Study on Existence & Effectiveness of Turbulence in combustion chamber of a Diesel engine

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Abstract

Complete combustion will leads to significant improvement in engine performance as well as reduction of pollutants in emission. Researches emphasize that analyzing the fluid dynamics in combustion chamber will show the right path to achieve maximum thermal efficiency in diesel engine. Due to the high velocities inside the combustion chamber the flow has been termed as turbulence. Heat transfer, fuel air mixing and rate of combustion were increased due to this turbulence. This turbulence categorized as squish, swirl and tumble. The rotational motion of the fluid mass within the cylinder is termed as swirl. It can be generated by means of suitable design of inlet manifolds, valves and piston faces. It improves the combustion process by rapid fuel air mixing. Radially inward flow occurring at the end of the compression stroke is called as squish which helps with better fuel air mixing. After reaching the TDC the squish motion generates a secondary flow called as tumble. In this paper we put front the existence of these turbulence and significant effects on the complete combustion in a diesel engine.

Keywords: Turbulence, combustion chamber, swirl, squish, tumbles

1. Introduction

Often called the heart of the engine, the fuel injection system [1] is without any doubt one of the most important system. It meters the fuel delivery according to engine requirements, it generates the high injection pressure required for fuel atomization, for air fuel mixing and for combustion and contributes to the fuel distribution[2]in the combustion system hence it significantly affects engine performance emissions & noise. Liquid fuel is injected through the nozzle by the fuel injection system into the cylinder through the end of compression stroke. The liquid jet leaving the nozzle becomes turbulent [3] and spreads out as it entrains and mixes with the in-cylinder air. The sprayed fuel stream encounters the resistance from the dense in-cylinder fluids and breaks into droplets. Then they vaporize and mix with the high pressure, temperature in cylinder fluids. It causes the fuel to ignite spontaneously and initiate the combustion at various locations, where desired condition is available.

During the intake stroke the air enters into the combustion chamber based on the geometry of inlet valve & engine head swirl is generated. During compression stroke air get compressed to a high pressure, when piston approaches TDC fuel is injected with very high pressure. Fuel gets vaporized and get ignited where the turbulent kinetic energy (TKE) is maximum. So in order to reduce the ignition delay TKE locations should be more in combustion chamber. The geometry of piston crown, valve face, and combustion chamber head can decide the TKE points inside the combustion chamber. Zhang et al. [4] carried out an experimental study aiming to investigate the effects of combustion chamber geometry on combustion process in an optically accessible direct injection diesel engine. Flame movement behaviors such as the distribution of flame velocity vectors and the averaged flame velocity inside and outside the combustion chamber are measured by means of cross-correlation method. Swirl motion of the air is usually generated due to the design of the intake port. A good intake port design will generate higher swirl and help to improve combustion [5]. When there is swirl in the in-cylinder air, the swirl–squish interaction produces a complex turbulent flow field at the end of compression. Further, intensification of swirl and turbulence are observed around TDC of compression. Around this time, most of the in-cylinder air is compressed into a smaller diameter combustion chamber. Thus, by conservation of angular momentum, as the radius of rotation reduces, the speed of rotation increases. Intensification of turbulence is due to the highly turbulent squish and reverse-squish motions of the air near TDC of compression. Because of these, usually two peaks in turbulence, one just before TDC and the other just after the TDC, are observed [6]. Prasad et al. observed that highly re-entrant piston bowl and without a central projection was found to be the best for swirl and turbulent kinetic energy intensification around top dead center. [7]

2. Fuel injection system

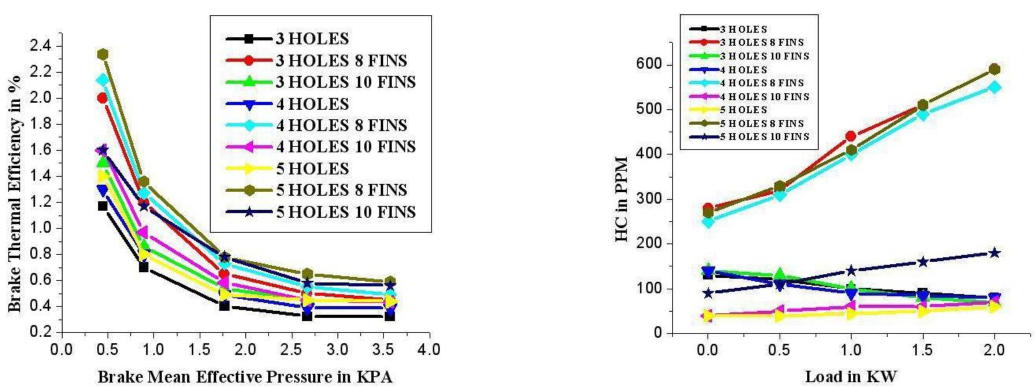
In diesel engines the Analysis of fuel spray with various injection orientations has high influence on engine performance as well as exhaust gas emissions Dr. Hiregoudar Yerrennagoudaru et.al., conducted research on diesel injection system with variety of hole & fin combination and orientations(Fig.1).

