Modelling of Internal Combustion (IC) Engine using MATLAB

Final Presentation

Nonit Gupta

Department of Chemical Engineering
Indian Institute of Technology Kanpur

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Outline

Otto Cycle

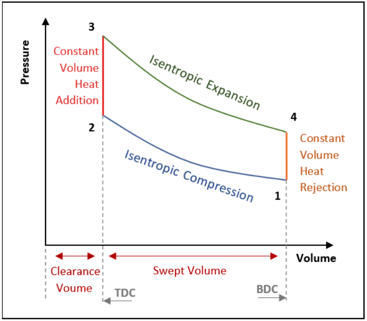
Definition: The Otto cycle is an idealized thermodynamic cycle that describes the functioning of a spark-ignition internal combustion engine.

Key Phases:

- **Intake & Compression:** Air-fuel mixture is drawn in and compressed.
- **Power (Combustion & Expansion):** Ignition causes combustion, expanding gases perform work.
- **Exhaust:** Burnt gases are expelled.

Real world application:

- Used in gasoline engines found in cars, motorcycles, and small generators.



Otto Cycle Diagram

Terms involved

- **TDC (Top Dead Center)**
  The highest position of the piston in the cylinder.
- **BDC (Bottom Dead Center)**
  The lowest position of the piston in the cylinder.
- **Swept Volume (V_{swept})**
  The volume displaced by the piston as it moves from TDC to BDC.

$$V_{swept} = \pi \frac{D^2}{4} \times L$$

  where D = Bore diameter, L = Stroke length.
- **Clearance Volume ($V_{clearance}$)**
  The smallest volume in the cylinder when the piston is at TDC. It determines the compression ratio of the engine.

Terms involved (contd.)

- **Compression Ratio (r)**
  Ratio of total cylinder volume to clearance volume:

$$r = \frac{V_{max}}{V_{min}} = \frac{V_{swept} + V_{clearance}}{V_{clearance}}$$

- **Thermal Efficiency (η)**
  Efficiency of the engine in converting heat into work:

$$\eta = 1 - \frac{1}{r^{\gamma-1}}$$

  Where γ is the ratio of heat capacities of air at constant pressure and volume, and r is the compression ratio.

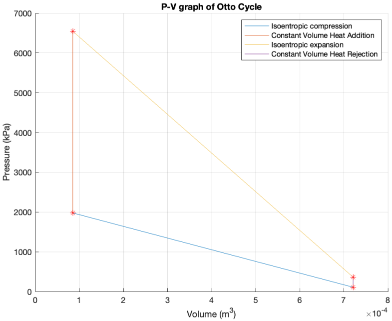
- **Crank Angle (θ)**
  The crank angle is the angular position of the crankshaft, measured in degrees relative to the top dead center (TDC) of the piston.

Initial Implementation

For the first simulation of the **P-V curve** of an **Otto cycle**, I had the following information and initial conditions available to me:

- Specific heat ratio (γ) $= 1.35$
- Initial Pressure (P_1) $= 110$ kPa
- Initial Temperature (T_1) $= 400K$
- Peak Temperature (T_3) $= 2800K$
- Compression ratio (r) $= 8.5$

The above conditions were sufficient to use thermodynamic formulas and get the pressure-volume conditions at the start of each subsequent process, and is shown by ($*$) in the graph.



First Implementation

Problem

- The four pressure-volume points are simple to obtain using the known thermodynamic processes equations' involved.
- However, an issue arises in how to join those points so as to best replicate the actual processes.
- Linearly joining those points does not give us the desired replication.
- Hence we will now use **piston kinematics** to better replicate those thermodynamic processes.

Piston Kinematics

- Piston Kinematics will help us to determine how the volume change from TDC to BDC and how combustion volume changes as a function of the crank angle.

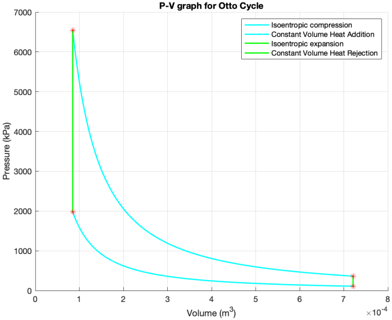
$$\frac{V}{V_c} = 1 + 0.5 \times (r - 1) \times (R + 1 + cos(\alpha) - \sqrt{R^2 - sin^2\alpha}$$

Where:
R = Length of connecting rod/Crankpin radius
Crankpin Radius = Stroke length/2
α = Crank angle

Second Implementation

Now using the previously obtained pressure-volume points for the given initial conditions and information, for each process end points, and using piston kinematics to determine a better relationship for volume determination.

The resulting P-V curve obtained is shown on the side, and it models the actual processes occurring in an IC Engine.



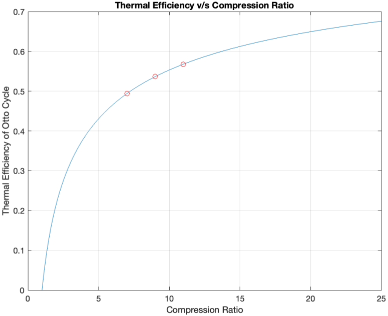
Implementation with piston kinematics

Thermal Efficiency

As defined earlier, the thermal efficiency of an Otto Cycle is the efficiency of the engine in converting heat into work and is given by:

$$\eta = 1 - \frac{1}{r^{\gamma - 1}}$$

The graph on the side helps us visualize how the thermal efficiency changes with compression ratio. This graph hold special importance is choosing our compression ratio to find out the optimal value which balances efficiency with cost and physical constraints.



Thermal Efficiency vs Compression Ratio

Conclusion

- I successfully modelled the P-V curve of an Otto cycle which is critical for spark engines in automobile industries.
- Key findings include that the thermal efficiency of the Otto cycle depends on the compression ratio (r), increasing as r rises, and that piston kinematics help us model the real process more efficiently.
- This project was extremely informative and helped me learn the real world applications of classroom topics.

Thank you!

Questions?