INDEPENDENT UNIVERSITY, BANGLADESH

School of Engineering and Technology

Department of Electrical and Electronics Engineering

Course Code: Mechanical Engineering Fundamental
Course Title : EEE_223

Assignment: Overview of Otto Cycle and Diesel Cycle

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Date of Submission: December 7, 2023

EEE_223_Assignment

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Overview of Otto Cycle

Working principle:

The Otto cycle is a theoretical thermodynamic cycle that represents the functioning of a conventional spark-ignition internal combustion engine, which is found in the majority of gasoline-powered automobiles. The Otto cycle is divided into four major processes: intake, compression, power, and exhaust.

Intake: During the first stroke, the engine's intake valve opens, allowing a mixture of air and fuel to enter the cylinder. This process is isentropic, meaning it occurs at a constant entropy.
Compression: The intake valve closes, and the piston compresses the air-fuel mixture. This compression process is adiabatic, meaning it occurs without the exchange of heat with the surroundings. The temperature and pressure of the mixture increase during this stage.
Power: At the top of the compression stroke, a spark plug ignites the compressed air-fuel mixture. This ignition causes a rapid combustion, leading to a sharp increase in pressure and temperature. The high-pressure gasses force the piston down, converting the chemical energy of the fuel into mechanical work. This process is also adiabatic.
Exhaust: Finally, the exhaust valve opens, and the piston pushes the remaining exhaust gasses out of the cylinder during the exhaust stroke.
The Otto cycle is used as a theoretical reference to understand and analyze the performance of gasoline-powered internal combustion engines. In practice, real engines deviate from this idealized cycle due to various factors, but it serves as a valuable foundation for engine design and optimization.

Rational graph of pressure:

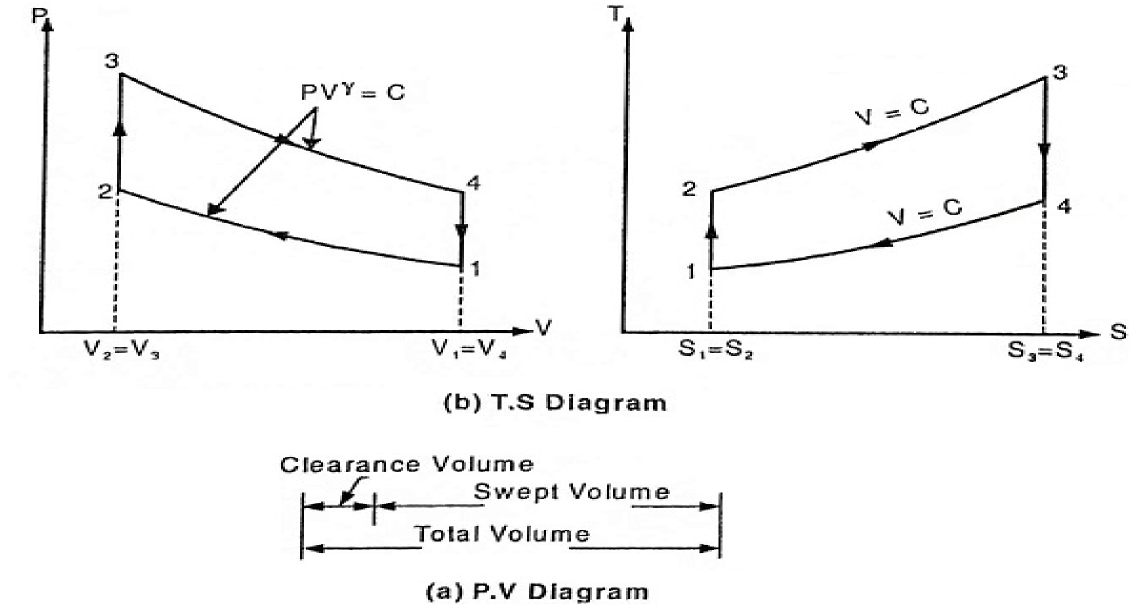
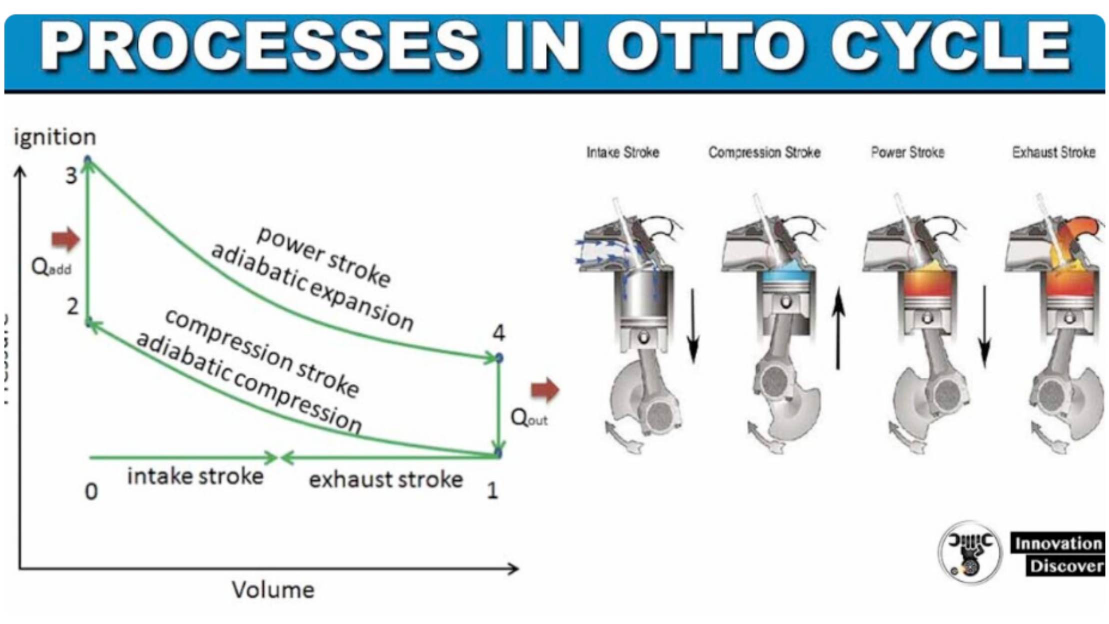


