MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

Estd. 2000

LECTURE HANDOUTS

L - 1

MECH

Year/Sem : IV / VII

Course Name with Code : Advanced IC Engine / 16MEE03

Course Faculty : Mr. S.Perumal

Unit : I – Spark Ignition Engines **Date of Lecture:**

Topic of Lecture: Introduction

Introduction :
A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work.

Prerequisite knowledge for Complete understanding and learning of Topic Gear terminology

1. Classification of Engine
2. Working Principle of SI Engine

Detailed content of the Lecture:

A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work. It is classified into two types-

(a) External combustion engine
(b) Internal combustion engine

External combustion engine:

In this engine, the products of combustion of air and fuel transfer heat to a second fluid which is the working fluid of the cycle.

Examples:

*In the steam engine or a steam turbine plant, the heat of combustion is employed to generate steam which is used in a piston engine (reciprocating type engine) or a turbine (rotary type engine) for useful work.

*In a closed cycle gas turbine, the heat of combustion in an external furnace is transferred to gas, usually air which the working fluid of the cycle.

Internal combustion engine:

In this engine, the combustion of air and fuels take place inside the cylinder and are used as the direct motive force. It can be classified into the following types:

1. According to the basic engine design- (a) Reciprocating engine (Use of cylinder piston arrangement), (b) Rotary engine (Use of turbine)

2. According to the type of fuel used- (a) Petrol engine, (b) diesel engine, (c) gas engine (CNG, LPG), (d) Alcohol engine (ethanol, methanol etc)

3. According to the number of strokes per cycle- (a) Four stroke and (b) Two stroke engine 4. According to the method of igniting the fuel- (a) Spark ignition engine, (b) compression ignition engine and (c) hot spot ignition engine 5. According to the working cycle- (a) Otto cycle (constant volume cycle) engine, (b) diesel cycle (constant pressure cycle) engine, (c) dual combustion cycle (semi diesel cycle) engine. 6. According to the fuel supply and mixture preparation- (a) Carburetted type (fuel supplied through the carburettor), (b) Injection type (fuel injected into inlet ports or inlet manifold, fuel injected into the cylinder just before ignition). 7. According to the number of cylinder- (a) Single cylinder and (b) multi-cylinder engine 8. Method of cooling- water cooled or air cooled 9. Speed of the engine- Slow speed, medium speed and high speed engine 10. Cylinder arrangement-Vertical, horizontal, inline, V-type, radial, opposed cylinder or piston engines. 11. Valve or port design and location- Overhead (I head), side valve (L head); in two stroke engines: cross scavenging, loop scavenging, uniflow scavenging. 12. Method governing- Hit and miss governed engines, quantitatively governed engines and qualitatively governed engine 14. Application- Automotive engines for land transport, marine engines for propulsion of ships, aircraft engines for aircraft propulsion, industrial engines, prime movers for electrical generators.
Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=zKA4TYMgiqU
Important Books/Journals for further learning including the page nos.: R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 32- 35.

Course Faculty

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LECTURE HANDOUTS

L - 2

MECH

Year/Sem : IV / VII

Course Name with Code : **Advanced IC Engine / 16MEE03**

Course Faculty : **Mr. S.Perumal**

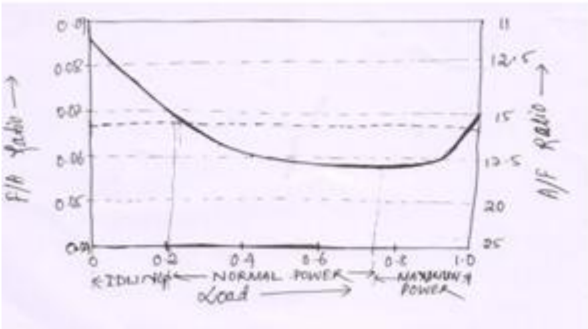
Unit : **I – Spark Ignition Engines** **Date of Lecture:**

Topic of Lecture: Mixture requirements
Introduction : A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work.
Prerequisite knowledge for Complete understanding and learning of Topic Gear terminology 3. Classification of Engine 4. Working Principle of SI Engine

Detailed content of the Lecture:

<u>Mixture requirements for steady state operation:</u>

Three main areas of steady state operation of automotive engine which require different air fuel ratio are discussed below,



4. Main areas of automotive engine operation

(a) Idling and low load:

- From no load to about 20% of rated power
- No load running mode is called idling condition
- Very low suction pressure give rise to back flow of exhaust gases and air leakage Increases the amount of residual gases and hence increase the dilution effects
- Rich mixture i.e. F/A ratio 0.08 or A/F ratio 12.5:1 provide smooth operation of the engine

(b) Normal power range or cruising range:

- From about 20% to 75% of rated power
- Dilution by residual gases as well as leakage decreases, hence fuel economy is important Consideration in this case
- Maximum fuel economy occurs at A/F ratio of 17:1 to 16.7:1
- Mixture ratios for best economy are very near to the mixture ratios for minimum emissions

(c) Maximum power range:

- From about 75% to 100% of rated power
- Mixture requirements for the maximum power is a rich mixture, of A/F about 14:1 or F/A 0.07.
- Rich mixture also prevents the overheating of exhaust valve at high load and inhibits detonation
- In multi-cylinder engine the A/F ratio are slightly lower

<u>Mixture requirements for transient operation:</u>

- Carburetor has to provide mixture for transient conditions under which speed, load, temperature, or pressure change rapidly
- Evaporation of fuel may be incomplete in the transient condition, quantity of fuel may be increasing and decreasing

(a) Starting and warm up requirements:

- Engine speed and temperature are low during the starting of the engine from cold
- During starting very rich mixture about 5 to 10 times the normal amount of petrol is sulpplied i.e. F/A ratio 0.3 to 0.7 or A/F ratio 3:1 to 1.5:1
- Mixture ratio is progressively made leaner to avoid too rich evaporated fuel-air ratio during warm up condition
- Too high volatility may form vapour bubbles in the carburettor and fuel lines particularly when engine temperatures are high
- Too low volatility may cause the petrol to condense on the cylinder walls, diluting and removing the lubricating oil film

(b) Acceleration requirements:

- Acceleration refer to an increase in engine speed resulting from the opening of the throttle acceleration pump is used to provide additional fuel
-

Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=ngXfCeGeeBg

Important Books/Journals for further learning including the page nos.:
R.K.Rajbut, "Internal Combustion Engines", Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 357- 366.

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Estd. 2000

LECTURE HANDOUTS

L - 3

MECH

Year/Sem : IV / VII

Course Name with Code : **Advanced IC Engine / 16MEE03**

Course Faculty : **Mr. S.Perumal**

Unit : **I – Spark Ignition Engines** **Date of Lecture:**

Topic of Lecture: Fuel injection systems

Introduction :
A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work.

Prerequisite knowledge for Complete understanding and learning of Topic Gear terminology

5. Classification of Engine
6. Working Principle of SI Engine

Detailed content of the Lecture:

Petrol injection:

- To avoid above problem of modern carburettor, petrol injection is used like in diesel engine -petrol injected during the suction stroke in the intake manifold at low pressure
- Injection timing is not much critical as like in diesel engine
  Continuous injection and timed injection methods are used

1.12.1. Continuous injection:

- The fuel is sprayed at low pressure continuously into the air supply -amount of fuel is governed by air throttle opening
- In supercharged engine, fuel injected in the form of multiple spray into the suction side of the centrifugal compressor
- It provide efficient atomisation of fuel and uniform mixture strength to all cylinder.
  higher volumetric efficiency.one fuel injection pump and one injector

1.12.2. Timed injection system:

- It is similar to high speed diesel engine
- The components are fuel feed or lift pump, fuel pump and distributor unit, fuel injection nozzles and mixture controls
- mixture controls are automatic for all engine operating conditions

(i) Multiple plunger jerk pump system:

- Pump with separate plunger and high injection nozzle pressure for each cylinder
  pressure is between 100 to 300 bar
- measured quantity of fuel for definite time and over definite period is delivered

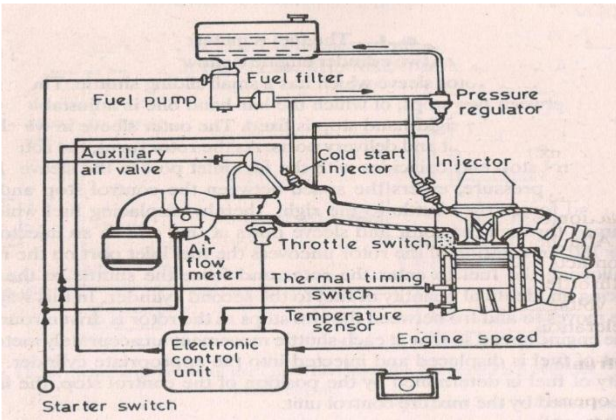
(ii) Low pressure single pump and distributor system:

- Single plunger or gear pump supply fuel at low pressure to a rotating distributor -
  pressure about 3.5 to 7 bar

(a) Lucas petrol injection system

- Firstly used in racing car
- Single distributor system with novel metering device Line pressure is maintained at 7 bar
- Metering distributor and control unit distributes the required amount of fuel at correct time and interval
- Has shuttle arrangements for metering unit
- In aircraft engine two injectors and spark plug provided for direct injection of fuel in combustion chamber

(B)Electronic fuel injection



<u>Fuel delivery system</u>

- Electrically driven fuel pump draws fuel from tanks to distribute Fuel and manifold pressure kept constant by pressure regulator

Air induction system:

- Air flow meter generate voltage signal according to air flow
- Cold start magnetic injection valve give good fuel atomisation and also provide extra fuel during warm up condition

Electronic control unit (ECU):

- Sensors for manifold pressure, engine speed and temperature at intake manifold -sensor measures operating data from locations and transmitted electrically to ECU

Injection timing:

- Injected twice for every revolution of crank shaft
  triggering of injectors

Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=qId3Th6_a4U

Important Books/Journals for further learning including the page nos.: R.K.Rajbut, "Internal Combustion Engines", Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 391- 393.

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LECTURE HANDOUTS

L - 4

MECH

Year/Sem : IV / VII

Course Name with Code : **Advanced IC Engine / 16MEE03**

Course Faculty : **Mr. S.Perumal**

Unit : **I – Spark Ignition Engines** **Date of Lecture:**

Topic of Lecture: Mono point, Multipoint & Direct injection

Introduction :

Fuel injection is the introduction of fuel in an internal combustion engine, most commonly automotive engines, by the means of an injector.

Prerequisite knowledge for Complete understanding and learning of Topic Gear terminology

1. Classification of Engine
2. Working Principle of SI Engine

Detailed content of the Lecture:

Single-point injection

- Single-point injection uses one injector in a throttle body mounted similarly to a carburetor on an intake manifold. As in a carbureted induction system, the fuel is mixed with the air before the inlet of the intake manifold.
- Single-point injection was a relatively low-cost way for automakers to reduce exhaust emissions to comply with tightening regulations while providing better "driveability" (easy starting, smooth running, freedom from hesitation) than could be obtained with a carburetor. Many of the carburetor's supporting components - such as the air cleaner, intake manifold, and fuel line routing - could be used with few or no changes. This postponed the redesign and tooling costs of these components.

Multi-point injection

- Multi-point injection injects fuel into the intake ports just upstream of each cylinder's intake valve, rather than at a central point within an intake manifold
- Typically, multi-point injected systems use multiple fuel injectors, but some systems such as the GM central port injection use tubes with poppet valves fed by a central injector instead of multiple injectors.

Injection schemes

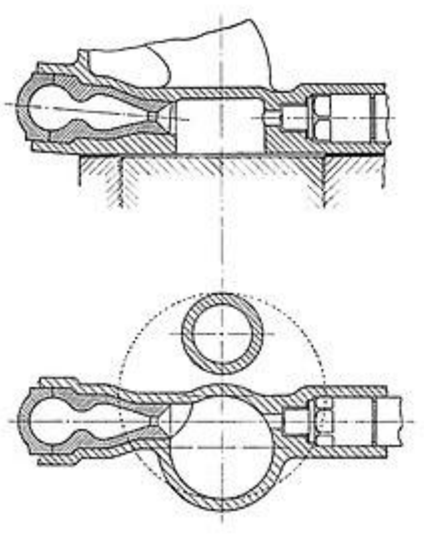
- Manifold injected engines can use several injection schemes: continuous and intermittent (simultaneous, batched, sequential, and cylinder-individual).
- In a continuous injection system, fuel flows at all times from the fuel injectors, but at a variable flow rate. The most common automotive continuous injection system is the Bosch K-Jetronic, introduced in 1974, and used until the mid-1990s by various car manufacturers.
- Intermittent injection systems can be sequential, in which injection is timed to coincide with each cylinder's intake stroke; batched, in which fuel is injected to the cylinders in groups, without precise synchronization to any particular cylinder's intake stroke; simultaneous, in which fuel is injected at

the same time to all the cylinders; or cylinder-individual, in which the engine control unit can adjust the injection for each cylinder individually.

Internal mixture formation

In an engine with an internal mixture formation system, air and fuel are mixed only inside the combustion chamber. Therefore, only air is sucked into the engine during the intake stroke. The injection scheme is always intermittent (either sequential or cylinder-individual). There are two different types of internal mixture formation systems: indirect injection, and direct injection.

Indirect injection



- Air-cell chamber injection – the fuel injector (on the right) injects the fuel through the main combustion chamber into the air-cell chamber on the left. This is a special type of indirect injection and was very common in early American diesel engines.
- Indirect injection as an internal mixture formation system (typical of Akroyd and Diesel engines); for the external mixture formation system that is sometimes called indirect injection (typical of Otto and Wankel engines),
- In an indirect injected engine, there are two combustion chambers: a main combustion chamber, and a pre-chamber, that is connected to the main one. The fuel is injected only into the pre-chamber (where it begins to combust), and not directly into the main combustion chamber. Therefore, this principle is called indirect injection. There exist several slightly different indirect injection systems that have similar characteristics. All Akroyd (hot-bulb) engines, and some Diesel (compression ignition) engines use indirect injection.

Direct injection

- Direct injection means that an engine only has a single combustion chamber, and that the fuel is injected directly into this chamber. This can be done either with a blast of air (air-blast injection), or hydraulically. The latter method is far more common in automotive engines.
- Typically, hydraulic direct injection systems spray the fuel into the air inside the cylinder or combustion chamber, but some systems spray the fuel against the combustion chamber walls (M-System). Hydraulic direct injection can be achieved with a conventional, helix-controlled injection pump, unit injectors, or a sophisticated common-rail injection system.
- The latter is the most common system in modern automotive engines. Direct injection is well-suited for a huge variety of fuels, including petrol (see petrol direct injection), and diesel fuel.
- In a common rail system, the fuel from the fuel tank is supplied to the common header (called the accumulator). This fuel is then sent through tubing to the injectors, which inject it into the combustion chamber. The header has a high pressure relief valve to maintain the pressure in the header and return the excess fuel to the fuel tank.

- The fuel is sprayed with the help of a nozzle that is opened and closed with a needle valve, operated with a solenoid. When the solenoid is not activated, the spring forces the needle valve into the nozzle passage and prevents the injection of fuel into the cylinder. The solenoid lifts the needle valve from the valve seat, and fuel under pressure is sent in the engine cylinder.
- Third-generation common rail diesels use piezoelectric injectors for increased precision, with fuel pressures up to 300 MPa or 44,000 lbf/in^2

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=GlM9MHOX6iY

Important Books/Journals for further learning including the page nos.: R.K.Rajbut, "Internal Combustion Engines", Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 425- 428.

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LECTURE HANDOUTS

L - 5

MECH

Year/Sem : IV / VII

Course Name with Code : **Advanced IC Engine / 16MEE03**

Course Faculty : **Mr. S.Perumal**

Unit : **I – Spark Ignition Engines** **Date of Lecture:**

Topic of Lecture: Stages of combustion

Introduction :
Combustion may be defined as a relatively rapid chemical combination of hydrogen and carbon in fuel with oxygen in air resulting in liberation of energy in the form of heat

Prerequisite knowledge for Complete understanding and learning of Topic Gear terminology
1. Classification of Engine
2. Working Principle of SI Engine

Detailed content of the Lecture:

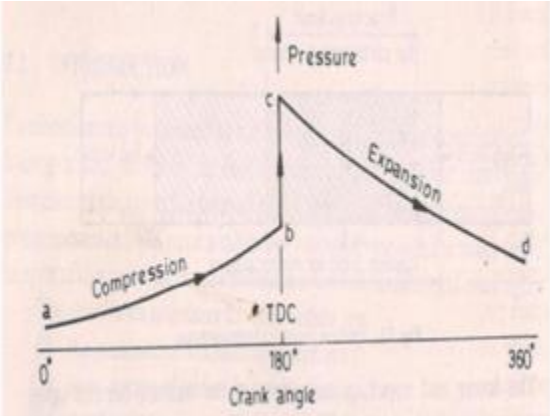
Combustion may be defined as a relatively rapid chemical combination of hydrogen and carbon in fuel with oxygen in air resulting in liberation of energy in the form of heat. Following conditions are necessary for combustion to take place: 1. The presence of combustible mixture 2. Some means to initiate mixture 3. Stabilization and propagation of flame in Combustion Chamber In S I Engines, carburetor supplies a combustible mixture of petrol and air and spark plug initiates combustion

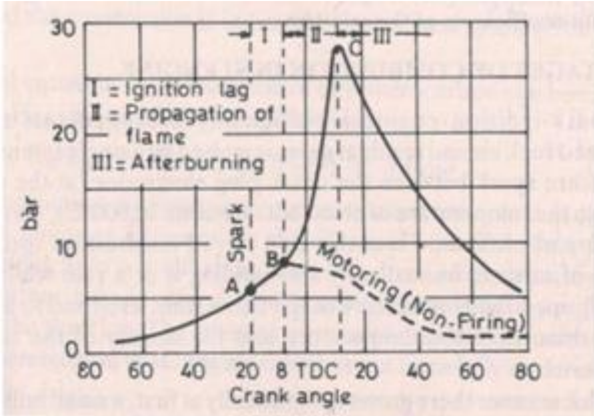
Ignition Limits

Ignition of charge is only possible within certain limits of fuel-air ratio. Ignition limits correspond approximately to those mixture ratios, at lean and rich ends of scale, where heat released by spark is no longer sufficient to initiate combustion in neighboring unburnt mixture. For hydrocarbons fuel the stoichiometric fuel air ratio is 1:15 and hence the fuel air ratio must be about 1:30 and 1:7.

Theories of Combustion in SI Engine

Combustion in SI engine may roughly is divided into two general types: Normal and Abnormal (knock free or knocking). Theoretical diagram of pressure crank angle diagram is shown in figure below. (a $\rightarrow$ b) is compression process, (b $\rightarrow$ c) is combustion process and (c $\rightarrow$ $\rightarrow$ d) is an expansion process. In an ideal cycle it can be seen from the diagram, the entire pressure rise during combustion takes place at constant volume i.e., at TDC. However, in actual cycle this does not happen.





<u>Richard Theory of Combustion</u>:

Sir Ricardo, known as father of engine research describes the combustion process can be imagined as if it is developing in two stages: 1. Growth and development of a self-propagating nucleus flame. (Ignition lag) 2. Spread of flame through the combustion chamber

Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=Y8l6AEquy94

Important Books/Journals for further learning including the page nos.:
R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 226- 234.

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LECTURE HANDOUTS

L - 6

MECH

Year/Sem : IV / VII

Course Name with Code : **Advanced IC Engine / 16MEE03**

Course Faculty : **Mr. S.Perumal**

Unit : **I – Spark Ignition Engines** **Date of Lecture:**

Topic of Lecture: Normal and Abnormal combustion

Introduction :

Combustion may be defined as a relatively rapid chemical combination of hydrogen and carbon in fuel with oxygen in air resulting in liberation of energy in the form of heat.

Prerequisite knowledge for Complete understanding and learning of Topic Gear terminology

1. Classification of Engine
2. Working Principle of SI Engine

Detailed content of the Lecture:

Normal combustion

- Spark-ignited flame moves steadily across the combustion chamber until the charge is fully consumed.
- A combustion process which is initiated solely by a timed spark and in which the flame front moves completely across the combustion chamber in a uniform manner at a normal velocity.