Fig.1 Injectors with fin and without fin model

Fig.2 8-Fin model

Fig.3 10-Fin model

The results were compared with the results of measurements at steady state conditions and fuel injection characteristics are required to deal effectively with major diesel engine design problem achieving sufficiently rapid fuel-air mixing rates to complete the fuel burning Process in the time available(Refer Fig.4). The fuel injector orientation plays very important role in fuel air mixing. A single cylinder four stroke DI diesel engine with fuel injector having multi-hole nozzle injector is considered for the analysis.



4(A). Brake Thermal efficiency Vs BMEP

4(B) Hydrocarbon in PPM Vs Load in kW

Fig.4 Comparison among various configuration of nozzle tip

The geometry of the diesel fuel injection nozzle and fuel flow characteristics in the nozzle significantly affects the processes of fuel atomization, combustion and formation of pollutant emissions in a diesel engine. In this experiment it has been investigated the effect of injector nozzle holes and models created such as fins for fuel spray on the performance of diesel engine such as fuel consumption and fuel in-engine cylinder the analysis of a swirl diesel engine research also reveals the effects of swirl in combustion chamber of a diesel engine depending on the shape, angle, and area of the jet passage, effects of the pressure, heat release HC, and CO concentrations[11].

3. Combustion process

In a diesel engine, the fuel is introduced into the chamber by the fuel injector, which breaks the fuel into tiny droplets that spread through the compressed air. As soon as the cool fuel comes in contact with the hot air, it takes heat from the air and an envelope of vapour forms around the droplets. The air that has cooled, have to regain its heat from the main body of air and as it does, the vapour also becomes hotter until it ignites. As soon as this occurs, the heat of combustion supplies the necessary heat to completely vaporize the fuel.

If the air is stationary in the combustion chamber, the burnt gas from the first combustion will surround each burning droplets and will suffocate it. If, on the other hand, the air is continuously moving the burnt gas will move away from each fuel particle and fresh air will take its place, ensuring a plentiful supply of oxygen for continued combustion.

Again, if the particles are very fine, the total surface area exposed to the compressed air will be large, and great amount of fuel will be vaporized almost immediately. Once combustion starts, entire vaporized fuel will be burnt rapidly, and a very quick and high pressure rise will occur in the combustion chamber.

4. The stages of combustion

Combustion of diesel engine may be divided into four distinct stages or phases:

A. *Delay period.*

This is the period of crank-shat rotation between the start of injection and the first ignition of the fuel charge. During this time, fuel is being injected continuously.

B. *Uncontrolled combustion.*

Once ignition of the fuel in the combustion chamber starts all the fuel that has accumulated during the delay period burns very rapidly, which causes a sudden pressure rise. This stage usually occurs from few degrees before TDC to a few degrees after TDC, giving a high cylinder pressure at the beginning of the power stroke. Obviously, the fuel injected during the uncontrolled combustion period burns as soon as it is injected.

C. *Controlled combustion.*

When the uncontrolled combustion completed, the fuel burns as it is injected into the combustion chamber, the rate of admission of the fuel giving accurate control of the cylinder pressure. Immediate combustion the fuel as it is injected during the controlled combustion period is ensured by the heat and pressure generated during the uncontrolled combustion period. At large throttle openings, the injection and the controlled combustion periods are longer than at small throttle openings, the rate of admission of the fuel being constant for the period during which it lasts. This means that the maximum cylinder pressure (as a result of combustion) for a particular engine is the same regardless of the throttle opening, the extra power being derived from longer combustion period.

D. *After- burning*

During the controlled combustion period, almost entire fuel burns. However, some fuel particles fail to find the necessary air for combustion during this stage of combustion and these particles burn after the injection has ceased. Again, some of the particles of the fuel that settled on the combustion chamber walls during injection evaporate and burn during this final stage.

