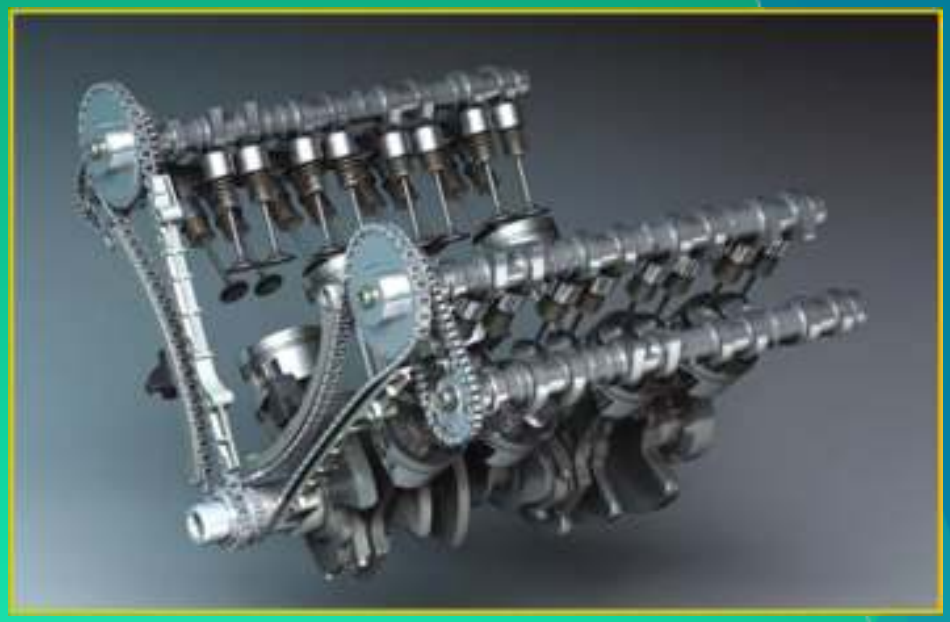


Internal Combustion Engine Theory

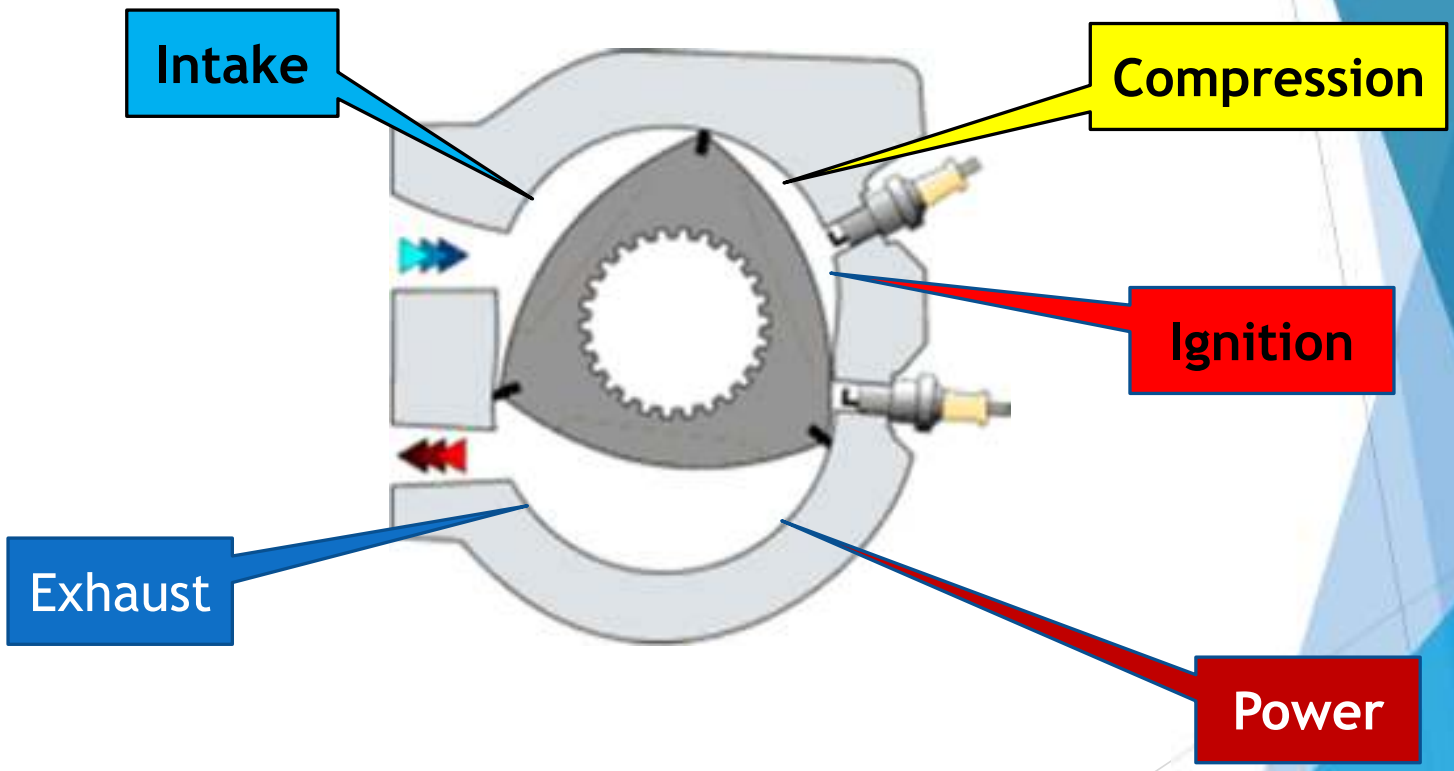
Part 2

Objectives

- Understand basic Rotary Engine theory
- Understand basic diesel engine theory

Wankel Engine

- Known as the “Rotary engine”
- Invented by Felix Wankel in 1929
- Uses a rotor instead of pistons to convert pressure into motion
- The rotor is similar in shape to a Reuleaux triangle but with sides that are flatter
- The rotor is located inside of an oval-like epitrochoid-shaped housing
- Its four stroke cycle occurs in one revolution of the rotor


Intake
Compression
Ignition
Exhaust
Power

Advantages

- Smooth operation
- Capable of high RPM because there is no reciprocating weight mass
- Few moving parts the a reciprocating engine gives the engine high reliability

Diesel Engine Theory

- German engineer Rudolf Diesel -1893
- Compression ignition engine
- Fuel is injected directly into the combustion chamber at the end of the compression stroke
- Fuel is ignited by the heat of the compressed air in the cylinder
- Compression ratios can be as high as 22:1
- In comparison gasoline compression ratios range from 8:1 to 12:1

Diesel Engine Fuel Supply

- A diesel engine uses a fuel system with an injection pump and individual fuel injectors.
- The pump delivers fuel to the injectors at a high pressure and at timed intervals.
- Each injector sprays fuel into the combustion chamber at the precise moment required for efficient combustion.

