Title:
A Brief Look at a Gasoline Engine

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I. Preface

Cars. Whether you like to admit it or not, they are a part of your daily life. You drive a car to work, drive a car to the supermarket, drive a car to pick your child up from school...you even drive a car just for the fun of it! But it was not always that way. There was a time when the only means of transportation was walking. It was a tiring thing to do, but there was no other way. When you wanted to buy some vegetables from the local market, you walked there. When you wanted to get some meat from the slaughterhouse, you walked there. Rain, snow, sleet, hail – no matter the weather, no matter the distance, you walked.

In the eighteenth century, however, James Watt decided to change that.\(^1\) He invented the steam engine, which later evolved into the gasoline engine we use in today’s automobiles.

<table>
<thead>
<tr>
<th>Year</th>
<th>Country</th>
<th>Person</th>
<th>Achievement</th>
<th>Effect on industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>1765</td>
<td>England</td>
<td>James Watt</td>
<td>Invented steam engine</td>
<td>Start of the automobile industry</td>
</tr>
<tr>
<td>1769</td>
<td>France</td>
<td>N.J. Cugnot</td>
<td>Fitted steam engine on car</td>
<td>First car with its own power source</td>
</tr>
<tr>
<td>1876</td>
<td>Germany</td>
<td>Otto</td>
<td>Implemented the four-cycle engine</td>
<td>Today’s cars still use Otto’s four-cycle engine</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(see Image 2-3 for more information)</td>
</tr>
<tr>
<td>1886</td>
<td>Germany</td>
<td>Benz &amp; Daimler</td>
<td>Used internal combustion engine on cars</td>
<td>Their invention is the basis for all cars today.</td>
</tr>
<tr>
<td>1897</td>
<td>Germany</td>
<td>Diesel</td>
<td>Created a compressed spark ignition</td>
<td>Today’s low speed diesel engines use this principle</td>
</tr>
<tr>
<td>1908</td>
<td>America</td>
<td>Henry Ford</td>
<td>1. Invented Model T</td>
<td>This sparked the growth of the automobile industry in America</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Used silent timing gear</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3. Created assembly line for faster production</td>
<td></td>
</tr>
<tr>
<td>1924</td>
<td>Germany</td>
<td>Mercedes Benz</td>
<td>Created high-speed diesel engine</td>
<td>Cars can use diesel fuel as power source</td>
</tr>
<tr>
<td>1950</td>
<td></td>
<td></td>
<td>Cars start using injection systems</td>
<td>Gasoline engines became more powerful</td>
</tr>
<tr>
<td>1952</td>
<td>America</td>
<td>Bendix</td>
<td>Researched electronic control units (E.C.U.)</td>
<td></td>
</tr>
<tr>
<td>1957</td>
<td>America</td>
<td>Bendix</td>
<td>Created the electronic control unit</td>
<td></td>
</tr>
<tr>
<td>1958</td>
<td>Germany</td>
<td>Bosch</td>
<td>Created injection</td>
<td></td>
</tr>
</tbody>
</table>
I wanted to write this thesis because cars are, really, all-that. Starting as just a steam engine in the hands of James Watt, cars evolved into big machines. Nowadays there are car dealers all over the world, parking lots in every place imaginable; there are call-in talk shows made especially for car lovers, magazines that test new cars and people who write editorials for them – and today, scientists are even testing cars that run on electricity or hydrogen! Just imagine what Watt would say if he saw these new hybrids.

My thesis will start with an introduction to the basic principles of a four-cycle (as opposed to a two-cycle) gasoline engine, as well as some formulas that are relevant to the functions of an automobile. I will then explain the more important components and accessories that make up an engine. Thereafter, I will talk about each of the four strokes that an engine has to go through in order to create movement. This thesis will end with my own conclusion and thoughts.

Buckle up!

II. Main Text

II-1. Introduction to Principles

Gasoline engines use a great amount of energy. From the 2200°C temperature (A) that a normal engine produces, a third of it is converted to movement, another third is released into the air, and the rest of it is cooled down by the cooling system. From the 12V (volts) of electricity (B) the battery produces, a much higher 20,000V (20kV) of electricity is made from the ignition coil. Derived from both of those energies comes the best part: horsepower (C), the muscle of the car. Let’s examine some basic laws of physics that are important to an automobile.

A. Heat

\[ 1J = 0.24C \]

J: Joule, a unit of power or energy  
C: Cal, a unit of heat

\[ H = mS\Delta T \]

H: Necessary amount of heat to make object change temperature  
m: Mass  
S: Specific heat  
\( \Delta T \): Change in temperature, or \( |T_1 - T_0| \)
As mentioned above, gasoline engines produce an incredible amount of heat. Some of that heat can be converted into power, but most of it is wasted. Therefore, a powerful cooling system is necessary on all automobiles. The formulas above describe how heat can be measured in different units, and also how different materials can affect the conduction of heat depending on its specific heat.

