IC ENGINE FUELS

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TYPES

- SOLID, GASEOUS, LIQUID
  - Difficult to handle Solid fuels and combustion products. Ex: coal.
  - Gaseous fuels are ideal due to homogenous mixing, ease of distribution and starting. But storage and handling is difficult. Ex: Natural gas
  - Most popular among mobile engines due to ease of handling. Main fuel is Petroleum oil

PETROLEUM OIL

Is a mixture of many hydrocarbons with differing molecular structure.

  - Paraffins (Alkanes)..C_nH_{2n+2}..chain..saturated..stable
  - Olefins (Alkenes) ..C_nH_{2n} ..chain ..unsaturated ..unstable
  - Naphthenes (cyclanes)/ Cyclo Paraffins..C_nH_{2n} ..ring ..saturated ..stable
  - Aromatics (Benzene Derivatives) ..C_nH_{2n-6} ..ring ..unsaturated

Calorific Value of fuels

Higher Calorific Value (HCV)

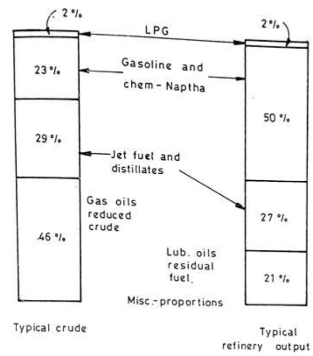
- The amount of heat evolved when a unit weight (or volume in the case of gaseous fuels) of the fuel is completely burnt and the products of combustion cooled to the normal conditions (with water vapor condensed as a result). The heat contained in the water vapor must be recovered in the condensation process.

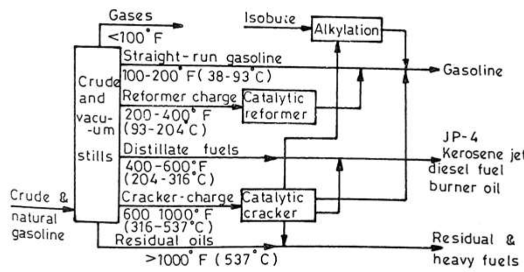
Lower Calorific Value (LCV)

- The amount of heat evolved when a unit weight (or volume in the case of gaseous fuels) of the fuel is completely burnt and water vapor leaves with the combustion products without being condensed.

REFINING PROCESS

- Thermal Cracking
  - Heavier HCs to lighter HCs (gasoline) at high Pressure & Temperature
- Catalytic Cracking
  - Heavier to lighter at presence of catalyst. This improves knock characteristics.
- Polymerisation
  - Olefins polymerised to heavier stable compounds in the gasoline range.
- Alkylation
  - Olefins + Iso paraffins to produce high octane gasolines.
- Isomerisation
  - Normal to isomer for alkylation and increasing knock characteristics
- Reforming
  - Increase anti knock quality
- Blending
  - Mixing different products for desired effects





Boiling points of various hydrocarbons increases with an increase in molecular weight. By using this fact crude oil can be separated on the basis of molecular weight by fractional distillation, obtaining different groups of similar hydrocarbons (with similar molecular weights and having similar characteristics)

In this process petroleum in vapor state at about 600 ^{0}C is admitted at the bottom of fractionating tower. Then passed upwards in a labyrinth like arrangement of plates which direct the vapor through trays of liquid fuel maintained at different temperatures. The heavier compounds which have higher boiling points gets condensed at lower levels while lighter ones with lower boiling points, at progressively higher levels. The lightest fractions form natural gas. Then Gasoline, Naphtha, Kerosene, Diesel, Heavy oils in the order of increasing molecular weight.

As the above figure depicts, the gasoline yield from a typical crude is much less than its demand. This led to refinery processes listed above. The figure below depicts a simplified refining process.

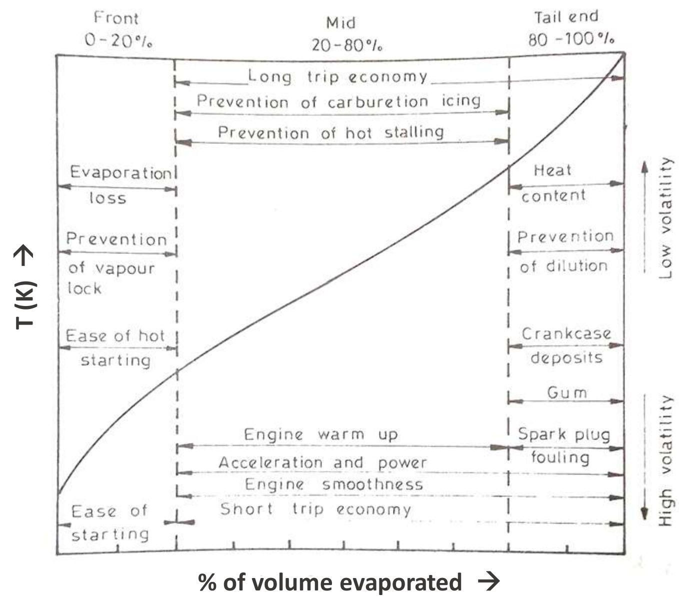
Important qualities of SI engine fuels

1. Volatility

Front End Volatility (0-20%)
- Cold Starting
- Hot Starting (Percolation)
- Vapour Lock
- Evaporative loss

Mid Range Volatility (20-80%)
- Warmup
- Short and Long trip economy
- Acceleration , Smoothness
- Carburettor Icing

Tail End Volatility (80-100%)
- Crankcase dilution
- Deposits & Spark plug Fouling



Relation of Engine Characteristics to Distillation Range

Volatility is the ability of fuel to form vapor.
The figure shows a distillation curve (% of volume evaporated vs Temperature). It is divided into 3 regions (front end, mid-range, tail end). Performance characteristics written above the curve will benefit from upward shift in the curve (i.e., lower fuel volatility) and vice versa.
There is a range of A/F ratio (8:1 on the richer side to 20:1 on the leaner side; 12:1 being ideal) suitable for combustion, richer or leaner than the range will fail to produce combustion.