Three Stage of Combustion:

- According to Ricardo, There are three stages of combustion in SI Engine as shown
- Ignition lag stage
- Flame propagation stage
- After burning stage

1. **Ignition lag stage**:
   - There is a certain time interval between instant of spark and instant where there is a noticeable rise in pressure due to combustion. This time lag is called IGNITION LAG. Ignition lag is the time interval in the process of chemical reaction during which molecules get heated up to self ignition temperature , get ignited and produce a self propagating nucleus of flame. The ignition lag is generally expressed in terms of crank angle (1θ).
   - The period of ignition lag is shown by path (a-b). Ignition lag is very small and lies between 0.00015 to 0.0002 seconds. An ignition lag of 0.002 seconds corresponds to 35 deg crank

rotation when the engine is running at 3000 RPM. Angle of advance increase with the speed. This is a chemical process depending upon the nature of fuel, temperature and pressure, proportions of exhaust gas and rate of oxidation or burning. 125

2. Flame propagation stage:

- Once the flame is formed at "b", it should be self sustained and must be able to propagate through the mixture. This is possible when the rate of heat generation by burning is greater than heat lost by flame to surrounding. After the point "b", the flame propagation is abnormally low at the beginning as heat lost is more than heat generated. Therefore pressure rise is also slow as mass of mixture burned is small.
- Therefore, it is necessary to provide angle of advance (30-35) degrees, if the peak pressure to be attained (5-10) degrees after TDC. The time required for crank to rotate through an angle (θ_2) is known as combustion period during which propagation of flame takes place.

3. After burning:

Combustion will not stop at point "c" but continue after attaining peak pressure and this combustion is known as after burning. This generally happens when the rich mixture is supplied to engine

Abnormal combustion

- Fuel composition, engine design and operating parameters, combustion chamber deposits may prevent occurring of the normal combustion process.A combustion process in which a flame front may be started by hot combustion-chamber surfaces either prior to or after spark ignition, or a process in which some part or all of the charge may be consumed at extremely high rates

There are two types of abnormal combustion:

- Knock
- Surface ignition

Video Content / Details of website for further learning (if any):
Https://www.youtube.com/watch?v=Vtvy4NODK08

Important Books/Journals for further learning including the page nos.: R.K.Rajbut, "Internal Combustion Engines", Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 201- 208.

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LECTURE HANDOUTS

L - 7

MECH

Year/Sem : IV / VII

Course Name with Code : **Advanced IC Engine / 16MEE03**

Course Faculty : **Mr. S.Perumal**

Unit : **I – Spark Ignition Engines** **Date of Lecture:**

Topic of Lecture: Knock

Introduction :

- Knock is the auto ignition of the portion of fuel, air and residual gas mixture ahead of the advancing flame that produces a noise.

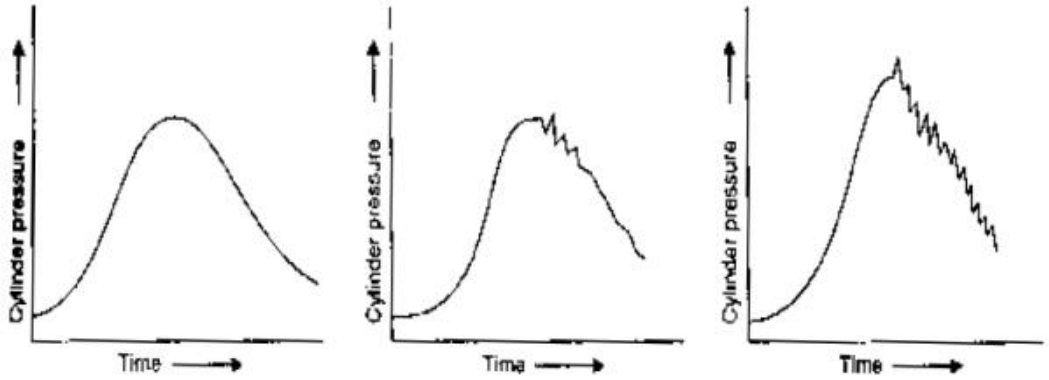
Prerequisite knowledge for Complete understanding and learning of Topic Gear terminology

1. Classification of Engine
2. Working Principle of SI Engine

Detailed content of the Lecture:

PHENOMENON OF KNOCKING IN SI ENGINE:

- Knocking is due to auto ignition of end portion of unburned charge in combustion chamber. As the normal flame proceeds across the chamber, pressure and temperature of unburned charge increase due to compression by burned portion of charge.
- This unburned compressed charge may auto ignite under certain temperature condition and release the energy at a very rapid rate compared to normal combustion process in cylinder.
- This rapid release of energy during auto ignition causes a high-pressure differential in combustion chamber and a high-pressure wave is released from auto ignition region.
- The motion of high-pressure compression waves inside the cylinder causes vibration of engine parts and pinging noise and it is known as knocking or detonation. This pressure frequency or vibration frequency in SI engine can be up to 5000 Cycles per second.
- Denotation is undesirable as it affects the engine performance and life, as it abruptly increases sudden large amount of heat energy. It also put a limit on compression ratio at which engine can be operated which directly affects the engine efficiency and output.



(i) Normal combustion with no knock (ii) Combustion with slight knock (iii) Combustion with heavy knock

Auto ignition

A mixture of fuel and air can react spontaneously and produce heat by chemical reaction in the absence of flame to initiate the combustion or self-ignition. This type of self-ignition in the absence of flame is known as Auto-Ignition. The temperature at which the self-ignition takes place is known as self-igniting temperature. The pressure and temperature abruptly increase due to auto-ignition because of sudden release of chemical energy. This auto-ignition leads to abnormal combustion known as detonation which is undesirable because its bad effect on the engine performance and life as it abruptly increases sudden large amount of heat energy. In addition to this knocking puts a limit on the compression ratio at which an engine can be operated which directly affects the engine efficiency and output.

Pre-ignition

Pre-ignition is the ignition of the homogeneous mixture of charge as it comes in contact with hot surfaces, in the absence of spark. Auto ignition may overheat the spark plug and exhaust valve and it remains so hot that its temperature is sufficient to ignite the charge in next cycle during the compression stroke before spark occurs and this causes the pre-ignition of the charge. Pre-ignition is initiated by some overheated projecting part such as the sparking plug electrodes, exhaust valve head, metal corners in the combustion chamber, carbon deposits or protruding cylinder head gasket rim etc. pre-ignition is also caused by persistent detonating pressure shockwaves scoring away the stagnant gases which normally protect the combustion chamber walls. The resulting increased heat flow through the walls, raises the surface temperature of any protruding poorly cooled part of the chamber, and this therefore provides a focal point for pre-ignition.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=uWx1cXR7x_M

Important Books/Journals for further learning including the page nos.: R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 208- 210.

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LECTURE HANDOUTS

L - 8

MECH

Year/Sem : IV / VII

Course Name with Code : **Advanced IC Engine / 16MEE03**

Course Faculty : **Mr. S.Perumal**

Unit : **I – Spark Ignition Engines** **Date of Lecture:**

Topic of Lecture: Factors affecting knock

Introduction :
A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work.

Prerequisite knowledge for Complete understanding and learning of Topic Gear terminology

1. Classification of Engine
2. Working Principle of SI Engine

Detailed content of the Lecture:

Effects of Detonation

The harmful effects of detonation are as follows:

1. Noise and Roughness: Knocking produces a loud pulsating noise and pressure waves. These waves which vibrates back and forth across the cylinder. The presence of vibratory motion causes crankshaft vibrations and the engine runs rough.

2. Mechanical Damage:

(a) High pressure waves generated during knocking can increase rate of wear of parts of combustion chamber. Sever erosion of piston crown(in a manner similar to that of 133 marine propeller blades by capitation), cylinder head and pitting of inlet and outlet valves may result in complete wreckage of the engine.

(b) Detonation is very dangerous in engines having high noise level. In small engines the knocking noise is easily detected and the corrective measures can be taken but in aero-engines it is difficult to detect knocking noise and hence corrective measures cannot be taken. Hence severe detonation may persist for a long time which may ultimately result in complete wreckage of the piston.

3. **Carbon deposits:**

Detonation results in increased carbon deposits.

4. **Increase in heat transfer:** Knocking is accompanied by an increase in the rate of heat transfer to the combustion chamber walls. The increase in heat transfer is due to two reasons: • The minor reason is that the maximum temperature in a detonating engine is about 150°C higher than in a non-detonating

engine, due to rapid completion of combustion • The major reason for increased heat transfer is the scouring away of protective layer of inactive stagnant gas on the cylinder walls due to pressure waves. The inactive layer of gas normally reduces the heat transfer by protecting the combustion and piston crown from direct contact with flame.

5. Decrease in power output and efficiency.

Due to increase in the rate of a detonating engine decreases.

6. Pre-ignition:

The increase in the rate of heat transfer to the walls has yet another effect. It may cause local overheating, especially of the sparking plug, which may reach a temperature high enough to ignite the charge before the passage of spark, thus causing pre-ignition. An engine detonating for a long period would most probably lead to pre ignition and this is the real danger of detonation

EFFECT OF ENGINE OPERATING VARIABLES ON THE ENGINE KNOCKING DETONATION

The various engine variables affecting knocking can be classified as:

- Temperature factors
- Density factors
- Time factors
- Composition factors

(A) TEMPERATURE FACTORS Increasing the temperature of the unburned mixture increase the possibility of knock in the SI engine We shall now discuss the effect of following engine parameters on the temperature of the unburned mixture:

(B) RAISING THE COMPRESSION RATIO: Increasing the compression ratio increases both the temperature and pressure (density of the unburned mixture). Increase in temperature reduces the delay period of the end gas, which in turn increases the tendency to knock.

(C) SUPERCHARGING: It also increases both temperature and density, which increase the knocking tendency of engine

(D) COOLANT TEMPERATURE: Delay period decreases with increase of coolant temperature , decreased delay period increase the tendency to knock

(E) TEMPERATURE OF THE CYLINDER AND COMBUSTION CHAMBER WALLS: The temperature of the end gas depends on the design of combustion chamber. Sparking plug and exhaust valve are two hottest parts in the combustion chamber and uneven temperature leads to pre-ignition and hence the knocking.

(F) DENSITY FACTORS increasing the density of un burnt mixture will increase the possibility of knock in the engine. The engine parameters that affect the density are as follows: Increased compression ratio increase the density increasing the load opens the throttle valve more and thus the density Supercharging increase the density of the mixture increasing the inlet pressure increases the overall pressure during the cycle. The high-pressure end gas decreases the delay period, which increase the tendency of knocking. 135 Advanced spark timing: quantity of fuel burnt per cycle before and after TDC, position depends on spark timing. The temperature of charge increases by increasing the spark advance and it increases with rate of burning and does not allow sufficient time to the end mixture to dissipate the heat and increase the knocking tendency.

(G) TIME FACTORS Increasing the time of exposure of the unburned mixture to auto-ignition conditions increase the possibility of knock in SI engines. Flame travel distance: If the distance of flame travel is more, then possibility of knocking is also more. This problem can be solved by combustion chamber design, spark plug location and engine size. Compact combustion chamber will have better anti-knock characteristics, since the flame travel and combustion time will be shorter. Further, if the combustion chamber is highly turbulent, the combustion rate is high and consequently combustion time is further reduced; this further reduces the tendency to knock. Location of sparkplug: A spark plug that is centrally located in the combustion chamber has minimum tendency to knock, as the flame travel is minimum. The flame travel can be reduced by using two or more spark plugs. Location of exhaust valve: The exhaust valve should be located close to the spark plug so that it is not in the end gas region; otherwise, there will be a tendency to knock. Engine size: Large engines have a greater knocking tendency because flame requires a longer time to travel across the combustion chamber. In SI engine therefore , generally limited to 100mm Turbulence of mixture decreasing the turbulence of the mixture decreases the flame speed and hence increases the tendency to knock. Turbulence depends on the design of combustion chamber and one engine speed.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=w2TWPDdHYVo

Important Books/Journals for further learning including the page nos.:
R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 209 - 210.

Course Faculty

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LECTURE HANDOUTS

L - 9

MECH

Year/Sem : IV / VII

Course Name with Code : **Advanced IC Engine / 16MEE03**

Course Faculty : **Mr. S.Perumal**

Unit : **I – Spark Ignition Engines** **Date of Lecture:**

Topic of Lecture: Combustion chambers

Introduction :

A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work.

Prerequisite knowledge for Complete understanding and learning of Topic Gear terminology

7. Classification of Engine
8. Working Principle of SI Engine

Detailed content of the Lecture:

Design of Combustion Chambers

It involves

- Shape of combustion chamber
- Location of spark plug.
- Position of inlet and exhaust valves.

COMBUSTION CHAMBERS DESIGN PRINCIPLES.

1. High volumetric efficiency – largest possible inlet valve.

2. To prevent knock

* Minimum flame travel.
* Bore limited up to 100 mm in SIE. In CIE there is no limit.
* Proper location of spark plug, valves, shape of CC.

3. To reduce knock

* No hot surface in end gas portion.
* Exhaust valve should not be in end gas region and it should be near spark plug.

4. Small exhaust valve – high lift can be used.

5. Short combustion duration

- High flame velocity.
- Optimum turbulence.
- Suitable position of inlet valve.
- Streamlined passages.

6. Shape of combustion chambers -

largest mass of charge burns as soon as possible after ignition.

7. To get high BTE

- Minimum heat loss.
- Minimum S/V ratio in combustion zone.
- Hemispherical shape gives minimum S/V ratio and minimum air pollution.

8. In end gas region S/V ratio should be large

* Good cooling in knock zone.
* Quench space in end gas region.

9. Cooled exhaust valve head

* Hottest region in combustion chambers.
* High velocity water stream.

DIFFERENT TYPES OF COMBUSTION CHAMBERS IN SI ENGINE

- T-head combustion chamber
- L-head combustion chamber
- I-head (or overhead valve) combustion chamber
- F-head combustion chamber

It may be noted that these chambers are designed to obtain the objectives namely:

- A high combustion rate at the start.
- A high surface-to-volume ratio near the end of burning.
- A rather centrally located spark plug.

i.T Head Type Combustion chambers

This was first introduced by Ford Motor Corporation in 1908. This design has following disadvantages.

- Requires two cam shafts (for actuating the in-let valve and exhaust valve separately) by two cams mounted on the two cam shafts.
- Very prone to detonation. There was violent detonation even at a compression ratio of 4. This is because the average octane number in 1908 was about 40 -50.

ii.L Head Type Combustion chambers

It is a modification of the T-head type of combustion chamber. It provides the two values on the same side of the cylinder, and the valves are operated through tappet by a single camshaft. This was first introduced by Ford motor in 1910-30 and was quite popular for some time. This design has an advantage both from manufacturing and maintenance point of view.

iii.Overhead valve or I head combustion chamber

The disappearance of the side valve or L-head design was inevitable at high compression ratio of 8:1 because of the lack of space in the combustion chamber to accommodate the valves. Diesel engines, with high compression ratios, invariably used overhead valve design. Since 1950 or so mostly overhead valve combustion chambers are used. This type of combustion chamber has both the inlet valve and the exhaust valve located in the cylinder head. An overhead engine is superior to side valve engine at high compression ratios.

The overhead valve engine is superior to side valve or L head engine at high compression ratios, for the following reasons:

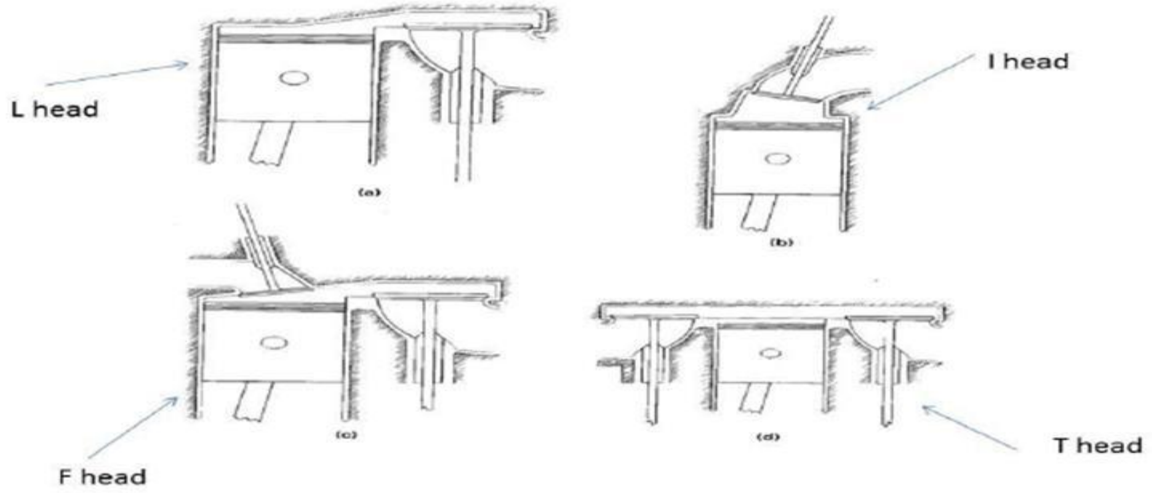

Fig.. Different Combustion Chambers

F- Head combustion chamber

In such a combustion chamber one valve is in head and other in the block. This design is a compromise between L-head and I-head combustion chambers. One of the most F head engines (wedge type) is the one used by the Rover Company for several years. Another successful design of this type of chamber is that used in Willeys jeeps.

Video Content / Details of website for further learning (if any):
https://unacademy.com/lesson/ic-engine-combustion-chambers-in-c-i-engine/4JQYJCLJ

Important Books/Journals for further learning including the page nos.:
R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 238 - 240.

Course Faculty

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LECTURE HANDOUTS

L - 10

MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.PERUMAL.

Unit : 2 - COMPRESSION IGNITION ENGINES

Date of Lecture :

Topic of Lecture : Diesel Fuel Injection Systems

Introduction:

The fuel is supplied through camshaft driven fuel pump. Fuel valve is also connected with high pressure airline to inject into cylinder. In multi-stage compressor which supply air at a pressure of about 60 to 70 bar

Prerequisite knowledge for Complete understanding and learning of Topic:

Air injection system, Solid injection system, Individual pump and injector or jerk pump system, Common rail system

Detailed content of the Lecture:

DIESEL INJECTION SYSTEM:

Requirements of diesel injection system:

- The fuel must introduce precisely defined period of cycle
- Amounts metered very accurately
- Rate of injection meet desired heat release pattern
- Quantities of fuel meet changing speed and load condition
- Good atomization of fuel
- Good spray pattern for rapid mixing of fuel and air
- No dribbling and after injection of fuel i.e. sharp injection
- Injection timing suits the speed and load requirements
- Distribution of fuel in multi
- Cylinder should uniform
- Weight, size and cost of fuel injection system should be less

Types of diesel injection system:

***(a)* Air injection system:**

The fuel is supplied through camshaft driven fuel pump. Fuel valve is also connected with high pressure airline to inject into cylinder. In multi-stage compressor which supply air at a pressure of about 60 to 70 bar.

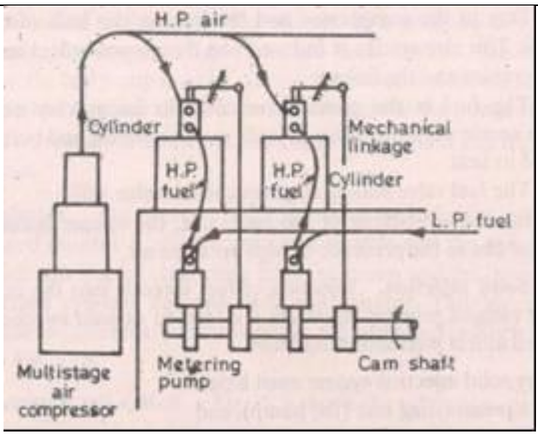

Fig. Air injection system

The blast air sweeps the fuel along with it. Good atomization results in good mixture formation and hence high mean effective pressure. Here heavy and viscous fuels are used. The fuel pump require small pressure. But it is complicated due to compressor arrangement and expensive.