Fig 2.1 Otto Cycle

Fig. 2.1 shows the theoretical P-V diagram and T- s diagrams of this cycle.

The otto cycle consists of four processes 1 – 2 – 3 – 4

Refer the P-V diagram and T- S diagram



Temperature or volume:

During the compression and expansion phases of the Otto cycle, temperature and volume are related. Throughout the compression stroke, the temperature and pressure rise while the volume of the air-fuel mixture decreases. This is because during this phase, no heat is transferred into or out of the system due to adiabatic compression. The relationship between temperature (T) and volume (V) is described by the ideal gas law, which states that temperature rises as volume decreases (compression). During the expansion (power) stroke, the opposite occurs. High-temperature, high-pressure gasses inside the cylinder expand, resulting in a drop in temperature and an increase in volume. Additionally, this phase of expansion is adiabatic, meaning no heat is exchanged.

Heat transfer in otto cycle :

While the compression and expansion strokes in the ideal Otto cycle are adiabatic (no heat transfer), heat transfer effects occur in real-world engines. Heat enters the system (from the surrounding environment) during the intake stroke and exits the system (to the environment) during the exhaust stroke. These heat transfer mechanisms can have an impact on the engine's efficiency and performance. Additionally, heat losses from engine components such as the cylinder walls and piston may occur owing to conduction and radiation. It is critical to minimize these heat losses when constructing more efficient engines.

Real time applications :

The Otto cycle, although originally a theoretical concept, serves as the foundation for the operation of internal combustion engines in a wide range of real-time applications. Here are some real-time applications of the Otto cycle:

Automobile Engines: The most common application of the Otto cycle is in gasoline-powered automobile engines. These engines use the principles of the Otto cycle to convert chemical energy in gasoline into mechanical work to power the vehicle.

Motorcycles: Many motorcycles are also equipped with small gasoline engines that operate on the Otto cycle.

Small Engines: Various small engines, such as those used in lawnmowers, generators, and chainsaws, are based on the Otto cycle.

Power Generators: Some portable power generators, often used for backup electricity supply, operate on the Otto cycle, typically using gasoline or natural gas as a fuel source.

Boats: Inboard and outboard boat engines, as well as personal watercraft, often use Otto cycle engines to provide propulsion.

Recreational Vehicles (RVs): Many RVs are equipped with internal combustion engines based on the Otto cycle for both propulsion and onboard power generation.

Small Aircraft: Some light aircraft, like those used for personal and recreational purposes, use Otto cycle engines for propulsion.

