REPORT

COMPARISON OF OTTO CYCLE, DIESEL CYCLE AND DUAL CYCLE UNDER CONSTANT COMPRESSION RATIO AND HEAT INPUT

THERMAL ENGINEERING -1

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CONTENTS

1. INTRODUCTION

The Internal combustion engine runs on three major cycles namely the OTTO cycle, Dual cycle and Diesel cycle. Each is different in its build and the cycle they follow, they also differ in the efficiency they provide under various conditions. This project features a software program built using the python programming language to analyse the trend in the efficiency of the ideal cycles under constant compression ratio and constant heat input. It is done by comparing the diesel and the Otto cycle's Pressure vs Volume diagram (PV diagram). The trend in the practical environment will also be the same as that in the ideal conditions. Hence the ideal cycles are used to understand the efficiency trend. And calculating the efficiencies from the Pressure vs Volume Diagram. This helps in choosing the type of engine to use under available situations.

1.1. OTTO CYCLE

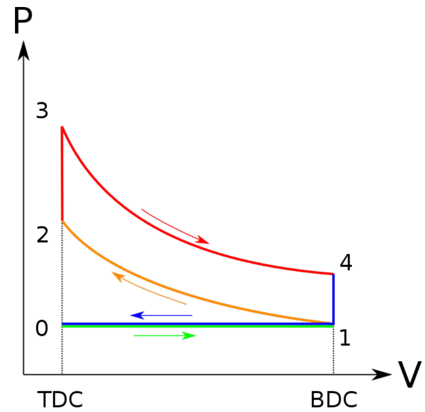


Fig. 1. PV diagram of an ideal Otto cycle.

An Otto cycle is an idealised thermodynamic cycle that describes the functioning of a typical spark ignition piston engine. The PV diagram of the Otto cycle is shown in fig. 1.

The Otto cycle is constructed from:

- Top and bottom of the loop: a pair of quasi-parallel and isentropic processes (frictionless, adiabatic reversible).
- Left and right sides of the loop: a pair of parallel isochoric processes (constant volume).

1.2. DIESEL CYCLE

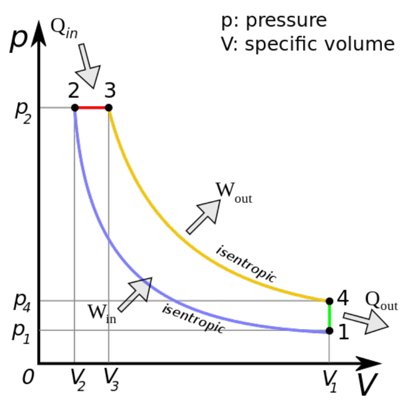


Fig. 2. PV diagram of an ideal Diesel cycle

The Diesel cycle is a combustion process of a reciprocating internal combustion engine. In it, fuel is ignited by heat generated during the compression of air in the combustion chamber, into which fuel is then injected. The PV diagram of the diesel cycle is shown in fig. 2.

The diesel cycle follows four distinct processes namely,

- 1→2: isentropic compression of the fluid
- 2→3: reversible constant pressure heating
- 3→4: isentropic expansion
- 4→1: reversible constant volume cooling

1.3. DUAL CYCLE

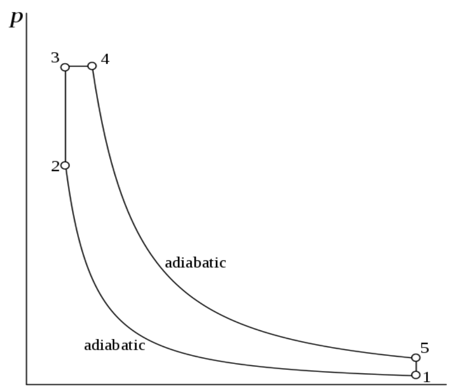


Fig. 3. PV diagram of an ideal Dual cycle

The dual combustion cycle is a thermal cycle that is a combination of the Otto cycle and the Diesel cycle. The PV diagram of the dual cycle is shown in fig. 3.

The dual cycle consists of the following operations:

- Process 1-2: Isentropic compression
- Process 2-3: Addition of heat at constant volume.
- Process 3-4: Addition of heat at constant pressure.
- Process 4-5: Isentropic expansion.
- Process 5-1: Rejection of heat at constant volume.

2. METHODOLOGY

The Efficiency is calculated by the formula

$$\text{Efficiency} = \frac{\text{Work done}}{\text{Input Heat}} \quad \text{.................................} \quad \textbf{equ } 1$$

In this task we take the input heat as constant, hence the trend of efficiency could be obtained by comparing the Work done alone. The work done could be found by finding the area under the PV diagram of the cycles.

3. PROGRAM

The flow of the program is made such that all the prerequisites are kept ready and the pressure and the volume of each point and process are defined and plotted.

3.1. PREREQUISITES

Several prerequisites must be kept ready to plot the PV diagram and calculate the area under the curve.