5. Combustion chambers with turbulence effect

In some diesel engines, the combustion chamber is formed in the cylinder head, while in others it is formed in the crown of the piston. Regardless of where it is situated, the combustion chamber must be designed so that it is capable of producing maximum turbulence, not only during injection, but also when combustion is in progress. This high degree of turbulence is necessary for three reasons:

i. To ensure complete mixing of the fuel and air.
ii. To provide a continuous supply of air to the burning fuel particles.
iii. To sweep burnt gas from the injector area so that, as more fuel is injected, it meets fresh air.

When regard to the mixing of the fuel and air, it must be remembered that the fuel charge is not injected into the combustion chamber until the piston is 30 and 15 degree of crankshaft rotation from TDC. Suppose the speed of the engine is 1900 rpm, the time available for the fuel to be injected, mixed with the air and burnt is approximately $1/500^{th}$ of a second. It should be obvious that high air turbulence is necessary to mix the air and fuel thoroughly and quickly. The duration of 'delay period' is largely dependent on the efficient mixing of fuel and air in combustion chamber. If mixing is quick and efficient, the delay period will be greatly reduced and this in turn reduce diesel knock. On the other hand, if the mixing is slow and inefficient, a longer delay period will result and diesel knock will become more severe. If the supply of fresh air required to prevent 'suffocation' of the burning fuel particles (and to sweep burnt gas from the injection area) is not continuous, complete combustion cannot take place. If combustion is incomplete, thermal efficiency must drop with a corresponding increase in fuel consumption and a loss of power. Complete combustion must also be achieved if a condition known as 'crankcase dilution' is to be avoided. This condition is caused by unburnt fuel passing the rings and mixing with the lubricating oil in the crankcase. As a result of this contamination, the lubricating properties of the oil are greatly reduced and severe engine wear results. The paramount aim of combustion chamber design, therefore must be to create turbulence so that the atomized fuel and air are thoroughly mixed and complete combustion is achieved.

Due to the amount of research carried out over the years, many types of combustion chamber have been developed. These are generally divided into two categories:

I. Direct injection combustion chambers
II. Indirect injection combustion chambers

However, engines are usually classified as either 'direct injection' or 'indirect injection' the word 'combustion chamber' being dropped.

The main types combustion chamber in use today have been classified as follows:

A. Open combustion chamber (direct injection)
B. Pre-combustion chamber (indirect injection)
C. Compression swirl combustion chamber (indirect injection)
D. Air cell or energy cell combustion chamber (indirect injection)

The choice of the combustion chamber design for a particular engine depends largely on its rpm, its principle of operation (two or four stroke), the size of the engine and the purpose for which it is to be used.

5.1 The open combustion chamber

The trend in modern high-speed diesel engines is towards the open combustion chamber. This system has developed from a small combustion chamber in the cylinder head to the modern system, which makes use of a flat cylinder head and a specially shaped cavity in the piston crown. It is usual for the piston to protrude slightly above the block surface, giving minimum clearance between the piston crown and the head, thus ensuring good turbulence and combustion within the piston cavity. Almost all two stroke diesel use this system because of the ease of 'scavenging'.

A multi-hole-type injector with a wide spray angle is located directly above the piston cavity and sprays into this cavity where since there is very little clearance between the piston crown and the head almost all the compressed air is concentrated. High injection pressure is needed to ensure droplet penetration and efficient air-fuel mixing.

5.1.1 Piston cavities and squish

Piston cavities are cast in the piston crown and take many different forms. The most common type is the ‘toroidal piston cavity’- a circular cavity usually symmetric about the piston axis with a small cone projecting upwards from the bottom of the cavity towards the cylinder head(Refer Fig.5). Some manufacturers favour a simple hemispherical cavity while others use a dished piston crown, although the latter is fairly rare. Yet another manufacturer uses a simple deep cylindrical cavity, which is almost flat on the bottom. It is important to realize that each cavity must be used in conjunction with a particular injector nozzle and the fitting of a nozzle with slightly different spray angle can result in holes being burnt in the piston crown.