(b) Solid injection system:

The fuel is directly injected to combustion chamber without primary atomization termed as solid injection. It is also known as airless mechanical injection. 2 units are there, 1.Pressurise and 2.Atomising unit

3 different types which are described below,

(i) Individual pump and injector or jerk pump system:

The separate metering and compression pump is used for each cylinder. The reciprocating fuel pump is used to meter and set the injection pressure of the fuel. The heavy gear arrangements which gives jerking noise, hence name is given is jerk pump. The jerk pump is used for medium and high speed diesel engines

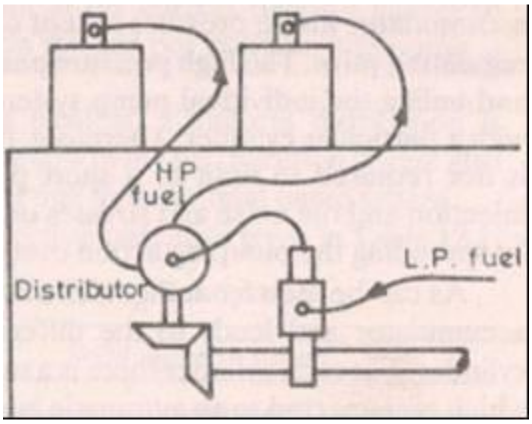

Fig. . Individual pump and injector or jerk pump system

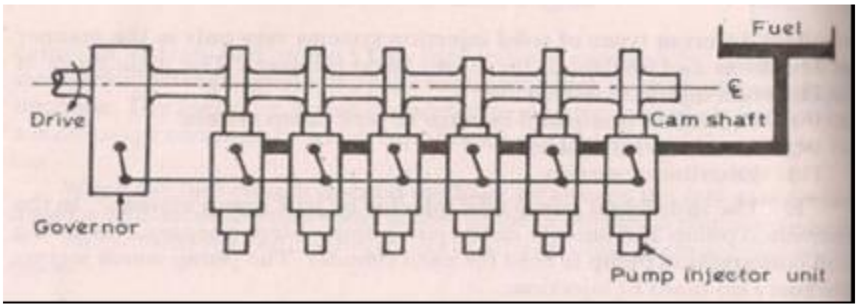

Fig. Unit injector

(ii) Common rail system:

The high pressure fuel pump delivers fuel to an accumulator whose pressure is constant. Here plunger type of pump is used. The driving mechanism is not stressed with high pressure hence noise is reduced. The common rail or pipe is connected in between accumulator and distributing elements. It is separate metering and timing elements connected to automatic injector.

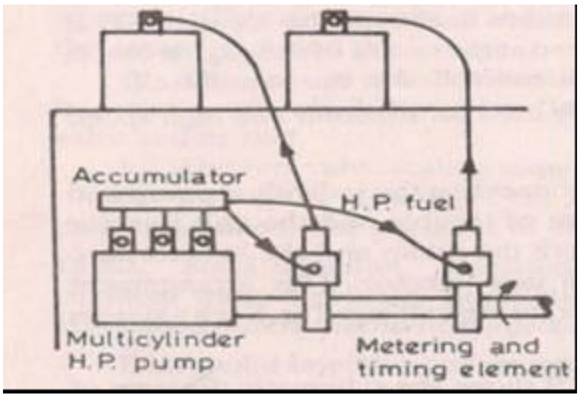

Fig. Common rail system

(iii) Distributor system:

The fuel pump pressurizes, meters and times the fuel supply to rotating distributor. The number of injection strokes per cycle for the pump equals to the number of cylinder. One metering element which ensure uniform distribution

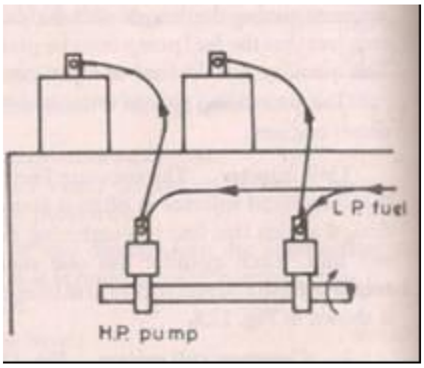

Fig.. Distributor system

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=H28bE6gf5qQ

Important Books/Journals for further learning including the page nos.:
R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 226-228.

Course Faculty

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LECTURE HANDOUTS

L - 11

MECH

IV/VII

Course Name with Code: ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.PERUMAL.

Unit : COMPRESSION IGNITION ENGINES

Date of Lecture :

Topic of Lecture : Stages of combustion

Introduction:

Stages of combustion consists of our stages like Ignition delay period, Rapid or uncontrolled or pre-mixed combustion phase, Controlled or diffusion combustion phase, After burning or late combustion phase.

Prerequisite knowledge for Complete understanding and learning of Topic:

Ignition delay period, Rapid or uncontrolled or pre-mixed combustion phase, Controlled or diffusion combustion phase, After burning or late combustion phase

Detailed content of the Lecture:

Stages of combustion in CI engine

1*. Ignition delay period*:

The period between the start of fuel injection into the combustion chamber and the start of combustion is termed as ignition delay period. The start of combustion is determined from the change in slope on p-θ diagram or from heat release analysis of the p-θ data, or from luminosity detector in experimental conditions. Start of injection can be determined by a needle-lift indicator to record the time when injector needle lifts off its seat. Start of combustion is more difficult to determine precisely. It is best identified from the change in slope of heat release rate, determined from cylinder pressure data. In DI engines ignition is well defined, in IDI engines ignition point is harder to identify

Both physical and chemical processes must take place before a significant fraction of the chemical energy of the injected liquid is released.

Physical processes are fuel spray atomization, evaporation and mixing of fuel vapour with cylinder air. Good atomization requires high fuel-injection pressure, small injector hole, optimum fuel viscosity, high cylinder pressure (large divergence angle).

Rate of vaporization of the fuel droplets depends on droplet diameter, velocity, fuel volatility, pressure and temperature of the air.

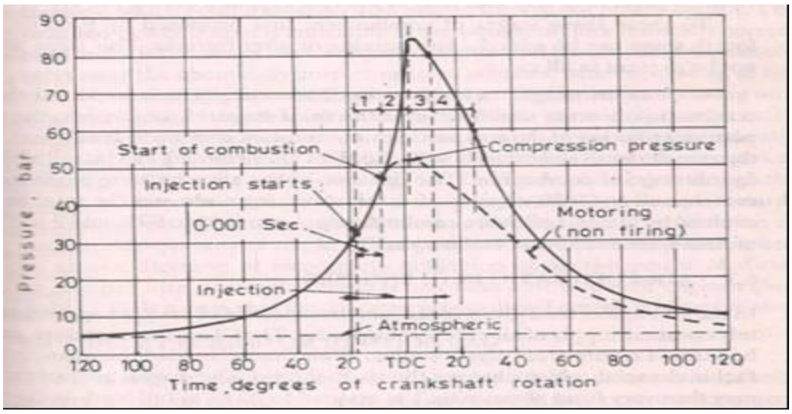

Fig.7. Stages of combustion in CI engine

Chemical processes similar to that described for auto ignition phenomenon in premixed fuel-air, only more complex since heterogeneous reactions (reactions occurring on the liquid fuel drop surface) also occur.

Chemical delay is more effective for the duration of the ignition delay period. Ignition delay period is in the range of

0.6 to 3 ms for low-compression ratio DI diesel engines,

0.4 to 1 ms for high-compression ratio, turbocharged DI diesel engines, 0.6 to 1.5 ms for IDI diesel engines

2. Rapid or uncontrolled or pre-mixed combustion phase:

Combustion of the fuel which has mixed with air within flammability limits during ignition delay period occurs rapidly in a few crank angle degrees - high heat release characteristics in this phase. If the amount of fuel collected in the combustion chamber during the ignition delay is much - high heat release rate results in a rapid pressure rise which causes the diesel knock.

For fuels with low cetane number, with long ignition delay, ignition occurs late in the expansion stroke - incomplete combustion, reduced power output, poor fuel conversion efficiency. If the pressure gradient is in the range 0.4 - 0.5 MPa/°CA, engine operation is not smooth and diesels knock starts. This value should be in the range 0.2 to 0.3 MPa/°CA for smooth operation (max allowable value is 1.0 MPa/°CA) of the engine.

3. Controlled or diffusion combustion phase:

Once the fuel and air which is pre-mixed during the ignition delay is consumed, the burning rate (heat release rate) is controlled by the rate at which mixture becomes available for burning. The rate of burning in this phase is mainly controlled by the mixing process of fuel vapour and air. Liquid fuel atomization, vaporization, pre flame chemical reactions also affect the rate of heat release.

Heat release rate sometimes reaches a second peak (which is lower in magnitude) and then decreases as the phase progresses. Generally it is desirable to have the combustion process near the TDC for low particulate (soot) emissions and high performance (and efficiency).

4. After burning or late combustion phase:

Heat release rate continues at a lower rate into the expansion stroke -there are several reasons for this: a small fraction of the fuel may not yet burn, a fraction of the energy is present in soot and fuel-rich combustion products and can be released. The cylinder charge is non-uniform and mixing during this phase promotes more complete combustion and less dissociated product gases. Kinetics is slower.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=H28bE6gf5qQ

Important Books/Journals for further learning including the page nos.:

R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 32- 35.

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LECTURE HANDOUTS | **L - 12**

MECH | **IV/VII**

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.PERUMAL.

Unit : COMPRESSION IGNITION ENGINES

Date of Lecture :

Topic of Lecture : Knocking

Introduction:

CI engine detonation occurs in the beginning of combustion. In CI engine the fuel and air are imperfectly mixed and hence the rate of pressure rise is normally cause audible knock. Rate of pressure rise may reach as high as 10 bar/°CA-High engine vibration is the symptoms of knocking -no pre-ignition or premature ignition as like SI engine.

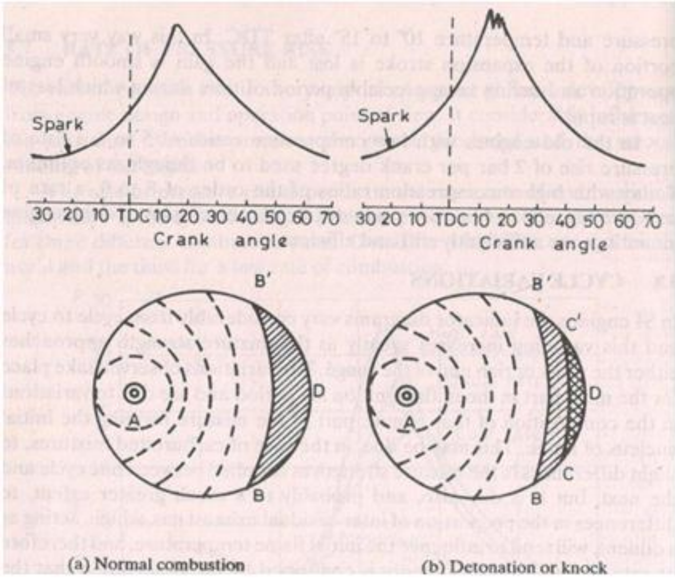
Prerequisite knowledge for Complete understanding and learning of Topic:

Factors affecting knocking in SI engines, Methods Of Controling Diesel Knock

Detailed content of the Lecture:

knocking

Knocking is due to auto ignition of end portion of unburned charge in combustion chamber. As the normal flame proceeds across the chamber, pressure and temperature of unburned charge increase due to compression by burned portion of charge. This unburned compressed charge may auto ignite under certain temperature condition and release the energy at a very rapid rate compared to normal combustion process in cylinder. This rapid release of energy during auto ignition causes a high pressure differential in combustion chamber and a high pressure wave is released from auto ignition region. The motion of high pressure compression waves inside the cylinder causes vibration of engine parts and pinging noise and it is known as knocking or detonation. This pressure frequency or vibration frequency in SI engine can be up to 5000 Cycles per second. Denotation is undesirable as it affects the engine performance and life, as it abruptly increases sudden large amount of heat energy. It also put a limit on compression ratio at which engine can be operated which directly affects the engine efficiency and output.



Detonation in CI engine

Auto ignition

A mixture of fuel and air can react spontaneously and produce heat by chemical reaction in the absence of flame to initiate the combustion or self-ignition. This type of self-ignition in the absence of flame is known as Auto-Ignition. The temperature at which the self-ignition takes place is known as self-igniting temperature. The pressure and temperature abruptly increase due to auto-ignition because of sudden release of chemical energy. This auto-ignition leads to abnormal combustion known as detonation which is undesirable because its bad effect on the engine performance and life as it abruptly increases sudden large amount of heat energy. In addition to this knocking puts a limit on the compression ratio at which an engine can be operated which directly affects the engine efficiency and output.

Pre-ignition

Pre-ignition is the ignition of the homogeneous mixture of charge as it comes in contact with hot surfaces, in the absence of spark. Auto ignition may overheat the spark plug and exhaust valve and it remains so hot that its temperature is sufficient to ignite the charge in next cycle during the compression stroke before spark occurs and this causes the pre-ignition of the charge. Pre-ignition is initiated by some overheated projecting part such as the sparking plug electrodes, exhaust valve head, metal corners in the combustion chamber, carbon deposits or protruding cylinder head gasket rim etc. pre-ignition is also caused by persistent detonating pressure shockwaves scoring away the stagnant gases which normally protect the combustion chamber walls. The resulting increased heat flow through the walls, raises the surface temperature of any protruding poorly cooled part of the chamber, and this therefore provides a focal point for pre-ignition.

Effects of Pre-ignition

-It increase the tendency of denotation in the engine

-It increases heat transfer to cylinder walls because high temperature gas remains in contact with for a longer time

-Pre-ignition in a single cylinder will reduce the speed and power output

-Pre-ignition may cause seizer in the multi-cylinder engines, only if only cylinders have pre-ignition

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=H28bE6gf5qQ

Important Books/Journals for further learning including the page nos.:
R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 228-230.

Course Faculty

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LECTURE HANDOUTS

L - 13

MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.PERUMAL.

Unit : COMPRESSION IGNITION ENGINES

Date of Lecture :

Topic of Lecture : Factors affecting knock

Introduction:

CI engine detonation occurs in the beginning of combustion. In CI engine the fuel and air are imperfectly mixed and hence the rate of pressure rise is normally cause audible knock. Rate of pressure rise may reach as high as 10 bar/^{o}CA-High engine vibration is the symptoms of knocking -no pre-ignition or premature ignition as like SI engine.

Prerequisite knowledge for Complete understanding and learning of Topic:

Factors affecting knocking in SI engines,
Methods Of Controling Diesel Knock

Detailed content of the Lecture:

FACTORS AFFECTING KNOCKING IN SI ENGINES

CI engine detonation occurs in the beginning of combustion. In CI engine the fuel and air are imperfectly mixed and hence the rate of pressure rise is normally cause audible knock. Rate of pressure rise may reach as high as 10 bar/^{o}CA-High engine vibration is the symptoms of knocking -no pre-ignition or premature ignition as like SI engine.

Knocking is violet gas vibration and audible sound produced by extreme pressure is going through differentials leading to the very rapid rise during the early part of uncontrolled to the second phase of combustion.

In C.I. engines the injection process takes place over a definite interval of time. Consequently, as the first few droplets injected are passing through the ignition lag period, additional droplets are being injected into the chamber. If the ignition delay is longer, the actual burning of the first few droplets is delayed and a greater quantity of fuel droplets gets accumulated in the chamber. When the actual burning commences, the additional fuel can cause too rapid a rate of pressure rise, as shown on pressure crank angle diagram above, resulting in Jamming of forces against the piston (as if struck by a hammer) and rough engine operation. If the ignition delay is quite long, so much fuel can accumulate that the rate of pressure rise is almost instantaneous. Such, a situation produces extreme pressure differentials and violent gas vibration known as knocking (diesel knock), and is evidenced by audible knock. The phenomenon is similar to that in the SI engine. However, in SI Engine knocking occurs near the end of combustion whereas in CI engine, knocking the occurs near the beginning of combustion.

Delay period is directly related to Knocking in CI engine. An extensive delay period can be due to following factors:

A low compression ratio permitting only a marginal self-ignition temperature to be reached.

- A low combustion pressure due to worn out piston, rings and bad valves
- Low cetane number of fuel
- Poorly atomized fuel spray preventing early combustion
- Coarse droplet formation due to malfunctioning of injector parts like spring
- Low intake temperature and pressure of air

METHODS OF CONTROLING DIESEL KNOCK

We have discussed the factors which are responsible for the detonation in the previous sections. If these factors are controlled, then the detonation can be avoided.

Using a better fuel:

Higher Cetene number fuel has lower delay period and reduces knocking tendency.

Controlling the Rate of Fuel Supply:

By injecting less fuel in the beginning and then more fuel amount in the combustion chamber detonation can be controlled to a certain extent. Cam shape of suitable profile can be designed for this purpose.

Knock reducing fuel injector:

This type of injector avoids the sudden increase in pressure inside the combustion chamber because of accumulated fuel. This can be done by arranging the injector so that only small amount of fuel is injected first. This can be achieved by using two or more injectors arranging in out of phase.

By using Ignition accelerators:

C N number can be increased by adding chemical called dopes. The two chemical dopes are used are ethyl-nitrate and amyle ”nitrate in concentration of 8.8 gm/Litre and 7.7 gm/Litre. But these two increase the NOx emissions.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=H28bE6gf5qQ

Important Books/Journals for further learning including the page nos.:

R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 236-238.

Course Faculty

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LECTURE HANDOUTS

L - 14

MECH **IV/VII**

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.PERUMAL.

Unit : COMPRESSION IGNITION ENGINES

Date of Lecture :

Topic of Lecture : Direct and Indirect injection systems

Introduction:

An indirect injection diesel engine delivers fuel into a chamber of the combustion chamber, called a pre-chamber or ante-chamber, where combustion begins and then spreads into the main combustion chamber, assisted by turbulence created in the chamber.

Prerequisite knowledge for Complete understanding and learning of Topic:

Direct and Indirect Injection Systems

Detailed content of the Lecture:

DIRECT AND INDIRECT INJECTION SYSTEMS

1. Direct injection diesel engines have injectors mounted at the top of the combustion chamber.
2. The injectors are activated using one of two methods - hydraulic pressure from the fuel pump, or an electronic signal from an engine controller.
3. Hydraulic pressure activated injectors can produce harsh engine noise.
4. Fuel consumption is about 15 to 20% lower than indirect injection diesels.
5. The extra noise is generally not a problem for industrial uses of the engine, but for automotive usage, buyers have to decide whether or not the increased fuel efficiency would compensate for the extra noise.
6. Electronic control of the fuel injection transformed the direct injection engine by allowing much greater control over the combustion.

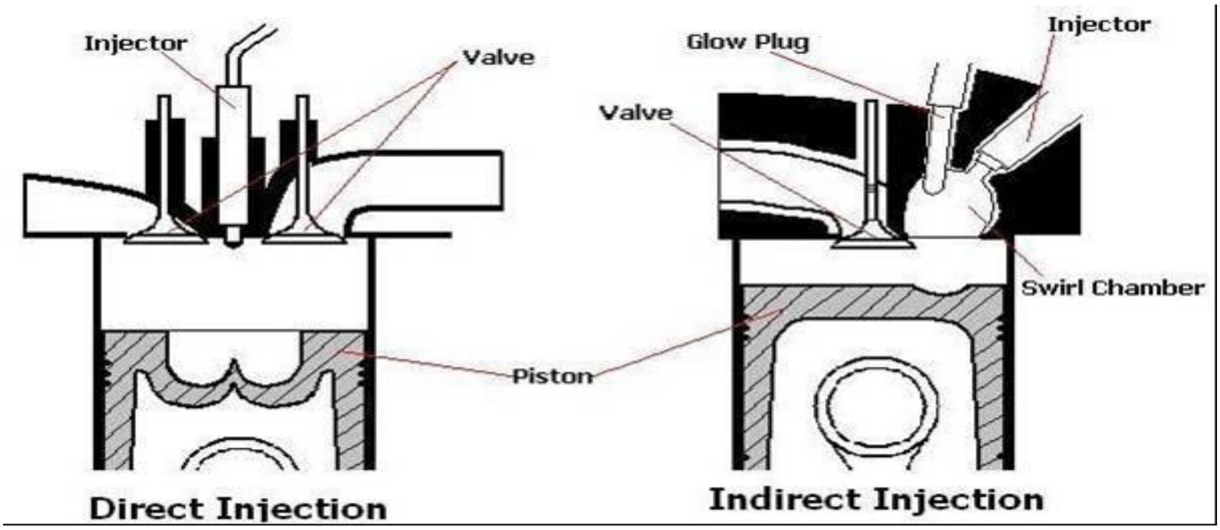

Fig.Direct and Indirect Injection Systems

INDIRECT INJECTION DIESEL ENGINE

1. An indirect injection diesel engine delivers fuel into a chamber off the combustion chamber, called a pre-chamber or ante-chamber, where combustion begins and then spreads into the main combustion chamber, assisted by turbulence created in the chamber.

