Lecture-15

Prepared under
QIP-CD Cell Project

Internal Combustion Engines

Alternative Fuels

Ujjwal K Saha, Ph.D.
Department of Mechanical Engineering
Indian Institute of Technology Guwahati

Background

The *increasing motorization* of the world has led to a steep rise in the demand of petroleum products. But petroleum resources are :

- **Finite**
- **Highly concentrated in certain regions of the world**
- **Source of environmental pollution.**

Background

The transportation sector consumes 65 percent of the total petroleum products supplied. In India, the transportation sector contributes:

- **about 1/3rd of CO_2 emissions**
- **about 1/3rd of NOx emissions**
- **nearly 77 % of CO emissions**
- **around 45 % of particulate matter (PM)**

How to reduce our reliance on petroleum-based fuels ?

Alternative Fuels!

"Alternative fuel" means fuel that is

(a) for use in motor vehicles to deliver direct propulsion,

(*b*) less damaging to the environment than conventional fuels, and

(*c*) prescribed by regulation,

including, without limiting the generality of the foregoing, ethanol, methanol, propane gas, natural gas, hydrogen or electricity when used as a sole source of direct propulsion energy.

Alternative fuels include :

- Methanol and ethanol (Alcohol fuels)
- Natural gas (compressed or liquefied)
- Liquefied petroleum gas
- Hydrogen
- Biodiesel
- Electricity (Batteries and Fuel Cells)

Methanol

What it is: Methanol is an alcohol fuel. The primary alternative methanol fuel being used is M-85, which is made up of 85 percent methanol and 15 percent gasoline. In the future, neat methanol (M-100), may also be used.

How it is produced: Methanol is created from a synthesis gas (hydrogen and CO), which is reacted in the presence of a catalyst. Methanol can also be produced from non-petroleum feed-stocks such as coal and biomass.

Environmental Characteristics:

Emissions from M-85 vehicles are slightly lower than in gasoline powered vehicles. Smog-forming emissions are generally 30-50 percent lower; NOx and hydrocarbons emissions from M-85 vehicles are similar to slightly lower. However, CO emissions are usually equal or slightly higher than in gasoline vehicles.

Advantages:

- **High octane and performance characteristics.**
- **Only minor modifications are needed to allow gasoline engines to use methanol.**
- **There is a significant reduction of reactive emissions when using M-85.**

Ethanol

***What it is*:** **It's a cheap non-petroleum based fuel. As with methanol, E-85 is the primary ethanol alternative fuel. The use of ethanol in vehicles is not a new innovation. In the 1880s, Henry Ford built one of his first automobiles to run on ethanol.**

***How is it produced*:** **It can be produced by fermentation of vegetables and plant materials. In India, its main source is molasses - a byproduct of sugarcane. Its done in three stages**

1. **Extraction of juice from sugarcane**
2. **Fermentation of the juice**
3. **Distillation**

Environmental Characteristics: **It has approximately 30-50% fewer smog forming emissions than a gasoline vehicle. Air toxics are also reduced by about 50 percent when compared to gasoline. As with all internal combustion engines, vehicles using ethanol emit minor amounts of aldehydes. This is resolved by installing advanced catalytic converters on the vehicles.**

Major problem with ethanol is the corrosion. Ethanol driven vehicles require lines, hoses and valves to be resistant to the corrosion that alcohol can induce. Alcohol corrodes lead-plated fuel tanks; magnesium, copper, lead, zinc, and aluminum parts; and some synthetic gaskets.

Natural Gas - LNG & CNG

- ***What it is:*** **Natural gas is a mixture of hydrocarbons - mainly methane (CH_4). It can be stored on a vehicle either in a compressed gaseous state (CNG) or in a liquefied state (LNG).**

- ***How it is produced:*** **Natural gas is primarily extracted from gas wells or in conjunction with crude oil production; it can also be produced as a "by-product" of landfill operations.**

- ***Environmental Characteristics:*** **Natural gas has low CO emissions, virtually no PM (particulate matter) emissions, and reduced volatile organic compounds. Per unit of energy, natural gas contains less carbon than any other fossil fuel, leading to lower CO_2 emissions per vehicle mile traveled.**

- **Advantages**

  1. Its cheap
  2. It's Engine-Friendly
  3. It's safe
  4. There is lot of it in India.
  5. It's clean, easy to trap and odorless.

