Lectures

8th Semester B. Tech. Mechanical Engineering

Subject: Internal Combustion Engines

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Chapter: Combustion in Spark Ignition Engines

Topic: Essential Features of Process- 01-05-2020

Normal Combustion In SI Engines:

Practical Significance Of Normal Combustion:

Normal combustion is the combustion that occurs only by the propagation of flame from the spark plug in an engine cylinder. It depends on the flame speed which depends on engine design parameters, the engine operating parameters and the fuel being used.
During normal combustion the heat release rate and the corresponding rise and fall of in-cylinder pressure with respect to crank angle is smooth and within the control of the engine designer.

Essential Features of Combustion Process:

Intake Process: In a conventional spark ignition engine during intake process the piston moves downwards. This creates a low pressure in the intake pipe or intake manifold which makes the air to flow in towards the engine cylinder. Simultaneously the electronic solenoid injectors inject fuel into this air at the intake port of the cylinder. The fuel gets vaporized and mixed with air. The air-fuel mixture enters the engine cylinder where it further mixes with the residual gas from the previous cycle present in the clearance volume of cylinder.
Compression Process: The mixture then gets compressed during the compression process.
Combustion: Towards the end of the compression stroke the combustion is initiated at the **spark plug** by means of an **electric discharge.**
A **turbulent flame** develops which **propagates** through this essentially premixed fuel, air, burned gas mixture until it reaches the combustion **chamber walls** where it **extinguishes**.

The High Speed Color Movie For A Single Cylinder SI Engine Fitted With A Glass Piston Crown Shows:

1. Spark discharge is at -30 degrees of crank angle.
2. The flame first becomes visible at about -24 degrees of crank angle
3. The **flame**, approximately **circular** in outline in this view through the piston, then propagates outwards from the spark plug location.
4. A strong **blue light** is emitted from the front side of this propagating flame.

5. The flame front has an **irregular shape** because of its **turbulent motion**.
6. **At TC** the diameter of the flame is about **two-thirds** of cylinder **bore**.
7. The **flame** reaches the cylinder **wall** farthest from the spark plug at about **15 degrees after TC**.
8. The **combustion** continues for another **10 degrees** of crank angle in the **peripheral volumes** of the combustion chamber.
9. At about **10 degrees** of crank angle **ATC** some burned **mixture** around the spark plug and **behind** the propagating **flame produces a** white afterglow which soon turns into pink color. This is due to the development of highest temperatures inside the combustion chamber during this part of combustion process.

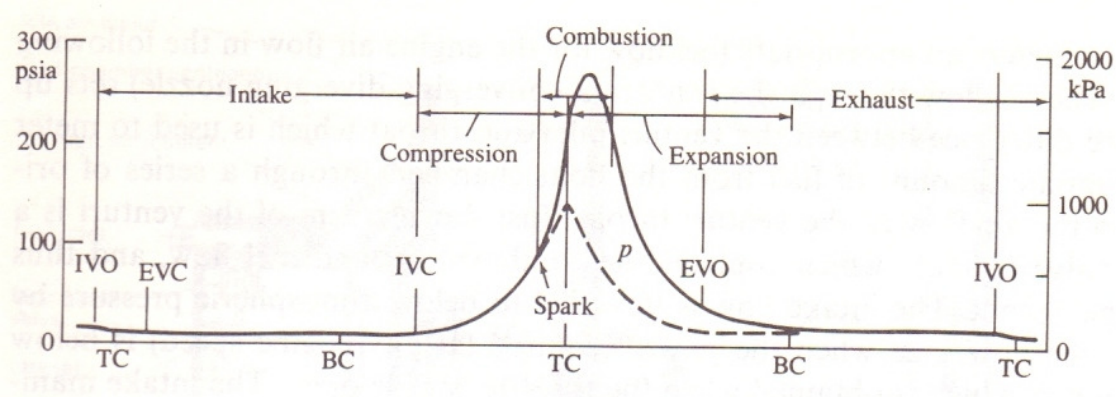


Fig. Pressure Versus Crank Angle Diagram – Combustion in 4S SI Engines

Cyclic Variations In The Combustion Process:

The flame growth depends on local mixture motion and composition. These quantities vary in successive cycles in any given engine cylinder and may also vary cylinder to cylinder for a multi-cylinder engine. The mixture motion and composition near the spark plug at the time of spark discharge are most significant. This is because these factors govern the early stages of flame development. The flame development and flame propagation therefore vary cycle by cycle which change the shape of the pressure versus volume diagram for the subsequent combustion cycles. This variation in subsequent combustion cycles as dictated by the changing pressure-volume diagrams is defined as the cyclic variations in combustion process. The extreme cycles limit the operating regime of the engine.