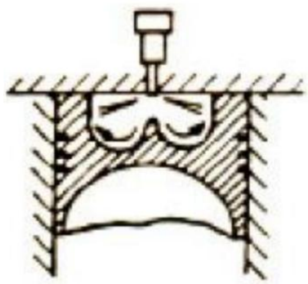


Fig.5 Toroidal Piston chamber

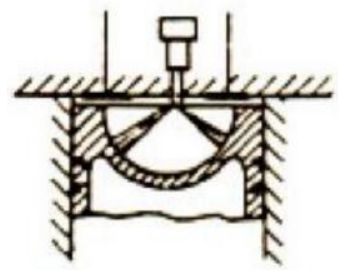


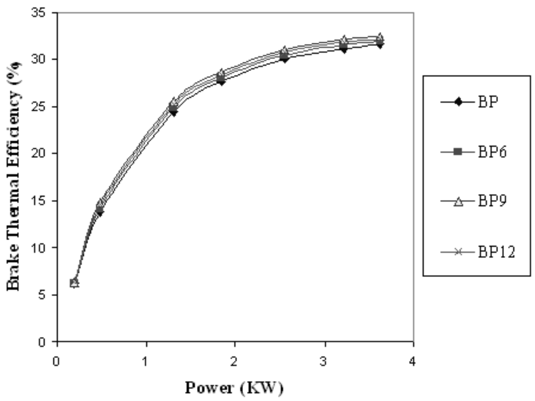
Fig.6 Hemispherical chamber

Regardless of the piston cavity design the turbulence in the cylinder is created in the same way. As the piston approaches TDC on the compression stroke, the major portion of the air in the cylinder is compressed into the piston cavity. Because of the ‘squish’ effect a high velocity is imparted to the air when it moves towards the piston cavity, thus causing a high degree of rotational turbulence in the piston cavity itself. The fuel injector is positioned above the piston so that fuel is injected directly into the turbulent air in the piston cavity, promoting efficient air fuel mixing. It should be mentioned here that some engine manufacturers such as perkins, have the toroidal cavity in piston slightly offset to promote swirl in predetermined direction.

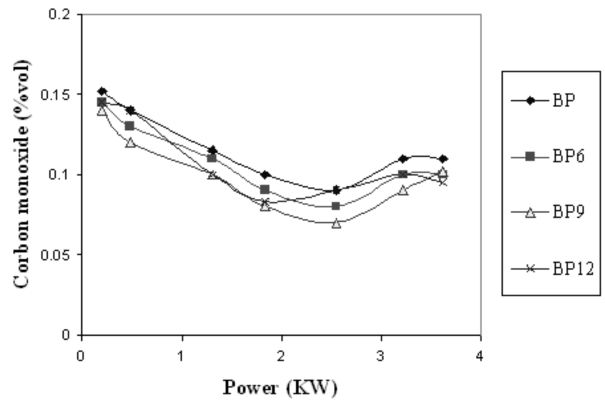
Squish may be defined as the rapid movement of the air being compressed in the cylinder of an open combustion chamber engine, from the cylinder walls towards the center of the combustion chamber. It is most effectively created by using either a toroidal cavity piston or a plain cavity piston, the crown of which has only the necessary clearance from the cylinder head when it is at TDC. As the piston approaches TDC on the compression stroke, the air trapped between the squish band on the piston periphery and the cylinder head is forced inwards at high velocity, into the cavity in the piston crown. At or near the center of the cavity, air meeting air cause mutual deflection towards the bottom of the piston cavity, beginning the circular turbulence . the degree of squish produced is largely dependent on the width of the squish band formed on the piston crown, with maximum squish velocity occurring at approximately 8° before TDC. Another design of combustion chamber utilizing squish to cause turbulence known as a ‘squish lip’, it has a much larger squish band than the conventional toroidal cavity piston and because of this increased area, the air flow velocity is increased, improving combustion. Usually some means of imparting a swirling motion to the air as it enters the cylinder on the induction stroke is used, giving the air moving towards the center of the combustion chamber on the compression stroke a swirling motion, which helps to promote turbulence.

Sunil kumar reddy et.al., conducted experimental analysis on grooved piston insert with various configuration of grooves (fig.7), results gives strong evidence of maximization of brake thermal efficiency occurs when rate of turbulence effect increase in the combustion chamber. The research reveals the significant effect on emission gases. The exhibits show the combustion efficiency improvement at the same time considerable reduction in emission gases [8].

Fig.7 Photographic view of Brass crown piston with various configurations of grooves
(BP-Plain brass piston, BP6- brass piston with 6 grooves, BP9- brass piston with 9 grooves, BP12-brass piston with 12 grooves)



(8A) Brake thermal efficiency Vs power



(8B) carbon monoxide % Vs Power

Fig.8 comparison among various groove configurations

Somender Singh has come up with a way to provide a faster, hence more efficient burn, with less loss of heat, through his design to improve turbulence in combustion chambers. His patented work was been featured in the Sept. 24 2004 Popular Science magazine, and has been written about extensively on the net. He created grooves, channels and passages (Refer fig.9&10) with different configuration in cylinder head, the attempt of generating high turbulence inside the combustion chamber. He recorded drastic improvement in thermal efficiency. Results from a dynamometer test by the Automotive Research Association of India (ARAI) showed a reduction of 42.5% in BSFC / fuel consumption when fully loaded, producing more torque and power at lower temperatures. The Patent, awarded in May, 2001, describes a combustion chamber design layout of grooves or channels or passages formed in the squish band to further enhance turbulence in the charge prior to ignition as compared to existing designs with squish bands or hemispherical layouts in internal combustion engines. These grooves or channels or passages after ignition direct the flame front to cause multipoint ignition during the combustion cycle resulting in the following distinct advantages over existing designs in practice. First, quicker and complete clean burn combustion; second, lower operating temperatures due to the higher flame velocities; third, enhanced torque and power through the entire range resulting in better fuel economy with lower emissions; and fourth, smoother engine operation through the entire range, enhancing engine life[9].