**B. Electricity**

<table>
<thead>
<tr>
<th>Commonly Used Units</th>
<th>Table 2-1 Commonly used units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit Symbol</strong></td>
<td><strong>Unit Name</strong></td>
</tr>
<tr>
<td>C</td>
<td>Coulomb</td>
</tr>
<tr>
<td>A</td>
<td>Ampere</td>
</tr>
<tr>
<td>V</td>
<td>Volt</td>
</tr>
<tr>
<td>Ω</td>
<td>Ohm</td>
</tr>
<tr>
<td>S</td>
<td>Mho</td>
</tr>
<tr>
<td>H</td>
<td>Henry</td>
</tr>
<tr>
<td>F</td>
<td>Farad</td>
</tr>
<tr>
<td>W</td>
<td>Watt</td>
</tr>
<tr>
<td>J</td>
<td>Joule</td>
</tr>
</tbody>
</table>

\[ 1C = 6.25 \times 10^{18} \text{e}^- \]
\[ Q = It \]
\[ I = \frac{nAve}{t} = nAve^{[4]} \]
\[ W = QV = Pt \]

\[ P = \frac{W}{t} = \frac{VQ}{t} = \frac{Vet}{t} = VI \]
\[ R = \rho \frac{\ell}{A} \]
\[ R_2 = R_1[1 + a_1(t_2 - t_1)] \]
Contrary to popular belief, electricity is one of the most important things in operating an engine. Without the 12V battery found in cars, an engine would have no possible way to start. Subsequently, a chain sequence will begin. *Without a continuous 20kV of electricity, a car using a distributor cap would not be able to supply the spark plugs with energy; without that spark of energy, the air/fuel mixture inside the cylinder block will be unable to combust.* In short, the car will not be able to move. This will be explained in more detail further on.

### C. Performance

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1HP = 746W = 550ft-lb/sec = 2545Btu/hr</td>
<td></td>
</tr>
<tr>
<td>HP: Horsepower</td>
<td></td>
</tr>
<tr>
<td>ft: Foot</td>
<td></td>
</tr>
<tr>
<td>lb: Pound</td>
<td></td>
</tr>
<tr>
<td>Btu: British Thermal Unit</td>
<td></td>
</tr>
<tr>
<td>V = (πD_o^2/4)×h</td>
<td>Cylinder volume</td>
</tr>
<tr>
<td>D_o: External diameter</td>
<td></td>
</tr>
<tr>
<td>h: Height of cylinder</td>
<td></td>
</tr>
<tr>
<td>V' = (πD_i^2/4)×h'</td>
<td>Cubic measure</td>
</tr>
<tr>
<td>D_i: Internal diameter</td>
<td></td>
</tr>
<tr>
<td>P.D.V. = (πD^2/4)×S×n</td>
<td>Piston Displacement Volume</td>
</tr>
<tr>
<td>D: Piston’s external diameter</td>
<td></td>
</tr>
<tr>
<td>S: Stroke</td>
<td></td>
</tr>
<tr>
<td>n: Amount of cylinders in engine</td>
<td></td>
</tr>
<tr>
<td>I.H.P. = P_i×L×A×N×n×n/K = P.D.V.×P_i×N/K</td>
<td>Indicated Horsepower</td>
</tr>
<tr>
<td>P_i: Effective pressure</td>
<td></td>
</tr>
<tr>
<td>L: Piston stroke cycle</td>
<td></td>
</tr>
<tr>
<td>A: Cylinder area</td>
<td></td>
</tr>
<tr>
<td>N: Amount of power strokes per minute</td>
<td></td>
</tr>
<tr>
<td>n: Amount of cylinders in engine</td>
<td></td>
</tr>
<tr>
<td>K: A constant</td>
<td></td>
</tr>
<tr>
<td>R.H.P. = (D^2×n)/K</td>
<td>Rated (or Taxable) Horsepower</td>
</tr>
<tr>
<td>K: A constant; 16.13 in the metric system</td>
<td></td>
</tr>
</tbody>
</table>
Performance is the thing many people care about in a car. Who has the most horsepower? Who can get the most miles per gallon? Who can accelerate the fastest? On the highways of America, engine performance is so looked upon that a devoted driver can get road rage when another driver accelerates in front of him!

The above formulas explain the important aspects of an engine: its cylinder volume, horsepower, and torque. All need to work in perfect synergy to squeeze the best performance out of the engine. Let us examine some basic knowledge about four-cycle engines before we head on.

