UNIT IV

ALTERNATE FUELS

ALTERNATIVE FUEL

- 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, coal, propane, and natural gas), as well as nuclear materials such as uranium and thorium.

TYPES OF ALTERNATIVE FUELS

- Alcohols
- Vegetable oils
- Bio-diesel
- Bio-gas
- Natural Gas
- Liquefied Petroleum Gas
- Hydrogen

CLASSIFICATION OF ALTERNATIVE FUELS

- Gasoline type fuels
  - *Butanol as a direct replacement for gasoline*
  - *Ethanol or blending with gasoline*

- Diesel type fuels
  - *Straight vegetable oils*
  - *Biodiesel*

CLASSIFICATION OF ALTERNATIVE FUELS

- Gaseous
  - *Natural gas, compressed or liquefied*
  - *Propane (LPG)*
  - *Syngas*
  - *Biogas*
- Alternative Drivetrains
  - *Electric vehicles*
  - *Solar cell – powered or charged electric cars*
  - *Hydrogen fuel cell*
  - *Air car working on compressed air*

ALCOHOLS

- The first four aliphatic alcohols like methanol, ethanol, propanol, and butanol can be used as fuels.
- They can be synthesized chemically or biologically.
- The general chemical formula for alcohol fuel is given by

$$C_nH_{2n+1}OH$$

ALCOHOLS

- 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.
- Bio butanol has the advantage in combustion engines in that its energy density is closer to gasoline than the simpler alcohols.
- There is no chemical difference between biologically produced and chemically produced alcohols.

METHANOL

- As the most basic alcohol, methanol is a desirable choice as a transportation fuel due to its efficient combustion, ease of distribution and wide availability around the globe.
- Methanol is used in transportation in 3 main ways
  - *directly as fuel or blended with gasoline*
  - *converted in dimethyl ether (DME) to be used as a diesel replacement*
  - *as a part of the biodiesel production process*

METHANOL PRODUCTION

- It can be produced from a variety of abundant sources, including natural gas, coal, waste from pulp and paper mills, forest products, agricultural by-products, municipal waste and dedicated fuel crops such as switch grass.
- It is manufactured directly from synthesis gas produced by the gasification of coal or biomass, or through natural gas reforming.
- Among the various processes for chemical conversion of natural gas, direct synthesis of methanol is the most efficient process.

METHANOL COMBUSTION

- The methanol combustion is given by the following chemical reaction,

$$2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O + heat$$

ADVANTAGES OF METHANOL

- Methanol is liquid under normal condition, allowing it to be stored, transported and dispensed easily, much like gasoline.
- It has higher octane number than the gasoline, and hence it can be used in SI engines.
- Methanol can be efficiently produced from a variety of sources like fossil fuels like coal, but also from wood pyrolysis and municipal waste.
- It can be blended with gasoline at any ratio.

DISADVANTAGES OF METHANOL

- It is toxic in nature.
- Its energy density is one half of that of gasoline and 24% less than ethanol.
- It is corrosive to some metals including aluminium, zinc and manganese.
- Cold starting is poor due to low volatility in cold weather.
- It is hydrophilic in nature, resulting in phase separation and difficulty in starting the engine.

ETHANOL

- Ethanol also known as ethyl alcohol is a renewable fuel made from various plant materials collectively known as "biomass.“
- Anhydrous ethanol, that is, ethanol without water, can be blended with gasoline in varying quantities to reduce the consumption of petroleum fuels, as well as to reduce air pollution.

ETHANOL PRODUCTION

- Ethanol can be produced from many different raw materials, which are grouped according to the type of carbohydrates they contain like sugar, starch or cellulose.
- Well established production processes includes fermentation of molasses, beet and cane or grain sugars.

ETHANOL COMBUSTION

- The ethanol combustion is given by the following chemical reaction,

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O + heat$$

ADVANTAGES OF ETHANOL

- 10% ethanol blend reduce carbon monoxide and HC emission better than any other reformulated gasoline blend by as much as 25%.
- Ethanol contains 35% oxygen by weight, making it burn cleaner than gasoline.
- Ethanol is highly biodegradable, making it safer for environment.
- Ethanol contains 80% fewer gum forming compounds than gasoline.
- It can be generated from waste or biomass.

DISADVANTAGES OF ETHANOL

- Higher ethanol blend require vehicle modifications.
- Sustained availability of ethanol is difficult.
- It has lower energy density than gasoline.
- It leads to increase engine wear and tear due to low lubricity.
- Deposits and fouling are some effects of ethanol on fuel injection equipment.

