. At present, the environment pollution in very worse, such as CO, NO_x, soot, SO_2, ect., like these pollutants not only make the environment bad but also affect human's health, respiratory disease, visual induced diseases, various kinds human diseases. On the basic, the greenhouse gases get the important effect with the environment make the earth hotter, and make the above of the earth to the bigger ozone hole, let the ultraviolet ray make the human diseases products. So in the future, use the biodiesel or another clean fuel for the engine, or electric power as automobile power.

In this article, we will combine the throttle body and the piston surface shape for finding the effect of the air and fuel flow into the cylinder at the constant speed and induction stroke. Find the location of the throttle valve opening and the piston surface shape. Because this is important parts for improving property about the engine, air–fuel first time into cylinder need to premix, only the premix get a good blend, can get the complete combustion later(compression stroke).

2. Method and program

In this simulation, we will get various models for comparing the effects and find the better device location for air–fuel flow into

cylinder premix. The models like the throttle valve's angle are 30, 45, 60, three kinds location for comparing, and the piston surface shape is flat base, single round, double rounds to set for comparing. In this simulation compare the airflow velocity and pressure, and air into cylinder product eddies more intensity. When eddies are got more intensity can make the air-fuel premix as if this can make the combustion complete. Use the ANSYS FLUENT program to make the simulation, and make the model 2D status for going, in these models must get the good mesh for analysis, so set the mesh size is 2mm, like Figure 1, and these models can get better simulated. And set the input pressure is standard atmospheric pressure, and the air flow velocity is set 0.5 m/s, and after through the throttle valve the speed is set 0.2 m/s, at the condition, we did the simulation.

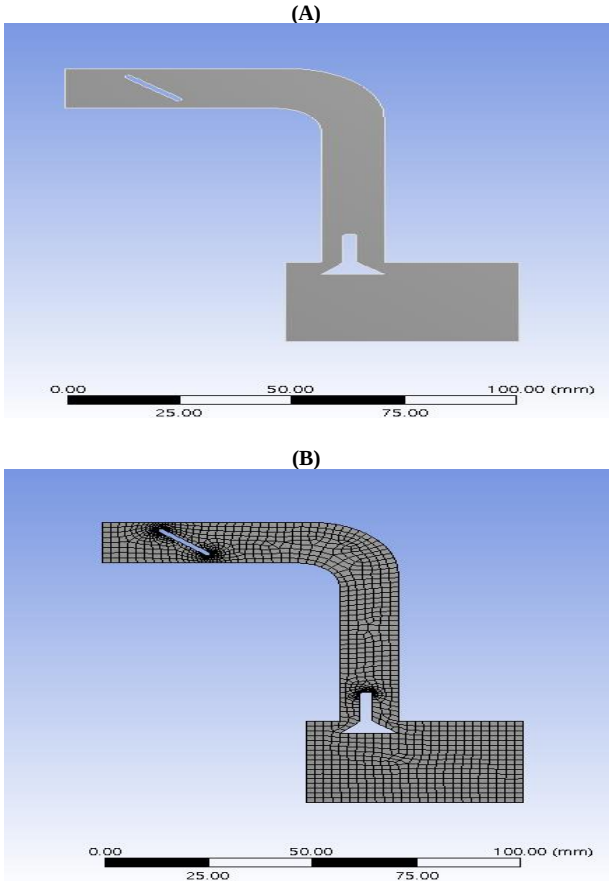


Fig. 1: The Basic Model of Simulation with 30° Angle.

3. Previously research

Previously there were many researchers have investigated related to the throttle body effects with engine intake system and related to the piston shapes and cylinder geometries effects about the engine. In these researches, change the throttle bodies' shapes or change the center of the throttle valve for varying the airflow velocity and make the airflow smooth into cylinder, in addition, some of researchers change the cylinder volume or change the piston surface geometry, or add some part for varying the direction of airflow, such as add a thin slice for changing the airflow flow direction to make the air into cylinder can product many eddies and make the eddy viscosity to bigger, like this the air and fuel can mix completely. As experimental work requires a lot of money and human power, researches turned their attention towards the theoretical prediction for the optimization techniques. Researchers such as Mobasheri and Peng [1] studied the effect of Re-entrant combustion geometry in Computational Fluid Dynamics (CFD) in a high speed diesel engine (HSDI). And these researchers reported that combustion bowl parameters had a huge effect on the emission and performance characteristics, among which lowering the bowl depth resulted in higher NO_X emission. And other research workers such as Raj et al. [3] 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 in-cylinder air-fuel mixing. And researcher Kidoguchi and Yang [5] stated that combustion bowl with lower throat diameter and higher squish magnitude results in simultaneous reduction of particulate matters and oxides of nitrogen which are harmful to the environment and human health. And another investigator Subramanian et al. [9] optimized the combustion chamber using CFD for a diesel engine with mono cylinder. The researchers concluded that turbulent kinetic energy and swirl ratio profile had a huge impact on the combustion bowl profiles. The researcher Lin et al. [8] examined the performance and in-cylinder air gesture for three different combustion chamber geometries for a diesel engine used in agricultural land. With this research optimization om the bowl parameters trend to have an effect of turbulence, find the optimization geometry of the cylinder for add the eddy viscosity and improve the turbulent kinetic energy, improve the air-fuel mixing, diffusion phase of combustion, use least fuel consumption, and NO_x and smoke emissions. Researchers, Gafoor and Gupta[14] reported numerical examine on various swirl ratios on the piston swirl had a great effect on the cylinder pressure and emission behavior with high bore to bowl ratio. In these researches reasoned out that enhancement in turbulence would have an effect on fuel consumption, soot, and NO_x emission. Prasad et al. [13] found the consequence of various re-entrant bowl produced better swirl and turbulent kinetic energy and reduced NO_x and soot emission levels. Zhu et al. [15] tested the combustion performance and emission behaviors of various piston bowl parameters. 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. With a lot of researchers investigated on the field of optimization of the combustion bowl, mainly on the re-entrant design with respect to the fuel, load, and speed conditions. Use this re-entrant bowl, the engine can reduce the emission and soot particular.