2. This system allows for a smoother, quieter running engine, and because combustion is assisted by turbulence, injector pressures can be lower, about 100 bar (10 MPa; 1,500 psi), using a single orifice tapered jet injector.

3. Mechanical injection systems allowed high-speed running suitable for road vehicles (typically up to speeds of around 4,000 rpm).

4. The pre-chamber had the disadvantage of increasing heat loss to the engine's cooling system, and restricting the combustion burn, which reduced the efficiency by 5”10%.[35] Indirect injection engines are cheaper to build and it is easier to produce smooth, quiet-running vehicles with a simple mechanical system.

5.In road-going vehicles most prefer the greater efficiency and better controlled emission levels of direct injection.

6. Indirect injection diesels can still be found in the many ATV diesel applications.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=H28bE6gf5qQ

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LECTURE HANDOUTS

L - 15

MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.PERUMAL.

Unit : COMPRESSION IGNITION ENGINES

Date of Lecture :

Topic of Lecture : Combustion chambers

Introduction:

An indirect injection diesel engine delivers fuel into a chamber of the combustion chamber, called a pre-chamber or ante-chamber, where combustion begins and then spreads into the main combustion chamber, assisted by turbulence created in the chamber.

Prerequisite knowledge for Complete understanding and learning of Topic:

Direct Injection Chambers,

Indirect Injection Combustion Chambers,

Detailed content of the Lecture:

TYPES OF COMBUSTION CHAMBERS- CI Engines

CI engine combustion chambers are classified into two categories:

1. OPEN INJECTION (DI) TYPE:

This type of combustion chamber is also called an Open combustion chamber. In this type the entire volume of combustion chamber is located in the main cylin and the fuel is injected into this volume.

2. INDIRECT INJECTION (IDI) TYPE:

in this type of combustion chambers, the combustion space is divided into two parts, one part in the main cylinder and the other part in the cylinder head. T fuel "injection is effected usually into the part of chamber located in the cyl head. These chambers are classified

1. DIRECT INJECTION CHAMBERS – OPEN COMBUSTION CHAMBERS

Shallow Depth Chamber:

In shallow depth chamber the depth of the cavity provided in the piston is quit small. This chamber is usually adopted for large engines running at low speeds Since the cavity diameter is very large, the squish is negligible.

Hemispherical Chamber:

This chamber also gives small squish. However, the depth to diameter ratio for cylindrical chamber can be varied to give any desired squish to give better performance.

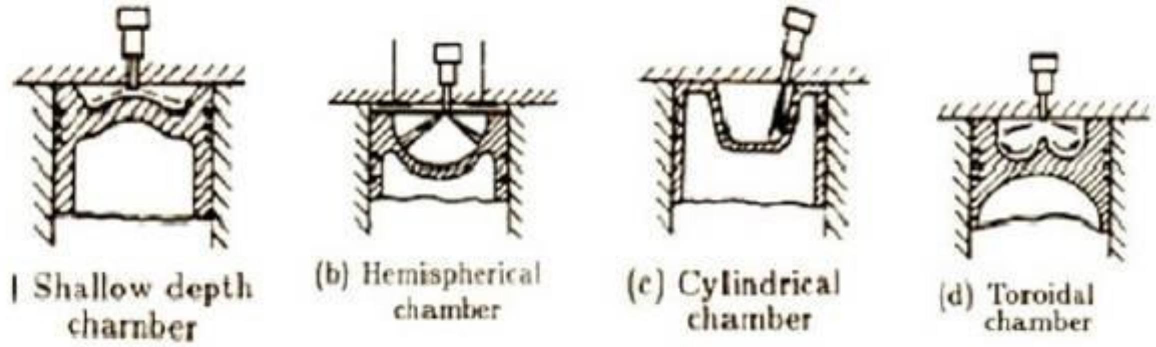

Fig.9 Different combustion chambers

Cylindrical Chamber:

This design was attempted in recent diesel engines. This is a modification of t cylindrical chamber in the form of a truncated cone with base angle of 30°. The swirl was produced by masking the valve for nearly 1800 of circumference. Squi can also be varied by varying the depth.

Toroidal Chamber:

The idea behind this shape is to provide a powerful squish along with the air movement, similar to that of the familiar smoke ring, within the toroidalchamb Due to powerful squish the mask needed on inlet valve is small and there is better utilisation of oxygen. The cone angle of spray for this type of chamber 150° to 160°.

2. INDIRECT INJECTION COMBUSTION CHAMBERS

(a) Ricardo's Swirl Chamber:

Swirl chamber consists of a spherical shaped chamber separated from the engine cylinder and located in the cylinder head. In to this chamber, about 50% of the air is transferred during the compressionstroke. A throat connects the chambe the cylinder which enters the chamber in a tangential direction so that the ai 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. The use of single hole of larger diameter the fuel spray nozzle is often important consideration for the choice of swirl chamber engine.

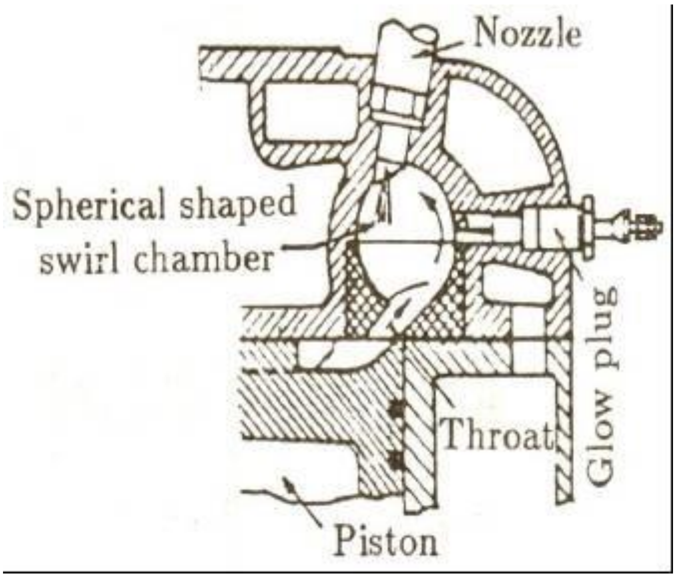

Fig . Ricardo's Swirl Chamber:

(a) Pre Combustion Chamber

Typical pre-combustion chamber consists of an anti-chamber connected to the ma chamber through a number of small holes (compared to a relatively large passag in the swirl chamber). The pre-combustion chamber is located in the cylinder h and its volume accounts for about 40% of the total combustion, space. During th compression stroke the piston forces the air into the pre-combustion chamber. fuel is injected into the pre-chamber and the combustion is initiated. The res pressure rise forces the flaming droplets together with some air and their combustion products to rush out into the main cylinder at high velocity throug small holes.

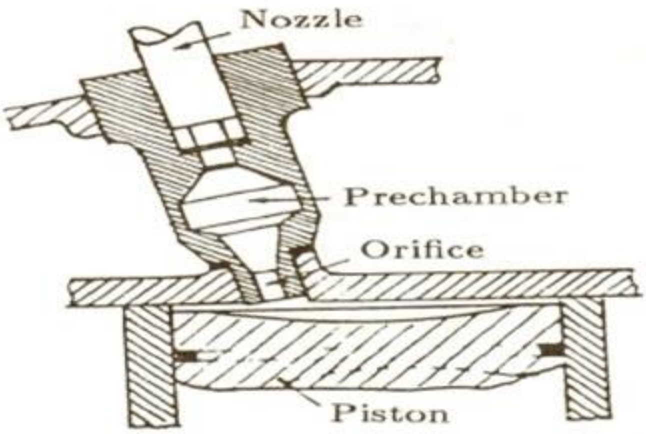

Fig. Pre Combustion Chamber

(a) Energy cell:

The ‘energy cell’ is more complex than the precombustion chamber. As the pisto moves up on the compression stroke, some of the air is forced into the major an 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 firs commences in the main combustion chamber where the temperatures higher, but the rate of burning is slower in this location, due to insufficient mixing of t and air. The burning in the minor cell is slower at the start, but due to bette mixing, progresses at a more rapid rate. The pressure built up in the minor cel therefore , force the burning gases out into the main chamber, thereby creatin added turbulence and producing better combustion in the this chamber.

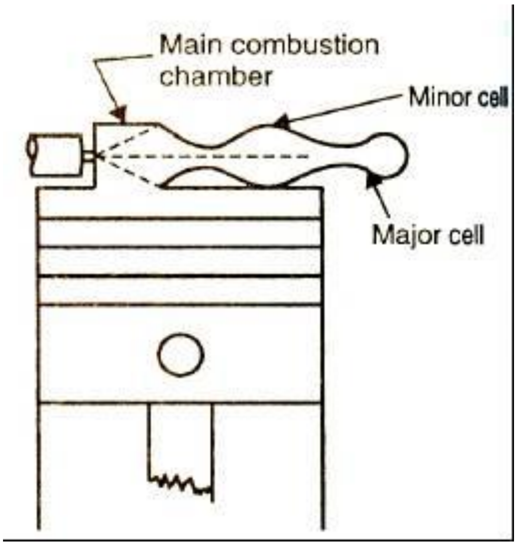

Fig. Energy cell:

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=H28bE6gf5qQ

Important Books/Journals for further learning including the page nos.:
R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X 239-240.

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LECTURE HANDOUTS

L - 16

MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.PERUMAL.

Unit : COMPRESSION IGNITION ENGINES

Date of Lecture :

Topic of Lecture : Fuel Spray behavior

Introduction:

- Depending on the mechanism to characterize, diesel spray can be analyzed in a macroscopic or microscopic point of view.
- With the purpose of understanding in detail this process, the various physical parameters involved
- during the transition of a pulsed diesel spray will be expressed in this chapter,
- however it is essential to know the systems that make possible for an injection process to take place

Prerequisite knowledge for Complete understanding and learning of Topic:

Diesel spray characteristics, Atomization

Detailed content of the Lecture:

Diesel spray characteristics

- Depending on the mechanism to characterize, diesel spray can be analyzed in a macroscopic or microscopic point of view. With the purpose of understanding in detail this process, the various physical parameters involved during the transition of a pulsed diesel spray will be expressed in this chapter.
- however it is essential to know the systems that make possible for an injection process to take place. These are the injection nozzle, active fluid to inject (liquid), and the working fluid on which the liquid is injected, as seen in figure 1.

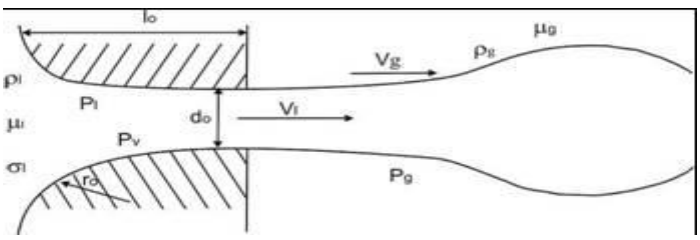

Fig. Meaningful variables of the injection process

Reynolds Number: Density and kinematic viscosity must be particularized for liquid or gas, furthermore these properties can be evaluated for intermediate conditions between both fluid film conditions. These parameters can be divided into two groups:

1. External flow parameters (relation of densities, Weber number, Taylor parameter), these parameters control the interaction between the liquid spray and the surrounding atmosphere.
2. Internal flow parameters (Reynolds number, cavitation parameter, length/diameter relation, nozzle radius entrance/diameter relation, discharge coefficient): these parameters control the interaction between the liquid and the nozzle.

ATOMIZATION

- Disintegration of fuel stream issuing from the injector nozzle into droplets of different sizes. Disintegration presents large surface and quicker heating and vaporization of droplets. Caused by friction between stream of fuel and air in Combustion chamber. Previous studies have shown that a spray penetration overcomes that of a single droplet, due to the momentum that the droplets.
- Located in the front of the spray experiment, accelerating the surrounding working fluid, causing the next droplets that make it to the front of the spray an instant of time later to have less aerodynamic resistance. We must emphasize that diesel fuel sprays tend to be of the compact type, which causes them to have large penetrations.
- Several researchers have studied the front penetration and have found a series of correlations that allow us to establish the main variables that affect or favour the penetration of a pulsed diesel spray. The following are some of the most relevant. From the theory of gaseous sprays, was one of the pioneers in the study of spray phenomena.
- The author proposed an experimentally adjusted correlation which is applicable to pulsed diesel sprays; this correlation was the compared by with other correlations, finding certain discrepancies between them. However, this correlation is considered to be applicable in a general form to diesel sprays

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=H28bE6gf5qQ

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LECTURE HANDOUTS

L - 17

MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.PERUMAL.

Unit : COMPRESSION IGNITION ENGINES

Date of Lecture :

Topic of Lecture : Spray structure and spray penetration and Air Motion

Introduction:

- The injection front penetration (S) is defined as the total distance covered by the spray in a control volume, and it's determined by the equilibrium of two factors,
- first the momentum quantity with which the fluid is injected and
- second, the resistance that the idle fluid presents in the control volume, normally a gas

Prerequisite knowledge for Complete understanding and learning of Topic:

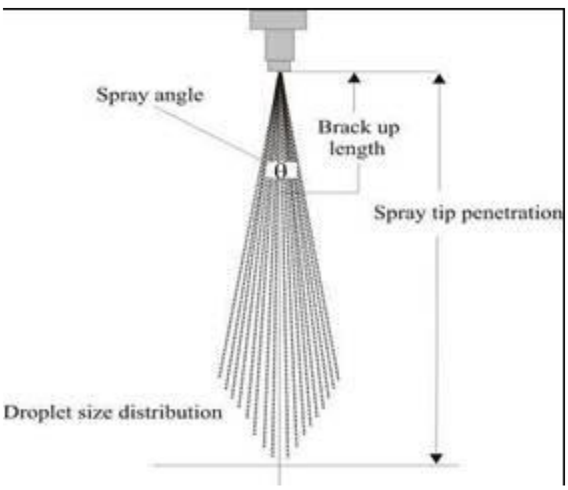
1. Spray tip penetration,
2. Spray angle,
3. Break up length

Detailed content of the Lecture:

1.Spray tip penetration

2.Spray angle

3.Air Motion



Physical parameter of a diesel spray

1. **Front Penetration**

    - The injection front penetration (S) is defined as the total distance covered by the spray in a control volume, and it's determined by the equilibrium of two factors, first the momentum quantity with which the fluid is injected and second, the resistance that the idle fluid presents in the control volume, normally a gas.

- Due to friction effects, the liquids kinetic energy is transferred progressively to the working fluid. This energy will decrease continuously until the movement of the droplets depends solely on the movement of the working fluid inside the control volume.
- Previous studies have shown that a spray penetration overcomes that of a single droplet, due to the momentum that the droplets.
- located in the front of the spray experiment, accelerating the surrounding working fluid, causing the next droplets that make it to the front of the spray an instant of time later to have less aerodynamic resistance.
- We must emphasise that diesel fuel sprays tend to be of the compact type, which causes them to have large penetrations.Several researchers have studied the front penetration and have found a series of correlations that allow us to establish the main variables that affect or favour the penetration of a pulsed diesel spray.
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- However, this correlation is considered to be applicable in a general form to diesel sprays

$$S(t) = 3,07\left(\frac{\Delta P}{\rho_a}\right)^{\frac{1}{4}}\left(\frac{294}{T_a}\right)^{\frac{1}{4}}\sqrt{d_o t}$$

2. **Cone angle**

- The cone angle is defined as the angle formed by two straight lines that stat from the exit orifice of the nozzle and tangent to the spray outline (sprays morphology) in a determined distance.
- The angle in a diesel spray is formed by two straight lines that are in contact with the spray's outline and at a distance equivalent to 60 times de exit diameter of the nozzles orifice.
- This angle usually is between 5 and 30 degrees. This determines greatly the fuels macroscopic distribution in the combustion chamber. In one hand, the increase in angle decreases the penetration and can cause interference between sprays (when sprays are injected using multi -orifice nozzles) in the same chamber favouring the merging of droplets.
- On the other hand, an excessive penetration is favoured when the angle decreases lower than certain values, causing the spray to collide with the piston bowl or the combustion chamber.
- In previous studies there have been a series of proposals to determine the cone angle, some of the most important are as follows:

$$\tan\frac{\theta}{2} = 0,13\left(1 + \frac{\rho_a}{\rho_1}\right)$$

3. Air Motion

- The liquid length of the spray is a very important characteristic to define the behaviour of the spray in the combustion chamber. This zone of the spray is also called continuous or stationary and it is understood as being from the nozzle exit to the point were the separation of the first droplets occur.
- To define this zone the use of diverse measurements methods and techniques is of vital importance. In the literature we find some of the most useful measurement methods and techniques in the analysis of the liquid length
- To analyze the internal structure of the spray, identified two zones inside the atomizing regime, the zone of the incomplete spray and the zone of the complete spray. Figure shows structure in a general way.
- The difference between them is due to the fact that with the incomplete sprays the disintegration of the surface of the spray begins at a certain distance from the point of the nozzle of the injector, indicating a distance Lc, while in the case of the incomplete sprays distance Lc is nearly cero and Lb is maintained virtually constant on increasing speed.
- Furthermore show that cavitation greatly favours the atomization process in the complete spray regime.
- To define liquid length a series of expressions have been proposed which have been suggested in specific conditions according to each case and among the most relevant the following can be cited:

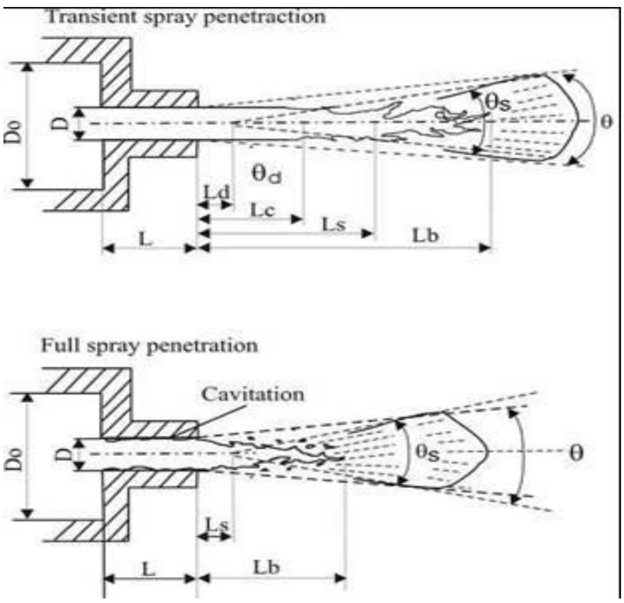

Fig. Internal structure of complete and incomplete spray

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=H28bE6gf5qQ

Important Books/Journals for further learning including the page nos.:
R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 241-243.

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LECTURE HANDOUTS

L - 18

MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.PERUMAL.

Unit : COMPRESSION IGNITION ENGINES

Date of Lecture :

Topic of Lecture: Introduction to Turbo charging.

Introduction:

A turbocharger or turbo is a forced induction device used to allow more power t be produced for an engine of a given size. A turbocharged engine can be more powerful and efficient than a naturally aspirated engine because the turbine f more air, and proportionately more fuel, into the combustion chamber than atmospheric pressure alone.

