Internal Combustion Engine 1

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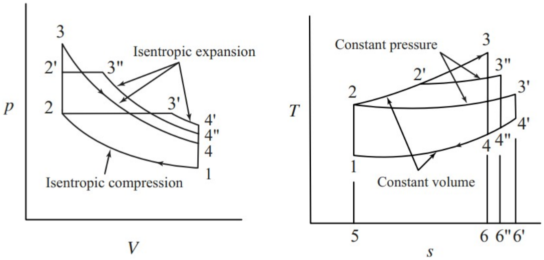
Comparison of cycles

Summary and Comparison with Otto and Diesel Cycles

- The Dual cycle combines features of both the Otto and Diesel cycles, with heat addition at both constant volume and constant pressure.
- The efficiency of the Dual cycle lies between that of the Otto and Diesel cycles for a given compression ratio.
- For $r_c = 1$, the cycle reduces to an Otto cycle, and for $r_p = 1$, it becomes a Diesel cycle.
- The work output and mean effective pressure are critical parameters for understanding engine performance in this mixed cycle.

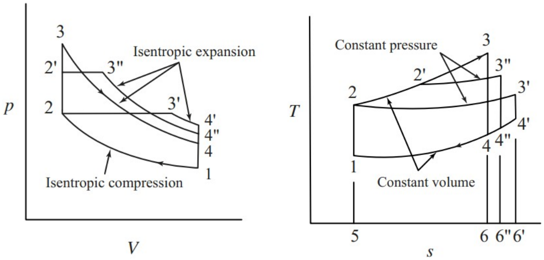
Same Compression Ratio and Heat Addition

- The Otto cycle $1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 1$.
- The Diesel cycle $1 \rightarrow 2 \rightarrow 3' \rightarrow 4' \rightarrow 1$.
- The Dual cycle $1 \rightarrow 2 \rightarrow 2'' \rightarrow 3'' \rightarrow 4'' \rightarrow 1$.
- Cycles are shown in $p - V$ and $T - s$ diagrams.



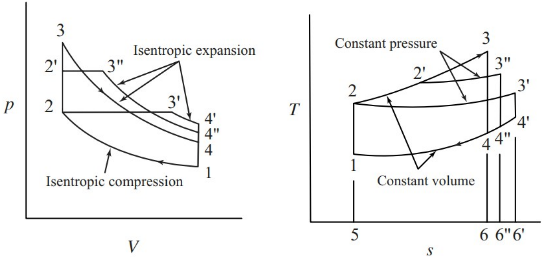
Same Compression Ratio and Heat Addition

- From the $T - s$ diagram:
  - Area 5236 = Area $523'6'$ = Area $522'3''6''$, representing the same heat input for all cycles.
- All cycles have the same compression ratio and heat input.
- All cycles start from the same initial state (point 1), and air is compressed from state 1 to 2.



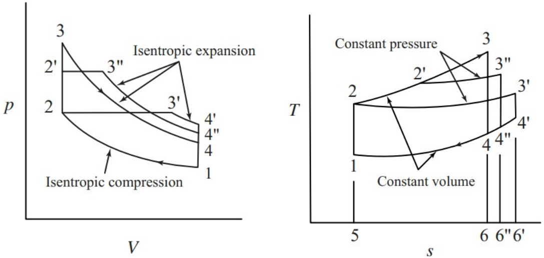
Same Compression Ratio and Heat Addition

- For the same heat input:
  - Heat rejection in the Otto cycle (area 5146) is minimum.
  - Heat rejection in the Diesel cycle (area 514'6') is maximum.



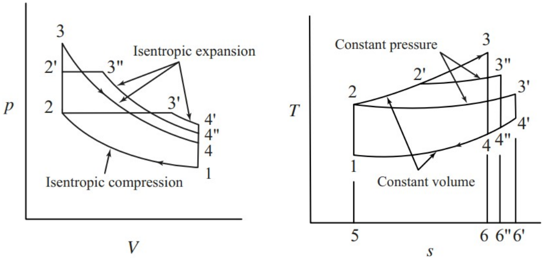
Same Compression Ratio and Heat Addition

- Therefore:
  - The Otto cycle has the highest work output and efficiency.
  - The Diesel cycle has the least efficiency.
  - The Dual cycle has efficiency between the Otto and Diesel cycles.
- For the same compression ratio and heat addition, $\eta_{\text{Otto}} > \eta_{\text{Dual}} > \eta_{\text{Diesel}}$.



