

Combustion Chambers in CI Engines: A Review

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Abstract: CI engines are widely used in stationary as well as mobile applications. Stationary applications include typical gen-set, etc. and mobile applications include heavy automobiles, forestry equipments, etc. as well as other applications in day-to-day life. Since the turbulence is necessary for better mixing and the fact that it can be controlled by shape of the combustion chamber, makes this review paper necessary. This paper re-visits and draws on the essentials of combustion chamber, their design, influence in combustion process, timing, etc. This paper is meant to emphasize research on newer designs requirement for combustion chambers. CI engines find widespread applications due to their robustness, high compression ratio and hence high thermal efficiency and usage of non-volatile fuel generally diesel oil.

Keywords: combustion chamber, compression ignition, swirl, squish, turbulence

1. Introduction

The compression ignition engine is an internal combustion engine that uses the increase in temperature in the compression stroke to ignite a fuel charge (fuel-air mixture). This is also called auto-ignition. These engines are always fuel injected. Air is drawn into the cylinder through the intake manifold and compressed by the piston.

The most important function of the CI engine combustion chamber is to provide proper mixing of fuel and air (called carburetion) in a short time to lessen the ignition lag phase. In order to achieve this, an organized air movement called air swirl is provided to produce high relative velocity between fuel droplets and air. When the liquid fuel is injected into the combustion chamber, the spray cone gets disturbed due to the air motion and turbulence inside. The onset of combustion will cause an added turbulence that can be guided by the shape of the combustion chamber.

Swirl is defined as organized rotation of charge about the cylinder axis. Swirl is created by bringing an intake flow into the cylinder with an initial angular momentum. Swirl is used in CI engine concepts to promote more rapid mixing between the inducted air charge and the injected fuel. Swirl is also used to speed up the combustion process and in two-stroke engines, it improves scavenging.

Squish is the name given to the radially inward or transverse gas motion that occurs towards the end of the compression stroke when apporation of piston face and cylinder head approach each other closely.

2. Types of Chambers

2.1 Direct Injection (DI) Type

It is also called an open combustion chamber. An open combustion chamber is defined as one in which the combustion space is essentially a single cavity with little restriction on one part of the chamber to the other and hence with no large difference in pressure between parts of the chamber during the combustion process. DI chambers are of following types:

- **Shallow Depth Chamber:** The depth of the cavity provided in the piston is quite small. This chamber is usually adopted for large engines running at low speeds. Since the cavity diameter is very large, the squish is negligible.

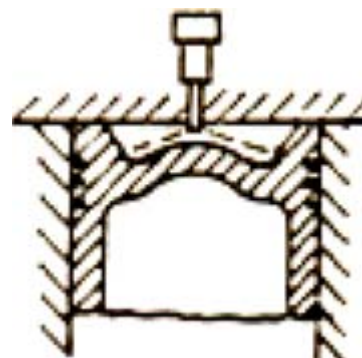


Figure 1: Shallow Depth Chamber

- **Hemispherical Chamber:** This chamber also gives small squish. However, in this case desired squish can be obtained by varying depth to diameter ratio.

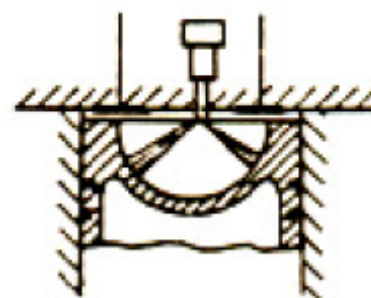


Figure 2: Hemispherical Chamber

- **Cylindrical Chamber:** This design was attempted in recent diesel engines. The swirl is produced by masking the cone for nearly 180° of circumference. In this case also, squish can be varied by varying the depth.

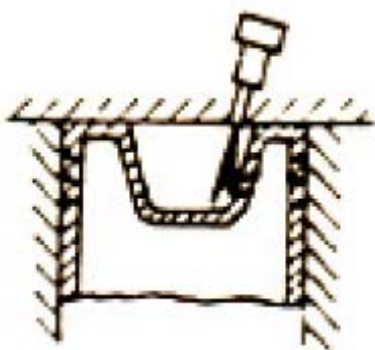


Figure 3: Cylindrical Chamber

- Toroidal Chamber: It provides a powerful squish along with air movement. Due to powerful squish, the mask needed on inlet valve is small and there is better utilization of oxygen. Cone angle of spray for this type of chamber is 150° to 160° .

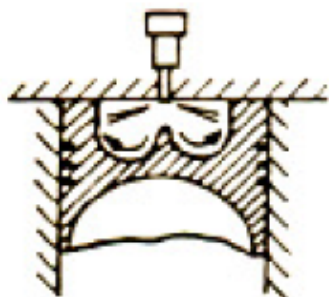


Figure 4: Toroidal Chamber

Indirect Injection (IDI) Type

In this type of combustion chambers, the combustion space is divided into two parts – main cylinder and cylinder head connected by restricted passages. This creates considerable pressure differences between them during the combustion process. IDI chambers are of following types:

- Swirl Chamber: Swirl chamber consists of a spherical shaped chamber separated from the engine cylinder and located in the cylinder head. Into this chamber, about 50% of the air is transferred during the compression stroke. A throat connects the chamber to the cylinder which enters the chamber in a tangential direction so that the air coming into this chamber is given a strong rotary movement inside the swirl chamber and after combustion, the products rush back into the cylinder through same throat at much higher velocity. This causes considerable heat loss to walls of the passage which can be reduced by employing a heat insulated passage. However, in this type of combustion chambers even with an insulated passage, the heat loss is greater than that in an open combustion chamber which employ induction swirl. This type of combustion chamber finds its application where fuel quality is difficult to control, where reliability under adverse conditions is more important than fuel economy. The use of single hole of larger diameter for the fuel spray nozzle is often important consideration for the choice of swirl chamber engine.