D. Basic Knowledge

**Engine Cycle**
Below is the engine cycle. There are four strokes an engine must go through: intake, compression, power, and exhaust. These four strokes help the machinery inside the engine operate.

**Piston Movements**
The piston moves up and down the cylinder according to the crankshaft’s rotation. See Image 2-2 for a more detailed explanation.

- **Top Dead Center (T.D.C.):** The piston reaches its highest point; the connecting rod and the crankshaft create a straight line.
- **Bottom Dead Center (B.D.C.):** The piston arrives at its lowest point.

When the piston reaches top/bottom dead center, its instantaneous speed is zero. Instantaneous speed is defined as: 

$$|\dot{\mathbf{v}}| = \frac{\int_{t_0}^{t_1} [\dot{\mathbf{v}}(t)] dt}{\Delta t}$$

Don’t worry: you don’t need to memorize that!
Otto Cycle
As you know from reading Table 1-1, the Otto Cycle was created by Otto of Germany in the year of 1876. This direction of this cycle is A→B→C→D. From this chart, we find out that segment BC is gaining pressure, but its volume doesn’t change.
Heat, electricity, and performance are the three very basic principles that help create movement in an engine. In the following section, I will explain the details: how does an engine implement those three principles? What is their role in creating movement?

II-2. Inside the Engine

If an engine were Father Christmas, then heat, electricity, and performance would only be his little elf helpers. Santa without his helpers would definitely not be able to function. But the bulk of it all, the very point of Christmas, is still Santa. Just like an engine. The above three principles works together to help the big guy, the engine, do its work. Inside the engine, there are four main sections, each with important components that will be thoroughly explained. At the very top, there is cylinder head (A), the place where the rocker arm rests. Following is the cylinder block (B), the place where the pistons rock up and down. Next is the most important: the crank shaft (C). Last is the base of the lubrication system (D), the oil pan.

After examining the picture, we find out that:
A: Piston starts to move up
B: Spark plug fires strong electrical current
C: Piston passes top dead center (T.D.C.) and creates a large amount of pressure
D: Exhaust valve opens

Image 3-1 The four main sections of an engine
A. Cylinder Head

i. Valve
In a four-cycle engine, there are at least two valves per cylinder: one controls the intake of air (called the “intake valve”), the other controls the exhaust emissions (called the “exhaust valve”). During the four cycles of the engine, the camshaft pushes the valve lifter, which pushes the push rod up. The push rod then lifts one end of the rocker arm up, leaving the other end being pushed down, which in turn pushes the valve open.

![Image 3-2 Engine valves]

This is the engine valve. To see whether it is an intake or exhaust valve, we must look at its sequence number.

ii. Rocker Arm
The rocker arm is responsible for pushing the valves open when the camshaft pushes a lever. When an engine is running, the rocker arm moves at a very fast speed, so fast you cannot see it moving up and down. Therefore, before testing any engine, you must make sure the rocker arm is safely secured onto the cylinder head.

B. Cylinder Block

i. Cylinder
The cylinder is essentially just a cylinder. Its size is precisely measured, as to make sure the piston can easily slide up and down inside.

ii. Camshaft
The cams are pointed at different angles throughout the camshaft. These angles are also precisely measured so that when one valve is open, another is closed; when one cylinder is going through the intake
stroke, another is going through the exhaust.

![Image 3-3 Camshaft]

Notice how the pointed ends are all angled differently.

### iii. Spark Plug

The spark plug is attached into the side of the cylinder block. It deals with electricity, and as said before, electricity is one of the most important things needed to operate an engine. **The spark plug is an amazing conductor: it takes 20kV of electricity from the high tension cables and sends it into the cylinder to create a spark.** [6]

![Image 3-4 Location of the spark plug]
The picture above shows the location of the spark plug. It is attached into the side of the cylinder block, and there is a high tension cable connected to it.

Image 3-5 Structure of a spark plug

The spark plug clearance is usually 1~1.2mm in length. That is the place where the high voltage electricity jumps, from one pole to the other, bringing the cylinder into its power stroke. [7]

iv. Distributor

The distributor has three main jobs:

1. Converts the 12V electric flow into ON/OFF signals
2. Adjusts the ignition advance according to engine load
3. Sends high voltage electricity through high tension cables to the spark plugs

The distributor consists of many gears and cams, as well as the contact point assembly, ignition advance system, a condenser, and a rotor.

a. Contact Point Assembly: The contact point assembly has an important job: it controls the electric ON/OFF signals that, in turn, tells the ignition coil to charge or release its magnetism.