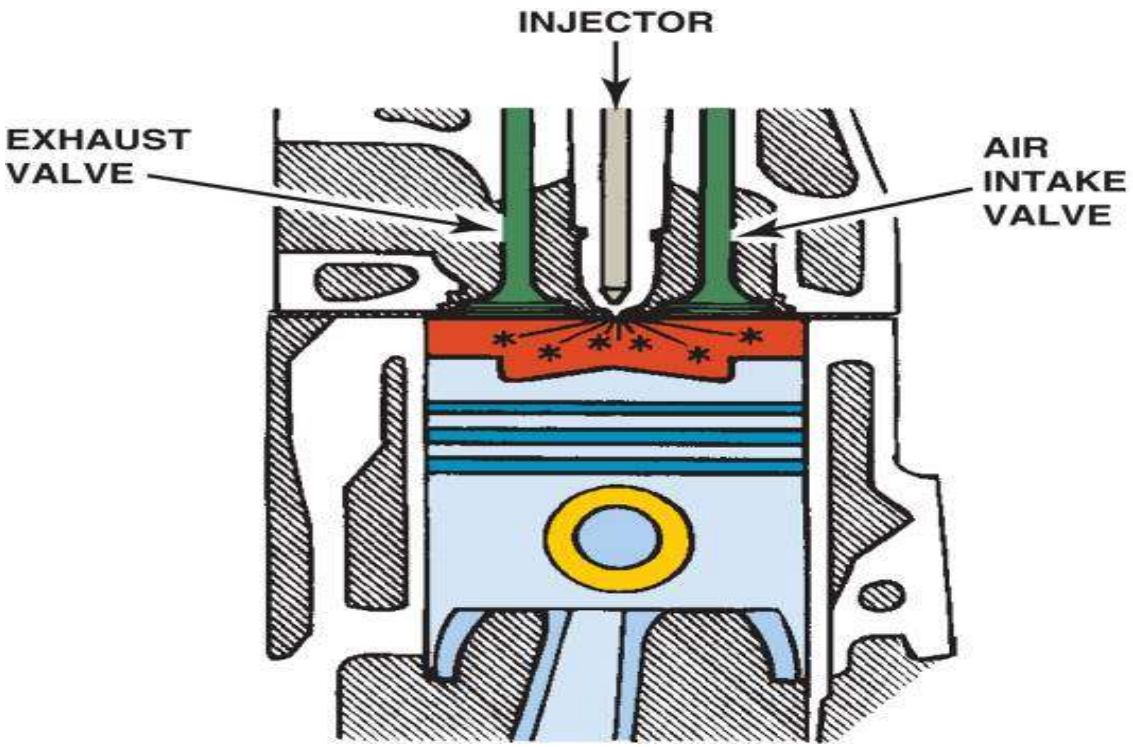


FIGURE 11-1 Diesel combustion occurs when fuel is injected into the hot, highly compressed air in the cylinder.

Diesel Strokes Compared to Gasoline

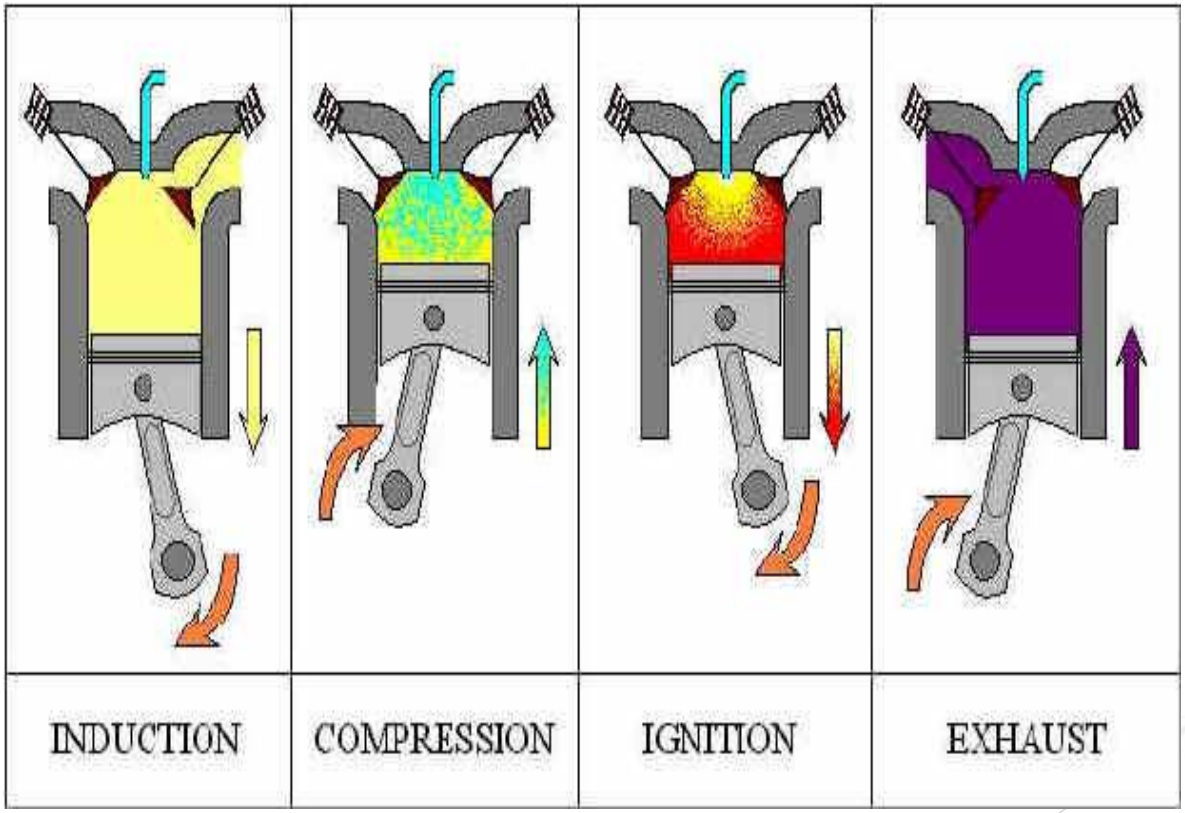
Diesel

- Intake : draws in air
- Compression: air is compressed to about 1/14th to 1/25th of its original size.
- Power: fuel is injected at a high pressure into the hot air in the cylinder, causing it to ignite
- Exhaust: upward stroke pushes the spent gases out of the cylinder

Gasoline

- Intake: draws in air and fuel
- Compression: mixture is compressed to about 1/8th to 1/12th of its original size
- Power: mixture is ignited using a spark plug
- Exhaust: upward stroke pushes the spent gases out of the cylinder