In the context, due to the fossil energy source and the production after combustion, some researchers carried out with some various combustion bowl geometries with the alternative energy sources using theoretical and experiments. Such as Li et al. [7] carried out the impact of piston bowl geometry use CFD tool and the fuel using biodiesel powered diesel engine with three different combustion bowls, and the name of three bowls are Hemispherical, Shallow depth, and Omega Combustion cylinder with the same cylinder. With this research can be found the Omega Combustion chamber got high-speed engines owing to superior squish motion, and the geometry of piston made the fuel and air complete mixture cause the engine performance improvement. And Ramesh Bapu et al. [16] probed the consequence of a modified combustion bowl profile on a diesel engine powered by Calophylluminophyllum methyl ester. With this investigation can be found that the bowl with the lower diameter to depth ratio would have superior squish flow resulting in the enhancement of the performance characteristics. Jaichandar and Annamalai [12] experimentally studied the toroidal and shallow depth re-entrant combustion bowl using Pongamia biodiesel to power a diesel engine. So they found the reentrant bowls tended to improve the mixture formation by better fuel and air interaction resulting in the improvement of the performance characteristics. And another researcher Wamankar and Murugan [6] experimentally analyzed the effect of internal jet induced piston bowl with emulsified diesel fuel. With this piston bowl achieved a superior emission reduction through the modified piston bowl owing to swirl variation and fuel-air interaction. About above of paper, can be found clearer that combustion bowl profile modification can be utilized for the improvement of performance and emission behavior of diesel and biodiesel fuels. Against this background, we can found various researches for discovering the effect of the engine cylinder and piston geometry, with this geometry of piston bowl on the various performance,

combustion and emission factors but still many factors can affect the air and fuel mixture like the throttle body, in order to investigate the effect of throttle body and geometry of the piston for the engine performance, so do some simulation for this assumption.

4. Research background

The combustion and emission formation in diesel engines have a close relationship and get the important effect with the piston bowl geometry and throttle body together which these positions can strongly affect the air and fuel mixing before the combustion starts(let us call premix). The shape of the combustion chamber and the fluid dynamics inside the chamber are important in diesel combustion. As the piston moves upward, the gas is pushed into piston bowl. The geometry of the piston bowl can be designed to produce a squish and swirling action which can improve the fuel/air mixture formation before ignition take place(let us call premix). The main goals desired from the design of chamber geometry are to optimize the mixing of the fuel and air, before and during ignition, and to improve the flow of the exhaust products once combustion is complete [18]. After TDC, high swirl ratio appears to increase diffusion combustion. This stroke likes the induction stroke that shows the air-fuel mixture is similar to air into the cylinder. In the context above this paper, much more researchers have discovered the effect for the engine. In this paper, we set the throttle body with different angles like set the throttle valve open angle to 30°, 45° 60° through in the open angle base and with the same cylinder with different geometry of piston surfaces, the surface like base flat, single half round and double half round. Use the throttle valve opening angle and piston surface geometries with the combination, compare the results and find the optimized combination for improving the performance to the engine.

5. Data analysis

In order to analyze the engine performance and relationship about emissions, reduce the matter of the emission, so the simulation is very important, and set the model use the ANSYS program, and in this program, in this research, in this study, use the engine model is a two-valve, four-stroke engine with straight intake system which gets the throttle body and manifold has been considered for the CFD analysis. And a schematic diagram of the engine with the flat piston is as shown Figure 1. And the specifications of the engine are shown in Table 1. And in this progress set the logogram CAD refers to Crank Angle Degree. And the bBDC refers to before bottom dead center, and the aTDC refers to after top dead center. IVO refers to intake valve open, IVC refers to intake valve close. EVO refers to exhaust valve open, EVC refers to exhaust valve close.

