Conventional fuels

Introduction:

- In IC engines, heat energy obtained from the combustion of fuel is converted into mechanical energy.
- Understanding of combustion process, requires proper understanding of the fuels, their characteristics.
- Fuel properties have considerable influence on various factors like engine design, efficiency, output, reliability and durability.
- Fuel properties also influence engine exhaust emissions.
Conventional fuels

Fuels:
- Generally, liquid and gaseous fuels are used in IC engines
- Mostly, derivatives of liquid petroleum are used.
- Commercial liquid fuels are benzyl, alcohol and petroleum products.
- Gaseous fuels are mostly used for stationary power sources.
- Storage and handling problems restrict the use of solid fuels in automobiles

Petroleum based liquid fuels

- Crude petroleum is a mixture of large number of hydrocarbon compounds differing widely in:-
  - Molecular structure
  - Sulphur, oxygen, nitrogen content
  - Impurities
- For purpose of comparison, it is desirable to arrange these hydrocarbon compounds into families based on the hydrogen and carbon arrangement within the molecules.

<table>
<thead>
<tr>
<th>Family</th>
<th>General Formula</th>
<th>Molecular Arrangement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraffins</td>
<td>C_nH_{2n+2}</td>
<td>Chain</td>
</tr>
<tr>
<td>Olefins</td>
<td>C_nH_{2n}</td>
<td>Chain</td>
</tr>
<tr>
<td>Di-olefins</td>
<td>C_nH_{2n-2}</td>
<td>Chain</td>
</tr>
<tr>
<td>Naphthene</td>
<td>C_nH_{2n}</td>
<td>Ring</td>
</tr>
<tr>
<td>Aromatics</td>
<td>C_nH_{2n-6}</td>
<td>Ring</td>
</tr>
</tbody>
</table>
Petroleum based liquid fuels

- **Paraffins.** The normal paraffin hydrocarbons consist of straight chain (open chain) molecular structure. Straight chain paraffins are termed as saturated compounds and are characteristically very stable.

![Butane](image1)

![Isobutane](image2)

Another variation of the paraffin family consists of an open chain structure with an attached branch, and is usually termed branch chain paraffin.

Isobutane, shown above, is an example of this type. This is also a saturated compound and is very stable. The branch chain paraffins have **good antiknock qualities when used as SI engine fuels.**

- **Olefins** are chain compounds similar to paraffins, but are unsaturated because they contain one double carbon to carbon bond. A typical example is butene. Olefins are not as stable as the single bond paraffins due to presence of double bond. Crude oil does not contain olefins and these result from certain refinery processes.

![Butene](image3)

Petroleum based liquid fuels

- **Diolefins:** are olefins with two double bonds. They are unsaturated and rather unstable.
- **Naphthenes:** have same general formula as olefins but have ring structure. Cyclopentane is a typical naphthene.
- **Aromatics:** Ring structure compounds based on the benzene ring. A double bond indicates unsaturation. For e.g.: Benzene

![Butadiene](image4)

![Benzene](image5)

![Cyclopentane](image6)
Characteristics of these families

- The anti-knock quality of a fuel when used in a SI engine appears to be poorest in the normal paraffins and improves generally in the order Olefins, Diolefins, Naphthenes, Aromatics.

- The suitability of these fuels for CI engine is in the inverse order of their suitability for SI engine. For CI engine, normal paraffins are better fuels and aromatics are the least desirable.

- In general, as the number of atoms in the molecular structure increases, the boiling point temperature rises.

- As the proportion of the hydrogen atoms to carbon atoms in the molecule increases, the heating value generally increases. Paraffins have greatest heating value and aromatic least.