BUTANOL AND PROPANOL

- Propanol and butanol are considerably less toxic and less volatile than methanol.
- Propanol (C_3H_7OH), is not often used as a direct fuel source for petrol engines (unlike ethanol, methanol and butanol), with most being directed into use as a solvent.
- However, propanol is used as a source of hydrogen in some types of fuel cell; it can generate a higher voltage than methanol, which is the fuel of choice for most alcohol-based fuel cells.

BUTANOL AND PROPANOL

- Butanol is a four carbon alcohol, which is double the amount of carbon in ethanol.
- It has a calorific energy 25% more than ethanol.
- The octane rating of n-butanol is similar to that of gasoline but lower than that of ethanol and methanol.
- Compared to ethanol, butanol can be mixed in higher ratios with gasoline.

BUTANOL AND PROPANOL PRODUCTION

- Isopropanol is typically produced from propene from decomposed petroleum, but can also be produced from fermentation of sugars.
- Butanol is produced by petrochemical methods as well as by fermentation of corn, grass, leaves, agricultural waste and other biomass.
- The butanol obtained from biomass is called bio-butanol.

ADVANTAGES

- Higher energy content than ethanol.
- Not as corrosive as ethanol.
- Uses an air/fuel ratio which is close to that of gasoline.
- Can replace gasoline at any percentage up to 100%.
- Provides better mileage than ethanol.
- Safer to handle than ethanol.
- Assist in the conversion of vegetable oils into biodiesel.

DISADVANTAGES

- These fuels are not compatible with some fuel system component.
- Butanol is too expensive to compete with ethanol in the blended fuel market.

OVERVIEW OF ALCOHOL FUEL

- Methanol and ethanol are the only commercially viable fuels.
- Both methanol and ethanol have been blended with gasoline, but ethanol is the current choice for gasoline blends.
- Methanol has found its place in the market as an additive for biodiesel and as a fuel for direct methanol fuel cells.
- Butanol is too expensive to compete with ethanol in the blended fuel market.

ADVANTAGES OF ALCOHOLS

- Is cheaper and more efficient and does not damage environment as much.
- Made from a renewable energy source like corn, sugar cane.
- It reduces certain greenhouse emissions, CO and UHC's
- One advantage shared by the four major alcohol fuels is their high octane rating.
- Higher octane rating, engine can have higher compression ratio.
- This tends to increase their fuel efficiency, thus resulting in comparable "fuel economy" in terms of kilometres per litre.

DISADVANTAGES OF ALCOHOLS

- Although these alcohols, when used near their stoichiometric air-fuel ratios, produce more power, a larger quantity of fuel is required to produce a specified power output.
- Less engine power is produced as the water content of an alcohol increases.
- Further, vapour lock, fuel mixing, and starting problems increase with water.
- May corrode parts of engine.

VEGETABLE OIL (SVO)

- Diesel Engine can run on straight vegetable oil.
- Either used cooking oil or new cooking oil can be used as fuel.
- A new vegetable oil tank must be installed and a heating source should be provided to heat the vegetable oil.
- A heater is necessary to keep the vegetable oil warmed to a certain temperature.
- The vehicle is started and stopped on diesel fuel, then switched over to vegetable oil

ADVANTAGES OF VEGETABLE OIL

- Cheaper fuel
- Boosts agro – economy.
- Can be derived from algae and non edible sources.
- Can be blended with other oils or converted into bio diesel.
- Environmental friendly.
- Higher energy density when compared to gaseous fuel.
- Storage is relatively easier.

DISADVANTAGES OF VEGETABLE OIL

- Viscosity is a problem for free fuel flow.
- Foaming tendency is high.
- Deposit formation is higher.
- Fouling of engine surfaces is high.
- NO_x emission is higher.
- Fuel availability is poor due to inadequate infrastructure.

BIODIESEL

- 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 with an alcohol producing fatty acid esters.
- 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 also be used as a low carbon alternative to heating oil.

ADVANTAGES OF BIODIESEL

- Biodiesel can be used in any diesel vehicle and it reduces HC emission, carbon monoxide emission and particulate emission.
- Biodiesel is a much better lubricant compared with petroleum diesel due to the presence of esters.
- As more and more biofuel is created there will be increased energy security for the country producing it.
- Biofuel operations help rural development.
- Biodiesel is biodegradable.

DISADVANTAGES OF BIODIESEL

- Biodiesel fuel disadvantage is that it can harm rubber hoses in some engines
- As Biodiesel cleans the dirt from the engine, this dirt can then get collected in the fuel filter, thus clogging it. So, filters have to be changed after the first several hours of biodiesel use.
- If not processed properly phase separation may take place.
- Gel formation at cold temperatures.