- **Disadvantages**

  1. The storage cylinder takes a lot of space.
  2. CNG gas stations are not widely available in India.

Liquified Petroleum Gas - LPG

***What it is*:** Liquefied petroleum gas (LPG) consists of various hydrocarbons, mainly propane, propylene, butane, and butylene in various mixtures. The main constituent, in most of the cases , is propane.

***How it is produced*:** LPG is a byproduct of natural gas processing and petroleum refining.

***Environmental Characteristics*:** The LPG run vehicles have lower emission of reactive hydrocarbons (about one-third less), NOx (20 percent less), and CO (60 percent less) than gasoline vehicles.

- ***Advantages***

1. Its cost is 60% of petrol with 90% of its mileage.

2. Has a higher octane number and burns more efficiently.

3. LPG has many of the storage and transportation advantages of liquids, along with the fuel advantages of gases.

4. Saves on the maintenance costs.

Hydrogen (H_2)

***What it is*:** Hydrogen gas (H_2)

***How it is produced*:** Hydrogen can be produced from a number of different sources, including natural gas, water, methanol etc. Two methods are generally used to produce hydrogen:

(1) Electrolysis

(2) Synthesis gas production from steam reforming or partial oxidation.

***Environmental Characteristics*:** When combusted (oxidized), only water vapor is produced. When burned in an internal combustion engine, small amounts of nitrogen oxides and small amounts of unburned hydrocarbons and carbon monoxide are produced, due to the use of engine lubricants.

Advantages

- Hydrogen-air mixture burns nearly 10 times faster than gasoline-air mixture.
- Hydrogen has high self-ignition temperature but requires very little energy to ignite it.
- Clean exhaust, produces no CO_2.
- As a fuel it is very efficient as there are no losses associated with throttling.

Disadvantages

- There is danger of back fire and induction ignition.
- Though low in exhaust , it produces toxic NOx.
- Its difficult to handle and store, requiring high capital and running cost.

Biodiesel

***What it is*:** **Biodiesel is a fuel made primarily from the oils and fats of plants. Although, it can be used as a straight replacement to diesel, the blend of biodiesel to diesel can be as low as 20% biodiesel, 80% diesel.**

***How it is produced*:** **Biodiesel can be produced through a transesterfication process, forming fatty esters. One of the byproducts of production is glycerol, which can then be sold as an independent product.**

Biodiesel

Environmental Characteristics: **Biodiesel has no aromatic content and only trace amounts of sulfur. In vehicle tests, it has lower emissions of carbon monoxide, soot, and polycyclic aromatic hydrocarbons than conventional diesel. With adjustments in the injection engine timing, it is possible to reduce the NOx emissions.**

- **Advantages**

  - Low Emissions
  - It is biodegradable and non-toxic
  - Low cost
  - High Cetane Number
  - High Lubricidity

Electricity (Batteries & Fuel Cells)

What it is: **Electricity is a type of energy where mechanical power is derived directly from it, as opposed to other alternative fuels, which release stored chemical energy through combustion to provide mechanical power. Electricity in vehicles is commonly provided by rechargeable batteries, but fuel cells are also being explored.**

Environmental Characteristics: **Battery-powered electric vehicles are almost zero-emission vehicles. Fuel cell emissions, using hydrogen as the fuel, are water vapor and heat.**

Batteries

- **Batteries are the storage "tanks" for electricity, and the quantity of potential power available from them is given by the battery rating (determined by plate size, quantity of electrolyte, etc.).**

Fuel Cells

- **Fuel cells do not store energy; instead chemical energy is converted into electricity. An external source of hydrogen (for example, from natural gas, gasoline, or one of the alcohol fuels) and oxygen (from air) are fed to the fuel cell. The electrolyte fuel cells employ the electrochemical reaction between hydrogen and oxygen to generate electricity.**

Conclusions

Our dependence on energy is central to our economy and way of life. Economically, we need to utilize new and renewable types of fuels, as our supplies of many current fuels are very limited. Environmentally, burning fossil fuels has been greatly affecting and damaging our planet.