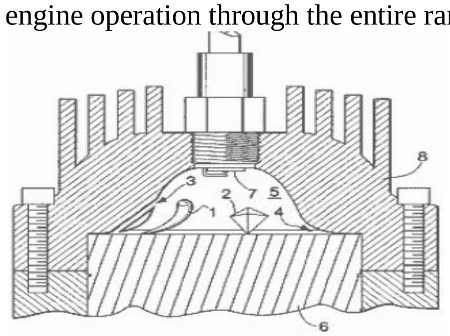


Fig. 9 Sectional view of Cylinder head with grooves, channels and passages

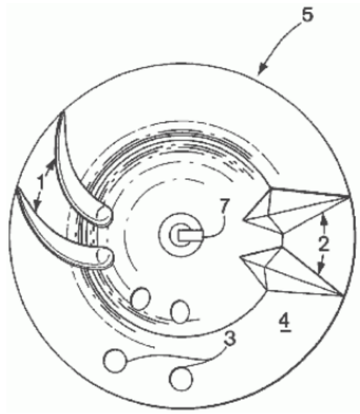


Fig. 10 Bottom view of Cylinder head with grooves, channels and passages

Issac Joshua ramesh lalvani et,al., investigated the combustion, performance and emission characteristics of a diesel engine powered with turbulence inducer piston (TIP)(Fig.11). The modified engine with turbulence inducer piston showed improved brake thermal efficiency, combustion characteristics and reduced hydro carbon, carbon monoxide and smoke emission. Nevertheless the nitrogen oxide emissions were slightly higher than the conventional unmodified engine [12].

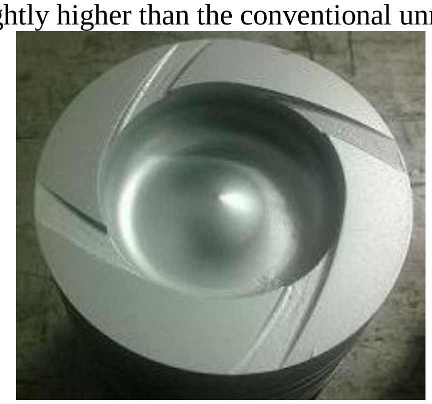


Fig.11 Turbulence Inducer Piston (TIP)

5.1.2 Directional ports

In order to achieve the necessary swirling motion in four stroke engines using the open combustion chamber system, directional ports are used. These curved induction ports impart a spiraling motion to the incoming air, which not only continues during the compression stroke but is intensified. Almost all manufactures use the combination of spiraling intake air and piston-induced squish to achieve effective turbulence in direct injection engines. The shape and position of the inlet port are directly responsible for the swirl characteristics of the incoming air, and a normal type of inlet valve is used for admitting the air to the cylinder. Some of the larger diesel engines use two directional ports and, of course two inlet valves to admit the air charge. Engines designed for automotive work, however use only one directional port and one or two inlet valves per cylinder. In earlier designs, masked valves were used to induce a directional swirl into the incoming air charge. The mask consisted of a curved deflecting shield located between the valve seat and the stem. In operation the masked valve had to be prevented from rotating to ensure mask alignment and subsequent correct air deflection. Because of the restriction this design imposed on incoming air flow, manufacturers have discontinued its use in modern diesel engines.

5.1.3 Tangential ports

Tangential inlet ports are used in two stroke diesel engines to create air turbulence. These ports are situated in the lower half of the cylinder liner and are machined at a tangent to the liner walls. The reason for this is to impart a rotary swirl to the air entering the cylinder. Tangential ports used in some large two stroke diesel engines are designed in such a way that the incoming air is deflected towards the top of the cylinder. This gives the air a swirling motion in the form of a spiral as it enters the cylinder, helping to achieve efficient cylinder scavenging as well as promoting turbulence given to the incoming air by the tangential ports not only continues, but is accelerated as the air is compressed on the compression stroke. This ensures good mixing of the air and the injected fuel with the result that the fuel charge is burnt efficiently.