3.1.1 REQUIRED LIBRARIES

Two libraries are an absolute necessity for this program. They are
- ***Pylab*** - it helps in plotting curves using an array of data points.
- ***NumPy*** - it is used to operate arrays

There is another library namely ***Tabulate*** that is not necessary but is used to show the fixed and constant parameters.
All these libraries are installed in the system and then imported into the program using the command in the terminal/command prompt.

pip install #library_name#

3.1.2. INTEGRATE FUNCTION

This is a user-defined function that is used to find the area obtained under a graph by an array of coordinates. This uses the NumPy array to obtain the area. It uses the trapezoidal method of area integration to find the area.

3.1.3. CONSTANT AND FIXED PARAMETERS

For this task we have some parameters kept constant and some parameters fixed initially to some value. All these parameters are assigned and displayed using *Tabulate*. The parameters are shown in fig. 4.

```
The constant parameters for this task are

+----------------------+---------+
| CONSTANT PARAMETER   |   VALUE |
+======================+=========+
| Compression Ratio    |     5   |
+----------------------+---------+
| Adiabatic constant   |     1.4 |
+----------------------+---------+

The fixed parameters for this task are

+-------------------+------------+
| FIXED PARAMETER   |      VALUE |
+===================+============+
| Minimum pressure  | 100000     |
+-------------------+------------+
| Maximum pressure  |      2e+06 |
+-------------------+------------+
| Maximum Volume    |      0.3   |
+-------------------+------------+
| Cutoff ratio      |      1.5   |
+-------------------+------------+
```

Fig. 4. The output of the constant and fixed parameters in tabular format

3.1.4. REQUIRED FORMULA

There are three main formulae used for this task despite the assigning of values based on the process. They are

1. Isentropic equation :

PV^gamma = constant …………….………………….. **equ 2**

2. Compression ratio :

r = v1/v2 = v4/v3 ….…………….…………….……….. **equ 3**

3. Cutoff ratio :

rc = v3/v2 …………………………………………. **equ 4**

3.2. OTTO CYCLE

3.2.1. FINDING THE PARAMETERS

All the parameters, that is the pressure and volume at all the four points are assigned and calculated using the given formulae and process.

3.2.1.1. PARAMETERS AT POINT 1 (p1, v1)

Initially, at point 1 the pressure and the volume are set to the minimum pressure and the maximum volume.

3.2.1.2. PARAMETERS AT POINT 2 (p2, v2)

Then by using the compression ratio and v1 volume at point 2 is found. And the pressure is found using the isentropic equation at point 1 and the volume v2.

3.2.1.3. PARAMETERS AT POINT 3 (p3, v3)

The pressure at point 3 is the maximum pressure and the volume remains the same as that of v2.

3.2.1.4. PARAMETERS AT POINT 4 (p4, v4)

The volume stays as same as that of v1 and the pressure at point 4 is found using the isentropic equation obtained from point 3 and the volume v4.

3.2.2. PLOTTING THE DIAGRAM

For each process, two variables namely p and v are assigned where p is the list of arrays that contain the pressure values of that of the process. Similarly, v contains the list of arrays with volume values corresponding to that of p. Then they are plotted with label and appropriate colour. The value of the volume array is first assigned and the value of the pressure is then assigned using an equation based on the process. If the process is isentropic then the isentropic equation is used. If the process is isochoric then the volume is kept as v2 and p is assigned with pressure values connecting the points. To plot the line from one point to another point, an array of values are generated by the process characteristic equation. This is achieved by using the function **linespace**.

Along with that, the integrate function defined earlier is used to find the area under the curve for each process and stored under variables. Then naming is done for every point.

3.3. DIESEL CYCLE

3.3.1. FINDING THE PARAMETERS

All the parameters, that is the pressure and volume at all the four points are assigned and calculated using the given formulae and process.

3.3.1.1. PARAMETERS AT POINT 1 (p1d, v1d)

Initially, at point 1 the pressure and the volume are set to the minimum pressure and the maximum volume.

3.3.1.2. PARAMETERS AT POINT 2 (p2d, v2d)

Then by using the compression ratio and v1d volume at point 2 is found. And the pressure is found using the isentropic equation at point 1 and the volume v2d.

3.3.1.3. PARAMETERS AT POINT 3 (p3d, v3d)

The pressure at point 3 is as same as that of point 2. The volume at point 3 was found using difference in the volume using input heat and ideal gas equation.

3.3.1.4. PARAMETERS AT POINT 4 (p4d, v4d)

The volume stays as same as that of v1d and the pressure at point 4 is found using the isentropic equation obtained from point 3 and the volume v4d.