Industrial Equipment: Certain industrial equipment, such as forklifts and material handling machinery, rely on Otto cycle engines to provide power and mobility.

Power Equipment: Some power equipment like pressure washers and air compressors use Otto cycle engines as a source of power.

Home Backup Generators: Residential backup generators, which are used to provide electricity during power outages, are often equipped with Otto cycle engines.

Thermodynamics law this cycles represent:

The first law of thermodynamics, usually known as the law of energy conservation, is represented by the Otto cycle. This law states that energy cannot be generated or destroyed, but it can change form. It reflects the conversion of chemical energy in the fuel into mechanical work and the transport of heat into and out of the system in the context of the Otto cycle.

Advantages of the otto cycle:

Otto cycle engines have a high power density relative to their size and weight, making them appropriate for a wide range of applications such as automobiles and small machinery.

Smooth Operation: Otto cycle gasoline engines run more smoothly than other engine types, which helps to drive comfort in automotive applications.

Quick Start-Up: These engines start rapidly and are ideal for applications requiring rapid power generation.
Lower Noise and Vibration: Compared to other engine types, Otto cycle engines typically produce less noise and vibration, making them more acceptable for a variety of applications, including passenger automobiles.
Suitable for light to medium loads: Otto cycle engines are effective in applications with variable loads, such as cars, where power demands can fluctuate rapidly.

Disadvantage :

Lower Thermal Efficiency: Otto cycle engines are frequently less thermally efficient than diesel engines, resulting in lower fuel efficiency and higher emissions for the same power output.

Fuel Flexibility: These engines are designed to run on gasoline, and while some can run on other fuels such as ethanol, their flexibility is restricted in comparison to other engine types.

Higher Emissions: Otto cycle engines can emit more CO_2 and other greenhouse gasses than more efficient engine designs, contributing to environmental issues.

Sensitivity to Combustion Timing: The timing of spark ignition in the Otto cycle is crucial, and improper combustion timing can result in decreased efficiency and increased emissions. Reduced Efficiency at Low Loads: Otto cycle engines can become inefficient at low power outputs, which can be problematic in applications with changeable loads.

In conclusion, the Otto cycle, which symbolizes the first rule of thermodynamics, has benefits such as high power density, smooth operation, and adaptability for quick start-up and lower noise. However, it has drawbacks such as decreased thermal efficiency, restricted fuel flexibility, higher emissions, sensitivity to combustion timing, and low-load efficiency. The type of engine chosen is determined by the application's specific requirements and priorities.

Overview of Diesel Cycle

Working principle :

In the Diesel cycle, compressed air is heated by burning fuel, and as the hot gas expands, the piston is forced upward in the cylinder. This is the part of the cycle where the crankshaft of the car rotates, contributing its beneficial work. Assuming everything is perfect, we assume that this step of a Diesel cycle is isentropic.

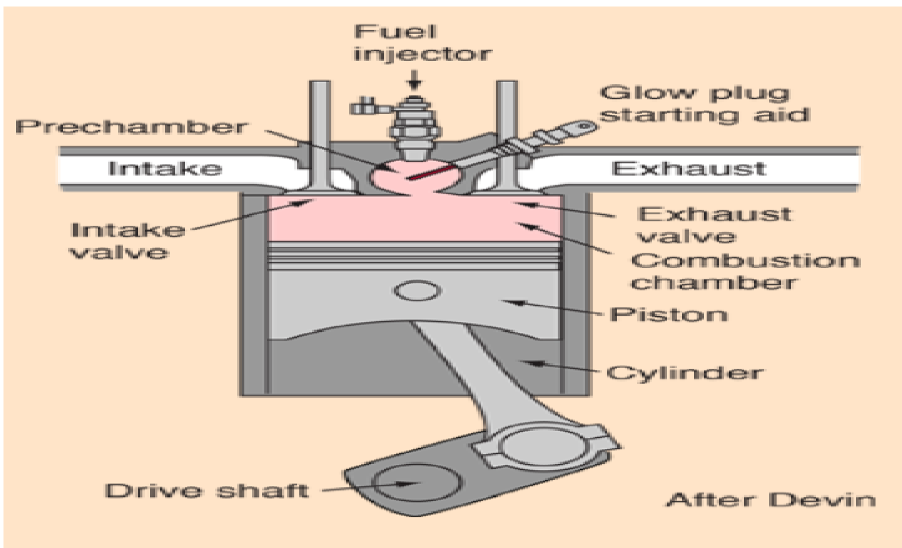
The Diesel cycle is divided into four major processes: intake, compression, power, and exhaust.