Table 1: Specifications of Engine

Type	Single cylinder, vertical Diesel engine, two-valve, four-stroke engine
Bore	87.5 mm
Stroke	110 mm
Compression ratio	10:1
Speed	1500rev/min
Maximum intake valve lift	7.9 mm
IVO: 4.5 CAD bTDC	EVO: 35 CAD bBDC
IVC: 35 CAD aBDC	EVC: 4.5 CAD aTDC

6. The analysis of the models

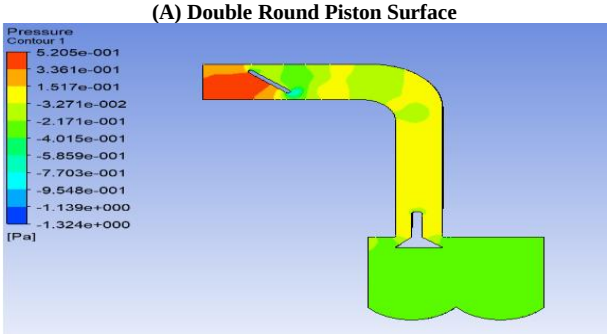
Use the ANSYS program to analyze the model of engine intake system and cylinder piston surface geometry, through the air flow mass into the pump of nearby the geometry, throttle body and make air through the throttle valve under with change the valve angle compare the angle effect and through the different valve and change the air flow mass and pressure, velocity, cause the different eddy product in the cylinder when the engine induction stroke, because the air through the throttle body can product the eddy production and make the air not smooth, so in order to make the air smooth into cylinder, set the different angle for air across, and reduce noise because the air and fuel before expansion stroke need premix, so inside of cylinder the air and fuel through into the cylinder make eddy product, need the vortex for air and fuel better to mix. So when change the piston surface shapes and combine the throttle valve angle choose better valve angle and better shape for air and fuel mix, like this through these methods can improve the combustion and reduce the fuel consumption, and because the vortex production causes the better mixture of air and fuel. Cause the exhaust reduction. So in this study, we will find the optimization of the intake system and piston surface shape for the engine.

6.1. 30◦ Angle of the throttle valve

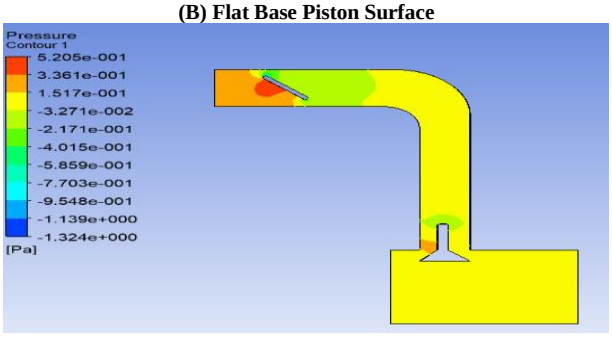
Firstly, let the air flow through the throttle body to check the effect with the difference of the valve angle. Check the valve opening angle is 30° 45°, 60° we use the ANSYS program to check. Through comparing the flow mass, flow velocity, pressure and Turbulence Kinetic Energy, and find the optimize valve angle for the engine. When with the difference of the valve angle, the effect is very important with the different of piston surface shapes. So with these questions, we set the simulations to be compared with 30 degrees with the effect of three different piston surface, 45 degrees with the effect of three different piston surface and 60-degree opening angle with the effect of three different piston surface.

Like as blew picture shown 30-degree angle of the throttle valve. The first is check the pressure effect with three different shapes at 30 degrees like below shown.

(A) Double Round Piston Surface



(B) Flat Base Piston Surface



(C) Single Round Piston Surface

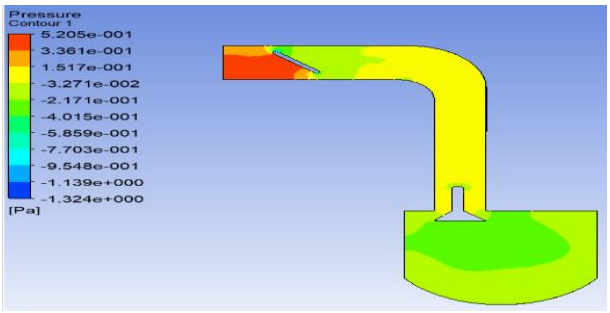


Fig. 2: The Pressure with Different Piston Shapes at 30 Degrees.

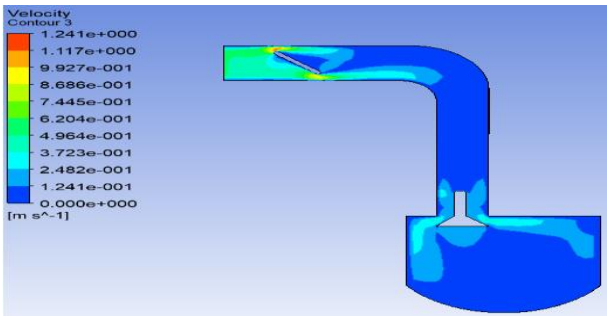
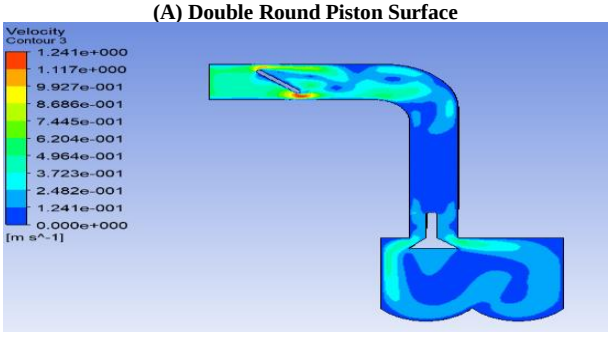


Fig. 3: The Velocity with Different Shapes at 30 Degrees.