4 Stroke Diesel Cycle



Three Phases of Combustion

- ***Ignition Delay:***
  - Injection begins near the end of the compression stroke, but ignition does not begin immediately
- ***Rapid Combustion:***
  - Fuel starts to burn which causes a rapid rise cylinder pressure
  - Rapid rise in pressure causes the diesel engine knock
- ***Controlled Combustion:***
  - After the rapid combustion the fuel continues to burn as it is injected


5
6
Glowplug
indicator light
ABS

Glow Plugs

- Pencil-shaped piece of metal with a heating element at the tip
- When turned on it heats due to its electrical resistance and begins to emit light
- The heat generated warms the engine block immediately surrounding the cylinders

Glow Plugs

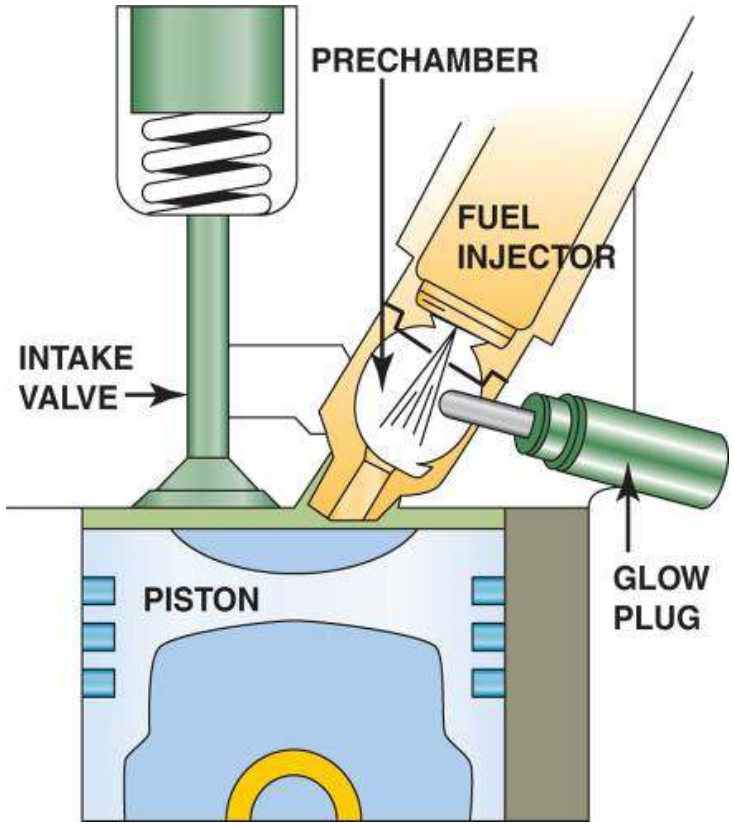
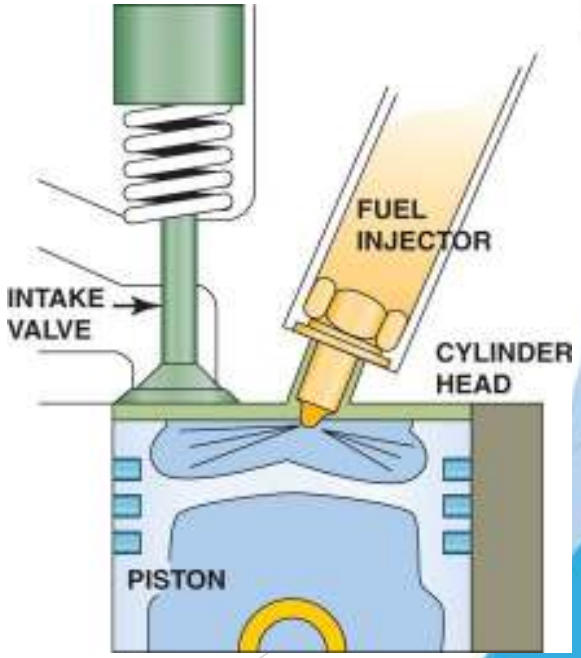


FIGURE 11-5 An indirect injection diesel engine uses a prechamber and a glow plug.