Environmental Implications of Using Fossil Fuels

- Reduction in underground based carbon energy sources
- Serious modifications in earth’s surface layer
- Subsidence of surface ground after extraction of minerals
- Increase in CO2 levels in atmosphere from 280 PPM in pre-industrial era to 350 PPM now
- CO2 levels are still climbing as a function of fuel burnt
- Green house effect
- Acid rains, smog and change of climate
Alternative Fuel Factors

- Modifications in the existing engine hardware
- Investment costs for developing infrastructure for processing alternative fuels
- Environmental compatibility compared to conventional fuels
- Additional cost to the user in terms of routine maintenance, engine wear and lubricating oil life

Alternative Fuels: An Overview

- Several alternative fuels have been used either on an experimental basis or occasionally on a commercially viable basis, in various parts of the world, for a long time motivated by availability of a local resource which became economically viable because of rising prices of petroleum products particularly since the OPEC oil embargo of the 70’s and occasionally by some environmental regulations.
- Not only will it adversely affect India’s energy security, but it will also mean a significant drainage of precious foreign exchange reserve.
- India’s dependence on imported oil is close to 80%.
- Without addition to the domestic reserve of crude oil and no switch to alternative energy, India’s dependence on imported oil may go up to 90% within a few years.
- India has moved to become road-dependent economy in the nineties from traditionally railroad dependent economy.
- A 1995 World Bank study shows that per capita travel per year in India is 2300 km much more than other countries relative to their respective income levels.
Alternative Fuels: An Overview

- With this growth of automobile sector, particularly of the two wheeler segment accounting for about 80% of the total number of vehicles, the impact on environment is likely to be significant.
- India has an abundant stock of coal reserve enough to meet India’s requirements for more than 200 years.
- Environmental friendly technologies are available to produce power or methanol from coal.
- Industry observers believe India’s resource balance may come out strongly in favour of alternative fuel driven vehicles.

ME 359  Fundamentals of IC Engines

Why should fuels change?

Local and global environmental concerns, availability, local issues....

- Enable or adapt to new engine technology – e.g. low sulphur fuels, fuels for HCCI engines?
- Renewable Biofuels
- Cleaner Hydrocarbon Fuels such as GTL diesel (coupled with improvements in internal combustion engines). LPG, CNG, Dimethyl Ether (DME)

Changes should be sustainable - fulfil primary requirements while reducing local and global environmental impact and Should be acceptable to consumers
Conventional Fuels

Will constitute a great majority and will need to change to fit with changes in engine technology

- Examples
  Sulphur levels will continue to come down in both gasoline and diesel fuels. The pace of this change should be driven by the pace at which new engine technology requiring such fuels is introduced but will be affected by legislative initiatives.
  Gasoline specifications will need to change
  Direct Injection Spark Ignition (DISI) engines might work better with higher volatility fuels.
  “Unconventional Fuels” – Biodiesel, Bio-Fuels, Gas-to-liquid (GTL) fuels, LPG, CNG, LNG, Hydrogen

Gas to Liquid (GTL) Fuels

- Make sense in the current environment if there is “stranded” gas. But there might be other scenarios in the future.
- Could also be made from biogas but significant challenges.
- Extremely high quality diesel product – 75-80 Cetane, zero sulphur and aromatics, odorless, colorless, non-toxic, biodegradable
- Emissions benefit, for pure and blended product, well established for existing engine technology.
- Sustainability – clear benefits over conventional diesel in NOx and SO2, neutral on CO2.
Alternate fuels

Reason for search of alternate fuels
- Limited petroleum resources
- Increasing demand
- Stringent emission norms
- Increasing petroleum fuel prices

Renewable Energy Resources
- Hydro
- Geothermal
- Solar PV
- Solar Thermal
- Wind
- Hydrogen
- Biomass and Biogas
- Alcohols
- Biodiesel
- CNG, LPG

Alternate fuels: Methanol

Alcohol fuels, methanol and ethanol have similar physical properties and emission characteristics
- Produced from Coal, Natural Gas, Crude Oil, Biomass or even organic waste
- Methanol CH₃OH is a simple compound
- Contains no sulphur or complex organic compounds
- Organic emissions (Ozone precursors) will have lower reactivity than gasoline hence lower Ozone forming potential
- If pure methanol is used then minimal emission of benzene, and PAHs
- Higher engine efficiency
- Less flammable than gasoline
Alternate fuels: Methanol

Limitations:
- Range as much as half less, so larger fuel tank
- M100 has invisible flames
- Explosive in enclosed tanks
- Cost somewhat higher than Gasoline
- Toxic, Corrosive characteristics, Ozone Creative formaldehyde emissions
- Environmental hazard in case of spill, as it is totally miscible with water.

