Simulation of an Ideal Internal Combustion Engine Using MATLAB

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Outline

What is an Internal Combustion Engine?

- An Internal Combustion (IC) Engine converts chemical energy in fuel into mechanical energy through combustion within a cylinder.
- It powers various applications, including automobiles, aircraft, and industrial machines.
- Two main types: Spark Ignition (SI) Engines and Compression Ignition (CI) Engines.

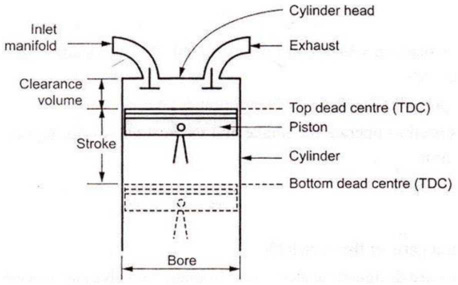
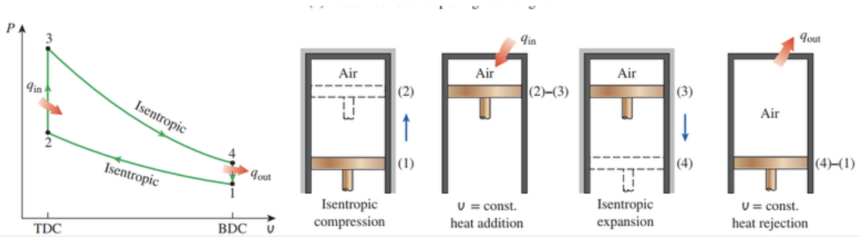


Figure: Ideal Otto Cycle parameters

Stages of an Otto Cycle

- **Intake Stroke:** Air-fuel mixture is drawn into the cylinder.
- **Compression Stroke:** Mixture is compressed, increasing temperature and pressure.
- **Power Stroke:** Combustion pushes the piston downward, generating work.
- **Exhaust Stroke:** Burnt gases are expelled from the cylinder.



Ideal cycle in spark ignition engine (Otto cycle) and it's P-v diagram.

Initial Conditions for Simulation

- **User Input Parameters:**
  - Initial Temperature, Initial Pressure, and Maximum Temperature.
  - Engine geometry: Stroke, Bore, Compression Ratio.
- **Derived Parameters:**
  - Swept Volume, Clearance Volume, and Mass of Air.
  - Specific heat capacities and specific heat ratio as functions of temperature.