Gasoline Direct Injection

- A system for admitting fuel into an internal combustion engine



Differences Between Diesel and Gas Engines

- Glow plugs to pre heat the combustion chamber
- Higher compression ratios
- Higher fuel pressure (30,000 psi)
- Does not have a throttle plate
  - Speed is controlled by varying the amount of fuel supplied to the cylinder

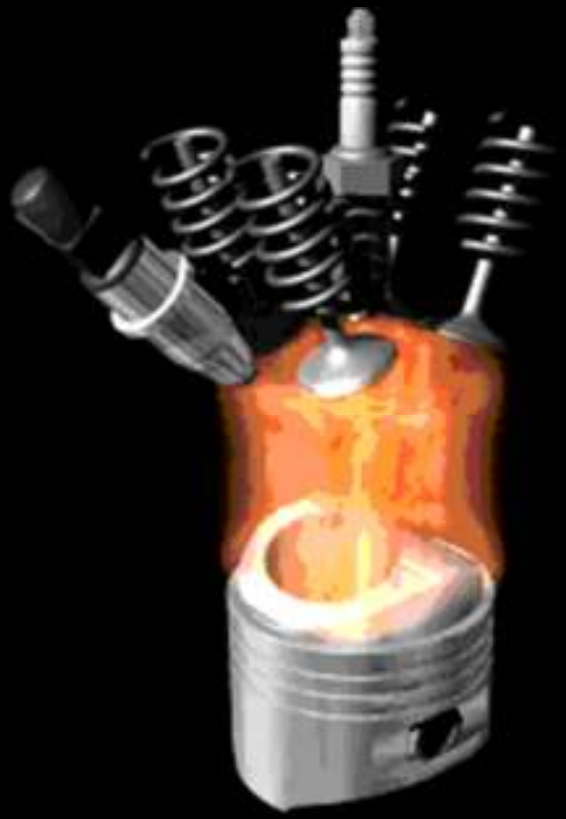
Advantages of Diesel vs. Gasoline

- Gasoline destroys lubrication; diesel does not.
- Electricity is not required – no spark is needed
- Better fuel efficiency due to higher compression ratio
- Highest thermal efficiency
- More durable

Disadvantages

- Particulate matter and NOx Emissions
- Engine noise
- Exhaust smell
- Require frequent maintenance as compared to gas engines
- Cold weather start-ability
- Requires vacuum pump for accessories

Gasoline Direct Injection



History of Gasoline Direct Injection (GDI)

- Invented by the French inventor of the V8 engine configuration, Leon Levavasseur in 1902.
- Used during the Second World War on almost all higher-output production aircraft powerplants made in Germany.
- In 1951, Bosch began designing GDI for German production cars.

GDI

- Places a fuel injector directly into the combustion chamber.
- Fuel system pressures are very high; 2900 psi.
- Compression ratios increased up to 12:1, vs. 10:1 for most non GDI engines.
- A/F ratios ranging from 14.7:1 to as lean as 65:1 are possible.

Advantages

- 8 - 22% increase in fuel economy:
  - More accurate fuel metering and injection timing
  - Can inject fuel anytime during the 4-stroke cycle of events
  - Leaner fuel mixtures
  - Reduced engine pumping losses
  - Better atomization of fuel and a more optimal spray pattern
- Increased torque and horsepower
  - Cylinder scavenging is greatly enhanced
  - Compression ratios can be higher
  - Reduced cylinder wall temperatures
  - Spark knock is reduced
- Adjustable fuel modes to target emission problems
  - Lower CO2 emission levels

Disadvantages

- Components are more expensive.
  - Fuel rail and lines are stainless steel
  - Many components are “one-time” use
  - Increased electrical power demands for injectors
- Technologies require technician training.
  - Special tools needed for service
  - Proper engine maintenance is critical
- Increased NO_x and PM emissions.
  - Lean burns increases NO_x
  - Fuel droplets on cylinder wall increase PM
- Carbon build-up on intake valves

How gasoline direct fuel injection works

- To inject fuel into the high-pressure of the compressed air in the cylinder, higher-pressure fuel injector must be used.
- Injectors must be able to reach injection pressure of 200 BAR or more.
- The system requires a two stage fuel delivery system:
  - Low pressure lift pump in the tank
  - High pressure engine driven injector pump at the injectors which provides the high pressure necessary.

GDI and Direct Start and Stop-Start Technology

- Current technology allows GDI engines to be started without starter motor.
- PCM identifies which piston is in the best position to rotate the engine, in terms of crank angle degrees and TDC.
- Fuel is then injected to the cylinder and ignited.
- There is no compression, but the combustion generates enough torque to rotate the engine.
- Once rotating, compression increases on the next cylinder.
- PCM transitions to the startup phase, as injections and ignitions increase engine RPM until idle speed is reached.
- GDI permits direct start and start/stop function, an innovative starting concept.
  - The time required for starting the engine is reduced by as much as 50%