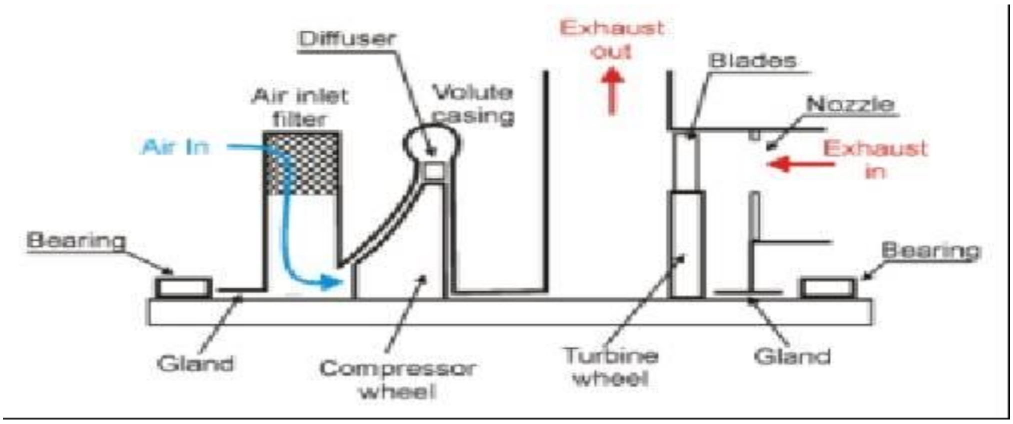
Prerequisite knowledge for Complete understanding and learning of Topic:

1. Turbo Charger
2. Working Principle
3. Component

Detailed content of the Lecture:

Turbocharger

A turbocharger or turbo is a forced induction device used to allow more power t be produced for an engine of a given size. A turbocharged engine can be more powerful and efficient than a naturally aspirated engine because the turbine f more air, and proportionately more fuel, into the combustion chamber than atmospheric pressure alone.



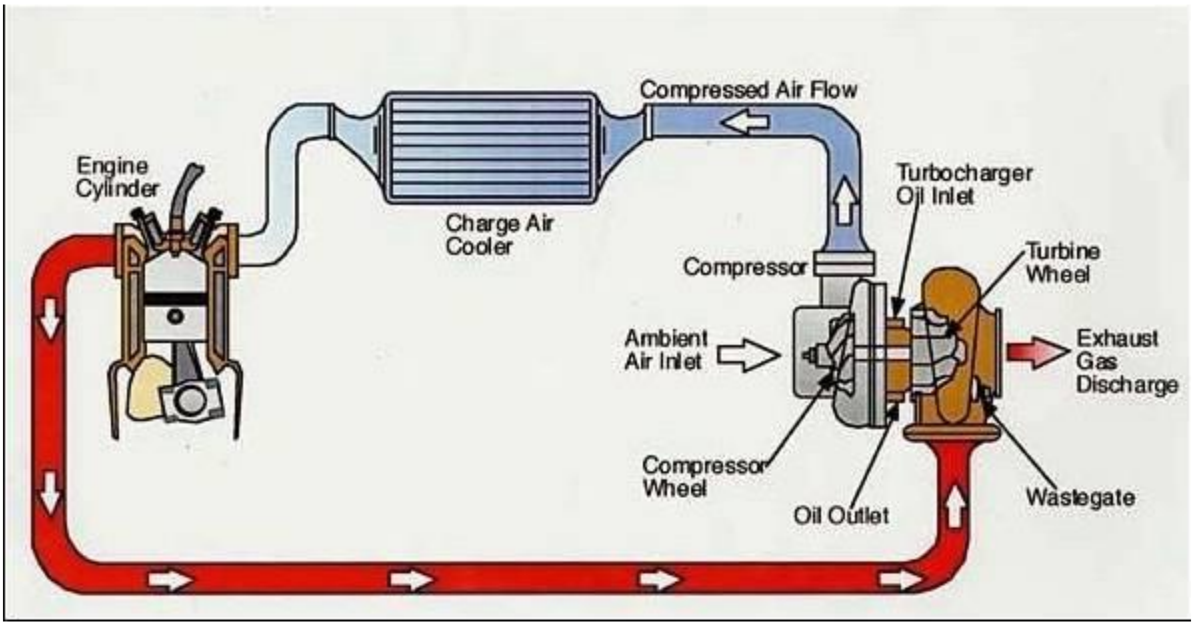


Fig. Turbocharger

Working principle

- a turbocharger is a small radial fan pump driven by the energy of the exhaust gases of an engine. A turbocharger consists of a turbine and a compressor on a shared shaft. The turbine section of a turbocharger is a heat engine in itself.
- It converts the heat energy from the exhaust to power, which then drives the compressor, compressing ambient air and delivering it to the air intake manifold of
- the engine at higher pressure, resulting in a greater mass of air entering each cylinder.
- In some instances, compressed air is routed through an intercooler before introduction to the intake manifold. Because a turbocharger is a heat engine, and is converting otherwise wasted exhaust heat to power, it compresses the inlet air to the engine more efficiently than a supercharger.

Components

- The turbocharger has four main components.
- The turbine (almost always a radial turbine) and impeller/compressor wheels are each contained within their own folded conical housing on opposite sides of the third component, the centre housing/hub

rotating assembly (CHRA).

- The housings fitted around the compressor impeller and turbine collect and direct the gas flow through the wheels as they spin. The size and shape can dictate some performance characteristics of the overall turbocharger.
- turbocharger assembly will be available from the manufacturer with multiple housing choices for the turbine and sometimes the compressor cover as well.
- the designer of the engine system to tailor the compromises between performance, response, and efficiency to application or preference.
- valve-operated exhaust gas inlets, a smaller sharper angled one for quick response and a larger less angled one for peak performance.

- The turbine and impeller wheel sizes also dictate the amount of air or exhaust that can be flowed through the system, and the relative efficiency at which they operate.
- Generally, the larger the turbine wheel and compressor wheel, the larger the flow capacity. Measurements and shapes can vary, as well as curvature and number of blades on the wheels. Variable geometry turbochargers are further developments of these ideas.

- The centre hub rotating assembly (CHRA) houses the shaft which connects the compressor impeller and turbine. It also must contain a bearing system to suspend the shaft, allowing it to rotate at very high speed with minimal friction.
- instance, in automotive applications the CHRA typically uses a thrust bearing or ball bearing lubricated by a constant supply of pressurized engine oil.
- also be considered "water cooled" by having an entry and exit point for engine coolant to be cycled.
- Water cooled models allow engine coolant to be used to keep the lubricating oil cooler, avoiding possible oil coking from the extreme heat found in the turbine. The development of air-foil bearings has removed this risk.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=H28bE6gf5qQ

Important Books/Journals for further learning including the page nos.:
R.K.Rajbut, "Internal Combustion Engines", Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X
520-526.

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LECTURE HANDOUTS

L -19

MECH **IV/VII**

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.Perumal.

Unit : 3- POLLUTANT FORMATION AND CONTROL

Date of Lecture :

Topic of Lecture : Pollutant Sources

Introduction:

Internal combustion engines (ICE) operate by burning fossil fuel derivatives. Exhaust Emissions are their major contribution to environmental pollution.

Prerequisite knowledge for Complete understanding and learning of Topic:

Typical emissions contain primary greenhouse gases – carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). All criteria pollutants – carbon monoxide (CO), total nitrogen oxides (NO_x), sulfur dioxide (SO_2), non-methane volatile organic compounds (NMVOC) and particulate matter (PM) are the other major components

Detailed content of the Lecture:

Internal Combustion Engines.

- ICE may be classified by different criteria. For instance, - according to fuel type, to power, to ignition type and so on. An appropriate classification from the point of view of combustion chemistry and air pollution will divide them into two major groups.
- The first group includes engines in which combustion is performed periodically in a chamber of changing volume (i. e. reciprocating piston engines).
- In the second group combustion takes place continuously (steady flow) in a chamber of constant volume.
- The first group may be further divided into spark ignition (SI) and compression ignition (CI) engines, although there are engines combining both principles.
- SI engines may be classified as two stroke and four stroke engines, CI engines – as direct and indirect injection engines.
- The second group includes the jet engines, which may use a gas turbine, liquid fuel, air

as oxidation agent and a turbo compressor (aircraft jet engines), and the rocket jet engines, which have chemical agents as fuels and oxidizers.

- Details of combustion systems, combustion processes, efficiencies, Another useful distinction between internal combustion engines is the fact that only in SI engines the fuel is evaporated and mixed with the oxidizing agent before the ignition takes place. In other designs, the fuel is sprayed in the combustion chamber, in the form of drops of different size.
- It is not the purpose of this chapter to describe the organization of the combustion Processes in the different engines. Its main task is rather to compare the main groups etc. can be found in Pollution Control through Efficient Combustion Technology. Have the important advantages of lower weight and cost per unit of power output.
- They are widely used in small motorcycles, as outboard motors and other small power equipment.
- The main pollutants from four-stroke gasoline engines are hydrocarbons, CO and nitrogen oxides. They are contained in exhaust emissions, but hydrocarbons are contributed both with the exhaust, and with the evaporative emissions.
- Particulate matter is usually negligible and is produced mainly from oil components brought in the combustion chamber by the piston. Sulfur oxides are typically low and for some time were not considered a problem. New regulations restrict drastically sulfur in gasoline, because of reconsidering its influence on catalysts.

SI/CI ENGINE EMISSIONS

1. Unburned Hydro Carbons
2. Carbon monoxide
3. Oxides of nitrogen
4. Oxides of sulphur and
5. Particulates including smoke

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=AVBjNCtqe4M&list=PL215741C530D11AFB&index=5&t=0s

Important Books/Journals for further learning including the page nos.:
R.K.Rajbut, "Internal Combustion Engines", Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 612-614.

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LECTURE HANDOUTS

L - 20

MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : MrS.Perumal.

Unit : 3 - POLLUTANT FORMATION AND CONTROL

Date of Lecture :

Topic of Lecture : Formation of Carbon Monoxide

Introduction:

The nitric oxide formation during the combustion process is the result of group of elementary reaction involving the nitrogen and oxygen molecules. Different mechanism proposed is discussed below.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Mechanism of NO formation
- Simple reaction between N2 and O2
- Zeldovich Chai Reaction mechanism

Detailed content of the Lecture:

Formation of NOX, HC/CO mechanism

Mechanism of NO formation:

The nitric oxide formation during the combustion process is the result of group of elementary reaction involving the nitrogen and oxygen molecules. Different mechanism proposed is discussed below.

a. Simple reaction between N_2 and O_2

$N_2 + O_2 \rightarrow 2\ NO$

This mechanism proposed by Eyzat and Guibet predicts NO concentrations much lower that those measured in I.C engines. According to this mechanism, the formation process is too slow for NO to reach equilibrium at peak temperatures and pressures in the cylinders.

b. Zeldovich Chai Reaction mechanism:

$O_2 \rightarrow 2\ O$------------- (1)

$O + N_2 \rightarrow NO + N$ ------(2)

$N + O_2 \rightarrow NO + O$ ------(3)

The chain reactions are initiated by the equation (2) by the atomic oxygen, formed in equation (1) from the dissociation of oxygen molecules at the high temperatures reached in the combustion process. Oxygen atoms react with nitrogen molecules and produces NO and nitrogen atoms. In the equation (3) the nitrogen atoms react with oxygen molecule to form nitric oxide and atomic oxygen.

According to this mechanism nitrogen atoms do not start the chain reaction because their equilibrium concentration during the combustion process is relatively low compared to that of atomic oxygen. Experiments have shown that equilibrium concentrations of both oxygen atoms and nitric oxide molecules increase with temperature and with leaning of mixtures. It has also been observed that NO formed at the maximum cycle temperature does not decompose even during the expansion stroke when the gas temperature decreases.

In general it can be expected that higher temperature would promote the formation of NO by speeding the formation reactions. Ample O_2 supplies would also increase the formation of NO. The NO levels would be low in fuel rich operations, i.e. A/F 15, since there is little O_2 left to react with N_2 after the hydrocarbons had reacted.

The maximum NO levels are formed with AFR about 10 percent above stoichiometric. More air than this reduces the peak temperature, since excess air must be heated from energy released during combustion and the NO concentration fall off even with additional oxygen.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=AVBjNCtqe4M&list=PL215741C530D11AFB&index=5&t=0s

Important Books/Journals for further learning including the page nos.:
R.K.Rajbut, "Internal Combustion Engines", Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 615-617.

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LECTURE HANDOUTS

L - 21

MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.Perumal.

Unit : 3 - POLLUTANT FORMATION AND CONTROL

Date of Lecture :

Topic of Lecture : Unburned hydrocarbon (HC)

Introduction:

Hydrocarbon exhaust emission may arise from three sources as,

a. Wall quenching

b. Incomplete combustion of charge

c. Exhaust scavenging in 2-stroke engines

Prerequisite knowledge for Complete understanding and learning of Topic:

Because of the cooling, there is a cold zone next to the cooled combustion chamber walls. This region is called the quench zone. Because of the low temperature, the fuel-air mixture fails to burn and remains unburned.

Detailed content of the Lecture:

Unburned hydrocarbon (HC) exhaust emission may arise from three sources as,

a. Wall quenching

b. Incomplete combustion of charge

c. Exhaust scavenging in 2-stroke engines

In an automotive type 4-stroke cycle engine, wall quenching is the predominant source of exhaust hydrocarbon under most operating conditions.

The quenching of flame near the combustion chamber walls is known as wall quenching. This is a combustion phenomenon which arises when the flame tries to propagate in the vicinity of a wall. Normally the effect of the wall is a slowing down or stopping of the reaction.

Because of the cooling, there is a cold zone next to the cooled combustion chamber walls. This region is called the quench zone. Because of the low

temperature, the fuel-air mixture fails to burn and remains unburned.

Due to this, the exhaust gas shows a marked variation in HC emission.
The first gas that exits is from near the valve and is relatively cool. Due to this it is rich in HC. The next part of gas that comes is from the hot combustion chamber and hence a low HC concentration. The last part of the gas that exits is scrapped off the cool cylinder wall and is relatively cool. Therefore it is also rich in HC emission.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=AVBjNCtqe4M&list=PL215741C530D11AFB&index=5&t=0s

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LECTURE HANDOUTS

L - 22

MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.Perumal.

Unit : 3- POLLUTANT FORMATION AND CONTROL

Date of Lecture :

Topic of Lecture : Oxides of Nitrogen (NO)

Introduction:

The nitric oxide formation during the combustion process is the result of group of elementary reaction involving the nitrogen and oxygen molecules. Different mechanism proposed is discussed below

Prerequisite knowledge for Complete understanding and learning of Topic:

$$N_2 + O_2 \rightarrow 2\ NO$$

This mechanism proposed by Eyzat and Guibet predicts NO concentrations much lower that those measured in I.C engines. According to this mechanism, the formation process is too slow for NO to reach equilibrium at peak temperatures and pressures in the cylinders.

Detailed content of the Lecture:

Mechanism of NO formation:

The nitric oxide formation during the combustion process is the result of group of elementary reaction involving the nitrogen and oxygen molecules. Different mechanism proposed is discussed below.

a. Simple reaction between N_2 and O_2

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LECTURE HANDOUTS

L - 23

MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.Perumal.

Unit : 3- POLLUTANT FORMATION AND CONTROL

Date of Lecture :

Topic of Lecture : Smoke and Particulate matter

Introduction:

Engine exhaust smoke is a visible indicator of the combustion process in the engine. Smoke is due to incomplete combustion. Smoke in diesel engine can be divided into three categories: blue, white and black.

Prerequisite knowledge for Complete understanding and learning of Topic:

Large amounts of carbons will be formed, during the early stage of combustion. This carbon appears as smoke if there is insufficient air, if there is insufficient mixing or if local temperatures fall below the carbon reaction temperatures (approximately 1000C) before the mixing occurs.

Detailed content of the Lecture:

Blue smoke:

It results from the burning of engine lubricating oil that reaches combustion chamber due to worn piston rings, cylinder liners and valve guides.

White or cold smoke:

It is made up of droplets of unburnt or partially burnt fuel droplets and is usually associated with the engine running at less than normal operating temperature after starting, long period of idling, operating under very light load, operating with leaking injectors and water leakage in combustion chamber. This smoke normally fades away as engine is warmed up and brought to normal stage.

Black or hot smoke:

It consists of unburnt carbon particles (0.5 ” 1 microns in diameter) and other solid products of combustion. This smoke appears after engine is warmed up and is accelerating or pulling under load.

Formation of smoke in Diesel engines:

The main cause of smoke formation is known to be inadequate mixing of fuel and air. Smoke is formed when the local temperature is high enough to decompose fuel in a region where there is insufficient oxygen to burn the carbon that is formed. The formation of over-rich fuel air mixtures either generally or in localized regions will result in smoke. Large amounts of carbons will be formed during the early stage of combustion. This carbon appears as smoke if there is insufficient air, if there is insufficient mixing or if local temperatures fall below the carbon reaction temperatures (approximately 1000C) before the mixing occurs.

Acceptable performance of diesel engine is critically influenced by exhaust some emissions. Failure of engine to meet smoke legislation requirement prevents sale and particularly for military use, possible visibility by smoke is useful to enemy force. Diesel emissions give information on effectiveness of combustion, general performance and condition of engine.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=AVBjNCtqe4M&list=PL215741C530D11AFB&index=5&t=0s

Important Books/Journals for further learning including the page nos.:
R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 629-631.

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LECTURE HANDOUTS

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MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.Perumal.

Unit : POLLUTANT FORMATION AND CONTROL

Date of Lecture :

Topic of Lecture : Methods of controlling Emissions

Introduction:

The combustion chamber temperature can be decreased by

1. Decreasing compression ratio
2. Retarding spark timing
3. Decreasing charge temperature
4. Decreasing engine speed
5. Decreasing inlet charge pressure
6. Exhaust gas recirculation
7. Increasing humidity

Prerequisite knowledge for Complete understanding and learning of Topic:

Emissions from large ships were not restricted for many years, even after strict laws were enforced on other engines. It was reasoned that ships operated away from land masses most of the time and the exhaust gases could be absorbed by the atmosphere without affecting human habitat. However, most seaports are in large cities, where emission problems are most critical, and polluting from all engines is now restricted, incl.Mdingship engines.

Detailed content of the Lecture:

Methods of controlling emissions

1.NOx is decreased by,

A. Decreasing the combustion chamber temperature

The combustion chamber temperature can be decreased by

1. Decreasing compression ratio
2. Retarding spark timing
3. Decreasing charge temperature
4. Decreasing engine speed
5. Decreasing inlet charge pressure
6. Exhaust gas recirculation
7. Increasing humidity

B. By decreasing oxygen available in the flame front

The amount of oxygen available in the chamber can be controlled by

1. Rich mixture
2. Stratified charge engine
3. Divided combustion chamber

2. Hydrocarbon emission can be decreased by

1. Decreasing the compression ratio
2. Retarding the spark
3. Increasing charge temperature
4. Increasing coolant temperature
5. Insulating exhaust manifold
6. Increasing engine speed
7. Lean mixture

3. CO can be decreased by

1. Lean air fuel ratio

2. Adding oxygen in the exhaust

3. Increasing coolant temperature.

Chemical methods to reduce emissions

Development work has been done on large stationary engines using cyanuric acid to reduce NOx emissions. Cyanuric acid is a low-cost solid material that sublimes in the exhaust flow. The gas dissociates, producing isocyanide that reacts with NOx to form N2, H20, and CO2· Operating temperature is about 500°C. Up to 95% NOx reduction has been achieved with no loss of engine performance. At present, this system is not practical for vehicle engines because of its size, weight, and complexity. Research is being done using zeolite molecular sieves to reduce NOx emissions. These are materials that absorb selected molecular compounds and catalyse chemical reactions. Using both SI and CI engines, the efficiency of NOx reduction is being determined over a range of operating variables, including AF, temperature, flow velocity, and zeolite structure. At present, durability is a serious limitation with this method.

H2S emissions occur under rich operating conditions. Chemical systems are being developed that trap and store H2S when an engine operates rich and then convert this to S02 when operation is lean and excess oxygen exists. The reaction equation is

$$H_2S + 0_2 = S0_2 + H_2$$

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=AVBjNCtqe4M&list=PL215741C530D11AFB&index=5&t=0s

Important Books/Journals for further learning including the page nos.:
R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 629-631.

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LECTURE HANDOUTS

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MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.Perumal.

Unit : 3- POLLUTANT FORMATION AND CONTROL

Date of Lecture :

Topic of Lecture : Catalytic converters

Introduction:

A catalytic converter is a vehicle emissions control device which converts toxic by-products of combustion in the exhaust of an internal combustion engine to less toxic substances by way of catalysed chemical reactions. The specific reactions vary with the type of catalyst installed.