Same Compression Ratio and Heat Addition

- An important observation:
  - The Otto cycle allows the working medium to expand more compared to the Diesel cycle.
  - In the Otto cycle, heat is added before expansion, allowing a longer expansion phase.
  - In the Diesel cycle, the last portion of heat supplied has a relatively short expansion.

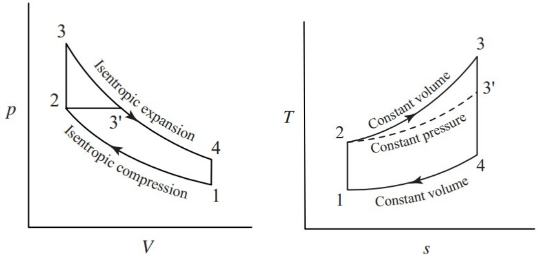


Same Compression Ratio and Heat Rejection

- The $p - V$ and $T - s$ diagrams.
- Efficiency of the Otto cycle:

$$\eta_{\text{Otto}} = 1 - \frac{Q_R}{Q_S}$$

where Q_S is the heat supplied in the Otto cycle, equal to the area under the curve $2 \rightarrow 3$ on the $T - s$ diagram.

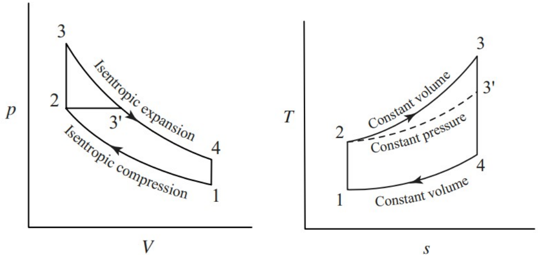


Same Compression Ratio and Heat Rejection

- Efficiency of the Diesel cycle:

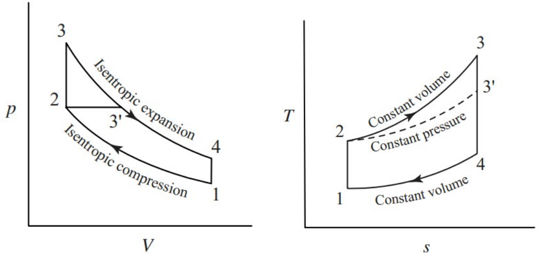
$$\eta_{\text{Diesel}} = 1 - \frac{Q_R}{Q'_S}$$

where Q'_S is the heat supplied in the Diesel cycle, equal to the area under the curve $2 \rightarrow 3'$ on the $T - s$ diagram.



Same Compression Ratio and Heat Rejection

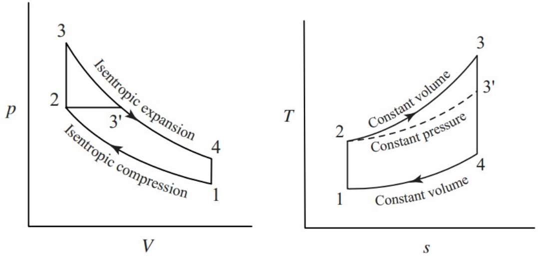
- From the $T - s$ diagram, it is clear that $Q_S > Q'_S$.
- This means the heat supplied in the Otto cycle is more than that in the Diesel cycle.
- Hence, the efficiency of the Otto cycle is greater than the efficiency of the Diesel cycle for a given compression ratio and heat rejection.



Same Compression Ratio and Heat Rejection

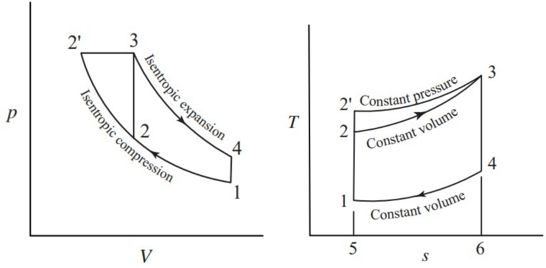
- For the same compression ratio and heat rejection:

$$\eta_{\text{Otto}} > \eta_{\text{Dual}} > \eta_{\text{Diesel}}$$



Same Peak Pressure, Peak Temperature, and Heat Rejection

- The Otto cycle $1 \rightarrow 2 \rightarrow 3 \rightarrow 4$ and Diesel cycle $1 \rightarrow 2' \rightarrow 3 \rightarrow 4$ are shown on $p - V$ and $T - s$ diagrams.
- The cycles have the same peak pressure, peak temperature, and heat rejection.