Higher volatility in the Front End;
Increases ease of Cold Starting (providing sufficient vapor at cold temperatures, to form a mixture suitable for proper combustion);
Decreases ease of hot starting (forming excessive vapor and there by decreasing A/F ratio, i.e., mixture becomes too rich);
May cause Vapor Lock (fuel pump is pumping vapor instead of liquid, causing less amount of fuel reaching the combustion chamber, increasing A/F ratio, i.e., mixture becomes too lean);
May also increase evaporative loss from the storage, carburettor or fuel lines.

2. Anti Knock Quality

   Depends on chemical composition and molecular structure. High compression ratios can be employed with high anti knocking quality.

3. Gum Content

   Reactive HCs and impurities tend to oxidize upon storage forming sticky substances (liquid & solid). Sticking valves/pistons, clogging of carburettor, carbon deposits etc. Least is desirable.

4. Sulphur Content

   May contain free sulphur, hydrogen sulphide and other sulphur compounds which increases corrosive nature of fuel. Also harmful emissions, increased knocking tendency etc. Least is desirable.

Higher Mid-Range Volatility;
Increases engine warm-up performance and reduces the warm-up period (providing sufficient vapor at temperatures less than operating temperatures);
Increases short trip economy (since most of operation is during the warm-up period);
Decreases long trip economy (warm-up is only during a short period; high volatility means lower density, i.e., lesser mass per litre and so lesser km per litre)
Increases acceleration, smoothness and power (due to better A/F ratios)
Increases likelihood of carburettor icing (high volatility ➔ more evaporation ➔ more cooling effect in carburettor ➔ forming ice if ambient temperature is already very low and humidity very high)

Higher Tail End Volatility;
Increases crankcase dilution (more liquid fuel in cylinder, which washes away lubricating oil and seeps into crank case diluting the oil)
Increases deposits (High volatility ➔ presence of high boiling hydrocarbons, which contributes to varnish and sludge deposition)
Increases chances for spark plug fowling (presence of high boiling hydrocarbons)

Important qualities of CI engine fuels

1. Satisfactory handling & storage
    1. Flash and fire points: indicates the temperature below which oil can be handled without danger of fire.
    2. Viscosity: should be low enough for easy pumping and high enough to provide some lubrication.
    3. Cloud point: The temperature below which the wax content separates out as solid is called cloud point. This waxy solids can clog fuel lines and filters. This should be low.
    4. Pour point: The temperature below which the fuel freezes making flow impossible. This should be low.

Important qualities of CI engine fuels

2. Smooth and efficient burning
   1. Volatility: should be high for proper mixing, burning and starting characteristics. Lower volatility ➔ less fuel boil off from injector ➔ less HC emissions. Lower volatility ➔ less NOx emissions. High volatility also slightly affects smoke density and odour of exhaust.
   2. Ignition delay: too long ➔ high knocking. Too short ➔ smoke due to insufficient mixing.
   3. Anti knock characteristics: should be good.
   4. Specific gravity: should be high ➔ high energy density.
   5. Heat of combustion: should be high.

Important qualities of CI engine fuels

3. Continued cleanliness during usage
    1. Contamination: sand/rust/abrasive particles/ice can clog or damage parts.
    2. Sulphur: causes corrosion, wear, sludge/sticky deposits.

Rating of SI Engine Fuels

OCTANE Number

- Knock quality is rated by comparing with Primary Reference Fuels (PRF)
  1. Iso-octane, C_8H_{18} (2-2-4- trimethyl pentane) …….O.N. – 100
  2. n-heptane, C_7H_{16} …….O.N. – 0
- The % by volume of Iso-octane in a mixture of iso-octane and n- heptane which exactly matches the knocking intensity of the test fuel in a standard engine under a set of standard operating conditions is defined as the Octane Number.
- Cooperative Fuel Research Engine (CFR); 900 rpm, 38 ^{0}C Intake T, Coolant temperature 100 ^{0}C, Ignition advance 13 BTDC

Rating of CI Engine Fuels

- CETANE Number
  - Knock quality is rated by comparing with Primary Reference Fuels (PRF)
    - n-cetane, $C_{16}H_{34}$ …….C.N. – 100
    - Alpha methyl naphthalene, $C_{11}H_{10}$ …….C.N. – 0
  - The % by volume of n-cetane in a mixture of n-cetane and Alpha methyl naphthalene which has the same ignition characteristics (ignition delay) as the test fuel in a standard engine under specified operating conditions is defined as Cetane Number.
  - Cooperative Fuel Research diesel Engine (CFR); 900 rpm, 65.5 ^{0}C Intake T, Coolant temperature 100 ^{0}C, injection advance 13^0 bTDC, ignition delay 13^0.