Alternate fuels: Ethanol

- Similar to Methanol, but considerably cleaner, less toxic and less corrosive
- Greater engine efficiency
- Grain alcohol, and can be produced from agricultural crops e.g. sugar cane, corn etc.

Limitations:
- More expensive to produce
- Lower range, Cold starting problems
- Require large harvest of these crops
- More energy input required in production
- Leads to environmental degradation problems such as soil degradation
Alternate fuels: CNG

Natural Gas can be used as CNG or LNG.

- Primarily CH4
- LNG is rarely used since it is expensive and more difficult to handle than CNG
- CNG is relatively well-tested fuel.
- Technology for substituting CNG is gasoline and diesel engine is more than 55 years old
- Millions of Vehicles use CNG as fuel. Safer fuel as it ignites at higher temp than diesel and gasoline
- Easy conversion of Gasoline cars to CNG. Much lower operating cost
- Lesser CO emissions than Gasoline or Methanol as CNG mixes better with air than liquid fuels
- Require less enrichment for engine start-up
- Essentially no unregulated pollutants (like Benzene), Smoke, SOx,
- Slightly less formaldehyde than gasoline vehicles
- Lower ozone forming potential
- Abundant Supply

Alternate fuels: CNG

Limitations:

- Extent of reduction of pollutants will depend on the emission control system.
- Emits similar or possibly higher NOx than Gasoline or Methanol vehicles
- Low range per filling
- Slower pick-up
- 10-15% Power loss
- Longer re-fuelling time
- Infrastructure for distribution needs
- Moderate performance of dual fuel “Transition” vehicles
LPG

- LPG mainly contains propane and Butane
- By-product of extraction and refining of crude oil and Natural Gas processing
- 10-15% quantity of Petroleum produced
- 3% of the quantity of Natural Gas

But

- Availability closely linked to crude oil production and refining therefore supply limitations
- Important Kitchen Fuel
- Lower HC, Higher NOx, Lower Pickup, Lower Power, Low Range.

LPG, LNG, CNG, DME

- Gases at normal temperature – require new infrastructure for transport and storage
- Significantly cleaner than conventional diesel for NOx, particulates. Lower CO2.
- Reduction in power?
- Potential as niche fuels, especially where urban air quality is problematic.
- (LPG quality better controlled and less bulky storage compared to LNG)
Hydrogen

- Attractive, Clean Combustion, except NOx
- Virtually non-polluting. Big greenhouse advantage
- Water as combustion product
- Domestically produced from water by electrolysis
- Significantly reduces transport related Ozone and CO
- Advanced lean burn hydrogen engines produce nominal amount of NOx.
- Hydrogen, if used in fuel-cell, doesn’t produce NOx.

But

- Technology has not matured.
- Limited Range, need heavy & bulky storage
- Hydrogen is expensive as yet.
- Availability? Infrastructure?

**Hydrogen as a Transport Fuel - Production**

- Not an energy source but an energy carrier. Production is energy intensive.
- Production from natural gas or coal, produces CO2
- Electrolysis of water using electricity from renewable (at the moment < 0.5% of total energy use) or nuclear (waste disposal, proliferation issues).
- Why convert electricity to H2?
- Much greater reduction in CO2 if renewable energy is used to replace coal-generated electricity.
- Hydrogen production must use CO2-free primary energy
Hydrogen - Transport and Storage

- Volumetric energy content ~ 3200 times lower than liquid fuels at room temperature/pressure.
- Compression (~25% energy lost).
- Liquefaction (~40% of energy lost).
- Storage in hydrides and carbon nanotubes not fully developed, currently not very efficient – exothermic (upto 30% energy loss).
- Significant safety issues
Thanks