Actual air cycles

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Power Losses due to ignition advance

Spark at TDC
Spark advance of 35 deg.
Optimum spark advance

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Ignition advance</th>
<th>Max. cycle pressure bar</th>
<th>mep</th>
<th>efficiency %</th>
<th>Actual $\eta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel-air cycle</td>
<td>0°</td>
<td>44</td>
<td>10.2 bar</td>
<td>32.2</td>
<td>1.00</td>
</tr>
<tr>
<td>Actual cycle</td>
<td>0°</td>
<td>23</td>
<td>7.5 bar</td>
<td>24.1</td>
<td>0.75</td>
</tr>
<tr>
<td>&quot;</td>
<td>17°</td>
<td>34</td>
<td>8.35 bar</td>
<td>26.3</td>
<td>0.81</td>
</tr>
<tr>
<td>&quot;</td>
<td>35°</td>
<td>41</td>
<td>7.6 bar</td>
<td>23.9</td>
<td>0.74</td>
</tr>
</tbody>
</table>
Best compromise is to go for moderate spark advance so as to have smaller losses in both compression and expansion strokes.

**Heat loss**

This is due to the transfer of the heat through water jackets and cooling fins. Also, some heat is being transferred during the compression and expansion processes.

- Heat transfer from the burned gases have significant effect on the P-V line.
- Due to heat transfer during combustion, the pressure at the end of combustion in the real cycle will be lower.
- During expansion, heat transfer will cause the gas pressure in the real cycle to fall below an isentropic expansion line as the volume increases.
- A decrease in efficiency results from this heat loss.
Engine Heat Profile

Engine Heat Profile in various regions leading to heat losses

Exhaust blow down loss

Blowdown loss is due to the early opening of exhaust valves. This results in drop in pressure, and a loss of work output during expansion stroke. Too early opening results in loss of expansion work.

- In the real engine operating cycle, the exhaust valve is opened some 60° before BC to reduce the pressure during the first part of the exhaust stroke in four-stroke engines and to allow time for scavenging in two-stroke engines.
- The gas pressure at the end of the expansion stroke is therefore reduced below the isentropic line.
- A decrease in expansion-stroke work transfer results.
Effect of exhaust valve opening

The effects of exhaust valve early opening

The Time loss, heat loss & exhaust loss

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Loss due to gas exchange processes / Pumping losses

➢ Pumping work is the difference between the work done in expelling the gases (during exhaust stroke) and the work done in inducing the fresh charge (during suction stroke). The loss is due to the pumping gases from low inlet pressure to high exhaust pressure.
Crevice effect and leakage

- As the cylinder pressure increases, gas flows into crevices such as the regions between the piston, piston rings, and cylinder wall.
- These crevice regions can comprise a few percent of the clearance volume.
- This flow reduces the mass in the volume above the piston crown, and this flow is cooled by heat transfer to the crevice walls.
- In premixed charge engines, some of this gas is unburned and some of it will not burn.
- Though much of this gas returns to the cylinder later in the expansion, a fraction, from behind and between the piston rings, flows into the crankcase.
- All these effects reduce the cylinder pressure during the latter stages of compression, during combustion, and during expansion below the value that would result if crevice and leakage effects were absent.

Blowby losses

![Blowby Losses](image1)

![Piston rings](image2)
Rubbing friction losses

- Rubbing friction loss is due to friction between the piston and chamber walls, friction in various bearings and also includes the energy spent in operating various auxiliary equipment such as cooling fans, water pumps etc.

- The piston ring friction increases rapidly with engine speed. It also increases to a small extent with increase in mean effective pressure. The bearing friction and the auxiliary friction also increase with engine speed.

Incomplete combustion

- Combustion of the cylinder charge is incomplete; the exhaust gases contain combustible species.

- In spark-ignition engines the hydrocarbon emissions from a warmed-up engine are 2 to 3 percent of the fuel mass under normal operating conditions.

- Carbon monoxide and hydrogen in the exhaust contain an additional 1 to 2 percent or more of the fuel energy, even with excess air present.

- Hence, the chemical energy of the fuel which is released in the actual engine is about 5 percent less than the chemical energy of the fuel inducted.

- In diesel engines, the combustion inefficiency is usually less, about 1 to 2 percent, so this effect is smaller.
<table>
<thead>
<tr>
<th>S.No.</th>
<th>Item</th>
<th>At load</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Full load</td>
<td>Half load</td>
</tr>
<tr>
<td>(a)</td>
<td>Air-standard cycle efficiency ($\eta_{air-std}$)</td>
<td>56.5</td>
<td>56.5</td>
</tr>
<tr>
<td>1.</td>
<td>Losses due to variation of specific heat and chemical equilibrium, %</td>
<td>13.0</td>
<td>13.0</td>
</tr>
<tr>
<td>2.</td>
<td>Loss due to progressive combustion, %</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>3.</td>
<td>Loss due to incomplete combustion, %</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>4.</td>
<td>Direct heat loss, %</td>
<td>4.0</td>
<td>5.0</td>
</tr>
<tr>
<td>5.</td>
<td>Exhaust blowdown loss, %</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>6.</td>
<td>Pumping loss, %</td>
<td>0.5</td>
<td>1.5</td>
</tr>
<tr>
<td>7.</td>
<td>Rubbing friction loss, %</td>
<td>3.0</td>
<td>6.0</td>
</tr>
<tr>
<td>(b)</td>
<td>Fuel-air cycle efficiency = $\eta_{air-std} - (1)$</td>
<td>43.5</td>
<td>43.5</td>
</tr>
<tr>
<td>(c)</td>
<td>Gross indicated thermal efficiency ($\eta_{ith}$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>= Fuel-air cycle efficiency ($\eta_{ith}$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- (2 + 3 + 4 + 5)</td>
<td>32.0</td>
<td>31.0</td>
</tr>
<tr>
<td>(d)</td>
<td>Actual brake thermal efficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>= $\eta_{ith} - (6 + 7)$</td>
<td>28.5</td>
<td>23.5</td>
</tr>
</tbody>
</table>

