Mechanical Engineering

Internal Combustion Engines

Comprehensive Theory

with Solved Examples and Practice Questions

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Corporate Office: 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016
E-mail: infomep@madeeasy.in
Contact: 011-45124660, 8860378007

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CHAPTER 03

Fuels

3.1 Requirement for an IC Engine Fuel

- It should take very little time for combustion
- It should have high energy density
- Low deposit forming tendency.

3.2 The Constituents of Crude Petroleum and their Properties

- **Paraffins ($C_n H_{2n+2}$) like methane, propane, Iso-octane, n-Heptane.** They are saturated and stable compound. Branch chain or isoparaffins are highly knock resistant in SI engine than straight chain paraffins.
- **Olefins ($C_n H_{2n}$) like ethylene, propylene.** They are unsaturated and unstable compound. They cause gummy deposit after oxidation.
- **Napthenes (C_nH_{2n}) like cyclo butane, cyclo hexane.** They are cyclic and saturated compound. They are more stable than olefins.
- **Aromatics.** They have ring structure of benzene (C_6H_6) as central structure. They are highly active or even explosive (Like Toluene)

3.3 Important Products of Refining Process of Crude Petroleum

- **Natural Gas.** They are paraffinic compound mainly Methane.
- **Liquified Petroleum Gas (LPG).** These are also paraffinic compound propane and butane. They can be liquified in ambient condition by applying pressure.
- **Gasoline or Petrol**. It is the highest liquid petroleum fraction. All liquid fraction having boiling point upto 200°C are gasoline. Its specific gravity is 0.70 to 0.78.
- **Kerosene**. These have boiling range 150°C to 300°C and specific gravity 0.78 to 0.85. These are heavier than petrol.
- **Diesel**. These have boiling range 200°C to 370°C and wide range of specific gravity. These are having more specific gravity than petrol

3.4 Effect of Volatility on Petrol Engine Performance

- Volatility is the tendency of fuel to go from a liquid to a gaseous state on slow heating of fuel. Quantity of fuel evaporated with temperature is measured which is called distillation and this is a measure of volatility of the fuel.
- Front end volatility (0-20% evaporation)

  Cold starting, hot starting and vapour lock are three important performance characteristics which are affected by the front end volatility of the gasoline used.

  1. **Cold starting:** High front end volatility is required for easy starting of engine.
  2. **Hot starting:** If the front end volatility is very high, it will create problem in hot starting as more and more vapours will be present in the combustion chamber making the mixture too rich to ignite.
  3. **Vapour lock**: Low front end volatility is required so that sufficient amount of liquid fuel could be pumped as more vapourization makes air fuel mixture lean because of less quantity of vapour and liquid fuel.
- **Mid range volatility (20%-80% evaporation)**
  1. **Engine warm up, acceleration, smoothness and fuel economy:** The mid range volatility should be sufficient enough to get all these performances of the engine.
  2. **Carburettor icing:** A low mid range volatility is required to prevent carburettor icing. More volatile fuel evaporates rapidly, lowering the temperature of carburettor body. With high humidity content, water vapour in the fuel condense and freezes.
- **Tail end volatility (80%-100% evaporation)**

  High tail end volatility causes less crankcase dilution, less engine deposits, gum formation and spark fouling.
  - Aldehydes and peroxides formed after oxidation of unsaturated hydrocarbon are knock inducing compounds. So Alphanaphthol is used as antioxidant.
  - Sulphur in fuel causes corrosion, odour and poor explosion characteristic in petrol.

3.5 Octane Number

- It is percentage of iso-octane in the fuel containing iso-octane and n-Heptane that gives the same knocking intensity as that of the fuel whose octane number is calculated. Octane number 80 means the fuel is equivalent to 100% mixture of iso-octane and n-Heptane where iso-octane is 80% and n-Heptane is 20%.
- Octane number of a fuel can be increased by adding Tetra ethyl lead (TEL).
- TEL causes spark plug fouling so ethylene dibromide is used to avoid lead deposits for spark plug fouling.

3.6 Requirement of Diesel Fuel

- **Flash point:** It is the temperature at which a visible flame occurs for less than 5 seconds. It should be high.
- **Fire point:** It is the temperature at which the flame can sustain for more than, 5 seconds. It should be high.
- **Cloud point:** It is the temperature at which the wax content of the diesel separates out in the form of solid. It should be low.
- **Pour point:** it is the temperature below which the entire fuel freeze. It should also be very low.

3.7 Cetane Number

- It is the percentage by volume of cetane ($C_{16}H_{34}$) in a mixture of cetane and a-methyl napthalene ($C_{10}H_7CH_3$) that has the same performance in the standard test engine as that of the fuel whose cetane number is calculated. So if a fuel is equivalent to 100% mixture of cetane and α-methyl naphthalene where cetane is 85% and α-methyl naphthalene is 15% then cetane number of the fuel is 85.
- High cetane number of Diesel engine fuel reduce its knocking tendency.
- Octane number and cetane no. are related as

$$(C.N.) = \frac{104-(O.N.)}{2.5}$$

3.8 Alternative Fuels for I.C. Engines

LPG

- It is a mixture of mainly propane and some butane and iso-butane.
- Cheaper than gasoline.
- High knock resistant and do not pre-ignite easily.
- Better manifold distribution.
- Crankcase oil dilution is small.
- Efficiency of engine is lower due to high heat of vapourization.
- It requires higher compression ratio to have the above said advantages.