BIOGAS

- Biogas typically refers to a gas produced by the breakdown of organic matter in the absence of oxygen.
- The bio gas consist of following constituents,

Constituent	Percentage
Methane	50 – 60
Carbon dioxide	30 - 45
Hydrogen Sulfide	5 -10
Nitrogen	0.5 – 0.7
Water	Trace

BIOGAS PRODUCTION

- Biogas is produced by the anaerobic digestion or fermentation of biodegradable materials such as manure, sewage, municipal waste, green waste, plant material, and crops.

ADVANTAGES OF BIOGAS

- Cleaner burning fuel with less hydrocarbon emission, NOx, Particulate emission.
- Lower cost fuel.
- Ability to be generated from waste feedstocks.
- Traps and prevent greenhouse gas methane from being released into atmosphere.
- Displaces fossil fuel
- Promotes rural economy.
- Solves the waste problem for dairy, hog and poultry farmers.

DISADVANTAGES OF BIOGAS

- Biogas if untreated is corrosive in nature due to presence of hydrogen sulphide.
- It is flammable and explosive if accumulated in enclosed space.
- It is toxic if accumulated due to presence of carbon monoxide.

NATURAL GAS

- 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.
- It constituent of methane of about 85 – 95% by volume, remaining being HC, nitrogen and water.
- Natural gas is known as carbon poor fuel, which is the reason for low CO and CO_2 emissions.
- Natural gas is stored on board in high-pressure cylinders at pressure of 200 to 300 bar as compressed natural gas(CNG).
- Natural gas liquefies at -161^0 C at atmospheric pressure.

NATURAL GAS DEPOSITS

- Natural gas is found in deep underground natural rock formations or associated with other hydrocarbon reservoirs in coal beds.
- 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.

ADVANTAGES OF NATURAL GAS

- Octane number is about 100 – 130, because of this, the flame speed is higher and engine can operate with high compression ratio and better knock resistance.
- HC and CO emissions are lower and less aldehydes emission compared to methanol.
- It does not have to be vaporised for combustion as like liquid fuels. Therefore cold start problems and low temperature emissions due to cold-enrichment are minimised.
- Increasing the compression ratio helps to reduce the power loss in SI engine.

DISADVANTAGES OF NATURAL GAS

- HC emission may also increase as result of using NG gas in CI engines.
- Need of large pressurised fuel storage tank.
- Availability of refuelling facilities is less.
- Excessive water content in the NG fuel can cause corrosion in the gas cylinder and fuel systems.
- Either mechanical or electronic conversion kit is needed to inject the fuel in present engine system.

LIQUEFIED PETROLEUM GAS (LPG)

- LPG gas is mixture of propane or butane.
- It is obtained either from the natural gas processing or during petroleum refining.
- Composition of LPG varies very widely from country to country depending on the use and demand of butane.
- The pressure at which it becomes liquid at room temperature depends upon propane-butane ratio.
- The pressure inside storage tank keeps LPG liquid, and it becomes gas when released from the tank.

LIQUEFIED PETROLEUM GAS PRODUCTION

- 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.

ADVANTAGES OF LPG

- Good cold start and warm-up characteristics due its gaseous state.
- LPG has significantly lower smog formation potential compared to gasoline and diesel fuels.
- LPG is a relatively low sulphur fuel.
- Because of simple hydrocarbon molecules, LPG vehicles have lower emissions from compared to gasoline and diesel.
- Heat energy of LPG is about 12% higher than gasoline. So, LPG has better thermal efficiency.
- Uniform mixture can be supplied to multi-cylinder engines.