Example:

The idle speed of the Maruti Suzuki 800 cc car engine is 900±50 rpm.

The reason for this variation in idle speed is due to cyclic variations in combustion process. The extreme limits for idle speed could be 850 rpm and 950 rpm. This will correspond to the two extreme pressure versus volume diagrams developed during combustion under varying mixture motion and composition.

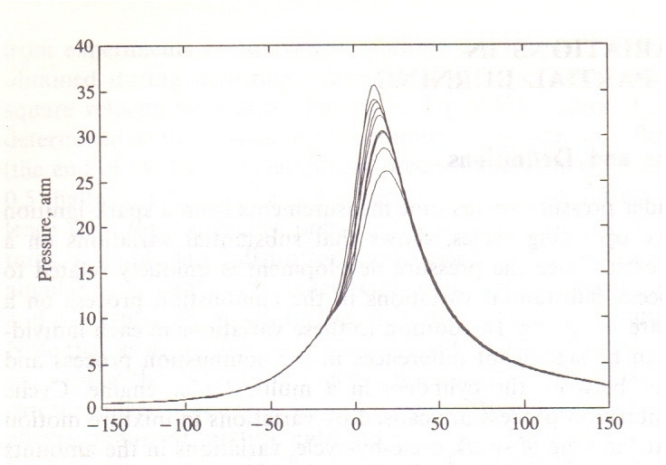


Fig. Cyclic variations in in-cylinder pressure with respect to crank angle for 10 cycles for a single cylinder SI engine at 1500 rpm

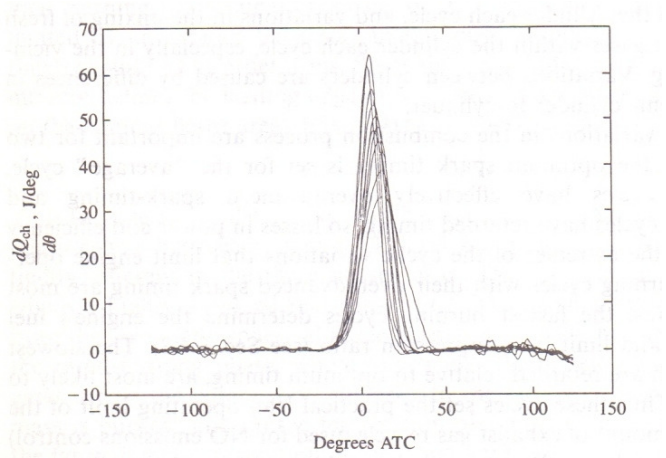


Fig. Cyclic variations in rate of heat release with respect to crank angle for 10 cycles for a single cylinder SI engine at 1500 rpm

Spark Timing:

The crank angle at which the spark is initiated at the spark plug is defined as the spark timing of the SI engine.

Maximum Brake Torque Timing or
MBT Timing:

If we introduce the concept of variable spark timing, It is possible either to advance the spark timing with respect to TC or retard the spark timing with respect to TC. Advancing or retarding the spark timing with respect to TC changes the brake torque and therefore brake power available at the crank shaft. This is because the pressure versus crank angle diagram changes by changing the spark timing.

By **advancing the spark timing** before TC, the **compression stroke** work transfer (which is from the piston to the cylinder gases) increases. This is because the piston has to do **additional work** of compression against the higher pressures getting developed by advanced combustion process.
By progressively **retarding the spark timing**, the peak cylinder pressures occur later in the expansion stroke and are also reduced in magnitude. This **reduces** the **area** under the **pressure versus volume diagram** which indicates a **decrease in the brake power** developed at the crank shaft.
The spark timing at which the magnitudes of these two opposing trends offset each other, and develops a maximum brake torque at the engine crank shaft, is known as maximum brake torque timing or MBT timing.