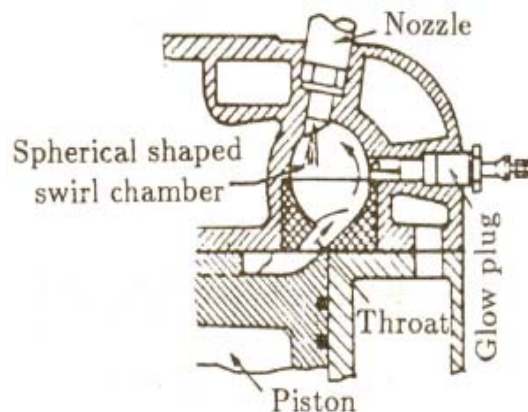


Figure 5: Swirl Chamber

- Pre-combustion Chamber: A typical pre-combustion chamber consists of an anti chamber connected to the main chamber through a number of small holes (compared to a relatively large passage in the swirl chamber). The pre-combustion chamber is located in the cylinder head and its volume accounts for about 40% of the total combustion, space. During the compression stroke the piston forces the air into the pre-combustion chamber. The fuel is injected into the pre-chamber and the combustion is initiated. The resulting pressure rise forces the flaming droplets together with some air and their combustion products to rush out into the main cylinder at high velocity through the small holes. Thus it creates both strong secondary turbulence and distributes the flaming fuel droplets throughout the air in the main combustion chamber where bulk of combustion takes place. About 80% of energy is released in main combustion chamber. The rate of pressure rise and the maximum pressure is lower compared to those in open type chamber. The initial shock if combustion is limited to pre-combustion chamber only. The pre-combustion chamber has multi fuel capability without any modification in the injection system because the temperature of pre-chamber. The variation in the optimum injection timing for petrol and diesel operations is only 2 deg. for this chamber compared to 8 to 10 deg in other chamber design.

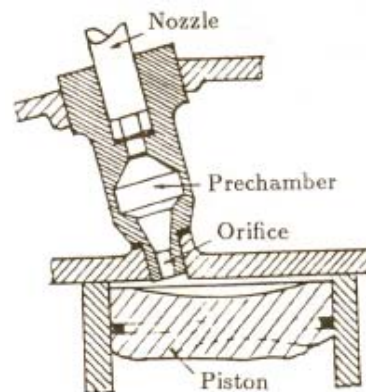


Figure 6: Pre-Combustion Chamber

- Air-Cell Chamber: The air cell is more complex than the pre-combustion chamber. As the piston moves up on the compression stroke, some of the air is forced into the major and minor chambers of the energy cell. When the

fuel is injected through the pintle type nozzle, part of the fuel passes across the main combustion chamber and enters the minor cell, where it is mixed with the entering air. Combustion first commences in the main combustion chamber where the temperature is higher, but the rate of burning is slower in this location, due to insufficient mixing of the fuel and air. The burning in the minor cell is slower at the start, but due to better mixing, progresses at a more rapid rate. The pressure built up in the minor cell, therefore, force the burning gases out into the main chamber, thereby creating added turbulence and producing better combustion in the this chamber. In mean time, pressure is built up in the major cell which then prolongs the action of the jet stream entering the main chamber, thus continuing to induce turbulence in the main chamber.

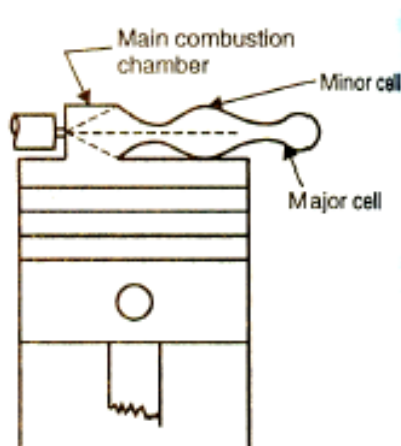


Figure 7: Air-Cell Chamber

3. Relevance with Current Practices

The CI applications include modern day diesel engines. Some of the common diesel engines used by automobile organizations like Hyundai, Honda, Volkswagen Group, Ford use diesel engines viz. CRDi, i-DTEC, TDi, duratorq which are way more efficient and clean due to improved combustion chamber design as one of the factors. Even engines using bio-diesel focus on combustion chamber design for increase in efficiency needless to mention the eco-friendliness. The new i-DTEC clean diesel engine was introduced to the North American market in 2009 subsequently coming to India as well. The i-DTEC engine reduces noxious exhaust emissions while boosting power and fuel efficiency. A combination of optimized combustion chamber design and reduced injection time results in a clean, quiet engine that delivers excellent performance for an enjoyable driving experience.

4. Conclusion

This review paper gives an insight into the importance and effects of good combustion chamber design. There is a strong necessity of research and innovation in combustion chamber design as with advent of new technologies in engine and fuel type innovations, this is indispensable. Moreover, whatever is the type of fuel, technology or engine used in present or in future, combustion will be always there

as through combustion of fuel only, power is generated. Hence study of combustion chamber is of prime importance and that too in CI engines because their applications are varied and widespread.

5. Future Scope

As we saw through this article, how important combustion process and combustion chambers are, future studies should emphasize on this technology and discover similar technology for improved combustion efficiency in CI engines.

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Author Profile



Arka Ghosh received B.Tech. degree in Mechanical Engineering from SRM University in 2014. Currently he is pursuing MBA from ISBR Business School. He has done research work on Fatigue Analysis and is currently doing research in metal matrix composites. Apart from this, he is into case-studies and business analysis.