THEORETICAL OTTO CYCLE

INTRODUCTION

When discussing engines, we must consider both the MECHANICAL OPERATION of the machine and the THERMODYNAMIC PROCESSES that enable the machine to produce useful WORK. On this page we consider the thermodynamics of a 4-STROKE INTERNAL COMBUSTION engine.

To understand how a propulsion system works, we must study the basic thermodynamics of GASES. Gases have various PROPERTIES that we can observe with our senses, including the gas PRRESSURE (P), TEMPERATURE (T), mass, and VOLUME (V) that contains the gas. Careful scientific observation has determined that these VARIABLES are related to one another, and the values of these properties determine the STATE of the gas.

INTRODUCTION

A thermodynamic process, such as heating or COMPRESSING the gas, changes the values of the state variables in a manner which is described by the LAWS OF THERMODYNAMICS. The WORK done by a gas and the HEAT transferred to a gas depend on the beginning and ending states of the gas and on the process used to change the state. It is possible to perform a series of processes, in which the state is changed during each process, but the gas eventually returns to its original state. Such a series of processes is called a CYCLE and forms the basis for understanding engine operation.

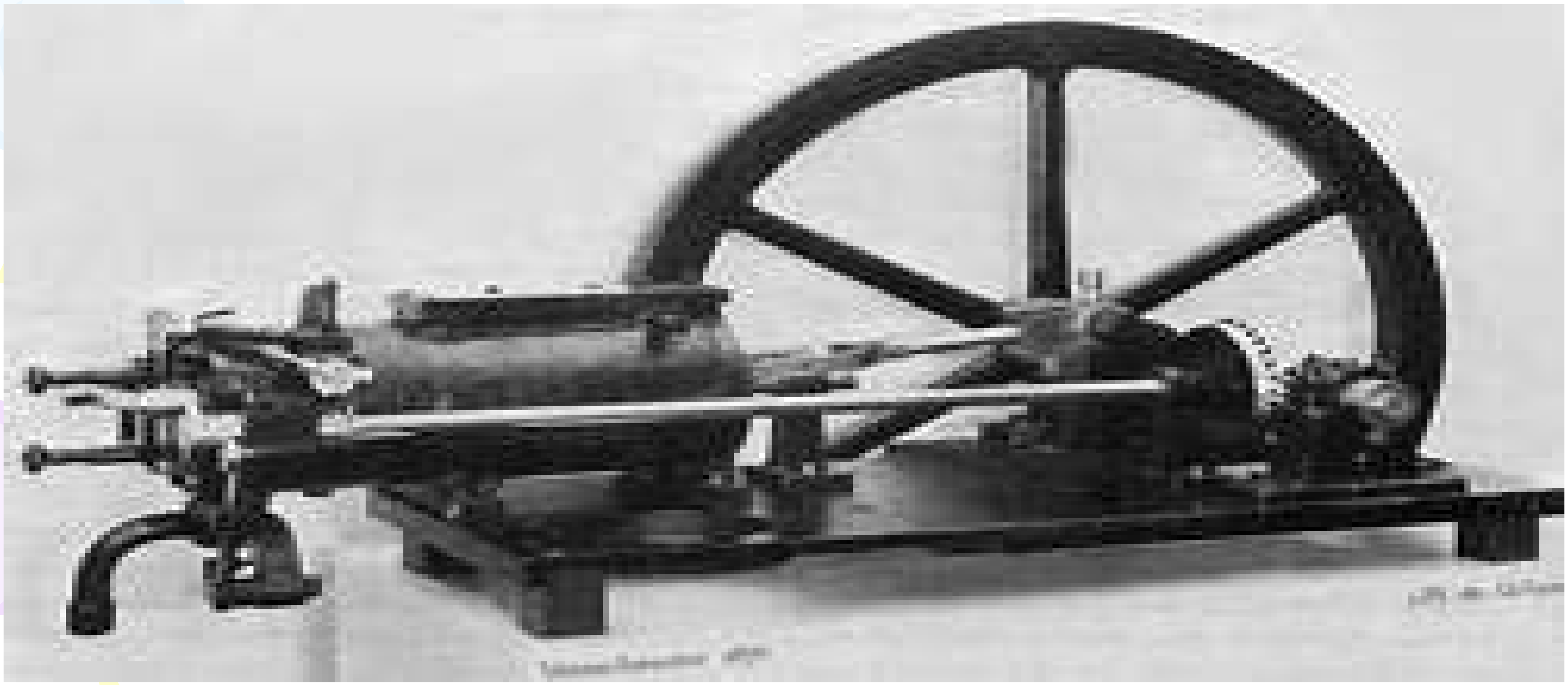
In 1862 a German engineer Nikolaus Augustus Otto began experimenting with different kinds of engines.