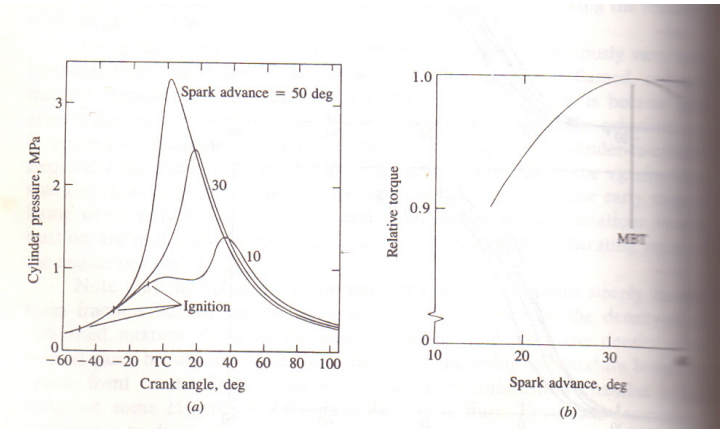


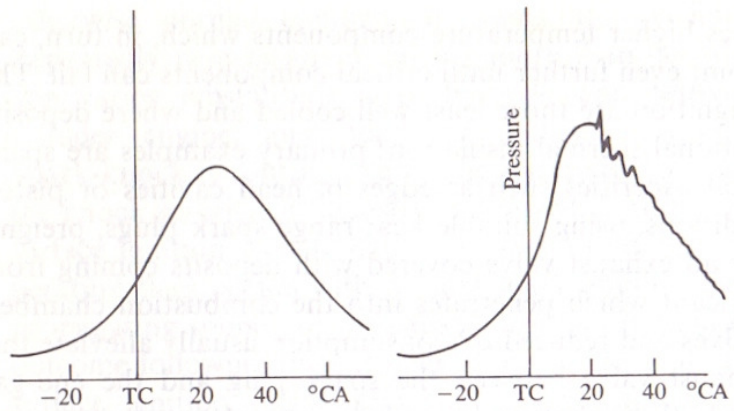
FIGURE 9-3
(*a*) Cylinder pressure versus crank angle for overadvanced spark timing (50°), MBT timing [illegible] retarded timing (10°). (*b*) Effect of spark advance on brake torque at constant speed and [illegible] wide-open throttle. MBT is maximum brake torque timing.[5]

Abnormal Combustion In SI Engines:
Abnormal combustion for an SI engine is defined as that type of combustion process in which the heat is released at an abnormal rate than desired. The corresponding rise and fall of pressure with respect to crank angle does not remain smooth.
During normal combustion the heat release rate and the corresponding rise and fall of in-cylinder pressure with respect to crank angle is smooth and within the control of the engine designer.

Two types of abnormal combustion have been identified: Knock and surface ignition.

Knock:
Knock is the most important abnormal combustion phenomenon. Its name comes from the noise that results from the auto-ignition of a portion of the fuel, air, residual gas mixture ahead of the advancing flame. As the flame propagates across the combustion chamber, the unburned mixture ahead of the flame – called the end gas- is compressed, causing its pressure, temperature, and density to increase. Some of the end gas fuel-air mixture may undergo chemical reactions prior to normal combustion. The products of these reactions may then auto-ignite i.e., spontaneously and rapidly release a large a large part or all their chemical energy. When this happens, the end gas burns very rapidly, releasing its energy at a rate 5 to 25 times that characteristic of normal

combustion. This causes **high frequency pressure oscillations** inside the cylinder that **produce** the sharp **metallic noise called knock.**



Surface Ignition:
Surface ignition is **ignition of the fuel-air charge** by **overheated valves or spark plugs**, by glowing combustion chamber **deposits**, or by any other **hot spot** in the engine combustion chamber.
It is the ignition **by any source other than normal spark ignition.**
It may occur **before the spark** plug ignites the charge (**pre-ignition**) or after normal ignition (post-ignition). It may produce **a single flame or many flames.**
Pre-ignition based abnormal combustion is most evident with its effects most severe.
However, even when surface ignition occurs **after the spark** plug fires (**post-ignition**), the spark discharge no longer has complete control of the combustion process.

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Text Book:
Internal Combustion Engine Fundamentals
By John B Heywood
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