Prerequisite knowledge for Complete understanding and learning of Topic:

Most present-day vehicles that run on gasoline are fitted with a three way converter, so named because it converts the three main pollutants in automobile exhaust: carbon monoxide, unburned hydrocarbon and oxides of nitrogen.

Detailed content of the Lecture:

carbon monoxide, unburned hydrocarbon and oxides of nitrogen

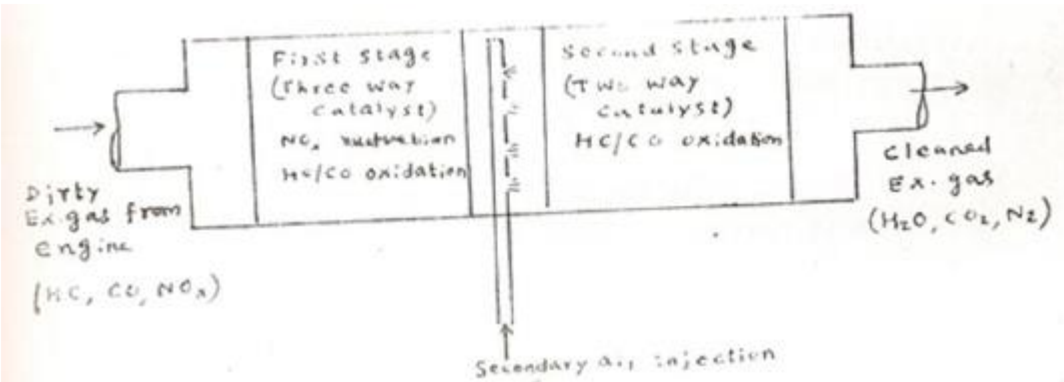

Fig. Catalytic converter

Figure shows a three way catalytic converter. The front section(in the direction of gas flow) handles NOx and partly handles HC and CO. The partly treated exhaust gas is mixed with secondary air. The mixture of partly treated exhaust gas and secondary air flows into the rear section of the chamber. The two way catalyst present in the rear section takes care of HC and CO.

1.Reduction of nitrogen oxides to nitrogen and oxygen: $2NO_x \rightarrow xO_2 + N_2$

2. Oxidation of carbon monoxide to carbon dioxide: $2CO + O_2 \rightarrow 2CO_2$

3. Oxidation of unburnt hydrocarbons (HC) to carbon dioxide and water:

$C_xH_{2x+2} + [(3x+1)/2]\ O_2 \rightarrow xCO_2 + (x+1)\ H_2O$.

CATALYSTS

I. supported catalysts

a) noble metals.

b) transition metals.

II. unsupported metallic alloys

NO REDUCTION CATALYSTS

- Copper oxide – chromia.
- Copper oxide - vanadia.
- Iron oxide – chromia.
- Nickel oxide pelleted on monolithic ceramic and metallic supports.
- Monel metal.
- Rare earth oxides.

HC / CO OXIDATION CATALYSTS

- Nobel metal catalysts such as activated carbon, palladium or platinum.
- Transition metal oxide catalysts such as copper, cobalt, nickel and iron chromate, vanadium or manganese promoted versions of these materials.

CATALYSTS REQUIREMENTS

- High conversion efficiency under transient conditions.
- Effective for wide range of T.
- Must withstand poisoning action of additives.
- Must be able to withstand thermal shock.
- Must be suitable for vehicle operation for 50,000 miles.
- Convert into harmless products.
- Cheap and readily available.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=AVBjNCtqe4M&list=PL215741C530D11AFB&index=5&t=0s

Important Books/Journals for further learning including the page nos.:
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LECTURE HANDOUTS

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MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.Perumal.

Unit : 3 - POLLUTANT FORMATION AND CONTROL

Date of Lecture :

Topic of Lecture : Selective Catalytic Reduction and Particulate Traps

Introduction:

A diesel particulate filter (or DPF) is a device designed to remove diesel particulate matter or soot from the exhaust gas of a diesel engine. Wall-flow diesel particulate filters usually remove 85% or more of the soot and under certain conditions can attain soot removal efficiencies of close to 100%.

Prerequisite knowledge for Complete understanding and learning of Topic:

, intended for disposal and replacement once full of accumulated ash. Others are designed to burn off the accumulated particulate either passively through the use of a catalyst or by active means such as a fuel burner which heats the filter to soot combustion temperatures; engine programming to run when the filter is full in a manner that elevates exhaust temperature or produces high amounts

Detailed content of the Lecture:

CATALYSTS REQUIREMENTS

- High conversion efficiency under transient conditions.
- Effective for wide range of T.
- Must withstand poisoning action of additives.
- Must be able to withstand thermal shock.
- Must be suitable for vehicle operation for 50,000 miles.
- Convert into harmless products.
- Cheap and readily available.

Diesel particulate filter (Particulate Trap)

A diesel particulate filter (or DPF) is a device designed to remove diesel particulate matter or soot from the exhaust gas of a diesel engine. Wall-flow diesel particulate filters usually remove 85% or more of the soot and under certain conditions can attain soot removal efficiencies of close to 100%. Some filters are single-use, intended for disposal and replacement once full of accumulated ash. Others are designed to burn off the accumulated particulate either passively through the use of a catalyst or by active means such as a fuel burner which heats the filter to soot combustion temperatures; engine programming to run when the filter is full in a manner that elevates exhaust temperature or produces high amounts

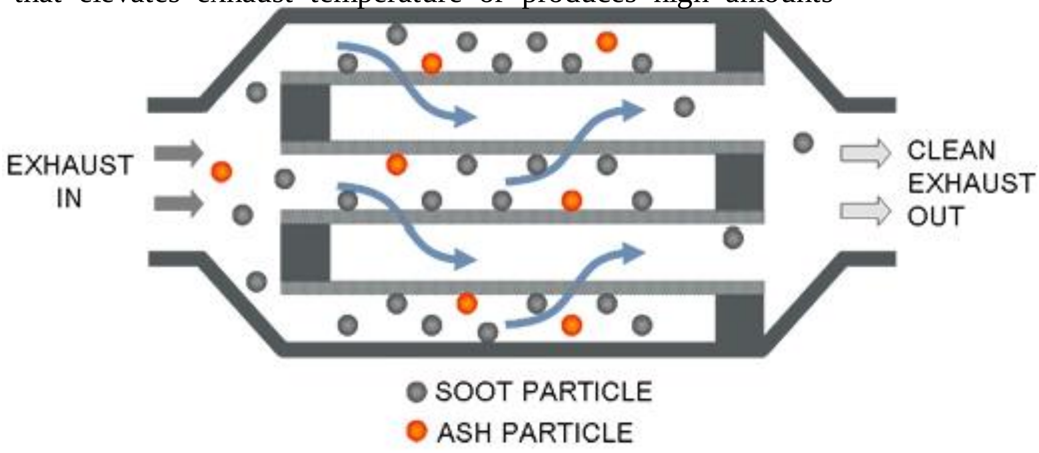

Fig. Diesel particulate filter

Of NO_x to oxidize the accumulated ash, or through other methods. This is known as "filter regeneration". Cleaning is also required as part of periodic maintenance, and it must be done carefully to avoid damaging the filter. Failure of fuel injectors or turbochargers resulting in contamination of the filter with raw diesel or engine oil can also necessitate cleaning.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=AVBjNCtqe4M&list=PL215741C530D11AFB&index=5&t=0s

Important Books/Journals for further learning including the page nos.:
R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 632-634.

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LECTURE HANDOUTS

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MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.S.Perumal.

Unit : POLLUTANT FORMATION AND CONTROL

Date of Lecture :

Topic of Lecture : Methods of measurement ,Emission norms and Driving cycles

Introduction:

An exhaust treatment technology that substantially reduces diesel engine particulateemissions is the trap oxidiir. A temperature-tolerant filter or trap removes the particulate material from the exhaust gas; the filter is then "cleaned off" by oxidizing the accumulated particulates.

Prerequisite knowledge for Complete understanding and learning of Topic:

- Smoke and Particulate measurement
- Indian Driving Cycles and emission norms
- Standards In India

Detailed content of the Lecture:

Smoke and Particulate measurement;

An exhaust treatment technology that substantially reduces diesel engine particulateemissions is the trap oxidiir. A temperature-tolerant filter or trap removes the particulate material from the exhaust gas; the filter is then "cleaned off" by oxidizing the accumulated particulates. This technology is difficult to implement because: (1) the filter, even when clean, increases the pressure in the exhaust system; (2) this pressure increase steadily rises as the filter collects particulate matter; (3) under normal diesel engine operating conditions the collected particulate matter will not ignite and oxidize; (4) once ignition of the particulate occurs, the burnup process must be carefully controlled to prevent excessively high temperatures and trap damage or destruction. Trap oxidizers have been put into production for light-duty automobile diesel engines. Their use with heavy-duty diesel engines poses more difficult problems due to higher particulate loading and lower exhaust temperatures.

Types of particulate filters include: ceramic monoliths, alumina-coated wire mesh, ceramic foam, ceramic fiber mat, woven silica-fiber rope wound on a porous tube. Each of these has different inherent pressure loss and filtering efficiency. Regeneration of the trap by burning up the filtered particulate material can be accomplished by raising its temperature to the ignition point while providing oxygen-containing exhaust gas to support combustion and carry away the heat released. Diesel particulate matter ignites at about **500** to 600·‹C. This is above the normal temperature of diesel exhaust so either the exhaust gas flowing through the trap during regeneration must be heated (positive regeneration) or ignition must be made to occur at a lower temperature with catalytic materials on the trap or added to the fuel (catalytic regeneration). Catalytic coatings on the trap reduce the ignition temperature by up to 200□C.

Indian Driving Cycles and emission norms

Driving Cycle:

The driving cycle for both CVS-1 and CVS-3 cycles is identical. It involves various accelerations, decelerations and cruise modes of operation. The car is started after soaking for 12 hours in a 60-80 F ambient. A trace of the driving cycle is shown in figure. Miles per hour versus time in seconds are plotted on the scale. Top speed is 56.7 mph. Shown for comparison is the FTP or California test cycle. For many advanced fast warm-up emission control systems, the end of the cold portion on the CVS test is the second idle at 125 seconds. This occurs at 0.68 miles. In the CVS tests, emissions are measured during cranking, start-up and for five seconds after ignition are turned off following the last deceleration. Consequently high emissions from excessive cranking are included. Details of operation for manual transmission vehicles as well as restart procedures and permissible test tolerance are included in the Federal Registers.

CVS-1 system:

The CVS-1 system, sometimes termed variable dilution sampling, is designed to measure the true mass of emissions. The system is shown in figure. A large positive displacement pump draws a constant volume flow of gas through the system. The exhaust of the vehicle is mixed with filtered room air and the mixture is then drawn through the pump. Sufficient air is used to dilute the exhaust in order to avoid vapour condensation, which could dissolve some pollutants and reduce measured values. Excessive dilution on the other hand, results in very low concentration with attendant measurement problems. A pump with capacity of 30-350 cfm provides sufficient dilution for most vehicles.

Before the exhaust-air mixture enters the pump, its temperature is controlled by the heat exchanger. Thus constant density is maintained in the sampling system and pump. A fraction of the diluted exhaust stream is drawn off by a pump P2 and ejected into an initially evacuated plastic bag. Preferably, the bag should be opaque and manufactured of Teflon or Teldar. A single bag is used for the entire test sample in the CVS-1 system.

Because of high dilution, ambient traces of HC, CO or NOx can significantly increase concentrations in the sample bag. A charcoal filter is employed for leveling ambient HC measurement. To correct for ambient contamination a bag of dilution air is taken simultaneously with the filling of the exhaust bag.

HC, CO and NOx measurements are made on a wet basis using FID, NDIR and chemiluminescent detectors respectively**.** Instruments must be constructed to accurately measure the relatively low concentrations of diluted exhaust.

Bags should be analyzed as quickly as possible preferably within ten minutes after the test because reactions such as those between NO, NO2 and HC can occur within the bag quite quickly and change the test results.

CVS-3 SYSTEM:

The CVS-3 system is identical to the CVS-1 system except that three exhaust sample bags are used. The normal test is run from a cold start just like the CVS-1 test. After deceleration ends at 505 seconds, the diluted exhaust flow is switched from the transient bag to the stabilized bag and revolution counter number 1 is switched off and number 2 is activated. The transient bag is analyzed immediately. The rest of the test is completed in the normal fashion and the stabilized bag analyzed. However in the CVS-3 test ten minutes after the test ends the cycle is begun and again run until the end of deceleration at 505 seconds. This second run is termed the hot start run.

A fresh bag collects what is termed the hot transient sample. It is assumed that the second half of the hot start run is the same as the second half of the cold start run and is not repeated. In all, three exhaust sample bags are filled. An ambient air sample bag is also filled simultaneously.

STANDARDS IN INDIA:

The Bureau of Indian Standards (BIS) is one of the pioneering organizations to initiate work on air pollution control in India. At present only the standards for the emission of carbon monoxide are being suggested by BIS given in IS: 9057-1986. These are based on the size of the vehicle and to be measured under idling conditions. The CO emission values are 5.5 percent for 2 or 3 wheeler vehicles with engine displacement of 75cc or less, 4.5 percent for higher sizes and 3.5 percent for four wheeled vehicles.

IS: 8118-1976 Smoke Emission Levels for Diesel vehicles prescribes the smoke limit for diesel engine as 75 Hatridge units or 5.2 Bosch units at full load and 60-70 percent rated speed or 65 Hatridge units under free acceleration conditions.

EMISSION STANDARDS:

- First Indian emission regulations-1989
- Indian started adopting European emission and fuel regulations for 4- wheeled light-duty and for heavy-duty vehicles.
- Indian emission regulations still apply to 2 and 3 wheeled vehicles.

REGULATORY AGENCIES:

- Ministry of Environment and Forests
- Central pollution control Board (CPCB)
- State pollution control Boards (SPCBs) in respective states.
- Pollution control committee- in respective territories.

OVERVIEW OF EMISSION NORMS IN INDIA:

1991 - idle to limits for Gasoline vehicles. Free acceleration smoke for Diesel vehicles.
1992 - Mass Emission Norms for Diesel vehicles.
1996 - Revision of Mass emission norms. Mandatory fitment of Catalytic converter in Metros on Unleaded gasoline.
2000 - India 2000(Equivalent to Euro I) Norms. Bharat stage II Norms for Delhi.
2001 - Bharat Stage II (Euro II) norms for All metres; Emission norms for CNG&LPG Vehicles
2003 - Bharat stage II (Euro II) Norms for II major cities.
2005 - April 1 – Bharat stage III (Euro III) norms for II major cities.
2010 - Bharat stage III Emission norms for 4 wheelers for entire country BS IV (Euro IV)- for II major cities.
11 major cities – Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Ahamedabad, Pune, Surat, Kanpur, Agra. Unleaded Gasoline- introduced in 1995 100% in 2000.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=AVBjNCtqe4M&list=PL215741C530D11AFB&index=5&t=0s

Important Books/Journals for further learning including the page nos.:
R.K.Rajbut, "Internal Combustion Engines", Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 635-639.

Course Faculty

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Course Name with Code : **ADVANCED I.C ENGINES &16 MEE03**

Course Faculty : **Mr.M.Soundarrajan.**

Unit : **IV- ALTERNATIVE FUELS**

Date of Lecture :

Topic of Lecture : Alcohol Properties, Suitability, Merits and Demerits

Introduction:

Alternative fuels, known as non-conventional or advanced fuels, are any materials or substances that can be used as fuels, other than conventional fuels. Conventional fuels include: fossil fuels (petroleum (oil), coal, propane, and natural gas), as well as nuclear materials such as uranium and thorium, as well as artificial radioisotope fuels that are made in nuclear reactors.

Prerequisite knowledge for Complete understanding and learning of Topic:

This mixture may also not be purified by simple distillation, as it forms an azeotropic mixture. Biobutanol has the advantage in combustion engines in that its energy density is closer to gasoline than the simpler alcohols (while still retaining over 25% higher octane rating); however, biobutanol is currently more difficult to produce than ethanol or methanol. When obtained from biological materials and/or biological processes, they are known as bio alcohols (e.g. "bioethanol"). There is no chemical difference between biologically produced and chemically produced alcohols.

Detailed content of the Lecture:

4.2 Types:

- Alcohols
- Vegetable oils
- Bio-diesel
- Bio-gas
- Natural Gas

- Liquefied Petroleum Gas
- Hydrogen

4.3 Alcohols

Alcohol has been used as a fuel. The first four aliphatic alcohols (methanol, ethanol, propanol, and butanol) are of interest as fuels because they can be synthesized chemically or biologically, and they have characteristics which allow them to be used in internal combustion engines. The general chemical formula for **alcohol fuel is CnH2n+1OH.**

Most methanol are produced from natural gas, although it can be produced from biomass using very similar chemical processes. Ethanol is commonly produced from biological material through fermentation processes. This mixture may also not be purified by simple distillation, as it forms an azeotropic mixture. Biobutanol has the advantage in combustion engines in that its energy density is closer to gasoline than the simpler alcohols (while still retaining over 25% higher octane rating); however, biobutanol is currently more difficult to produce than ethanol or methanol. When obtained from biological materials and/or biological processes, they are known as bio alcohols (e.g. "bioethanol"). There is no chemical difference between biologically produced and chemically produced alcohols.
One advantage shared by the four major alcohol fuels is their high octane rating. This tends to increase their fuel efficiency and largely offsets the lower energy density of vehicular alcohol fuels (as compared to petrol/gasoline and diesel fuels), thus resulting in comparable "fuel economy" in terms of distance per volume metrics, such as kilometres per liter, or miles per gallon.

Advantages

- Is cheaper and more efficient and does not damage environment as much.
- Made from a renewable energy source, corn in the US, sugar cane in Brazil, or anything else that can produce ethanol.
- It reduces certain greenhouse emissions, CO and UHC's
- Higher octane rating, engine can have higher compression

Disadvantages

- Less energy content, it has 1/3 less energy than gasoline
- Emits cancer causing emissions 40x more than gasoline. Acetaldehyde, and formaldehyde.
- Takes more energy to produce that it you get out. only 83% back.

Material incapability.

- Ethanol destroys aluminium, rubber, gaskets, and many other things, so special materials are used in FFV's and to transport it.

May corrode parts of engine, you may have to fill in more often as alcohol runs out quickly.
Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=zKA4TYMgiqU
Important Books/Journals for further learning including the page nos.: R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 32- 35.

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LECTURE HANDOUTS

MECH **IV/VII**

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.M.Soundarrajan.

Unit : IV-ALTERNATIVE FUELS

Date of Lecture :

Topic of Lecture : Hydrogen Properties, Suitability, Merits and Demerits

Introduction:

Hydrogen fuel is a zero-emission fuel which uses electrochemical cells or combustion in internal engines, to power vehicles and electric devices. It is also used in the propulsion of spacecraft and can potentially be mass-produced and commercialized for passenger vehicles and aircraft.

Prerequisite knowledge for Complete understanding and learning of Topic:

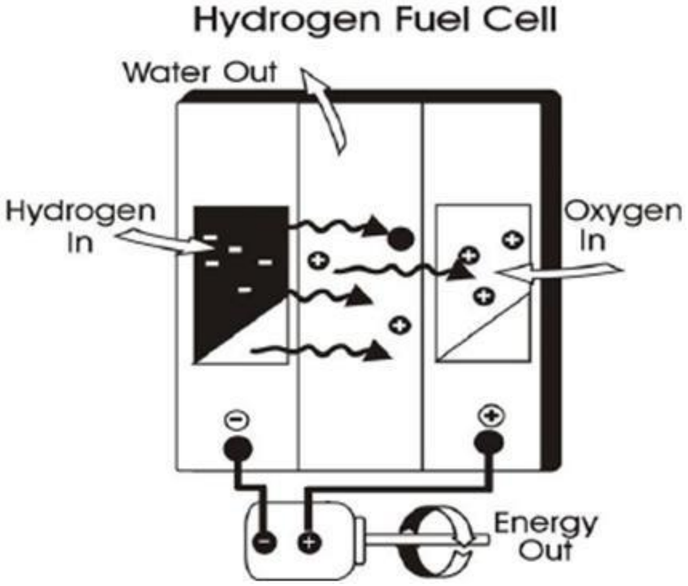
Hydrogen is one of two natural elements that combine to make water. Hydrogen is not an energy source, but an energy carrier because it takes a great deal of energy to extract it from water. It is useful as a compact energy source in fuel cells and batteries.