His first experiment was conducted on a 4-stroke engine. 10 years later he introduced to the world the Otto engine.

The 4-stroke engine consists of a 4-stroke cycle better known as the Otto cycle.

Nikolaus August Otto
(1832 - 1891)

The Otto engine is an internal combustion (IC) engine. The 4- stroke cycle of an IC engine is the cycle most commonly used for automotive and industrial purposes today. It is used for cars, trucks, generators and many more appliances, making this engine the most common engine type now-a-days.



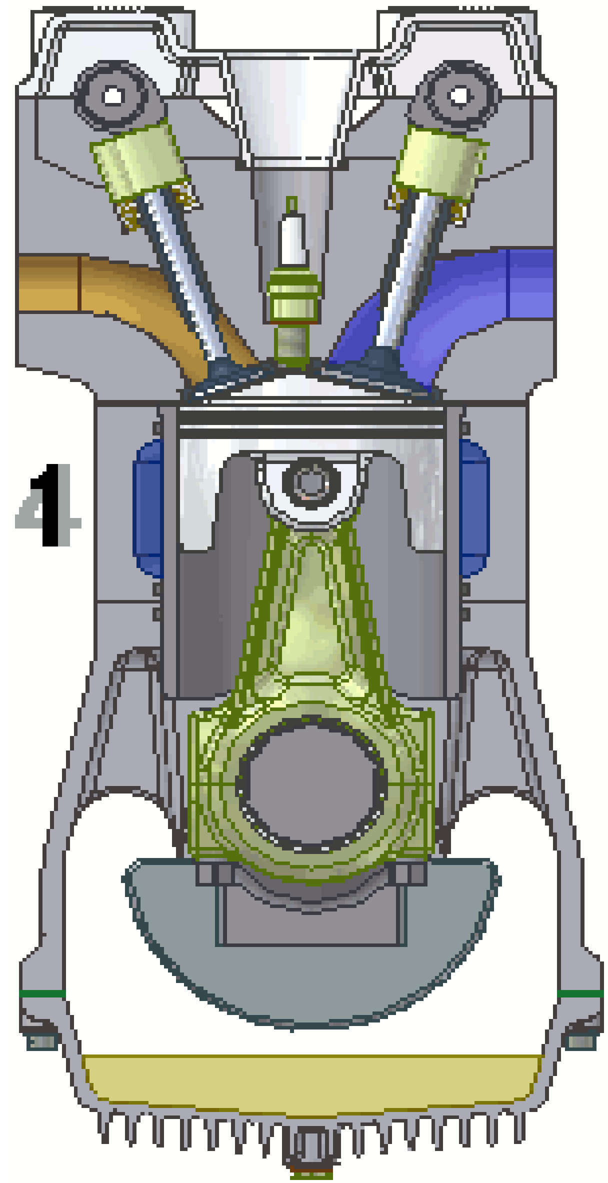
OTTO CYCLE

Each movement of the cylinder up or down the cylinder is one stroke of the four stroke combustion cycle or Otto cycle.

The four stroke cycle consists of

- induction stroke
- compression stroke
- ignition/power stroke
- exhaust stroke

A single cycle requires two revolutions of the crankshaft to complete.



OTTO CYCLE

The Otto cycle is very similar to that of the Diesel cycle in that both of these are closed cycles commonly used to model internal combustion engines.