DISADVANTAGES OF LPG

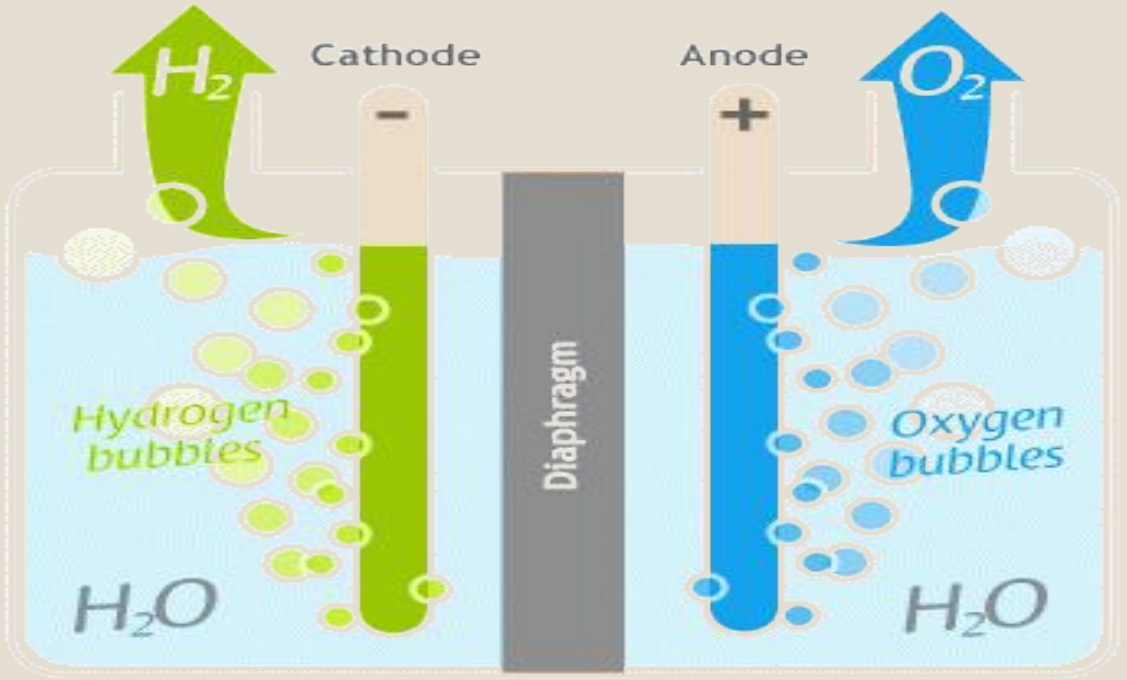
- It requires some modifications in SI engine, to convert liquid to vapour before injected into intake manifold.
- A special fuel feed system either mechanical or electronic conversion kit is required.
- Robust fuel tank of about 45% larger than gasoline tank.
- LPG is heavier than air, it is more likely to contribute to fire as a results of vehicle accidents than CNG.
- Vehicle weight increased due to high pressurized cylinder for LPG storage.
- Cooling system is required, because LPG vaporizer uses hot temperature from engine coolant to provide heat to convert liquid to gas.

HYDROGEN FUEL

- Hydrogen fuel is a zero-emission fuel which uses electrochemical cells or combustion in internal engines, to power vehicles and electric devices.
- 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.

HYDROGEN FUEL PRODUCTION

- The hydrogen is produced by electrolysis of water.
- This electrolysis of water is done using hydrogen fuel cell.



HYDROGEN FUEL PRODUCTION

- A DC electrical power source is connected to two electrodes, or two plates made up of platinum, stainless steel or iridium.
- The electrolysis of pure water takes place at a very slow rate because of the absence of free ions in it.
- When an electrolyte such as an acid or a base is added, the rate of electrolysis increases.
- When electricity is passed in the electrodes, Hydrogen will appear at the cathode - the negative electrode, where electrons enter the water.
- oxygen will appear at the anode - the positive electrode.
- The hydrogen thus produced can be stored as a gas, liquid, or solid and distributed as required.

ADVANTAGES OF HYDROGEN FUEL

- H_2 molecule and when oxidized forms water as an exhaust product.
- Heating value of H_2 is almost three times that of gasoline.
- H_2 engines are more efficient than gasoline or diesel engines.
- H_2 has high self-ignition temperature but requires very little energy to ignite it.
- Adiabatic flame temperature for H_2 is a little lower than for gasoline but rapid combustion allows very little heat loss to the surroundings.
- H_2 give (15 – 50 %) more thermal efficiency.

DISADVANTAGES OF HYDROGEN FUEL

- Nitrogen in the air contributes to the formation of NO_x in hydrogen engines.
- The problems in using H_2 are availability of fuel, storage and safety.
- Cost of production of H_2 approx. (2 – 10) times the cost of natural gas on energy equivalent basis.
- H_2 is highly flammable and its suitability as a fuel for on-board vehicle storage is questionable.
- Liquid H_2 tank occupy over three times the volumetric storage space of gasoline tank holding an equivalent amount of energy.

SUTABILITY

- The performance of the SI engine depends upon the following fuel characteristics,
  - Volatility
  - Sulphur content
  - Gum deposits
  - Antiknock quality

SUTABILITY

Volatility:

- Volatility is the tendency of a liquid to evaporate at given conditions.
- Petroleum fuels consist of a large number of different HC, each having a different boiling point.
- The fuel to be used in a SI engine should have high volatility.