Detailed content of the Lecture:

Hydrogen fuel is a zero-emission fuel which uses electrochemical cells or combustion in internal engines, to power vehicles and electric devices. It is also used in the propulsion of spacecraft and can potentially be mass-produced and commercialized for passenger vehicles and aircraft.

Hydrogen is one of two natural elements that combine to make water. Hydrogen is not an energy source, but an energy carrier because it takes a great deal of energy to extract it from water. It is useful as a compact energy source in fuel cells and batteries.

Hydrogen is the lightest and most abundant element in the universe. It can be produced from a number of feedstock's in a variety of ways. The production method thought to be most environmentally benign is the electrolysis of water, but



probably the most common source of hydrogen is the steam reforming of natural gas. Once produced, hydrogen can be stored as a gas, liquid, or solid and distributed as required. Liquid storage is currently the preferred method, but it is very costly. Hydrogen-powered vehicles can use internal combustion engines or fuel cells. They can also be hybrid vehicles of various combinations. When hydrogen is used as a gaseous fuel in an internal combustion engine, its very low energy density compared to liquid fuels is a major drawback requiring greater storage space for the vehicle to travel a similar distance to gasoline

Advantages:

- Emits only water vapour, assuming there is no leakage of hydrogen gas
- It can store up to 3x as much energy as conventional natural gas.

Disadvantages:

- Leakage of H gas (see above) will have detrimental impacts on the stratosphere (California Institute of Technology)
- Production of hydrogen gas currently relies on natural gas and electrolysis and to replace all the vehicles would require 10x as much as currently is used
- Storage is really tough because hydrogen is such a low density gas
- Distribution and infrastructure needs to be refurbished to cope with hydrogen, which can metals by making them brittle
- Use in fuel cells requires catalysts, which usually require a component metal (most often platinum). Platinum is extremely rare, expensive and environmentally unsound to produce.

Video Content / Details of website for further learning (if any): NIL
Important Books/Journals for further learning including the page nos.: Panneer Selvam, R, “Engineering Economics”, Prentice Hall of India Ltd, New Delhi, 2001. Pg no (4-6).

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LECTURE HANDOUTS

MECH | **IV/VII**

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.M.Soundarrajan.

Unit : IV- ALTERNATIVE FUELS

Date of Lecture :

Topic of Lecture : Compressed Natural Gas Properties, Suitability,

Introduction:

Natural gas is a naturally occurring hydrocarbon gas mixture consisting primarily of methane, but commonly including varying amounts of other hydrocarbons, carbon dioxide, nitrogen and hydrogen sulfide. Natural gas is an energy source often used for heating, cooking, and electricity generation. It is also used as fuel for vehicles and as a chemical feedstock in the manufacture of plastics and other commercially important organic chemicals

Prerequisite knowledge for Complete understanding and learning of Topic:

Natural gas is found in deep underground natural rock formations or associated with other hydrocarbon reservoirs in coal beds and as methane clathrates. Petroleum is also another resource found in proximity to and with natural gas. Most natural gas was created over time by two mechanisms: biogenic and thermogenic. Biogenic gas is created by methanogenic organisms in marshes, bogs, landfills, and shallow sediments. Deeper in the earth, at greater temperature and pressure, thermogenic gas is created from buried organic material.

Detailed content of the Lecture:

Natural gas is an energy source often used for heating, cooking, and electricity generation. It is also used as fuel for vehicles and as a chemical feedstock in the manufacture of plastics and other commercially important organic chemicals.

Natural gas is a naturally occurring hydrocarbon gas mixture consisting primarily of methane, but commonly including varying amounts of other hydrocarbons, carbon dioxide, nitrogen and hydrogen sulfide.

biogenic and thermogenic. Biogenic gas is created by methanogenic organisms in marshes, bogs, landfills, and shallow sediments. Deeper in the earth, at greater temperature and pressure, thermogenic gas is created from buried organic material.

Advantages:

- Natural gas (largely methane) burns more cleanly than the other fossil fuels (45% less carbon dioxide emitted than coal and 30% less than oil)
- It is easily transported via pipelines and fairly easily using tankers (land and sea)
- It can be piped into homes to provide heating and cooking and to run a variety of appliances.
- Where homes are not piped, it can be supplied in small tanks.
- It can be used as a fuel for vehicles (cars, trucks and jet engines) where it is cleaner than gasoline or diesel.
- It is used to produce ammonia for fertilizers, and hydrogen, as well as in the production of some plastics and paints.
- It's relatively abundant, clean burning and seems easy to distribute.
- It's also lighter than air, so if there is a leak it will tend to dissipate, unlike propane, which is heavier than air and pools into explosive pockets.
- It can be used for heating, cooking, hot water, clothes dryer, backup generator power, and so forth.
- Some places will supply it to your house by way of underground pipes.
- Natural gas is more economical than electricity,
- It is faster when used in cooking and water heating and most gas appliances are cheaper than electrical ones.
- Gas appliances also do not create unhealthy electrical fields in your house.

Disadvantages:

- Even though it is cleaner than coal and oil, it still contributes a large amount of carbon dioxide to greenhouse gases.
- By itself natural gas is mostly methane, which is 21 times more dangerous for greenhouse warming than carbon dioxide so any leakage of the gas (from animals, landfills, melting tundra, etc.) contributes strongly to greenhouse emissions.
- If your house is not properly insulated it can be very expensive.
- It can leak, potentially causing an explosion.

Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=zKA4TYMgiqU
Important Books/Journals for further learning including the page nos.: R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 32- 35.

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LECTURE HANDOUTS

MECH **IV/VII**

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.M.Soundarrajan.

Unit : IV- ALTERNATIVE FUELS

Date of Lecture :

Topic of Lecture : Compressed Natural Gas Merits and Demerits

Introduction:

Vegetable oil is an alternative fuel for diesel engines and for heating oil burners. For engines designed to burn diesel fuel, the viscosity of vegetable oil must be lowered to allow for proper atomization of the fuel; otherwise incomplete combustion and carbon build up will ultimately damage the engine.

Prerequisite knowledge for Complete understanding and learning of Topic:

This type of fuel is better for the atmosphere because, unlike other fuels, it does not give off harmful chemicals which can influence the environment negatively. The popularity of biodiesel fuel is consistently increasing as people search out alternative energy resources.

Biodiesel refers to a vegetable oil- or animal fat-based diesel fuel consisting of long-chain alkyl (methyl, propyl or ethyl) esters. Biodiesel is typically made by chemically reacting lipids (e.g., vegetable oil, animal fat with an alcohol producing fatty acid esters.

Detailed content of the Lecture:

Benefits of vegetable oil run vehicles:

- CO_2 neutral
- Economical, cheaper than diesel
- Excellent system-energy efficiency (from raw "crude" to refined product)
- Sulphur-free
- Protects crude oil resources
- 100% biodegradable

- Non-hazardous for ground, water, and air in case of a spill
- Low fire hazard (flashpoint > 220°C)
- Practical to refuel at home
- Easy to store, more ecological than bio-diesel
- A chance for the farming community and agriculture

Disadvantages of vegetable oil run vehicles:

- Loss of space and/or vehicle load capacity due to additional fuel storage
- Loss of manufacturer guarantee in new vehicles for use of an alternative fuel
- Motor oil needs to be replaced more often in a direct injection engine as a safety precaution to avoid build-up
- Currently no public network of filling stations are available, must refuel at home

Biodiesel

Fuel that is made from natural elements such as plants, vegetables, and reusable materials. This type of fuel is better for the atmosphere because, unlike other fuels, it does not give off harmful chemicals which can influence the environment negatively. The popularity of biodiesel fuel is consistently increasing as people search out alternative energy resources.

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Biodiesel is meant to be used in standard diesel engines and is thus distinct from the vegetable and waste oils used to fuel converted diesel engines. Biodiesel can be used alone, or blended with petro diesel. Biodiesel can also be used as a low carbon alternative to heating oil.

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LECTURE HANDOUTS

MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.M.Soundarrajan.

Unit : IV-ALTERNATIVE FUELS

Date of Lecture :

Topic of Lecture : Liquefied Petroleum Gas Properties, Suitability

Introduction:

Liquefied petroleum gas, also called LPG, GPL, LP Gas, liquid petroleum gas or simply propane or butane, is a flammable mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles. LPG is prepared by refining petroleum or "wet" natural gas, and is almost entirely derived from fossil fuel sources, being manufactured during the refining of petroleum (crude oil), or extracted from petroleum or natural gas streams as they emerge from the ground. **LPG is a mixture of propane and butane (this is called autogas).**

Prerequisite knowledge for Complete understanding and learning of Topic:

There is reduction in power output for LPG operation than gasoline operation.

- Starting load on the battery for an LPG engine is higher than gasoline engine due to higher ignition system energy required.
- LPG system requires more safety. In case of leakage LPG has tendency to accumulate near ground as it is heavier than air.
- This is hazardous as it may catch fire.
- Volume of LPG required is more by 15 to 20% as compared to gasoline.
- LPG operation increases durability of engine and life of exhaust system is increased.

Detailed content of the Lecture:

Relative fuel consumption of LPG is about ninety percent of that of gasoline by volume.

- LPG has higher octane number of about 112, which enables higher compression ratio to be employed and gives more thermal efficiency.
- Due to gaseous nature of LPG fuel distribution between cylinders is improved and smoother acceleration and idling performance is achieved.
- Fuel consumption is also better.
- Engine life is increased for LPG engine as cylinder bore wear is reduced & combustion chamber and spark plug deposits are reduced.
- As LPG is stored under pressure, LPG tank is heavier and requires more space than gasoline tank.
- There is reduction in power output for LPG operation than gasoline operation.
- Starting load on the battery for an LPG engine is higher than gasoline engine due to higher ignition system energy required.
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- LPG operation increases durability of engine and life of exhaust system is increased.
- LPG has lower carbon content than gasoline or diesel and produces less CO_2which plays a major role in global warming during combustion.

The normal components of LPG are propane (C_3H_8) and butane (C_4H_{10}).
Small concentrations of other hydrocarbons may also be present.
Methane - 0%, Ethane - 0.20%, Propane - 57.30%,Butane - 41.10%, Pentane - 1.40%

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LECTURE HANDOUTS

MECH **IV/VII**

Course Name with Code : **ADVANCED I.C ENGINES &16 MEE03**

Course Faculty : **Mr.M.Soundarrajan.**

Unit : **IV-ALTERNATIVE FUELS**

Date of Lecture :

Topic of Lecture : Liquefied Petroleum Gas Merits and Demerits

Introduction:

Liquefied petroleum gas, also called LPG, GPL, LP Gas, liquid petroleum gas or simply propane or butane, is a flammable mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles. LPG is prepared by refining petroleum or "wet" natural gas, and is almost entirely derived from fossil fuel sources, being manufactured during the refining of petroleum (crude oil), or extracted from petroleum or natural gas streams as they emerge from the ground. .

Prerequisite knowledge for Complete understanding and learning of Topic:

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- LPG has higher octane number of about 112, which enables higher compression ratio to be employed and gives more thermal efficiency.
- Due to gaseous nature of LPG fuel distribution between cylinders is improved and smoother acceleration and idling performance is achieved.
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Methane - 0%

Ethane - 0.20%

Propane - 57.30%

Butane - 41.10%

Pentane - 1.40%

Advantages

- LPG is cheaper than petrol (up to 50%)
- It produces less exhaust emissions than petrol
- It is better for the engine and it can prolong engine life
- In some vehicles, it can provide better performance
- Has a higher octane rating than petrol (108 compared to 91).

Disadvantages

- It isn't highly available
- The initial cost for converting your vehicle to LPG can cost up to $3000. However the average car can repay the cost of the conversion in about 2 years
- It has a lower energy density than petrol
- No new passenger cars come readily fitted with LPG (they have to be converted)
- The gas tank takes up a considerable amount of space in the car boot

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LECTURE HANDOUTS

MECH **IV/VII**

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.M.Soundarrajan.

Unit : IV-ALTERNATIVE FUELS

Date of Lecture :

Topic of Lecture : Bio Diesel Properties, Suitability

Introduction:

Fuel that is made from natural elements such as plants, vegetables, and reusable materials. This type of fuel is better for the atmosphere because, unlike other fuels, it does not give off harmful chemicals which can influence the environment negatively. The popularity of biodiesel fuel is consistently increasing as people search out alternative energy resources.

Prerequisite knowledge for Complete understanding and learning of Topic:

Biodiesel refers to a vegetable oil- or animal fat-based diesel fuel consisting of long-chain alkyl (methyl, propyl or ethyl) esters. Biodiesel is typically made by chemically reacting lipids (e.g., vegetable oil, animal fat with an alcohol producing fatty acid esters

Detailed content of the Lecture:

Biodiesel is meant to be used in standard diesel engines and is thus distinct from the vegetable and waste oils used to fuel converted diesel engines. Biodiesel can be used alone, or blended with petro diesel. Biodiesel can also be used as a low carbon alternative to heating oil.

Advantages:

Using biofuels can reduce the amount of greenhouse gases emitted. They are a much cleaner source of energy than conventional sources.

- As more and more biofuel is created there will be increased energy security for the country producing it, as they will not have to rely on imports or foreign volatile markets.

- First generation biofuels can save up to 60% carbon emissions and second.

Generation biofuels can save up to 80%.Biofuels will create a brand new job infrastructure and will help support local economies. This is especially true in third world countries. There can be a reduction in fossil fuel use.

- Biofuel operations help rural development.
- Biodiesel can be used in any diesel vehicle and it reduces the number of vibrations, smoke and noise produced.
- Biodiesel is biodegradable.

Disadvantages:

- Biofuel development and production is still heavily dependent on Oil.
- As other plants are replaced, soil erosion will grow.
- A lot of water is used to water the plants, especially in dry climates.
- Deforestation in South America and South Eastern Asia causes loss of habitat for animals and for indigenous people living there.
- New technologies will have be developed for vehicles for them to use these fuels. This will increase their prices significantly

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Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.M.Soundarrajan.

Unit : IV-ALTERNATIVE FUELS

Date of Lecture :

Topic of Lecture : Bio Diesel Merits and Demerits

Introduction:

Fuel that is made from natural elements such as plants, vegetables, and reusable materials. This type of fuel is better for the atmosphere because, unlike other fuels, it does not give off harmful chemicals which can influence the environment negatively. The popularity of biodiesel fuel is consistently increasing as people search out alternative energy resources..

Prerequisite knowledge for Complete understanding and learning of Topic:

Biogas typically refers to a gas produced by the breakdown of organic matter in the absence of oxygen. It is a renewable energy source, like solar and wind energy. Furthermore, biogas can be produced from regionally available raw materials and recycled waste and is environmentally friendly and CO2 neutral.

Detailed content of the Lecture:

Biogas is produced by the anaerobic digestion or fermentation of biodegradable materials such as manure, sewage, municipal waste, green waste, plant material, and crops. Biogas comprises primarily methane (CH4) and carbon dioxide (CO2) and may have small amounts of hydrogen sulphide (H2S), moisture and siloxanes.

The gases methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel. Biogas can be used as a fuel in any country for any heating purpose, such as cooking. It can also be used in anaerobic digesters where it is typically used in a gas engine to convert the energy in the gas into electricity and heat. Biogas can be compressed, much like natural gas, and used to power motor vehicles.

Advantages of Biogas Energy

- It's a renewable source of energy.
- It's a comparatively lesser pollution generating energy.
- Biomass energy helps in cleanliness in villages and cities.
- It provides manure for the agriculture and gardens.
- There is tremendous potential to generate biogas energy.
- Biomass energy is relatively cheaper and reliable.
- It can be generated from everyday human and animal wastes, vegetable and agriculture left-over etc.
- Recycling of waste reduces pollution and spread of diseases.
- Heat energy that one gets from biogas is 3.5 times the heat from burning wood.
- Because of more heat produced the time required for cooking is lesser.

Disadvantages of Biogas Energy

- Cost of construction of biogas plant is high, so only rich people can use it.
- Continuous supply of biomass is required to generate biomass energy.
- Some people don't like to cook food on biogas produced from sewage waste.
- Biogas plant requires space and produces dirty smell.
- Due to improper construction many biogas plants are working inefficiently.
- It is difficult to store biogas in cylinders.
- Transportation of biogas through pipe over long distances is difficult.
- Many easily grown grains like corn, wheat are being used to make ethanol. This can have bad consequences if too much of food crop is diverted for use as fuel.
- Crops which are used to produce biomass energy are seasonal and are not available over whole year.

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LECTURE HANDOUTS

MECH **IV/VII**

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.M.Soundarrajan

Unit : IV-ALTERNATIVE FUELS

Date of Lecture :

Topic of Lecture : Engine Modifications

Introduction:

Hydrogen fuel has higher brake thermal efficiency and even can operate at lower engine loads with better efficiency. It can be noticed that brake thermal efficiency is improved to about 31 percentage with hydrogen fuelled engine compared to gasoline fuelled engine. Comparison of brake thermal efficiency of the fuels is shown in Fig. Here brake thermal efficiency of hydrogen is much better than the brake thermal efficiency of gasoline engine even at a low speed.

Prerequisite knowledge for Complete understanding and learning of Topic:

NOx levels of both engines. Significant decrease in NOx emission is observed with hydrogen operation. Almost 10 times decrease in NOx can be noted, easily. The cooling effect of the water sprayed plays important role in this reduction. Also operating the engine with a lean mixture is kept NOx levels low.

Detailed content of the Lecture:

4.17 Engine Design modification for all other Alternative Fuels

Spark plugs

Use cold rated spark plugs to avoid spark plug electrode temperatures exceeding the auto-ignition limit and causing backfire. Cold rated spark plugs can be used since there are hardly any spark plug deposits to burn off.

Ignition system

Avoid uncontrolled ignition due to residual ignition energy by properly grounding the ignition system or changing the ignition cable's electrical resistance. Alternatively, the spark plug gap can be decreased to lower the ignition voltage.

Injection system

Provide a timed injection, either using port injection and programming the injection timing such that an initial air cooling period is created in the initial phase of the intake stroke and the end of injection is such that all fuel is inducted, leaving no fuel in the manifold when the intake valve closes; or using direct injection during the compression stroke.

Hot spots

Avoid hot spots in the combustion chamber that could initiate pre-ignition or backfire.

Compression ratio

The choice of the optimal compression ratio is similar to that for any fuel, it should be chosen as high as possible to increase engine efficiency, with the limit given by increased heat losses or appearance of abnormal combustion (in the case of fuel primarily pre-ignition).

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MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.M.Soundarrajan.

Unit : V - RECENT TRENDS

Date of Lecture :

Topic of Lecture : Air assisted Combustion

Introduction:

Homogeneous charge compression ignition (HCCI) is a form of internal combustion in which well-mixed fuel and oxidizer (typically air) are compressed to the point of auto-ignition. As in other forms of combustion, this exothermic reaction releases chemical energy into a sensible form that can be transformed in an engine into work and heat.