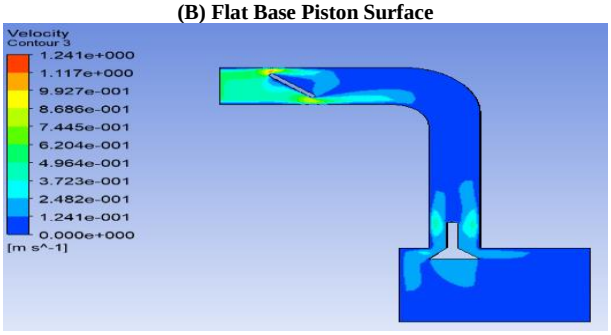
Like above shown with the pressure with the different shapes at 30 degrees, compare the three shapes at the same condition, nearby with the throttle valve we can find picture show us different state pressure in front of the valve, with 30 degrees, at different piston surface. Because this stroke is induction stroke that the air and fuel together into the cylinder when piston moves to the bottom of the cylinder. So the different surface can affect the air through the throttle body, affect the air pressure. With this question we can find the different pressure is shown in three pictures. With the comparison with three simulations, the double and single is better than flat base shape. That is because with the induction stroke that the piston is moved in the cylinder, inside of the cylinder make the pressure is smaller than the pump, with this reason we can decide the round shape is better. And compare the double and single round shape, that single round is not better than the double sound shape. Because in the part of the throttle valve the air need to smooth to move into cylinder, but the double round picture show us after the valve the pressure product many times change can make air smooth flow and the single round picture shown us the pressure suddenly to drop, like this phenomenon air through can make noise produce. It is not comfortable for drivers. In addition, inside of the cylinder in order to make air and fuel mixture, need the pressure difference, so the double round is better like the picture showed.

The second will to show the velocity of the air with three different piston shapes at 30-degree valve angle opening.

(A) Double Round Piston Surface



(B) Flat Base Piston Surface



(C) Single Round Piston Surface

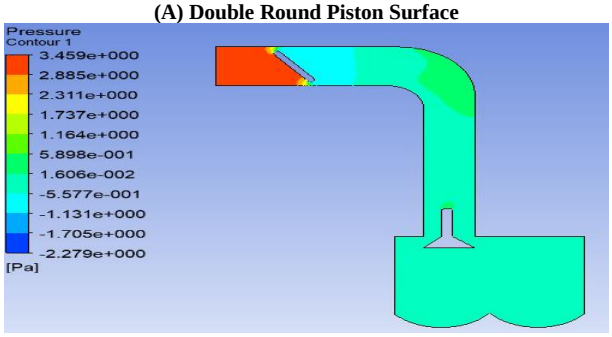
In this section, we can combine the pressure together to understand the velocity distribution, if under the pressure distribution, in this section is very easy to understand. See the picture we can find the better one is double round surface for the engine. That is because inside of the cylinder when induction stroke makes the air and fuel to premix complete need the vortex produced, like the picture shown. Due to the velocity difference can make eddies generation. And the velocity can be produced different because the pressure is different, velocity has a relationship with pressure. So the single velocity is similar with and flat round 's. Inside of cylinder, the air and fuel want to be completely mixed, depending on the airflow, so we main investigate the air flow in the engine.

6.2. 45◦ Angle of the throttle valve

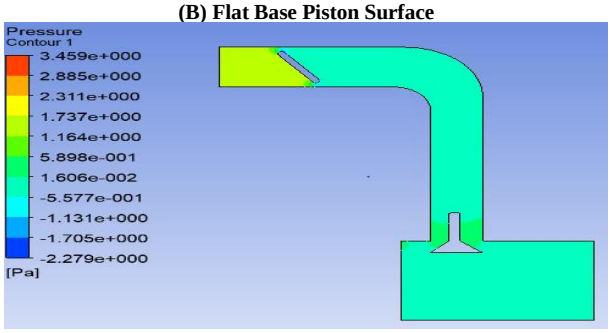
The first is shown the pressure of three different shapes of piston surface at 45-degree valve opening. Like above sentences shown compare the velocity and pressure, find the better shape for the engine, due to the different shapes with the air flow through throttle valve to different, so we can decide the shape of the piston can affect the pressure in the part of the throttle body.

As the same like above, the first part to check the pressure distribution at the different piston surface 45-degree angle opening.