Thus, it is important to compare all types of fuels, in order to determine the best ones, economically and environmentally, short term and long term. For this we need to develop alternative fuels.

References

1. **Crouse WH, and Anglin DL**, (1985), *Automotive Engines*, Tata McGraw Hill.
2. **Eastop TD, and McConkey A,** (1993), *Applied Thermodynamics for Engg. Technologists*, Addison Wisley.
3. **Fergusan CR, and Kirkpatrick AT**, (2001), *Internal Combustion Engines*, John Wiley & Sons.
4. **Ganesan V**, (2003), *Internal Combustion Engines*, Tata McGraw Hill.
5. **Gill PW, Smith JH, and Ziurys EJ**, (1959), *Fundamentals of I. C. Engines*, Oxford and IBH Pub Ltd.
6. **Heisler H,** (1999), *Vehicle and Engine Technology,* Arnold Publishers.
7. **Heywood JB,** (1989), *Internal Combustion Engine Fundamentals*, McGraw Hill.
8. **Heywood JB, and Sher E,** (1999), *The Two-Stroke Cycle Engine*, Taylor & Francis.
9. **Joel R,** (1996), *Basic Engineering Thermodynamics,* Addison-Wesley.
10. **Mathur ML, and Sharma RP,** (1994), *A Course in Internal Combustion Engines,* Dhanpat Rai & Sons, New Delhi.
11. **Pulkrabek WW,** (1997), *Engineering Fundamentals of the I. C. Engine*, Prentice Hall.
12. **Rogers GFC, and Mayhew YR,** (1992), *Engineering Thermodynamics*, Addison Wisley.
13. **Srinivasan S,** (2001), *Automotive Engines*, Tata McGraw Hill.
14. **Stone R,** (1992), *Internal Combustion Engines*, The Macmillan Press Limited, London.
15. **Taylor CF,** (1985), *The Internal-Combustion Engine in Theory and Practice*, Vol.1 & 2, The MIT Press, Cambridge, Massachusetts.

Web Resources

1. http://www.mne.psu.edu/simpson/courses
2. http://me.queensu.ca/courses
3. http://www.eng.fsu.edu
4. http://www.personal.utulsa.edu
5. http://www.glenroseffa.org/
6. http://www.howstuffworks.com
7. http://www.me.psu.edu
8. http://www.uic.edu/classes/me/ me429/lecture-air-cyc-web%5B1%5D.ppt
9. http://www.osti.gov/fcvt/HETE2004/Stable.pdf
10. http://www.rmi.org/sitepages/pid457.php
11. http://www.tpub.com/content/engine/14081/css
12. http://webpages.csus.edu
13. http://www.nebo.edu/misc/learning_resources/ ppt/6-12
14. http://netlogo.modelingcomplexity.org/Small_engines.ppt
15. http://www.ku.edu/~kunrotc/academics/180/Lesson%2008%20Diesel.ppt
16. http://navsci.berkeley.edu/NS10/PPT/
17. http://www.career-center.org/ secondary/powerpoint/sge-parts.ppt
18. http://mcdetflw.tecom.usmc.mil
19. http://ferl.becta.org.uk/display.cfm
20. http://www.eng.fsu.edu/ME_senior_design/2002/folder14/ccd/Combustion
21. http://www.me.udel.edu
22. http://online.physics.uiuc.edu/courses/phys140
23. http://widget.ecn.purdue.edu/~yanchen/ME200/ME200-8.ppt -
24. http://www.energy.ca.gov