SUTABILITY

Sulphur content:

- High sulphur content in SI fuels in the form of free sulphur, hydrogen sulphide and other sulphur compounds is undesirable because of the formation of SO_3.
- The combination SO_3 with water vapour forms H_2SO_4, which is a very corrosive substance that may attack various parts of the engine, thus affecting engine performance and life.
- Sulphur has low ignition temperature, the presence of sulphur can reduce the self-ignition temperature of the fuel, and thus promote knock in SI engine.

SUTABILITY

Gum deposits:

- Reactive HC and impurities in the fuel have a tendency to oxidize and form viscous liquids and solids called gum.
- High gum content will cause operating difficulties, such as sticking valves (reduce the volumetric efficiency) and piston rings, carbon deposits in the engine, gum deposits in the manifold, clogging of carburettor jets and lacquering of the valve stems, the cylinder and pistons.

SUTABILITY

Antiknock quality:

- Detonation in SI engine cause a very rapid and uncontrolled burning of the fuel and air mixture in a cylinder and this results in an abnormally rapid pressure rise.
- The anti-knock quality of a fuel depends on the self-ignition temperature of fuel and the chain reaction mechanism by which the fuel burns.
- In general, SI engine fuel should have highest anti-knock property, to permits higher compression ratio for higher thermal efficiency and power output.

SUTABILITY

- Some of the important characteristics of CI engine fuels are,
  - Ignition quality
  - Volatility
  - Viscosity
  - Corrosion and wear
  - Handling ease
  - Knock Rating of fuels

SUTABILITY

Ignition quality:

- It is a measure of ability of a fuel to ignite promptly after injection, thus enduring a progressive smooth burning and easy staring.
- The ignition quality is measured in terms of delay period(shorter period is preferable).
- A fuel with a higher cetane number gives better ignition quality in CI engines.
- The ignition quality of a CI engine fuel has cold starting, engine roughness and compression ratio.

SUTABILITY

Ignition quality:

a)Cold starting:

- Diesel fuels are less volatile and more viscous than gasoline.
- In order that the fuel should start the cold engine easily, a high cetane rating of the fuel is required.

b)Engine roughness:

- The intensity of vibration of various engine parts is the measure of engine roughness, which is caused by high rates of pressure rise in the combustion chamber.

SUTABILITY

Ignition quality:

c)Compression ratio:

- The CR is normally kept low in order to avoid excessively high cylinder pressure.
- With the increase in cetane number of the fuel, the ignition quality improves and the compression ratio can be lowered without facing the knocking problem in CI engines.

SUTABILITY

Volatility:

- Volatility affects the spray characteristics and may affect both power and efficiency.
- Increase in volatility increases the rate of evaporation of fuel and hence the rate of mixing of fuel and air.
- The fuel should be sufficiently volatile in the operating temperature range to produce good mixing and combustion, and thus reduce objectionable smoke and odour in the exhaust gases.

SUTABILITY

Viscosity:

- It is a measure of the resistance of fluid flow.
- It is an important characteristic as it affects the atomization of fuel and operation of the high pressure fuel pumps.
- The viscosity of oil increases with the increase in the number of carbon atom in it.
- The viscosity of fuel greatly influences the spray characteristics.
- High viscosity causes low atomization and high penetration of the spray jet.
- The lubricating qualities of low-viscosity fuels are poor, thus resulting in wear.

SUTABILITY

Corrosion and wear:

- The fuel should be such that it should not cause corrosion and wear before and after combustion.
- In order to avoid corrosion and wear, the fuel should not contain much sulphur, ash and carbon residue.

SUTABILITY

Handling ease:

- The fuel oil used in CI engines is a liquid that will readily flow under all conditions.
- This requirement is measured by the cloud point and the pour point of the fuel.

a)Cloud point: It is temperature below which the wax content of the petroleum oil separates out in the form of a solid. The waxy solid may clog the fuel lines and fuel filters.

b)Pour point: The pour point of an oil is found by cooling a sample in a test tube until no movement of the oil occurs for 5 seconds after the tube is titled from the vertical to the horizontal position. It is very important only when the engine has to run at low temperatures. In such cases, the oil should have a pour point 5 to 100 below the operating temperature.

SUTABILITY

Knock Rating of fuels:

- A practical measure of a fuel resistance to knock in SI engines is the fuel's octane number.
- The higher octane number indicates higher resistance to knock and the higher compression ratio may be used without knocking.
- The octane number used depends on the engine design and the operating conditions during the test.