(A) Double Round Piston Surface



(B) Flat Base Piston Surface



(C) Single Round Piston Surface

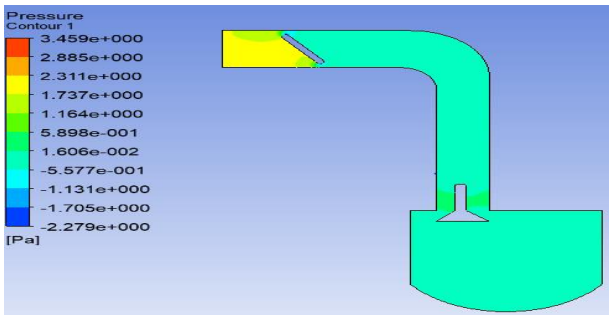
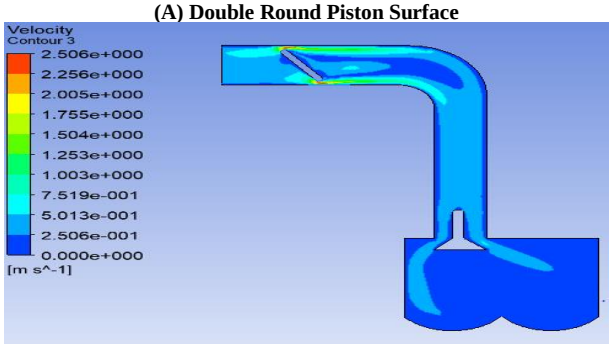


Fig. 4: The Pressure with Different Piston Shapes at 45 Degrees.

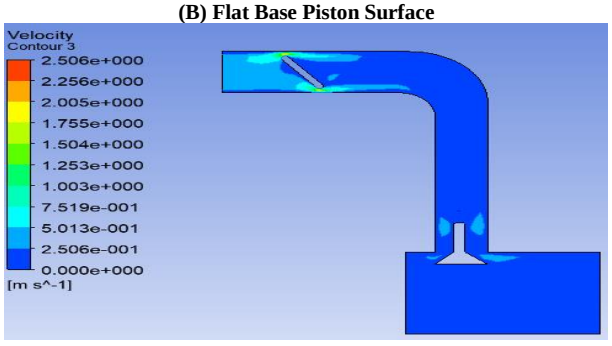
As like above picture shown, this part to check the pressure with different piston shapes at 45 degrees, as picture shown, in the part of throttle body before air into pump, the different pressure produced can be sawed, and compare with 30 degrees, it is different with 45 degrees, because the opening condition is different cause this phenomenon generated. In this section, double round shape affect the air flow make air before into cylinder pressure is a difference and due to this different pressure can make the noise generated, due to this season another shapes are better than double shape. Compare other a shape of piston, they are similar to be saw, and difficult to discover which one is better, in view of this reason, we can compare the valve of into cylinder, because this part is important to the engine, due to the shape of the cylinder is different, cause the valve pressure various. So I think the single round is a better shape for the engine. But we can from another point to investigate this pressure in the throttle body that due to the opening angle is smaller than 30 degree show the pressure bigger, and like this season, the air into the pump of the intake system can get much more kinetic energy for air and fuel mix because of the pressure difference. If this research is a success then the double round of piston surface is better than other shapes.

Due above picture cannot to show the optimum shape for engine detail, so in below will compare the velocity and Turbulence Kinetic Energy for investigating the effect of engine combustion.

(A) Double Round Piston Surface



(B) Flat Base Piston Surface



(C) Single Round Piston Surface

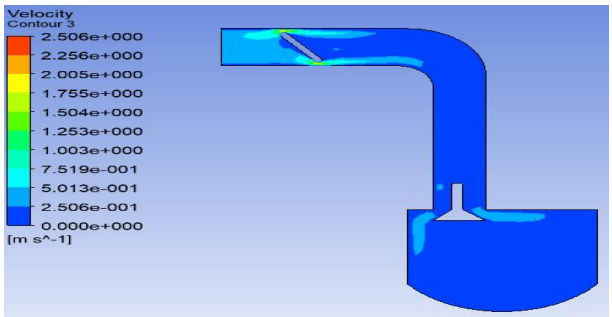
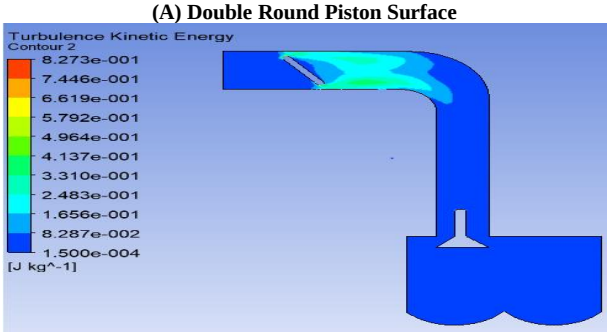
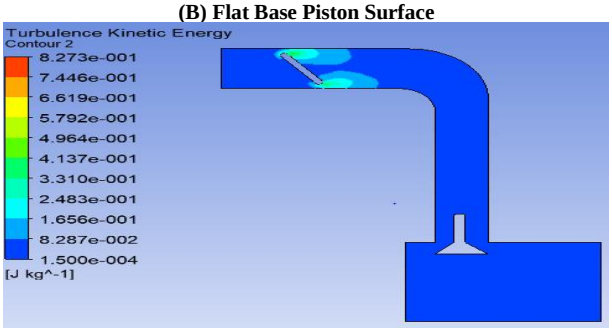


Fig. 5: The Velocity with Different Piston Shapes at 45 Degrees.