Intake: During the first stroke, the engine's intake valve opens, allowing a mixture of air and fuel to enter the cylinder. This process is isentropic, meaning it occurs at a constant entropy.

Compression: The intake valve closes, and the piston compresses the air-fuel mixture. This compression process is adiabatic, meaning it occurs without the exchange of heat with the surroundings. The temperature and pressure of the mixture increase during this stage.

Power: At the top of the compression stroke, a spark plug ignites the compressed air-fuel mixture. This ignition causes a rapid combustion, leading to a sharp increase in pressure and temperature. The high-pressure gasses force the piston down, converting the chemical energy of the fuel into mechanical work. This process is also adiabatic.

Exhaust: Finally, the exhaust valve opens, and the piston pushes the remaining exhaust gasses out of the cylinder during the exhaust stroke.

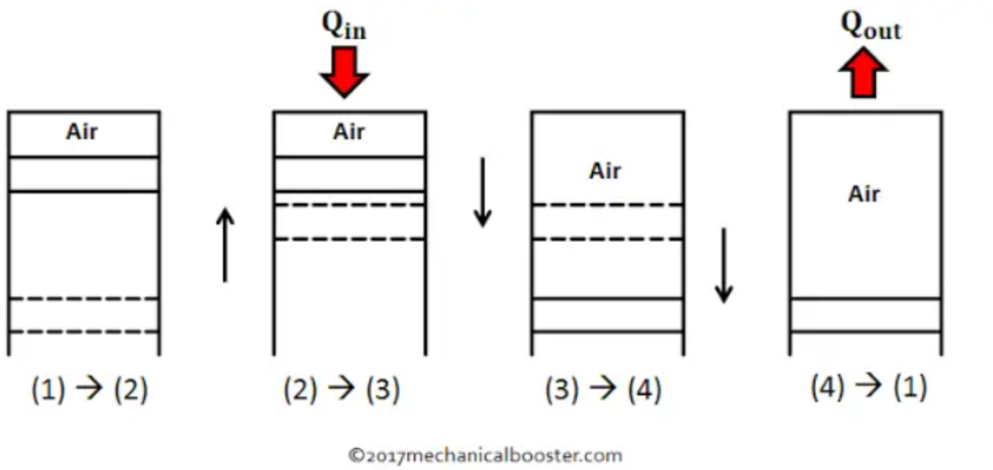


Working process:

These are the four working processes of diesel cycle engines that we have discussed. Now we will discuss how this cycle is implemented in the 4 stroke diesel engine. When this cycle is used in a 4 stroke diesel engine then we have 2 extra processes. One is the suction process and the other one is the exhaust process. For heat addition diesel is used as fuel which burns and adds heat.