Methanol (CH_3OH)

- The octane number of methanol is greater than petrol so with methanol, 20% greater output than petrol engine can be obtained due to higher compression ratio.
- Methanol engine has greater thermal efficiency.
- The mass of methanol consumed is 10% more than petrol due to lower calorific value of methanol.
- Methanol can be obtained from coal

$$\underset{\text{Coal}}{C} + \underset{\text{Steam}}{H_2O} \xrightarrow{\text{Partial combustion}} \underbrace{CO + H_2}_{\text{Synthesis gas}}$$

$$\underbrace{CO + 2H_2}_{\text{Synthesis gas}} \xrightarrow[\text{Low Pressure}]{Cu/Zn/Cr} CH_3OH$$

- Methanol can also be obtained from municipal solid waste
- Methanol is used in racing cars because of increased power due to high compression ratio

Ethanol (C_2H_5OH)

- Its octane number is greater than petrol so more thermal efficiency than petrol engine.
- The volumetric efficiency is also increased. So mean effective pressure and thus power output is more than petrol engine.
- Ethanol can be obtained from any feed stock containing carbohydrate such as corn, wheat, sugarcane, potatoes, starch in carbohydrate

$$\text{Starch in carbohydrate} \xrightarrow{\text{Enzyme}} \text{Sugar} \xrightarrow[\text{by yeast}]{\text{Fermentation}} \text{Ethanol}$$

- Vegetable oil particularly sunflower oil can be blended with diesel to reduce the consumption of diesel.

CNG (Compressed Natural Gas)

- It is a mixture of 90% Methane and remaining Ethane.
- It is a good SI engine fuel due to high Octane number.
- Fuel availability is large.
- It is cheap, odourless and safe in operation.
- Low engine emissions.

Summary

- It is percentage of iso-octane in the fuel containing iso-octane and n-Heptane that gives the same knocking intensity as that of the fuel whose octane number is calculated. Octane number 80 means the fuel is equivalent to 100% mixture of iso-octane and n-Heptane where iso-octane is 80% and n-Heptane is 20%.
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Objective Brain Teasers

Q.1 For determining the ignition quality of compression ignition engine fuels, the reference fuels used are
(a) Iso-octane and n-heptane
(b) Cetane and α-methylnapthalene
(c) Hexadecane and n-heptane
(d) Cetane and iso-octane

Q.2 Alcohols are unsuitable at diesel engine fuels because
(a) The cetane number of a alcohol fuels is very low which prevents their ignition by compression
(b) The cetane number of alcohol fuels is very high which prevents their ignition by compression
(c) The octane number of alcohol fuels is very low which prevents their ignition by compression
(d) None of the above

Q.3 Methane burns with stoichiometric quantity of air. The air-fuel ratio by weight is
(a) 4 (b) 14.7
(c) 15 (d) 17.16

Q.4 Match **List-I** (Fuels) with **List-II** (Characteristics/ usages) and select the correct answer using the codes given below the lists:

List-I

A. Semi-bituminous coal
B. High-speed dieseloil
C. Biogas
D. LPG

List-II

1. Methane and carbon dioxide
2. Propane and butane
3. Calorific value of 10,600 kcal/kg
4. Power plants

Codes:

	A	B	C	D
(a)	3	4	1	2
(b)	4	3	2	1
(c)	3	4	2	1
(d)	4	3	1	2

Q.5 In a petrol engine car, which one of the following performance characteristic is affected by the front-end volatility gasoline used?
(a) Hot starting and vapour lock
(b) Engine warm-up and spark plug fouling
(c) Spark plug fouling and hot starting
(d) Vapour lock, engine warm-up and spark plug fouling

Q.6 Consider the following statements:
1. Motor gasoline is a mixture of various hydrocarbons with a major proportional being aromatic hydrocarbons.
2. Compressed natural gas is a mainly composed of methane.
3. Producer gas has a Predominant component of hydrogen with lesser proportion of carbon monoxide.
4. Cetane number of fuel used in diesel engines in India is in the range of 80 to 90.

Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2, 3 and 4 (d) 1, 2, 3 and 4

Q.7 Which one of the following fuels can be obtained by fermentation of vegetable matter?
(a) Benzene (b) Diesel
(c) Gasoline (d) Alcohol

Answers

1. (a) **2.** (a) **3.** (d) **4.** (d) **5.** (a)
6. (a) **7.** (d)

Student's Assignments

Q.1 Discuss the important qualities of a SI engine fuel.

Q.2 What is vapour lock?

Q.3 What do you mean by ignition quality of a fuel?

Q.4 Discuss the basic qualities of a good CI engine fuel.

Q.5 Briefly discuss the rating of CI engine fuels.

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