(A) Double Round Piston Surface



(B) Flat Base Piston Surface



(C) Single Round Piston Surface

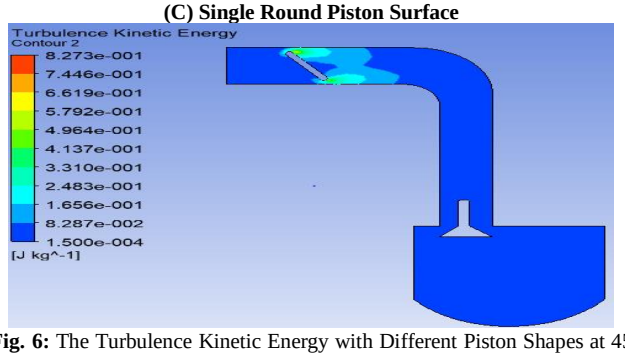
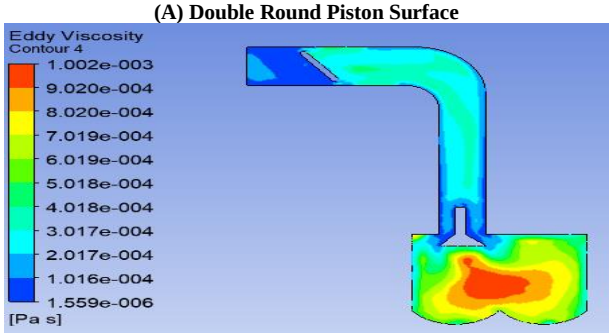


Fig. 6: The Turbulence Kinetic Energy with Different Piston Shapes at 45 Degrees.

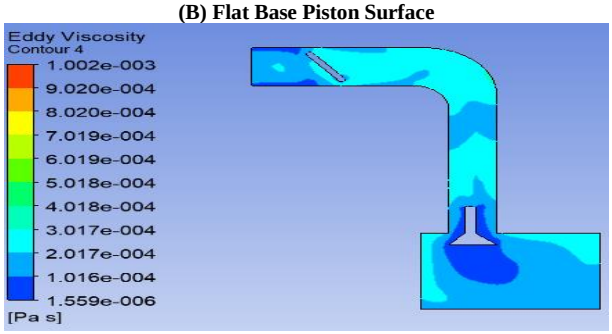
A kinetic image likes the one shown in Figure.6 mainly studies and compares the effect of air passing through a throttle body valve under three different piston shapes. By comparison, the shape of the piston can indeed affect the greater kinetic energy of air passing through the throttle valve. Through comparing the air flow velocity and Turbulence Kinetic Energy at 45 degree with three piston shapes, with into cylinder for mix the air and fuel for complete combustion, the air need large velocity, if get the large velocity into cylinder due to speed difference can make eddies generated, and like this analysis can get the reason that the shape of the piston surface can affect the air velocity into cylinder, in order to prove this reason, we can compare the turbulence kinetic energy, like Figure 6 shown, with different shapes of piston surface can get different energy at same angle degree. So in Figure 5, the velocity has shown for us that high speed into the cylinder to get many eddies on the induction stroke process. For throwing throttle valve with 45 degrees in three different piston shapes, it

can indeed produce different kinetic energy in throttle zone. On different piston surfaces, eddy currents with large differences can also be generated. Here we can compare the vortex viscosity to easily find the vortex strength of the piston surface. Because only the greater the eddy current intensity, the more eddy currents, cause the greater the viscosity of the eddy currents. So you can find out from the display in Figure 7. With comparing the eddy viscosity on three different shapes. We can find the double round piston surface (red zone) is a better shape for mixing the air-fuel on engine combustion process.

(A) Double Round Piston Surface



(B) Flat Base Piston Surface



(C) Single Round Piston Surface

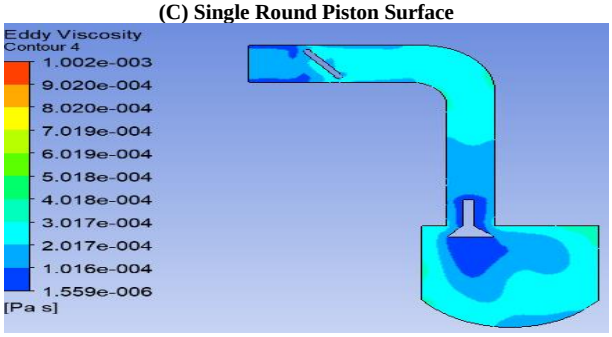


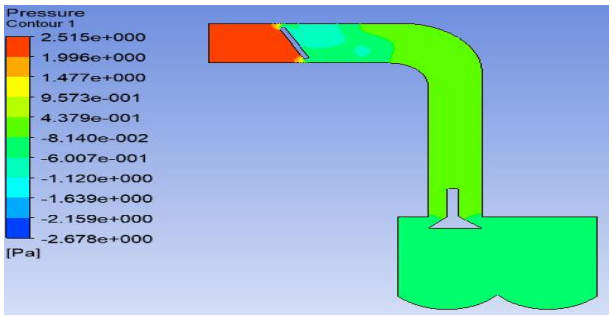
Fig. 7: The Eddy Viscosity with Different Piston Shapes at 45 Degrees.