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Provide the following initial conditions to simulate an ideal otto cycle:
Enter Initial Temperature (in K): 300
Enter Initial Pressure (in Pa): 100000
Enter Maximum Temperature (in K):1500
Enter connecting rod length (in m):0.14
Enter stroke (in m): 0.1
Enter bore (in m): 0.09
Enter compression ratio: 8.5
```

Figure: Parameters taken as input from the user

PV Diagram of an Ideal Otto Cycle

- **Process 1-2 (Compression):** Isentropic compression with increasing pressure and decreasing volume.
- **Process 2-3 (Heat Addition):** Pressure rises sharply at constant volume.
- **Process 3-4 (Expansion):** Isentropic expansion with decreasing pressure and increasing volume.
- **Process 4-1 (Heat Rejection):** Pressure drops sharply at constant volume.

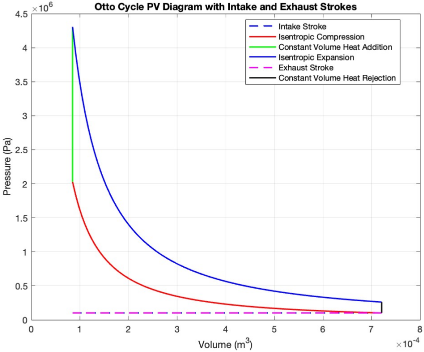

Figure: PV diagram illustrating the processes of an ideal Otto cycle.

Log(PV) Curve

- **Linear Representation:** The log(PV) plot highlights isentropic processes as linear.
- **Constant Volume Processes:** Heat addition and rejection appear as vertical transitions.

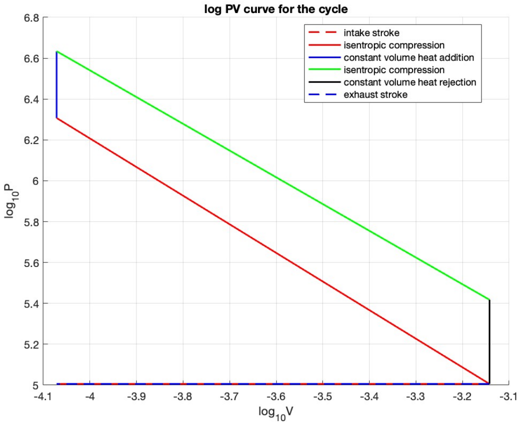

Figure: Log(PV) curve showing linear transitions of processes.

Compression Ratio vs Efficiency

- **Trend:** Efficiency increases with higher compression ratios.
- **Diminishing Returns:** Gains reduce at high compression ratios due to practical constraints.
- **Real-world Limits:** Knocking and material limitations restrict maximum compression ratios.

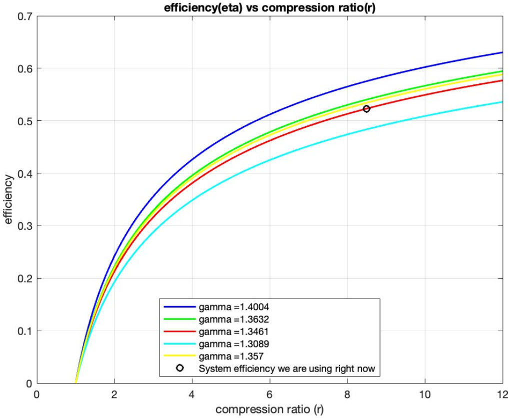

Figure: log(PV) curve showing linear process transitions.

Pressure vs Crank Angle

- **Pressure Rise:** Compression stroke shows a steep pressure increase.
- **Expansion:** Pressure decreases sharply during the power stroke.
- **Heat Transfer Effects:** Heat addition and rejection cause rapid pressure changes.

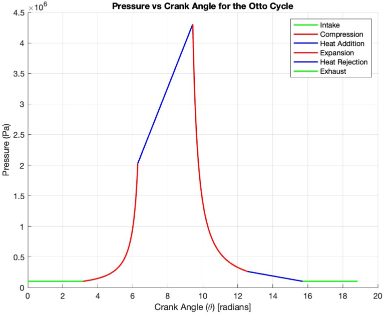

Figure: Pressure variation with crank angle.

Modifications to the Model

- Implemented variable specific heats for realistic gas behavior.
- Simulated piston-cylinder dynamics using crank angle calculations.
- Added dual input conditions for comparative performance analysis.

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Results for the simulation
Theoretical Efficiency of the system: 0.523198
State variables [P1, V1, T1]: [100.000000 kPa, 0.000721 m^3, 300.000000 K]
State variables [P2, V2, T2]: [2002.354735 kPa, 0.000085 m^3, 706.713436 K]
State variables [P3, V3, T3]: [4250.000000 kPa, 0.000085 m^3, 1500.000000 K]
State variables [P4, V4, T4]: [258.155867 kPa, 0.000721 m^3, 774.467602 K]
Heat (input) of cycle: 16.507290 kJ
Heat (output) of cycle: 8.645915 kJ
Work done of the cycle: 7.861375 kJ
Mean Effective Pressure (MEP): 12357.300459 kPa
```

Figure: Results obtained from the simulation

Comparison: Adiabatic vs Non-Adiabatic Processes

- **Compression:** Adiabatic processes show steeper pressure-volume curves.
- **Expansion:** Non-adiabatic processes exhibit smoother curves due to heat losses.
- **Efficiency:** Adiabatic assumptions predict higher efficiencies compared to real-world constraints.

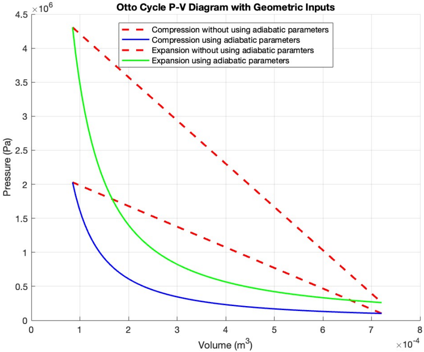

Figure: Adiabatic vs non-adiabatic PV curves.

Conclusion

- **Key Takeaways:**
  - Summarized the behavior of an ideal Otto cycle and its thermodynamic principles.
  - Highlighted performance characteristics of internal combustion engines.
- **Proposed Enhancements:**
  - Further refinements will include real gas behavior, heat losses, and frictional effects.
  - Optimizing the model for more practical simulations will improve accuracy.

Thank you!

Questions?