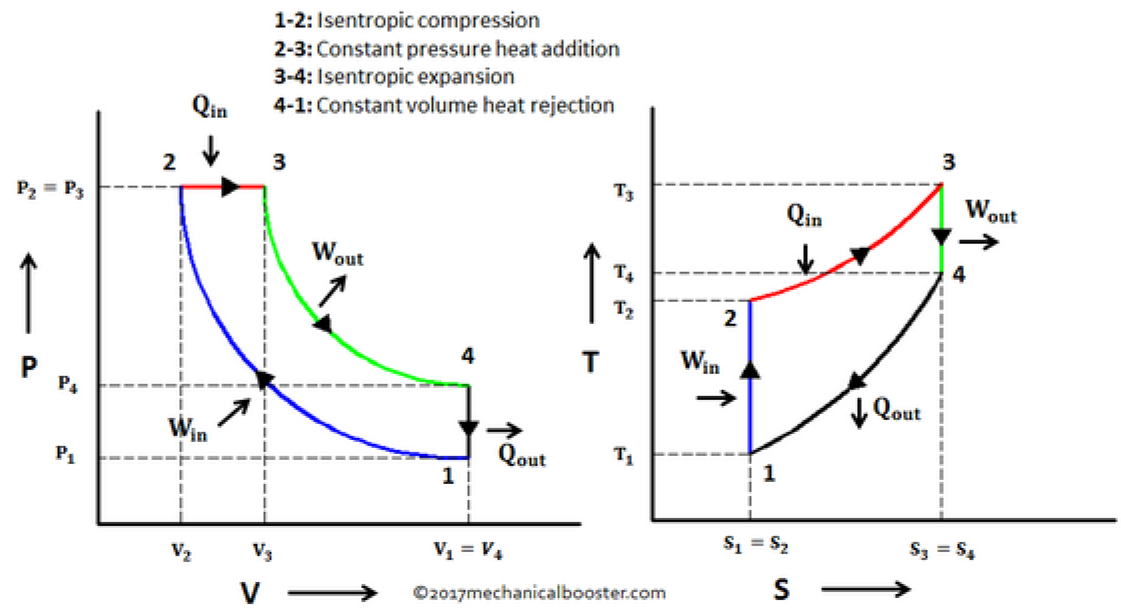
Let's discuss all the process in detail

- 0-1: Suction process (Suction stroke)
- 1-2: Isentropic compression process (compression stroke)
- 2-3: Constant volume heat addition (ignition and combustion of fuel)
- 3-4: Isentropic Expansion (power stroke)
- 4-1: Constant volume heat rejection (coolant comes in contact with cylinder walls)
- 1-0: Exhaust process (Exhaust stroke)

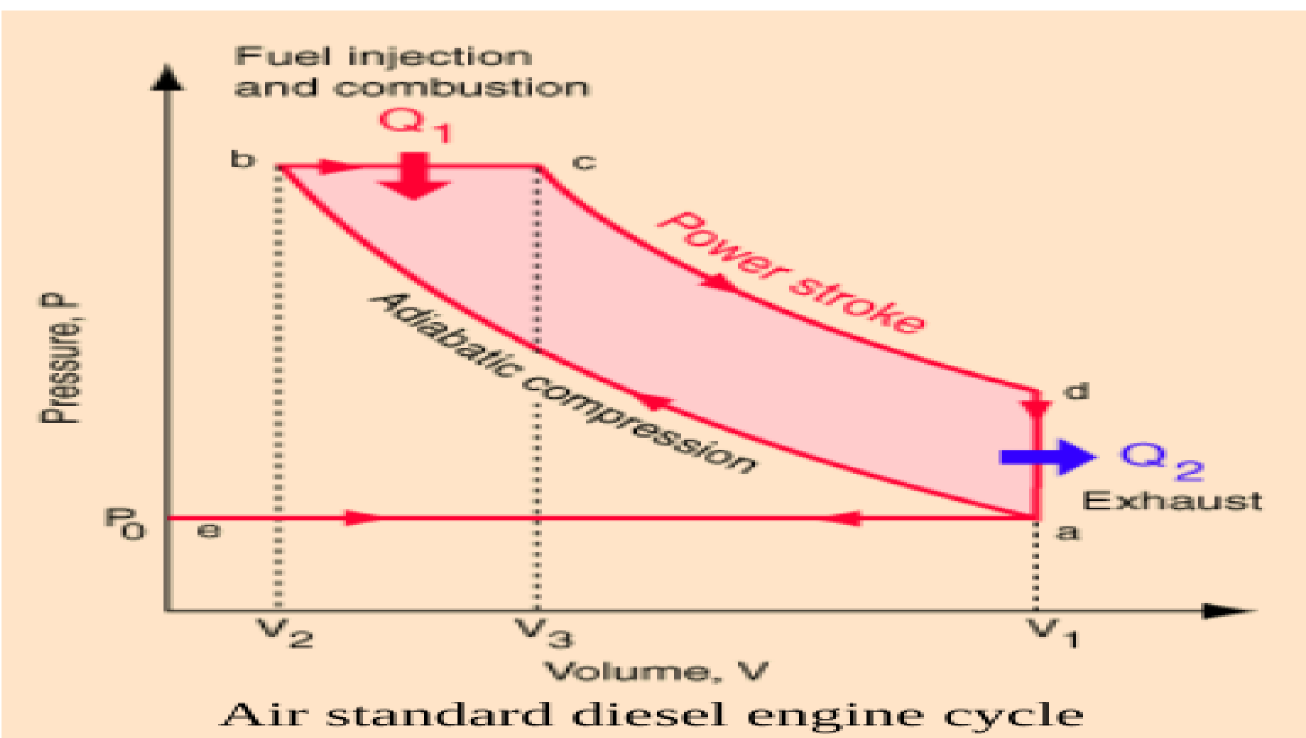


Piston Position in Diesel Cycle Process

Relational graph of pressure:



P-V and T-S Diagram of Diesel Cycle



Heat transfer :

Based on experiments conducted in an atmospheric test rig, where a diesel engine spray was impinging vertically and at an angle onto a heated plate with and without a cross-stream of air simulating swirl, and in a single-cylinder engine with a variable swirl mechanism, the heat transfer processes occurring in the combustion chambers of direct-injection diesel engines are reviewed. Based on the measured temperatures of the gas and the piston wall using two-color pyrometry and fast-response thermocouples, respectively, the convective heat transfer associated with the impinging spray on the piston-bowl wall and the radiative heat transfer associated with the high temperature soot particles formed during combustion were estimated for two swirl ratios.