6.3. 60◦ Angle of the throttle valve

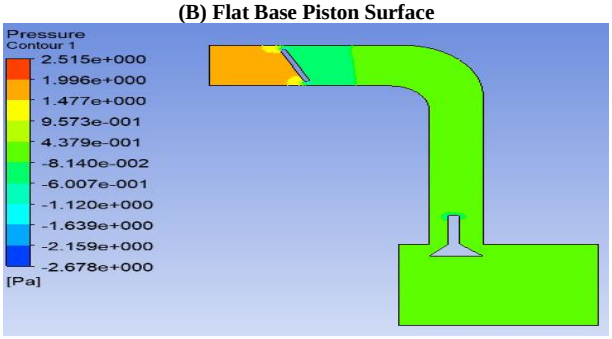
In this section, we will investigate the 60◦ Angle of the Throttle Valve with three shapes, and find the effect of the throttle and piston surface, and find the relationship of the throttle body and piston surface. Like above shown, we will analyze the pressure and velocity of into cylinder for air and fuel mixture for engine combustion.

We can find the below picture will be shown the 60-degree angle of three shapes of piston surface.

(A) Double Round Piston Surface



(B) Flat Base Piston Surface



(C) Single Round Piston Surface

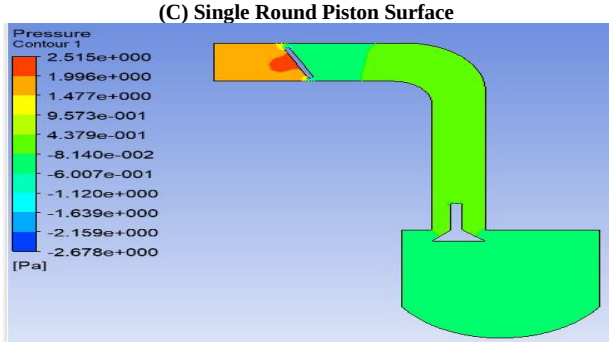
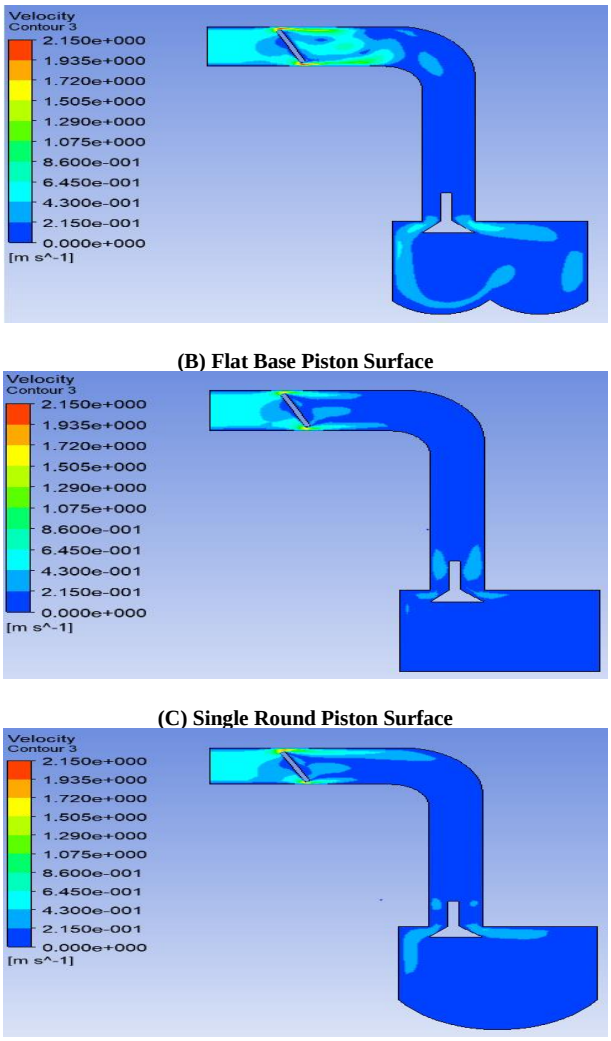


Fig. 8: The Pressure with Different Piston Shapes at 60-Degree Angle.

With this comparison of three piston surfaces, due to the opening angle is smaller, so in the picture shown the air into pump make bigger pressure generated, in view of the noise for driver comfortable, this structure is not good for engine although in the part of cylinder produced a good effect for combustion. So we find the good structure is single round surface at 60-degree. At the throttle body, the pressure is smooth changing that makes the air flow, and air into the cylinder can get the eddy produced for air and fuel mixture. If do not consider the driver comfort level, the double round surface is better than the single round, due to the pressure difference can get the much more kinetic energy. And air into cylinder part is similar to the single round. With the throttle valve opening changed, this part will change the pressure into the intake system, caused the good effect for airflow, reduce the noise produced. The other researchers in order to reduce air flow noise generated to set the resonator to intake system and optimize the resonator for reducing the noise. So with the researchers' investigations we can use the double round piston surface for combustion. The second part will investigate the velocity with three shapes at 60-degree. And through compare the velocity find the better shapes is double surface as engine piston surface.