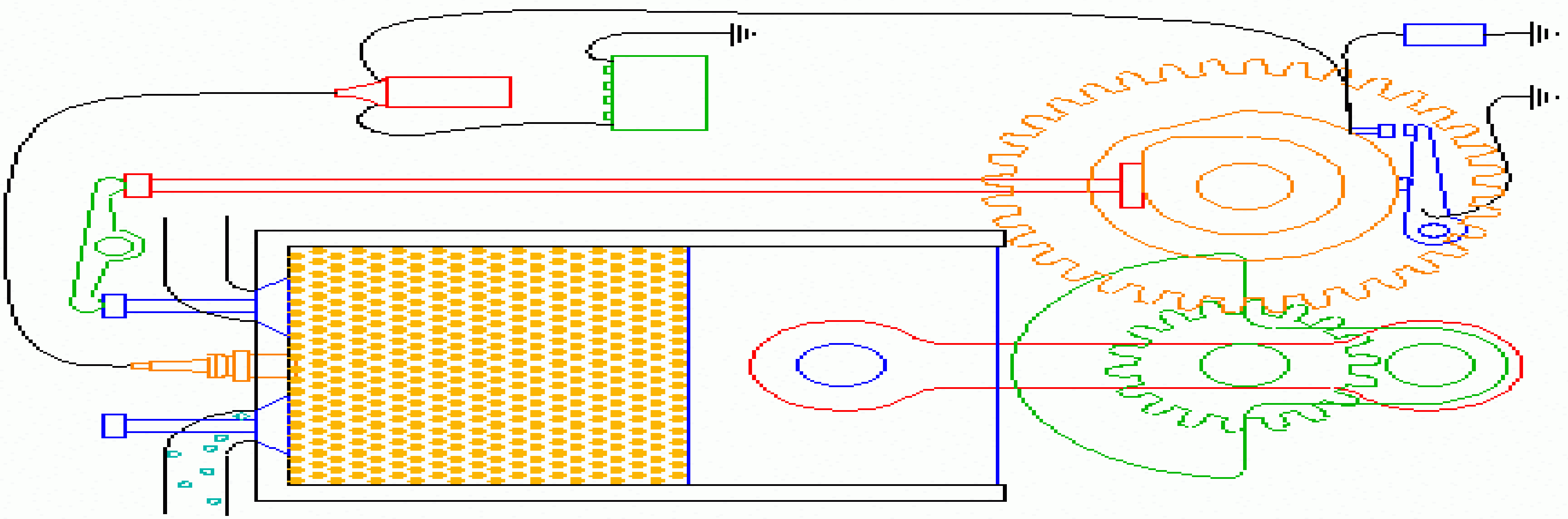
The difference between these two is that the Otto cycle is a spark-ignition cycle while the Diesel cycle consists of a compression-ignition cycle.

A spark-ignition cycle is designed to use fuels that require a spark to begin combustion.

When discussing engines, we must consider both the mechanical operation of the machine as well as the thermodynamic processes that enable the machine to produce useful work.

OTTO ENGINE

The Otto engine consists of many parts and each part is essential for the four-stroke cycle to occur. The main parts of a four-stroke cycle engine are the intake valve, the exhaust valve, the piston, the piston rings, the combustion chamber, the connection rod, the crankshaft, and the spark plug. These parts play an important role in the operation of this engine.



OPERATION OTTO CYCLE

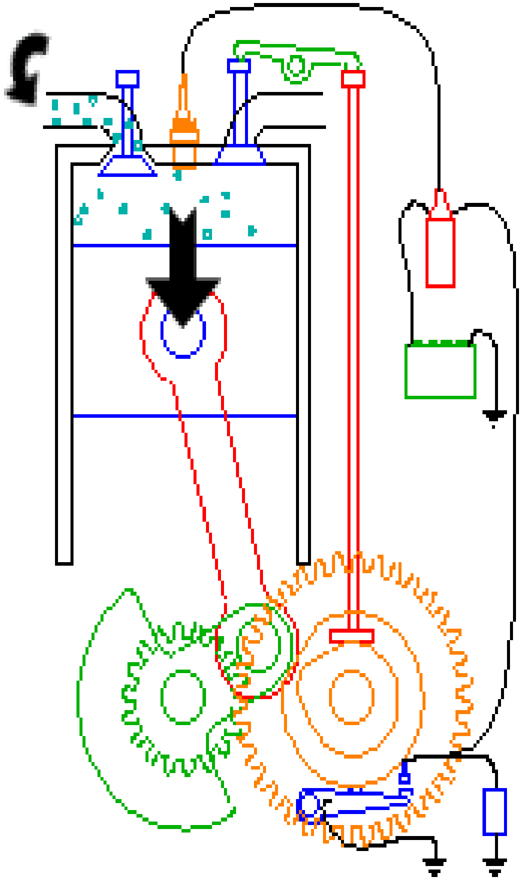
INTAKE STROKE:

intake valve starts opening

air-fuel mixture is sucked in the cylinder through the opened intake valve by the piston moving towards the crank shaft

exhaust valve remains closed

no ignition is given by the spark plug



OPERATION
OTTO CYCLE

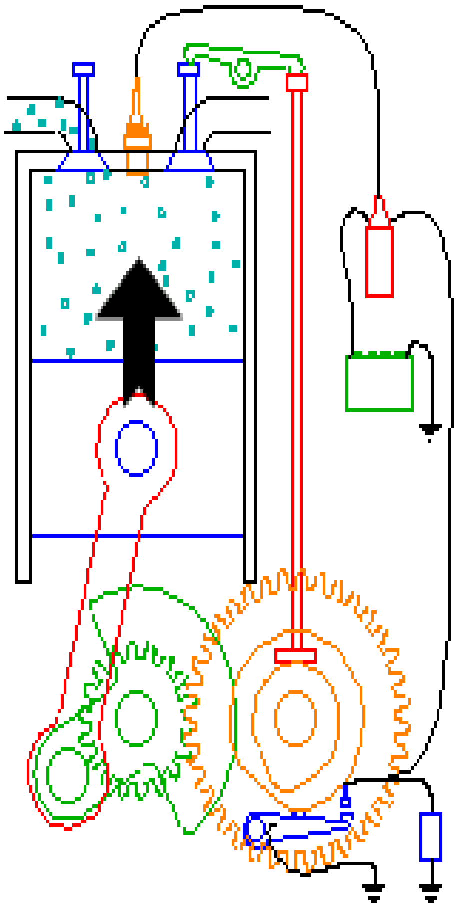
COMPRESSION STROKE:

intake valve closes

air-fuel mixture is compressed in the cylinder by the piston sliding away from the crank shaft

exhaust valve remains closed

no ignition is given by the spark plug till the piston reaches TDC.



OPERATION OTTO CYCLE

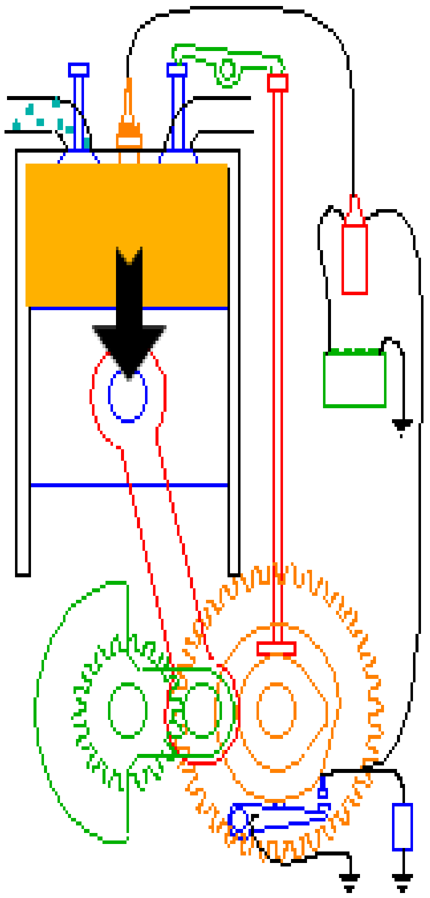
IGNITION/POWER STROKE:

\#   intake valve and exhaust valve remain closed

\#   ignition is given by the spark plug when the piston reaches TDC

\#   compressed air-fuel mixture ignited by the spark starts burning

\#   the gas expands in the cylinder pushing the piston towards the crankshaft generating rotary power at the crankshaft