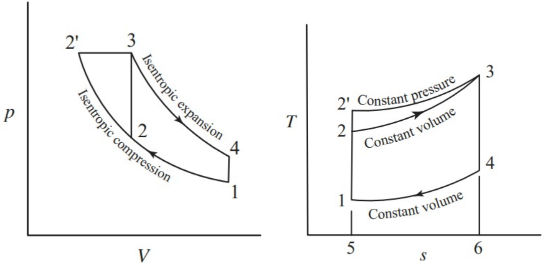


Same Peak Pressure, Peak Temperature, and Heat Rejection

- Efficiency of the Otto cycle:

$$\eta_{\text{Otto}} = 1 - \frac{Q_R}{Q_S}$$

where Q_S is the area under the curve $2 \rightarrow 3$.

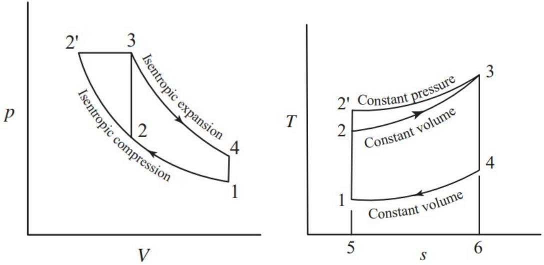


Same Peak Pressure, Peak Temperature, and Heat Rejection

- Efficiency of the Diesel cycle:

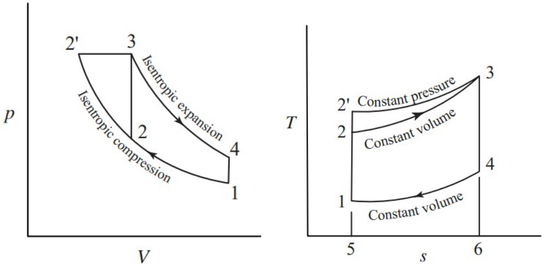
$$\eta_{\text{Diesel}} = 1 - \frac{Q_R}{Q'_S}$$

where Q'_S is the area under the curve $2' \to 3$.



Same Peak Pressure, Peak Temperature, and Heat Rejection

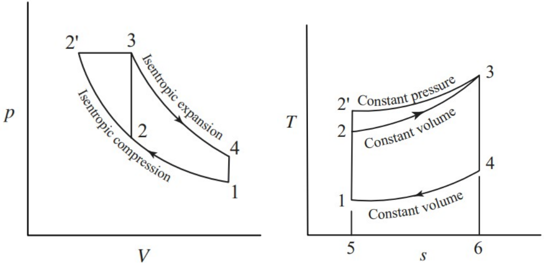
- From the figures, it is clear that $Q'_S > Q_S$.
- This implies the Diesel cycle efficiency is greater than the Otto cycle efficiency when both engines are designed to handle the same thermal and mechanical stresses.



Same Peak Pressure, Peak Temperature, and Heat Rejection

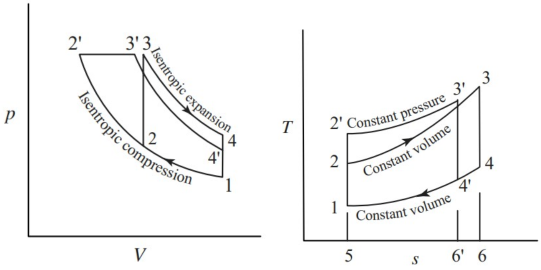
- For the same peak pressure, peak temperature, and heat rejection:

$$\eta_{\text{Otto}} > \eta_{\text{Dual}} > \eta_{\text{Diesel}}$$



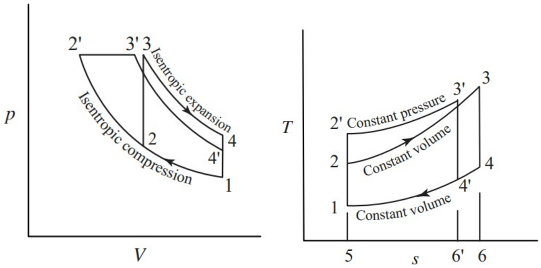
Same Maximum Pressure and Heat Input

- The Otto cycle ($1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 1$) and Diesel cycle ($1 \rightarrow 2' \rightarrow 3' \rightarrow 4' \rightarrow 1$) are shown on $p - V$ and $T - s$ diagrams.
- Both cycles have the same maximum pressure and heat input.



Same Maximum Pressure and Heat Input

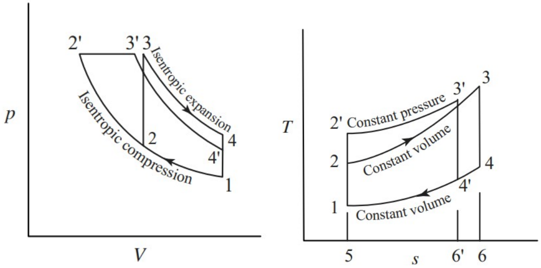
- It is evident that the heat rejection for the Otto cycle (area 1564 on $T - s$ diagram) is more than that in the Diesel cycle (area $156'4'$).
- Hence, the Diesel cycle is more efficient than the Otto cycle for the same maximum pressure and heat input.



Same Maximum Pressure and Heat Input

- The Diesel cycle has a higher compression ratio $\frac{V_1}{V_2}$ than the Otto cycle $\frac{V_1}{V_2'}$.
- The cycle with higher efficiency allows maximum expansion.
- The efficiency order for these conditions:

$$\eta_{\text{Otto}} > \eta_{\text{Dual}} > \eta_{\text{Diesel}}$$

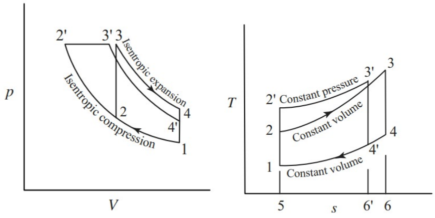


Same Maximum Pressure and Work Output

- The efficiency η can be expressed as:

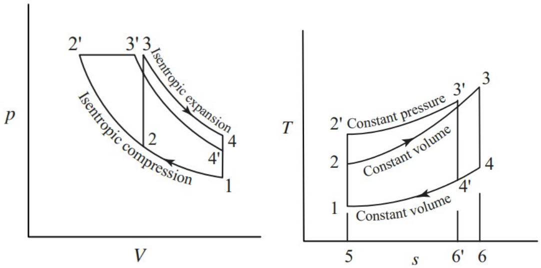
$$\eta = \frac{\text{Work done}}{\text{Heat supplied}} = \frac{\text{Work done}}{\text{Work done} + \text{Heat rejected}}$$

- For the same work output, the area 1234 (work output of Otto cycle) and area $12'3'4'$ (work output of Diesel cycle) are the same.



Same Maximum Pressure and Work Output

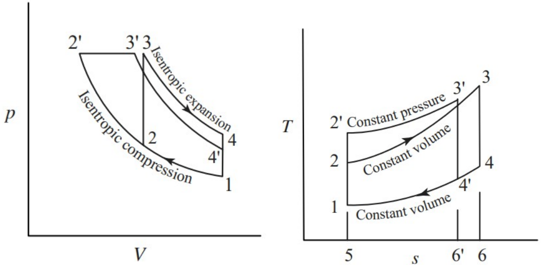
- To achieve this, the entropy at 3 should be greater than the entropy at 3′.
- It is clear that the heat rejection for the Otto cycle is more than that of the Diesel cycle.
- Hence, under these conditions, the Diesel cycle is more efficient than the Otto cycle.



Same Maximum Pressure and Work Output

- The efficiency of the Dual cycle lies between the two cycles.
- Therefore, for the same maximum pressure and work output:

$$\eta_{\text{Otto}} > \eta_{\text{Dual}} > \eta_{\text{Diesel}}$$



End of Lecture 14

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