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## HCCI Combustion Characteristics

Most common engines use Spark Ignition of a premixed air-fuel mixture or Diesel type combustion of a heterogeneous mixture formation to create power. Both types of combustion perform work ***as*** the medium expands.

**HCCI** is a **H**omogeneous **C**harge **C**ompression **I**gnition Combustion process that is characterized by the compression and spontaneous combustion of a homogenous fuel mixture. This combustion process performs work in a kinetic fashon that imparts a very high power burst of energy to the piston, from concentrated super high pressures . HCCI performes its work and immediately expands the medium to cool and reduce emissions.

* With Compression Ignition of a homogenous fuel mixture, **the fuel mixture in the cylinder is compressed further than conventional Spark Ignition mixtures.** This means major changes in engine operating characteristics. **As the piston travels further to TDC, the result is:**

  * there is less surface exposed to high level heat, thereby exposing less surface to cooling, which translates into **a reduction in cooling losses.**
  * extended piston travel enables the fuel mixture to be compressed further, which promotes longer and faster mixing of the fuel mixture, creating a hotter fuel mixture which burns quicker creating **more concentrated power.**
  * a shift in peak pressure closer to TDC creating more time for the combusted gases to cool and resulting in **reduced exhaust gas temperatures and losses.**
  * higher compression and concentrated power output enable **faster operating speeds that create reduced blowby.**
  * higher compression and concentrated power result in **less cyclic variation and smoother combustion.**

* With Compression Ignition of a homogenous fuel mixture, **combustion may be tailored more effectively to meet power, emissions and fuel economy.** The result is:

  * **reduced emissions of HC, CO & NOx due to a more thourough fuel mixing,** resulting in lower HC & CO, **extended lean limits and higher EGR capability** which tend to keep peak flame temperatures lower, and the formation of NOx lower, and the **instantaneous combustion and immediate expansion of gases** which do not allow NOx time to form.

* **higher brake effeciency is obtained** due to increased compression and lean tuning enabled by **HCCI**.

Common Otto Cycle Spark Ignition Engines compress the homogenous fuel mixture to approximately 15 .... 25 bar during the compression stroke creating mixture temperatures of 400 to 600 $^{0}$C which lie below the autoignition threshold.

* Works better without Swirl.
* Compression Ignition
* Lean Operation
* EGR Compatible
* Single Speed and Multi Speed Acceptable
* Engine Characteristics - Small Bore, Long Stroke
* Greatly Reduced NOx Emission, HC Emissions, CO Emissions
* Greatly Increased Mileage - Less Consumption per Power Output.
* Greatly Improved Thermal Efficiency.
* Peak Pressures Shifted Much Closer To TDC.
* Non Ideal Combustion & Blowby diminshed.
* Near Adaibatic

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**Mechanical Efficiencies**

Roughly 99 % of todays Internal Combustion engines are either Otto Cycle or Diesel Cycle construction. The origin of these **engines dates back over 100 years, Otto in 1867 and Diesel in 1892.** Since that time these engines have been one of the most studied and refined mechanisms known. Their development continues today, with electronics controlling more and more engine functions. A look into the mechanical design of these engines reveals an elaborate array of components set to obtain the best power, emissions and economy that is possible. One thing that hasn't changed over the years, is the mechanical arrangement of crankshaft, connecting rod and piston.

**Within these engines, total engine efficiency to convert a given fuel to usable power is about 30% of fuel BTU value.** This is due to losses in:

* **Inertia,** whereby energy is used to:
    - Rotate the mass of the crankshaft
    - move the mass of the connecting rods
    - move the mass of the pistons
    - move the mass of the valvetrain and overcome valvespring forces
    - move the mass of other misc. support systems such as
        oil pump and oil
        distributor / ignition system
        water pump and cooling water
* **Friction**, whereby energy is lost in:
    - crankshaft main bearings
    - crankpin bearings
    - piston wristpin
    - valvetrain
    - piston ring / cylinder wall
    - piston / cylinder wall
    - support systems
        oil circulation & pump
        cooling circulation & pump
        distributor / ignition system

* **Thermodynamic losses** in :
  - Radiator / cooling system from combustion heat radiation through the heads and cylinder walls
  - Block passive radiation
  - Oil cooling
  - Exhaust

## Mechanical Efficiencies - Continued

* **Pumping losses** in :
  - Intake charge through the
    - throttle body
    - intake manifold
    - heads
    - into the cylinder
  - compression in each cylinder
    - before combustion
    - during combustion (at spark initiation, 10 to 20 degrees BTDC, to TDC)
* **Electrical generation losses** in:
  - ignition system
  - computer operating systems

### Energy Balance - Otto Cycle Engine

| % Load | Fuel Energy BTU/Min. | Brake Load BTU/ Min. % | | Coolant Loss BTU/M in. % | | Exhaust Loss BTU/M in. % | | Misc. Losses Btu/mi n. % | |
|---|---|---|---|---|---|---|---|---|---|
| 50 | 3050 | 478 | 16 | 945 | 31 | 931 | 30 | 696 | 23 |
| 75 | 3813 | 853 | 22 | 1215 | 32 | 1150 | 31 | 595 | 15 |
| 100 | 4613 | 1126 | 24 | 1485 | 32 | 1458 | 32 | 544 | 12 |

* Applied Combustion pp. 345,346 by: Eugene L. Keating U.S. Naval Academy Annapolis, MD
Published by Marcel Dekker, Inc. 1993

**So we see that the typical Otto Cycle Engine is about 32% efficient at 50% Load, 29% Efficient at 75% Load and 24% Efficient at Full Load.**

| Gas Type | Otto Cycle Engine % Exhaust Gas | Diesel Cycle Engine % Exhaust Gas |
|---|---|---|
| HC | - | 0.16 |
| CO | 4.77 | 1.40 |
| CO2 | 9.54 | 6.23 |
| CH4 | 3.15 | - |
| H2 | 0.84 | 0.99 |
| H2O | - | 7.14 |
| O2 | 2.80 | 2.86 |
| N2 | 78.90 | 64.74 |
| NOx | - | 16.49 |

* Applied Combustion pp. 355, 451 by: Eugene L. Keating U.S. Naval Academy
Published by Marcel Dekker, Inc. 1993

**NOTE:** This table may not be reflective of real engines it is data from sample problems in the referenced book.