(A) Double Round Piston Surface



(B) Flat Base Piston Surface

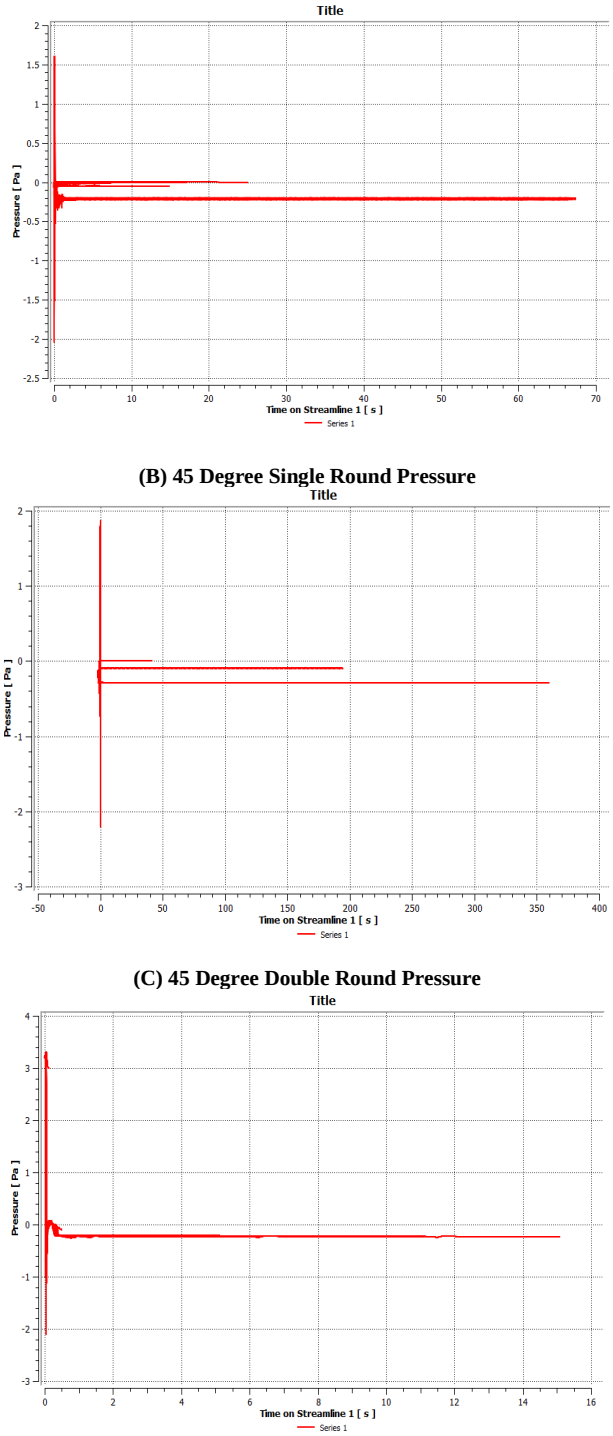
(C) Single Round Piston Surface

Fig. 9: The Velocity with Different Piston Shapes at 60-Degree.

In this section, we compared air flow velocity at 60-degree with three different shapes and get the results that the double round shape is better for engine combustion than other piston shapes in the induction stroke. the first part we could see the cylinder, if the air need to be complete mix with fuel, in the cylinder needs to be generated vortex, because the vortex can produce the pressure difference make the air velocity different, and in the induction stroke need air and fuel premix that this part need the vortex, in Figure 9 shown double round's cylinder produced the vortex, so the better shape is double round as the piston surface.

As mentioned above, the throttle body can be affected by the piston surface shapes, and with that piston shapes different change the air flow through the throttle body, we can set the same angle of throttle valve opening to compare the pressure with different piston surface shapes. Like below Figure 10 shown

(A) 45 Degree Flat Base Pressure



(B) 45 Degree Single Round Pressure

(C) 45 Degree Double Round Pressure

Fig. 10: The Pressure on Different Piston Shapes at 45 Degree.

Like the three pictures shown, the three geometries were got different pressure, like (a) and (b) seem to be similar, but have big difference these two shapes, on the comparison, the single round 's pressure is smoother than the flat base shape, however, the double round is smoother than the single round, due to the pressure smooth generated, cause the airflow flows smoothly into cylinder, in the flat base the pressure difference is 3.5par, and the single round 's pressure difference is 4 par, only the double round pressure difference is equal to 5 par. the differential pressure could be got when the first time air into the throttle body. So we can get the results that the piston shapes could affect the airflow pressure.

7. Conclusion

With all kinds of investigations, we can find the better shapes in each angle for engine combustion, due to the throttle valve in front

of the intake system, and many researchers have researched this part for reducing the noise that makes resonators set. Because of this reason, on author's opinion, the double round surface can as piston surface for the engine. Due to the piston surface get the effect with the throttle valve, we can find the effect of the investigation above.

And make the air and fuel complete mixture, the air flow plays an important role inside of the cylinder, so this paper main to research the airflow effect. Through the comparison with three shapes, not only through pressure but also through air velocity and turbulence kinetic energy could find the better shape is double round as piston surface at the time of induction stroke.

And in this research, it could found the effect of the throttle valve with different piston surface, the different piston surface can affect the airflow velocity and pressure when the air flow through throttle valve at a same throttle valve opening degree.

In this paper, just only to investigate the three shapes for comparing, other shapes will be investigated.

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