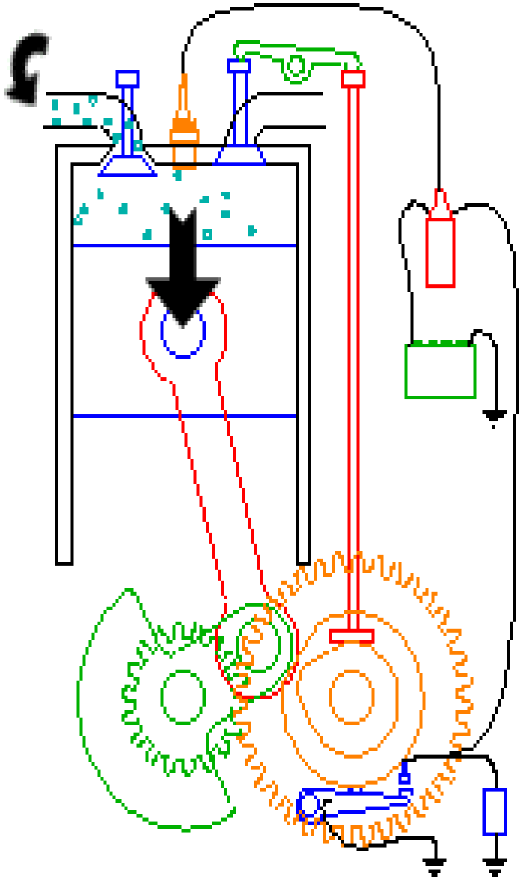
OPERATION OTTO CYCLE

EXHAUST STROKE:

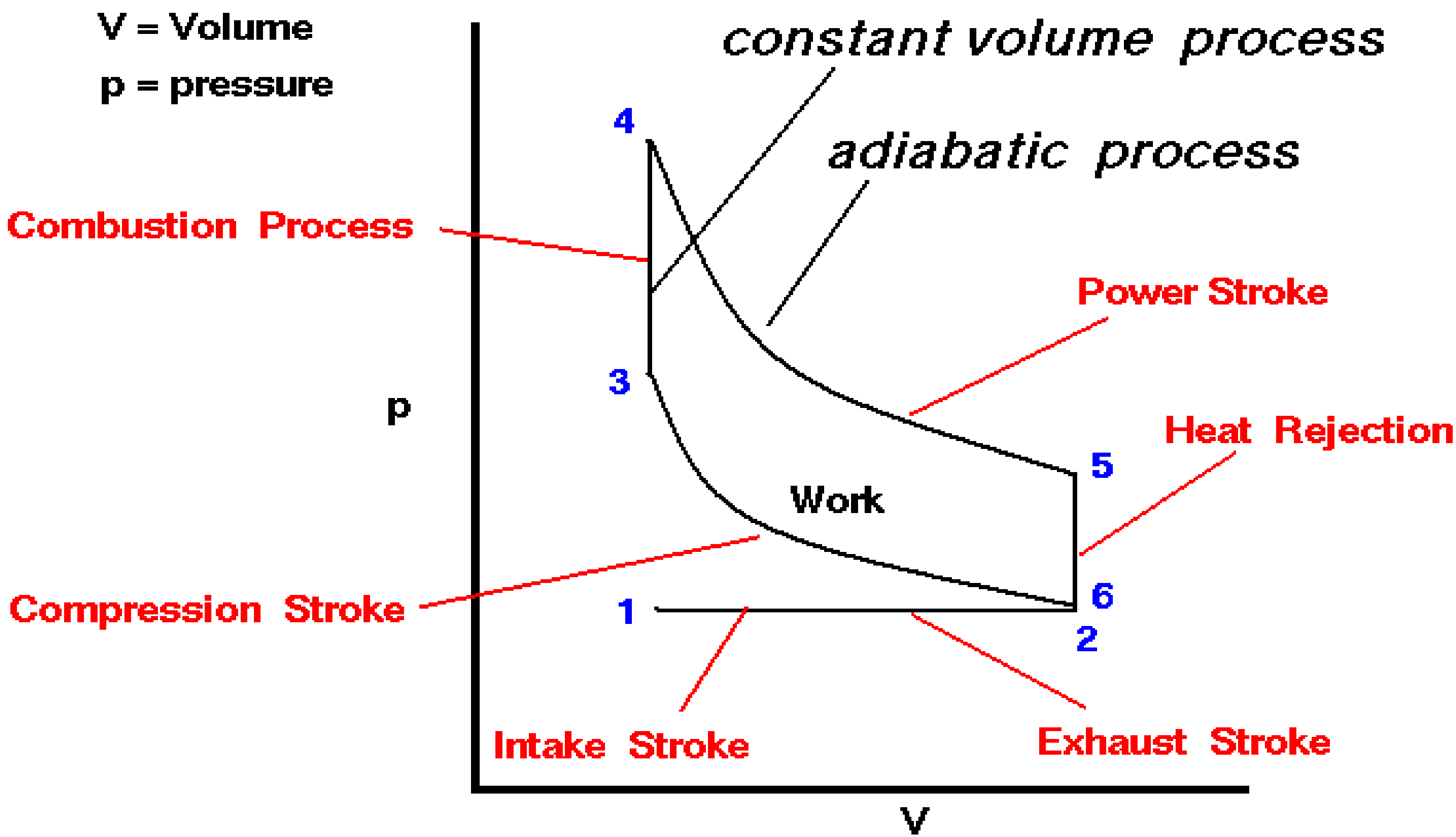
exhaust valve starts opening

burnt gas is pushed out of the cylinder through the opened exhaust valve by the piston moving away from the crankshaft

intake valve remains closed till the piston reaches TDC



THERMODYNAMIC PROCESSES
OTTO CYCLE (P-V DIAGRAM)



OPERATION
OTTO CYCLE

Stage 1 It is the beginning of the INTAKE STROKE of the engine. The pressure is near atmospheric pressure and the gas volume is at a minimum. Between Stage 1 and Stage 2 the piston is pulled out of the cylinder with the intake valve open. The pressure remains constant, and the gas volume increases as fuel/air mixture is drawn into the cylinder through the intake valve.

Stage 2 begins the COMPRESSION STROKE of the engine with the closing of the intake valve. Between Stage 2 and Stage 3, the piston moves back into the cylinder, the gas volume decreases, and the pressure increases because WORK IS DONE on the gas by the piston.

Stage 3 is the beginning of the COMBUSTION of the fuel/air mixture. The combustion occurs very quickly and the volume remains constant. HEAT is released during combustion which increases both the TEMPERATURE and the pressure, according to the EQUATION OF STATE.

OPERATION
OTTO CYCLE

Stage 4 Here begins the POWER STROKE of the engine. Between Stage 4 and Stage 5, the piston is driven towards the crankshaft, the volume in increased, and the pressure falls as WORK IS DONE by the gas on the piston.

Stage 5 Now the exhaust valve is opened and the residual heat in the gas is EXCHANGED with the surroundings. The volume remains constant and the pressure adjusts back to atmospheric conditions.

Stage 6 At this point begins the EXHAUST STROKE of the engine during which the piston moves back into the cylinder, the volume decreases and the pressure remains constant. At the end of the exhaust stroke, conditions have returned to Stage 1 and the process repeats itself.

OPERATION
OTTO CYCLE

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THERMODYNAMIC PROCESSES
OTTO CYCLE

- During the cycle, WORK is done on the gas by the piston between stages 2 and 3. Work is done by the gas on the piston between stages 4 and 5. The difference between the work done by the gas and the work done on the gas is the area enclosed by the cycle curve and is the work produced by the cycle. The work times the rate of the cycle (cycles per second) is equal to the POWER produced by the engine.

- The area enclosed by the cycle on a P-V DIAGRAM is proportional to the work produced by the cycle. On this page we have shown an ideal Otto cycle in which there is no heat entering (or leaving) the gas during the compression and power strokes, no friction losses, and instantaneous burning occurring at constant volume. In reality, the ideal cycle does not occur and there are many losses associated with each process. These losses are normally accounted for by efficiency factors which multiply and modify the ideal result. For a real cycle, the shape of the p-V diagram is similar to the ideal, but the area (work) is always less than the ideal value.

Any Questions

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