Typical losses in a gasoline engine for $r = 8$

**Fundamentals of IC Engines**

**Conventional fuels & Alternative fuels**

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Energy Scenario

Per capita primary energy consumption grows with income in a similar pattern across countries and time. Around $15,000 per capita ($1997 PPP) the relationship shifts: less energy-intensive services dominate economic growth. There are signs of saturation beyond $25,000 and evidence that later developers require less energy.

Challenge for us in India is to follow a flat trajectory of growth in fuel demand.

When per capita GDP (on a purchasing power parity basis) reaches some:
- $5,000 – demand explodes as industrialisation and personal mobility take off,
- $10,000 – demand slows as the main spur of industrialisation is completed,
- $15,000 – demand grows more slowly than income as services dominate economic growth and basic household energy needs are met,
- $25,000 – economic growth requires little additional energy.

Global energy consumption
Energy Scenario

Primary energy demand is expected to increase by 2.3 times over the next 20 years.

<table>
<thead>
<tr>
<th>Renewables</th>
<th>Nuclear</th>
<th>Hydro</th>
<th>Oil</th>
<th>Gas</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>(in million tonnes of oil equivalent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

India’s Energy demand

Source: BP Energy Outlook to 2035

Energy Scenario

Transportation energy consumption
quadrillion Btu

Global energy consumption

Source: U.S. Energy Information Administration
World Oil Demand and Supply Trends

- World oil production will peak but when? 10-30 years
- What is more important is “When will demand exceed supply?” - < 10 years according to pessimists
- Demand in 2004 ~ 82 M barrels a day, expected to rise to 84 M barrels a day in 2006 (source IEA) – pessimists say supply will not keep up, optimists say it will
- Are oil prices high now because of cyclical or structural reasons? Difficult to answer

Renewable Resources are Adequate to Meet all Energy Needs

GJ per capita

Figures based on 10 billion people.
Production and import of crude oil in India

- 196 MMt of crude oil (70% of our requirement) and petroleum products in 2016-17.
- causing a heavy burden on forex reserves.

<table>
<thead>
<tr>
<th>Year</th>
<th>Production (MMt)</th>
<th>Import (MMt)</th>
<th>Total requirement (MMt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>6.8</td>
<td>11.7</td>
<td>18.5</td>
</tr>
<tr>
<td>1981</td>
<td>10.5</td>
<td>16.2</td>
<td>26.7</td>
</tr>
<tr>
<td>1991</td>
<td>33</td>
<td>20.7</td>
<td>53.7</td>
</tr>
<tr>
<td>2000</td>
<td>32</td>
<td>57.9</td>
<td>89.9</td>
</tr>
<tr>
<td>2003-04</td>
<td>32.4</td>
<td>90.4</td>
<td>123.8</td>
</tr>
<tr>
<td>2004-05</td>
<td>33.4</td>
<td>100</td>
<td>133.4</td>
</tr>
</tbody>
</table>

- The known worldwide reserves of petroleum are 100 billion barrels and these are predicted to last about 40 years, hence the availability of petroleum is uncertain in future.
- Alternative fuels have to be considered in order to undertake energy security and import substitution for diesel and petrol fuels.
- No single fuel can sustain urban transport in the foreseeable future.

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How will the world manage energy in the future? – An optimistic view

- Technology and human ingenuity will ensure that future energy demands will be met fairly, cleanly and peacefully
  - Energy conservation
  - Development of renewable and biomass
  - Unconventional fossil fuels – heavy oil, tar sands (Alberta project), shale, coal bed methane
  - New oil production techniques
  - More oil fields
  - Development of coal technology
  - CO2 sequestration
  - Nuclear energy
Transport Fuels

- Primarily liquid fuels.
- Primarily made from crude oil in refineries.
- Why liquid fuels?
  - High energy density – Gasoline ~ 32 MJ/litre, Diesel ~36 MJ/litre
  - Easy transport, storage and handling
  - Extensive distribution network

• 75% of liquid fuels are used for transport. 70% of that in cars.
• Retail fuel is 95% fossil alkanes and 5% from a biological source.

By 2020, global demand for bio-derived fuels will be 500B litres.

OIL RESERVES

Of the 15 large companies that produce half the world’s oil, private sector companies hold only 5% of reserves

Source: IHS Energy © 2015 [Illustrations sourced from Shutterstock by HSI]
The 21st Century - Further Growth projected in Motorization

![Graph showing future vehicle growth by region from 2000 to 2050.]

Source: Sustainable Mobility Project calculations.

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There is no single solution for future fuels

- The next 20-30 years will see a wider range of vehicle technologies and fuel types especially in developed markets.

![Graph showing new car sales by fuel type from 2000 to 2030.]

Source: IEA, OXF, SH
Thanks