Real time application :

Diesel engines based on the Diesel cycle are widely utilized in a wide range of industrial applications, particularly those that require great torque, efficiency, and dependability. Among the real-time applications are:

Transportation:

Heavy-duty vehicles such as trucks, buses, trains, and ships frequently employ diesel engines. Because of their great torque and fuel efficiency, they are ideal for hauling heavy goods over long distances.

Power Generation:

Diesel generators are used when a dependable backup power source is required. They can be found in industrial buildings, hospitals, data centers, and isolated areas that are not connected to the power grid.

Construction and Mining:

Heavy machinery and equipment used in construction, mining, and excavation are powered by diesel engines. These engines are popular due to their durability and ability to withstand harsh operating conditions.

Agriculture:
Due to its great torque and dependability, diesel-powered tractors and agricultural equipment are widely utilized in farming and agricultural operations.

Maritime:
Due to their efficiency and capacity to deliver the necessary power for propulsion and auxiliary systems, diesel engines are employed in a wide range of maritime applications, from tiny boats to big cargo ships.

Industrial Machinery:
Diesel engines are used in industrial equipment such as pumps, compressors, and generators when a reliable power supply is required.

Military and Defense:
Due to their durability and fuel efficiency, diesel engines are employed in military vehicles, tanks, and other defense-related applications.

Thermodynamics law this cycles represent:

The Diesel cycle is an example of the first law of thermodynamics, or the law of energy conservation. This law states that energy cannot be generated or destroyed, but it can change form. It reflects the conversion of chemical energy in the fuel into mechanical work and the movement of heat into and out of the system in the context of the Diesel cycle.

Advantage:

High Thermal Efficiency: Diesel engines have a high thermal efficiency, which means they can transfer a considerable part of the energy in diesel fuel into mechanical work. When compared to other engine types, this results in improved fuel economy.

High Torque: Diesel engines provide a lot of torque, which makes them ideal for applications that require big loads to be moved or vehicles to accelerate while under load, such as trucks, buses, and industrial machines.

Diesel fuel and engines:

Diesel fuel has a higher energy density than gasoline, meaning it contains more energy per unit of volume. This enables diesel engines to deliver greater driving ranges while using less fuel.

Diesel engines are noted for their tough construction and longevity. They are built to endure greater compression ratios and harsher operating circumstances.

Longevity: Diesel engines typically have a longer service life than other engine types, making them an excellent choice for applications requiring dependability and longevity.

Disadvantage:

Higher Emissions of Particulate Matter and NOx: Diesel engines tend to produce higher levels of particulate matter and nitrogen oxides (NOx), which are pollutants that can have adverse environmental and health effects. This has led to stricter emission regulations for diesel engines.

Noise and Vibration: Diesel engines can be noisier and produce more vibration compared to some other engine types. This can affect the comfort of passengers in vehicles and the working environment in industrial applications.

Slower Acceleration: Diesel engines tend to have slower acceleration compared to gasoline engines, which can be a disadvantage in applications where quick acceleration is necessary.

Diesel engines are designed to run on diesel fuel, thus their fuel alternatives are more limited than those of other engine types. This can be a disadvantage in areas where diesel fuel is scarce.

Cold Weather Issues: Because greater compression ratios demand more heat for ignition, diesel engines often struggle to start in extremely cold temperatures. In chilly climates, glow plugs or block heaters may be required.

In summary, the Diesel cycle is a thermodynamic cycle that is utilized in diesel engines and has various advantages such as high efficiency, high torque, and durability. However, they have drawbacks like pollution problems, noise and vibration, slower acceleration, restricted fuel alternatives, and difficulties in cold weather. The type of engine chosen is determined by the application's specific requirements and priorities. Advances in technology and emission control systems are constantly addressing some of the drawbacks of diesel engines.