Advantages of open combustion chambers

a. Due to its compact form, the surface area of the combustion chamber is small, resulting in a relatively low heat loss to the cooling system, thus giving high thermal efficiency.
b. Because of the low heat loss, the compressed air loses very little heat, giving good cold starting ability without the need for heater plugs.
c. Again because of low heat loss, low compression ratios may be employed, while still giving good starting and efficient combustion.

Disadvantages of open combustion chambers

a. Since a number of small holes are used in the injector nozzle, instead of one large hole, blocking by carbon deposits is fairly common.
b. To ensure penetration of the fuel particles into the compressed air, high injection pressures are necessary. This suggests the need to maintain injection equipment to a higher standard than would be necessary if lower injection pressures were required.
c. Rough running at low speeds occurs due to the long delay period that results from rather limited turbulence. In this design, turbulence is largely dependent on the speed of the incoming air, which obviously increases with engine speed.

5.2 Precombustion chambers

A Precombustion chamber is a small auxiliary chamber situated in the cylinder head and connected directly to the main combustion chamber by a small passage (Fig.12) . In some designs, the Precombustion chamber is separated from the main chamber by a perforated plate made from heat resistant alloy.

When the piston is at TDC on compression stroke, the major portion of the air charge has been forced through the connecting passage into the Precombustion chamber. The remainder of the air is contained in the main chamber between the piston crown and the cylinder head. Some engine manufacturers use a piston with a dish shaped cavity in the crown, while others use a piston with a flat crown in conjunction with a Precombustion chamber. When a dished piston is used, between 35 to 40 percent of the air is displaced from the cylinder on the compression stroke and is forced into the Precombustion chamber, the remainder being left in the main combustion chamber. When the injection takes place, the fuel charge is injected into the hot compressed air in the Precombustion chamber and ignition occurs. The subsequent burning of the fuel charge produces a substantial pressure rise in the confined space of the Precombustion chamber and, owing to this increase in pressure; particles of burning and unburnt fuel are forced violently through the narrow connecting passage into the main combustion chamber between the piston crown and the cylinder head. Any unburnt or partly burnt fuel particles mix with the air present, and the combustion process is completed in the main chamber. Because of the restricted passage connecting the Precombustion chamber to the cylinder and the beginning of combustion in that chamber, the sudden pressure rise from the uncontrolled combustion occurs largely with within the chamber with minimal effect in the engine cylinder. Thus the high cylinder pressures are eliminated, keeping diesel knock to a minimum and reducing internal stress in the engine.

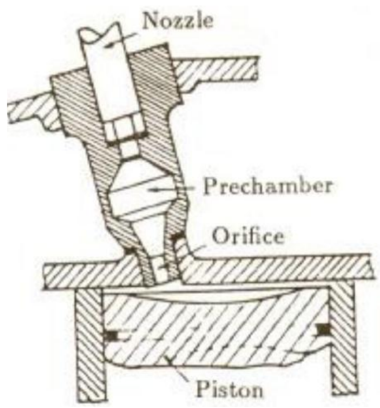


Fig.12 Precombustion chamber

Caterpillar used Precombustion chambers in its first diesel engines and is still using them, to a lesser extent, in its heavy-duty engines. The design is uncommon in that the Precombustion chamber is not cast or machined in the head, but is separate 'screw-in' unit into which the injector is directly fitted. The engine pistons have a heat resistant insert fitted into the piston crown directly below the outlet from the Precombustion chamber. This protects the alloy piston crown from the burning fuel particles, which are ejected at high velocity from the Precombustion chamber and which would eventually burn right through the piston crown. Because of the combustion characteristics, the degree of atomization of the fuel charge need not be as great as with direct injection engines, so that low injection pressures and pintle-type injector nozzles are usually employed. Caterpillar engines are a notable exception to the rule, using a single-hole nozzle of the firm's own design, featuring a very large orifice.

Advantages of Precombustion chamber

a. The pintle-type nozzle usually used in conjunction with Precombustion chambers has a relatively large orifice, plus a moving pintle, so that blockage due to carbon deposits is practically eliminated.
b. The fuel does not have to be as finely atomized as for direct-injection engines and consequently injection pressures are lower.
c. Because of high turbulence and efficient mixing of the fuel and air, the fuel quality does not have to be as high as with other types of combustion chamber.
d. Engine operation is smooth because maximum cylinder pressure during combustion is low.