Prerequisite knowledge for Complete understanding and learning of Topic:

A mixture of fuel and air will ignite when the concentration and temperat reactants is sufficiently high

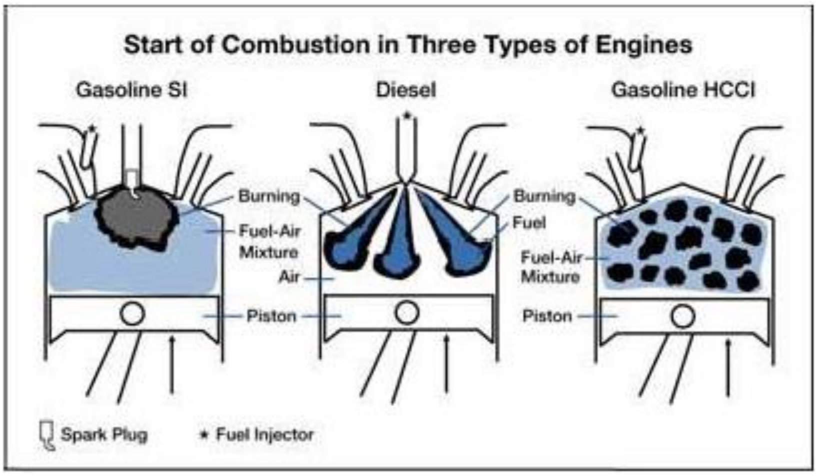
Detailed content of the Lecture:

Methods

A mixture of fuel and air will ignite when the concentration and temperature of reactants is sufficiently high. The concentration and/or temperature can be increasd by several different ways,

1. High compression ratio
2. Pre-heating of induction gases
3. Forced induction
4. Retained or re-inducted exhaust gases

Once ignited, combustion occurs very quickly. When auto-ignition occurs too early or with too much chemical energy, combustion is too fast and high in-cylinder pressures can destroy an engine. For this reason, HCCI is typically operated at lean overall fuel mixtures



In **an HCCI engine (which is based on the four-stroke Otto cycle)**, fuel delivery control is of paramount importance in controlling the combustion process. On the intake stroke, fuel is injected into each cylinder's combustion chamber via fuel injectors mounted directly in the cylinder head. This is achieved independently from air induction which takes place through the intake plenum. By the end of the intake stroke, fuel and air have been fully introduced and mixed in the cylinder's combustion chamber.

Fig .1 Homogeneous charge compression ignition

As the piston begins to move back up during the compression stroke, heat begins to build in the combustion chamber. When the piston reaches the end of this stroke, sufficient heat has accumulated to cause the fuel/air mixture to spontaneously combust (no spark is necessary) and force the piston down for the power stroke. Unlike conventional spark engines (and even diesels), the combustion process is a lean, low temperature and flameless release of energy across the entire combustion chamber. The entire fuel mixture is burned simultaneously producing equivalent power, but using much less fuel and releasing far fewer emissions in the process.

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Course Faculty : Mr.M.Soundarrajan.

Unit : RECENT TRENDS

Date of Lecture :

Topic of Lecture : Homogeneous charge compression ignition engines

Introduction:

The nitric oxide formation during the combustion process is the result of group of elementary reaction involving the nitrogen and oxygen molecules. Different mechanism proposed is discussed below.

Prerequisite knowledge for Complete understanding and learning of Topic:

This mechanism proposed by Eyzat and Guibet predicts NO concentrations much lower that those measured in I.C engines.

Detailed content of the Lecture:

Advantages

- HCCI provides up to a 30-percent fuel savings, while meeting current emissions standards.
- Since HCCI engines are fuel-lean, they can operate at a Diesel-like compression ratios (>15), thus achieving higher efficiencies than conventional spark-ignited gasoline engines.
- Homogeneous mixing of fuel and air leads to cleaner combustion and lower emissions. Actually, because peak temperatures are significantly lower than in typical spark ignited engines, NO_xlevels are almost negligible. Additionally, the premixed lean mixture does not produce soot.
- HCCI engines can operate on gasoline, diesel fuel, and most alternative fuels.
- In regards to gasoline engines, the omission of throttle losses improves

HCCI efficiency.

Disadvantages

- High in-cylinder peak pressures may cause damage to the engine.
- High heat release and pressure rise rates contribute to engine wear.
- The auto ignition event is difficult to control, unlike the ignition event in spark ignition (SI) and diesel engines which are controlled by spark plugs and in-cylinder fuel injectors, respectively.
- HCCI engines have a small power range, constrained at low loads by lean flammability limits and high loads by in-cylinder pressure restrictions.
- Carbon monoxide (CO) and hydrocarbon (HC) pre-catalyst emissions are higher than a typical spark ignition engine, caused by incomplete oxidation (due to the rapid combustion event and low in-cylinder temperatures) and trapped crevice gases, respectively.

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Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.M.Soundarrajan.

Unit : RECENT TRENDS

Date of Lecture :

Topic of Lecture : HCCI engines advantage Disadvantage

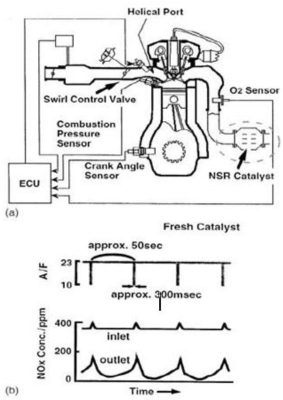
Introduction:

Internal combustion engines (ICE) operate by burning fossil fuel derivatives. Exhaust Emissions are their major contribution to environmental pollution.

Prerequisite knowledge for Complete understanding and learning of Topic:

Lean-burn means pretty much what it says. It is a lean amount of fuel supplied to and burned in an engine's combustion chamber. Normal air-to-fuel ratio is on the order of 15:1 (15 parts air to 1 part fuel). True lean-burn can go as high as 23:1.

Detailed content of the Lecture:



Working Principle

A lean burn mode is a way to reduce throttling losses.

- An engine in a typical vehicle is sized for providing the power desired for acceleration, but must operate well below that point in normal steady-speed operation. Ordinarily, the power is cut by partially closing a throttle.
- However, the extra work done in pumping air through the throttle reduces efficiency.
- If the fuel/air ratio is reduced, then lower power can be achieved with the throttle closer to fully open, and the efficiency during normal driving (below the maximum torque capability of the engine) can be higher.
- The engines designed for lean burning can employ higher compression ratios and thus provide better performance, efficient fuel use and low exhaust hydrocarbon emissions than those found in conventional petrol engines.
- Ultra lean mixtures with very high air-fuel ratios can only be achieved by direct injection engines.
- The main drawback of lean burning is that a complex catalytic converter system is required to reduce NOx emissions.
- Lean burn engines do not work well with modern 3-way catalytic converter which requires a pollutant balance at the exhaust port so they can carry out oxidation and reduction reactions so most modern engines run at or near the stoichiometric point.
- Alternatively, ultra-lean ratios can reduce NOx emissions.

Lean burn engine

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LECTURE HANDOUTS

MECH **IV/VII**

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.M.Soundarrajan.

Unit : V - RECENT TRENDS

Date of Lecture :

Topic of Lecture : Variable Geometry turbochargers

Introduction:

Internal combustion engines (ICE) operate by burning fossil fuel derivatives. Exhaust Emissions are their major contribution to environmental pollution.

Prerequisite knowledge for Complete understanding and learning of Topic:

An internal-combustion engine with a divided ignition cylinder that uses the ignition of rich fuel in a small chamber near the spark plug to improve the combustion of a very lean mixture throughout the rest of the cylinder.

Detailed content of the Lecture:

The stratified charge engine is a type of internal-combustion engine which runs on gasoline. It is very much similar to the Diesel cycle. The name refers to the layering of the charge inside the cylinder. The stratified charge engine is designed to reduce the emissions from the engine cylinder without the use of exhaust gas recirculation systems, which is also known as the EGR or catalytic converters.

Stratified charge combustion engines utilize a method of distributing fuel that successively builds layers of fuel in the combustion chamber. The initial charge of fuel is directly injected into a small concentrated area of the combustion chamber where it ignites quickly.

5.3.1 Principle:-

The principle of the stratified charge engine is to deliver a mixture that is sufficiently rich for combustion in the immediate vicinity of the spark plug and in the remainder of the cylinder, a very lean mixture that is so low in fuel that it

could not be used in a traditional engine. On an engine with stratified charge, the delivered power is no longer controlled by the quantity of admitted air, but by the quantity of petrol injected, as with a diesel engine. **5.3.2 Working:**   One approach consists in dividing the combustion chamber so as to create a pre-combustion chamber where the spark plug is located. The head of the piston is also modified. It contains a spheroid cavity that imparts a swirling movement to the air contained by the cylinder during compression. As a result, during injection, the fuel is only sprayed in the vicinity of the spark plug. But other strategies are possible. For example, it is also possible to exploit the shape of the admission circuit and use artifices, like ‚swirl' or ‚tumble' stages that create turbulent flows at their level. All the subtlety of engine operation in stratified mode occurs at level of injection.
Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=zKA4TYMgiqU
Important Books/Journals for further learning including the page nos.: R.K.Rajbut, “Internal Combustion Engines”, Lakshmi Publications of India LTD,Chennai, ISBN 81-7008-637-X.Pg No 32- 35.

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Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

L

LECTURE HANDOUTS

MECH **IV/VII**

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.M.Soundarrajan.

Unit : V - RECENT TRENDS

Date of Lecture :

Topic of Lecture : Common Rail Direct Injection Systems

Introduction:

This comprises two principal modes: a lean mode, which corresponds to operation at very low engine load, therefore when there is less call on it, and a ‚normal' mode, when it runs at full charge and delivers maximum power.

Prerequisite knowledge for Complete understanding and learning of Topic:

- In the first mode, injection takes place at the end of the compression stroke. Because of the swirl effect that the piston cavity creates, the fuel sprayed by the injector is confined near the spark plug. As there is very high pressure in the cylinder at this moment, the injector spray is also quite concentrated.

Detailed content of the Lecture:

- The ‚directivity' of the spray encourages even greater concentration of the mixture.
- A very small quantity of fuel is thus enough to obtain optimum mixture richness in the zone close to the spark plug, whereas the remainder of the cylinder contains only very lean mixture.
- The stratification of air in the cylinder means that even with partial charge it is also possible to obtain a core of mixture surrounded by layers of air and residual gases which limit the transfer of heat to the cylinder walls.
- This drop in temperature causes the quantity of air in the cylinder to increase by reducing its dilation, delivering the engine additional power.
- When idling, this process makes it possible to reduce consumption by almost

40% compared to a traditional engine. And this is not the only gain. Functioning with stratified charge also makes it possible to lower the temperature at which the fuel is sprayed.

- All this leads to a reduction in fuel consumption which is of course reflected by a reduction of engine exhaust emissions. When engine power is required, injection takes place in normal mode, during the admission phase.
- This makes it possible to achieve a homogeneous mix, as it is the case with traditional injection.
- Here, contrary to the previous example, when the injection takes place, the pressure in the cylinder is still low.
- The spray of fuel from the injector is therefore highly divergent, which encourages a homogeneous mix to form.

Advantages Of Stratified Charge Engine

- Compact, lightweight design &good fuel economy.
- Good part load efficiency.
- Exhibit multi fuel capability.
- The rich mixture near spark-plug &lean mixture near the piston surface
- provides Cushing to the exploit combustion.
- Resist the knocking & provides smooth resulting in smooth & quite engine
- operation over the entire speed & load range.
- Low level of exhaust emissions, Nox is reduced considerably.
- Usually no starting problem.
- Can be manufactured by the existing technology.

- **<u>Disadvatages</u>**

- For a given engine size, charge charge stratification results in reduced.
- These engines create high noise level at low load conditions.
- More complex design to supply rich & lean mixture & quantity is varied
- with load on the engine.
- Higher weight than of a conventional engine.
- Unthrotlled stratified charge emits high percentage of HC due to either
- incomplete combustion of lean charge or occasional misfire of the charge at
- low load conditions.
- Reliability is yet to be well established.
- Higher manufacturing cost.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=zKA4TYMgiqU

Important Books/Journals for further learning including the page nos.:

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LECTURE HANDOUTS

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MECH

IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.M.Soundarrajan.

Unit : V- RECENT TRENDS

Date of Lecture :

Topic of Lecture : Common Rail Direct Injection Systems

Introduction:

The initiation of a flame in the combustion chamber of an automobile engine by any hot surface other than the spark discharge

Prerequisite knowledge for Complete understanding and learning of Topic:

The hot bulb engine, or hot bulb or heavy oil engine is a type of internal combustion engine. It is an engine in which fuel is ignited by being brought into contact with a red-hot metal surface inside a bulb followed by the introduction of air (oxygen) compressed into the hot bulb chamber by the rising piston

Detailed content of the Lecture:

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. There is some ignition when the fuel is introduced but it quickly uses up the available oxygen in the bulb. Vigorous ignition takes place only when sufficient oxygen is supplied to the hot bulb chamber on the compression stroke of the engine.

Most hot bulb engines were produced as one-cylinder low-speed two-stroke crankcase scavenging units.

5.4.1 Operation and working cycle

The hot-bulb engine shares its basic layout with nearly all other internal combustion engines, in that it has a piston, inside a cylinder, connected to a flywheel via a connecting rod and crankshaft. The flow of gases through the engine is controlled by valves in four-stroke engines, and by the piston covering and uncovering ports in the cylinder wall in two-strokes. The type of blow-lamp used to start the Hot Bulb engine.

In the hot-bulb engine combustion takes place in a separated combustion chamber, the "vaporizer" (also called the "hot bulb"), usually mounted on the cylinder head, into which fuel is sprayed. It is connected to the cylinder by a narrow passage and is heated by the combustion while running; an external flame such as a blow-lamp or slow-burning wick is used for starting (on later models sometimes electric heating or pyrotechnics was used). Another method is the inclusion of a spark plug and vibrator coil ignition.[citation needed] The engine could be started on petrol and switched over to oil after it had warmed to running temperature.

The pre-heating time depends on the engine design, the type of heating used and the ambient temperature, but generally ranges from 2”5 minutes (for most engines in a temperate climate) to as much as half an hour (if operating in extreme cold or the engine is especially large). The engine is then turned over, usually by hand but sometimes by compressed air or an electric motor.

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Course Name with Code : **ADVANCED I.C ENGINES &16 MEE03**

Course Faculty : **Mr.M.Soundarrajan.**

Unit : **V-RECENT TRENDS**

Date of Lecture :

Topic of Lecture : Hybrid Electric Vehicles

Introduction:

Overhead camshaft, commonly abbreviated to OHC. a valve train configuration which places the camshaft of an internal combustion engine of the reciprocating type within the cylinder heads ('above' the pistons and combustion chambers) and drives the valves or lifters in a more direct manner compared to overhead valves (OHV) and pushrods

Prerequisite knowledge for Complete understanding and learning of Topic:

Typical emissions

contain primary greenhouse gases – carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). All criteria pollutants – carbon monoxide (CO), total nitrogen oxides (NO_x), sulfur dioxide (SO_2), non-methane volatile organic compounds (NMVOC) and particulate matter (PM) are the other major components

Detailed content of the Lecture:

Single overhead camshaft

Single overhead camshaft (SOHC) is a design in which one camshaft is placed within the cylinder head. In an inline engine, this means there is one camshaft in the head, whilst in an engine with more than one cylinder head, such as a V engine or a horizontally-opposed engine (boxer; flat engine) ,, there are two camshafts: one per cylinder bank.

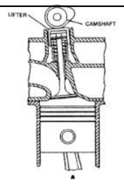

Fig.6.Single overhead camshaft

(b) **Double overhead camshaft**

A double overhead camshaft(DOHC) valve train layout (also known as 'dual overhead camshaft') is characterised by two camshafts located within the cylinder head, one operating the intake valves and one operating the exhaust valves. This design reduces valve train inertia more than a SOHC engine, since the rocker arms are reduced in size or eliminated.

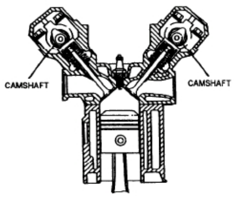

Fig.7. Double overhead camshaft

A DOHC design permits a wider angle between intake and exhaust valves than SOHC engines. This can allow for a less restricted airflow at higher engine speeds. DOHC with a multivalve design also allows for the optimum placement of the spark plug, which in turn, improves combustion efficiency.

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IV/VII

Course Name with Code : ADVANCED I.C ENGINES &16 MEE03

Course Faculty : Mr.M.Soundarrajan.

Unit : V-RECENT TRENDS

Date of Lecture :

Topic of Lecture : NOx Absorbers

Introduction:

The coolant sensor monitors engine temperature. The PCM uses this information to regulate a wide variety of ignition, fuel and emission control functions. When the engine is cold, for example, the fuel mixture needs to be richer to improve drivability. Once the engine reaches a certain temperature, the PCM starts using the signal from the O2 sensor to vary the fuel mixture

Prerequisite knowledge for Complete understanding and learning of Topic:

This is called "closed" operation, and it is necessary to keep emissions to a minimum.

Detailed content of the Lecture:

Throttle position sensor (TPS)

The throttle position sensor (TPS) keeps the PCM informed about throttle position. The PCM uses this input to change spark timing and the fuel mixture as engine load changes. A problem here can cause a flat spot during acceleration (like a bad accelerator pump in a carburetor) as well as other drivability complaints.

Airflow Sensor

The Airflow Sensor, of which there are several types, tells the PCM how much air the engine is drawing in as it runs. The PCM uses this to further vary the fuel mixture as needed. There are several types of airflow sensors including hot wire mass airflow sensors and the older flap-style vane airflow sensors. All are very expensive to replace

Manifold absolute pressure (MAP)

The manifold absolute pressure (MAP) sensor measures intake vacuum, which the PCM also uses to determine engine load. The MAP sensor's input affects ignition timing primarily, but also fuel delivery.

Knock sensors

Knock sensors are used to detect vibrations produced by detonation. When the PCM receives a signal from the knock sensor, it momentarily retards timing while the engine is under load to protect the engine against spark knock.

EGR position sensor

The EGR position sensor tells the PCM when the exhaust gas recirculation (EGR) valve opens (and how much). This allows the PCM to detect problems with the EGR system that would increase pollution.

Video Content / Details of website for further learning (if any):

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IV/VII

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Course Faculty : Mr.M.Soundarrajan.

Unit : V-RECENT TRENDS

Date of Lecture :

Topic of Lecture : Onboard Diagnostics

Introduction:

In internal combustion engines, Gasoline Direct Injection (GDI), also known as Petrol Direct Injection or Direct Petrol Injection or Spark Ignited Direct Injection (SIDI) or Fuel Stratified Injection (FSI), is a variant of fuel injection employed in modern two-stroke and four-stroke gasoline engines.

Prerequisite knowledge for Complete understanding and learning of Topic:

The gasoline is highly pressurized, and injected via a common rail fuel line directly into the combustion chamber of each cylinder, as opposed to conventional multi-point fuel injection that happens in the intake tract, or cylinder port.

Detailed content of the Lecture:

Operation

The major advantages of a GDI engine are increased fuel efficiency and high power output. Emissions levels can also be more accurately controlled with the GDI system. The cited gains are achieved by the precise control over the amount of fuel and injection timings that are varied according to engine load. In addition, there are no throttling losses in some GDI engines, when compared to a conventional fuel-injected or carbureted engine, which greatly improves efficiency, and reduces 'pumping losses' in engines without a throttle plate. Engine speed is controlled by the engine control unit/engine management system (EMS), which regulates fuel injection function and ignition timing, instead of having a throttle plate that restricts the incoming air supply. Adding this function to the EMS requires considerable enhancement of its processing and memory, as direct injection plus the engine speed management must have very precise algorithms for good performance and drivability.

The engine management system continually chooses among three combustion modes: ultra-lean burn, stoichiometric, and full power output.

Ultra lean burn or stratified charge mode is used for light-load running conditions, at constant or reducing road speeds, where no acceleration is required. The fuel is not injected at the intake stroke but rather at the latter stages of the compression stroke. The combustion takes place in a cavity on the piston's surface which has a toroidal or an ovoidal shape, and is placed either in the centre (for central injector), or displaced to one side of the piston that is closer to the injector. The cavity creates the swirl effect so that the small amount of air-fuel mixture is optimally placed near the spark plug. This stratified charge is surrounded mostly by air and residual gases, which keeps the fuel and the flame away from the cylinder walls. Decreased combustion temperature allows for lowest emissions and heat losses and increases air quantity by reducing dilation, which delivers additional power. This technique enables the use of ultra-lean mixtures that would be impossible with carburettors or conventional fuel injection.

Stoichiometric mode is used for moderate load conditions. Fuel is injected during the intake stroke, creating a homogeneous fuel-air mixture in the cylinder. From the stoichiometric ratio, an optimum burn results in a clean exhaust emission, further cleaned by the catalytic converter.

Full power mode is used for rapid acceleration and heavy loads (as when climbing a hill). The air-fuel mixture is homogeneous and the ratio is slightly richer than stoichiometric, which helps prevent detonation (pinging). The fuel is injected during the intake stroke.

Video Content / Details of website for further learning (if any):

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