b. Ignition Advance System: Combustion inside the cylinders doesn’t happen immediately. Therefore, the ideal time for combustion (the power stroke) is right after T.D.C. That means the spark must occur just before it reaches T.D.C., because combustion takes, on average, 0.003 seconds to finish. To make sure the spark plug sparks at the right time, each engine has an ignition advance system built into the distributor in the form of either a centrifugal advance or a vacuum advance.

c. Condenser: When the contact point assembly sends an OFF signal, the electric system is charging the ignition coil. There is an electromagnetic induction of 250V. The condenser stores this electric charge so that when the contact point assembly sends an ON signal, it can help create a longer spark.

d. Rotor: The rotor is made of a good quality bakelite or plastic. It spins around inside the distributor and sends the high voltage spark to each cylinder.
C. Crank Shaft

i. Crank Shaft

The crank shaft can be called the spine of the engine. It must handle the pistons’ enormous momentum and the huge amount of force applied onto it by the connecting rods. It is commonly made of the following three materials:

1. High-carbon steel
2. Chromium molybdenum steel
3. Various alloy steels

Depending on how many cylinders the engine has, the crank shaft’s number of raised and lowered pads changes. In the typical four cylinder engine, there are two raised and two lowered pads. With the pads arranged this way, there will be two pistons raised up and two lowered. The spark sequence for this type of engine is 1→3→4→2.

When the crank shaft is turning, it pushes two pistons into the cylinder and pulls two out. Depending on the position of the pistons, each cylinder is also at a different engine stroke.

Because a crank shaft rotates so fast, it must be balanced, or else it will create gigantic shock waves throughout the engine. A balanced crank shaft is achieved by drilling holes in parts of the metal throughout the assembly. Some luxury car companies such as Porsche hand-make each crank shaft, as opposed to mass-manufacturing only one kind. This kind of intricate designing creates unsurpassed performance and fewer engine problems. However, since hand making crank shafts consumes a lot of man-power and time, most companies opt for mass-manufacturing.
ii. Piston

A piston has several characteristics:

1. Can withstand high temperature and high pressure
2. Has a high conductance of heat
3. Small inflation coefficient
4. Small mass

The piston also has two rings around the top. One is the compression ring, the other is the oil ring.

a. Compression Ring: The compression ring is a C shaped ring larger than the diameter of the cylinder. When forced into the cylinder, it pushes out against the sides and therefore helps completely seal all openings into the cylinder.

b. Oil Ring: This ring helps scrape extra engine oil off the walls of the cylinder\(^8\)
iii. Fly Wheel
The fly wheel stores the energy given to it by the rotation of the crank shaft. It transfers this energy to the wheels, and makes the car move. There are two more functions of the fly wheel:

1. Makes the rotation of the engine more stable
2. Starts the starter motor

The size of the fly wheel depends on the amount of cylinders in the engine. The more cylinders there are, the smaller the fly wheel can be. If the fly wheel is small, the resistance caused by inertia is reduced, making the engine’s acceleration and performance better.

D. Lubrication System
i. Oil Pan
The oil pan stores all the engine oil. Engine oil is important for the lubrication of the engine. There are different kinds of engine oil for different purposes; they are distinguished by an SAE number. Taiwan automobiles use SAE30 engine oil.
The engine oil moves throughout the entire engine with a push from the oil pump. After completing its journey through the oil filter, the oil pressure gauge, and the bearings, the engine oil returns to the oil pan.

III. Conclusion

Cars are an important part of everyone’s lives. I know it. You know it. Cars are also the number one leading cause of global warming around the world. I know it. But do you know it?

Cars have already evolved to the point where the only thing left to change is the source of energy used by the engine. Currently, most automobiles use 92~98 unleaded gasoline, while some others use diesel fuel. Either way, Earth is running out of fossil fuels to provide for our cars. Some automobile companies such as Toyota have already created hybrid cars that run on half electricity and half gasoline. That is our first step to a greener Earth. The next step should be taking hydrogen running cars out of the drawing room and into production. Using hydrogen as fuel is a great way to stop global warming: during fuel-cell conversion, hydrogen is reacted with oxygen to produce water and electricity, both of which are useful and less harmful than normal gasoline exhaust fumes.

Of course, once people see hydrogen as the next fuel source for their cars, all the gas stations would have to change to hydrogen stations, and everyone would have to buy a new car. Trillions of dollars would go into designing and production; debates and arguments would arise, but once the dust settles, what we save is bigger than anything we might lose: our Earth.

In my opinion, it should not take more than two decades for hydrogen vehicles to become the new standard. With global warming on the rise and polar ice threatening to melt, anyone can see that something has to be done about today’s gas guzzling cars.

IV. Bibliography


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