Disadvantages of Precombustion chamber

a. In almost all types, heater plugs must be used when starting the engine in cold weather, because of the heat lost from the compressed air to the relatively large combustion chamber wall area.
b. The heat lost from the compressed air to the walls and at the throat of the Precombustion chamber is considerable and generally engines using this system have relatively low thermal efficiency and high fuel consumption.
c. Because of the heat loss to the combustion chamber, high compression ratios must be employed to achieve the necessary compressed air temperatures for efficient ignition.

5.3 Compression swirl combustion chamber

Although the trend appears to be towards direct injection, the compression swirl system is still very popular in the smaller automotive engines. A basic swirl chamber consists of an approximately spherical chamber in the cylinder head connected to the cylinder by a small passage. The passage joins to the side of the chamber at a tangent. This ensures that the air entering the chamber through the passage on the compression stroke swirls around inside the spherical chamber. The fuel is injected at a right angle to the swirling air, ensuring complete mixing. As soon as the pressure rise due to combustion is sufficient, a mixture of burnt, burning and unburnt fuel is ejected violently into the main chamber in the piston crown.

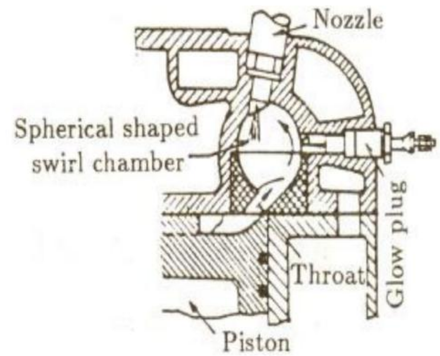


Fig.13 Compression swirl combustion chamber

The most popular compression swirl chamber used in modern high-speed diesel engines would appear to be based on sir Harry Ricardo's 'comet' design (Fig.13), of which there are many variants. This compression swirl chamber consists of a basic spherical chamber and tangential passage but in addition the top of the piston has a depression in its crown, which acts as part of the combustion chamber when the piston is at TDC, only very slight clearance being allowed between the flat of the piston crown and the head. The swirl chamber itself is made in two parts. As it formed in the cylinder head, the top half of the chamber is indirectly cooled by the engine's cooling system, but the bottom half is made of special heat resisting alloy steel, or in some cases satellite, and is not cooled in anyway. An air spaced is used to insulate the bottom half of the combustion chamber from the cylinder head, the only contact being a small area of the mounting flange that touches the cylinder head. This small contact area provides minimal conduction, keeping the bottom half of the combustion chamber hot so that it will heat the incoming air, and so reduce the delay period and improve combustion.

As the piston approaches TDC on the compression stroke, from 50 to 85 percent of the air (depending on the particular model of the chamber) is forced through the tangential passage and compressed in the swirl chamber. Because the connecting passage is tangential to the swirl chamber, the air entering the chamber is given a rapid circular swirling motion. The velocity of the swirling air is dependent on the engine rpm, so as the engine speed is increased and the air velocity increases, greater turbulence results. The fuel injector is positioned in such a way that when injection occurs, fuel is sprayed across and at right angles to the swirling air. When combustion begins, a pressure rise occurs in the swirl chamber and when the pressure in the chamber becomes greater than that of the incoming air, burning and partly burnt fuel particles are ejected at high velocity from the swirl chamber into the air remaining in the cavity in the piston crown. Turbulence results so particles are thoroughly mixed, completing combustion of the fuel charge. Because of the heat lost to the large surface area of the swirl chamber particularly the upper part on compression stroke cold starting devices are generally needed to allow easy starting in cold weather.

The compression swirl combustion chamber may easily be confused with the Precombustion chamber, since they are both separate chambers in the cylinder head in which fuel is injected and combustion starts. It is here that the similarity ends. The passage connecting the swirl chamber to the cylinder is much larger than the passage connecting the Precombustion chamber to the cylinder. Again the air enters the swirl chamber at a tangent and has the fuel sprayed across it, while air entering the Precombustion chamber does so centrally and has the fuel sprayed directly into it. Low injection pressures are used with compression swirl chambers, since thorough mixing and penetration are accomplished once combustion begins, making fine atomization unnecessary. For the same reason pintle injector nozzles are generally used, and these are, of course self cleaning. But pintaux nozzles have one very fine hole in addition to the pintle hole and this hole becomes choked with carbon very easily.

Advantages of compression swirl combustion chamber

a. Because of high turbulence and near perfect combustion, the odour-producing exhaust gas emissions are eliminated.
b. Relatively low injection pressures can be used.
c. Because of the high turbulence and good air-fuel mixing, the delay period is reduced and diesel knock is practically eliminated.

Disadvantages of compression swirl combustion chamber

a. Due to losses in thermal and mechanical efficiency slightly more fuel is used than in direct injection engines.
b. The heat lost by the compressed air to the top of the swirl chamber is considerable causing cold weather starting problems.
c. Owing to the design of the compression swirl chamber efficient scavenging of the burnt gas is a problem.

5.4 Air cell or energy cell combustion chamber

Over the years, many types of air cell have been developed, the most successful of these being the ‘Lanova’ energy cell. The most common version of this combustion chamber consists of a cell located in the cylinder head directly opposite the fuel injection nozzle. The energy cell is usually a removable unit screwed into the head and consists of two differently sized and shaped cells in series, connected by a venturi choke. The cells are permanently in communication with the combustion chamber, through another venturi at the inner end of the inner cell.

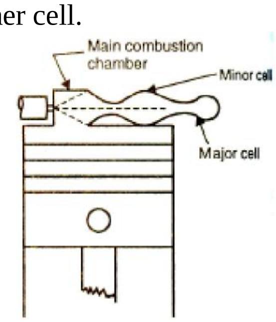


Fig.14 Air cell or Energy cell combustion chamber

In operation beginning with the induction stroke, the air enters through the inlet valve in one of the two recesses and, because of its offset position with respect to the cylinder axis, is given an initial swirling motion. On the compression stroke, this air is compressed into the confined space of the ‘8’-shaped combustion chamber continuing the swirling motion. When the top of the compression stroke is approached, the air above the flat portions of the piston crown is rapidly displaced into the chamber recesses attaining both high velocity and high temperature. During the compression stroke a small part of the air is forced into the energy cell, where owing to the restricted cooling it later attains a pressure higher than that in the combustion chamber. This high pressure however is confined within the cell where it cannot cause increased stress on the working parts of the engine but where on the other hand it serves a definite purpose in combustion control. At the proper instant, the fuel is sprayed by the nozzle directly across the chamber throat, the main body of the stream entering the energy cell and those portions near the edges being swept around the circular recesses in opposite directions, thus accelerating the already swirling air therein. As the fuel reaches the energy cell it ignites instantaneously and a rapid combustion takes place. However since the volume of air within the cell is small only a small part of the fuel is thus consumed and the balance the major portion is blown violently back against the continuing stream from the injection nozzle. It is divided by the form of the throat into two streams of highly atomized fuel and hot air in the process of combustion to swirl actively in opposite directions in two recesses. In doing so these streams oppose the direction of rotation of the air already there so that air and fuel are most intimately mixed.

Advantages of air cell combustion chamber

a. There is minimal shock loading on working components due to a high degree of controlled combustion.
b. A clean exhaust is possible over a fairly wide range of speeds, because the turbulence in the combustion chamber is induced by thermal expansion and is virtually independent of the engine speed.
c. Relatively low fuel injection pressures may be used because a high degree of atomization is not required.

Disadvantages of air cell combustion chamber

a. There are starting difficulties when cold due to the high loss of compressed air heat to the very large combustion chamber wall area.
b. Efficient scavenging of the energy cell is difficult to achieve.
c. The cylinder head is expensive because of the complicated moulding and machining involved in its manufacturing.

6. Conclusion

The time during which the fuel vaporizes and ignites is dependent on three factors:

i. The difference between the air temperature and the self-ignition temperature of the fuel.

   If the air temperature is much higher than the fuel self-ignition temperature, the fuel will vaporize and ignite quickly. The greater the difference, the quicker will be the vaporization, and the sooner ignition will occur.

ii. The pressure in the combustion chamber

   The greater the pressure, the more intimate the contact between the cold fuel and the hot air will be. The closer the contact between these two, the greater will be the rate of heat transfer from one to the other, again giving more rapid vaporization and ignition.

iii. The fineness of the fuel particles.

   If the fuel could be broken up into fine enough particles, the vaporization required for combustion would be practically negligible and ignition will start almost immediately. However, the mass of the fuel particles under these conditions would not be sufficient to carry the particle far from the injector nozzle, and complete combustion would not occur. For complete combustion, good depth of penetration of the fuel particles into the combustion chamber is necessary, and the particles must have sufficient mass to carry them deep into the compressed air.

The study reinforcing the existence of turbulence in combustion chamber, and detailed discussion carried out about the vital role of turbulence to achieve proper air-fuel mixing which can leads to complete combustion. Various types of combustion chamber were explained with respect to improve the turbulence effect inside the diesel engine combustion chamber. Turbulence inducing geometrical changes and auxiliary chambers are analyzed, Prons and Cons are listed.

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