3.3.2. PLOTTING THE DIAGRAM

For each process, two variables namely p and v are assigned where p is the list of arrays that contain the pressure values of that of the process. Similarly, v contains the list of arrays with volume values corresponding to that of p. Then they are plotted with label and appropriate colour. The value of the volume array is first assigned and the value of the pressure is then assigned using an equation based on the process. If the process is isentropic then the isentropic equation is used. If the process is isochoric then the volume is kept as v2 and p is assigned with pressure values connecting the points and vice versa for the isobaric process. To plot the line from one point to another point, an array of values are generated by the process characteristic equation. This is achieved by using the function **linespace**.

Along with that, the integrate function defined earlier is used to find the area under the curve for each process and stored under variables. Then naming is done for every point.

3.4. LABEL THE GRAPH AND LEGEND

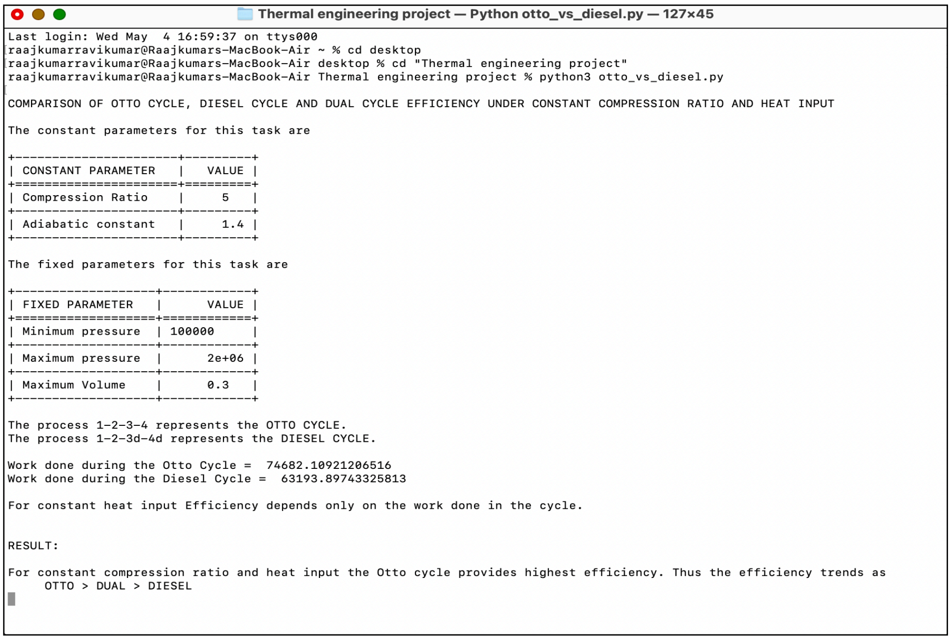
A label is created for the x and y axes along with a label for the graph. A legend is created with appropriate class labels and colours.

3.5. CALCULATION OF THE EFFICIENCY

The work done is calculated by taking the area under the graph of the cycle. Then the work done is compared to determine the efficiency as the input heat remains a constant and efficiency is directly proportional to the work done in the cycle. With an increase in the work done the efficiency also increases. Thus the cycle with the highest work done will have the highest efficiency. The cycle with the lowest work done will have the least efficiency and the dual cycle efficiency lies in between both Otto and diesel cycle. It is also observed in the graph as well. The graph is shown by using the **show( )** command at the end.

4. RESULT

The result for the program is shown in fig.5 and fig.6.



```
Thermal engineering project — Python otto_vs_diesel.py — 127×45
Last login: Wed May  4 16:59:37 on ttys000
raajkumarravikumar@Raajkumars-MacBook-Air ~ % cd desktop
raajkumarravikumar@Raajkumars-MacBook-Air desktop % cd "Thermal engineering project"
raajkumarravikumar@Raajkumars-MacBook-Air Thermal engineering project % python3 otto_vs_diesel.py

COMPARISON OF OTTO CYCLE, DIESEL CYCLE AND DUAL CYCLE EFFICIENCY UNDER CONSTANT COMPRESSION RATIO AND HEAT INPUT

The constant parameters for this task are

+---------------------+---------+
| CONSTANT PARAMETER  |   VALUE |
+=====================+=========+
| Compression Ratio   |    5    |
+---------------------+---------+
| Adiabatic constant  |     1.4 |
+---------------------+---------+

The fixed parameters for this task are

+------------------+------------+
| FIXED PARAMETER  |      VALUE |
+==================+============+
| Minimum pressure | 100000     |
+------------------+------------+
| Maximum pressure |      2e+06 |
+------------------+------------+
| Maximum Volume   |      0.3   |
+------------------+------------+

The process 1-2-3-4 represents the OTTO CYCLE.
The process 1-2-3d-4d represents the DIESEL CYCLE.

Work done during the Otto Cycle =  74682.10921206516
Work done during the Diesel Cycle =  63193.89743325813

For constant heat input Efficiency depends only on the work done in the cycle.


RESULT:

For constant compression ratio and heat input the Otto cycle provides highest efficiency. Thus the efficiency trends as
     OTTO > DUAL > DIESEL
```

Fig. 5. Output in the terminal with the efficiency trend

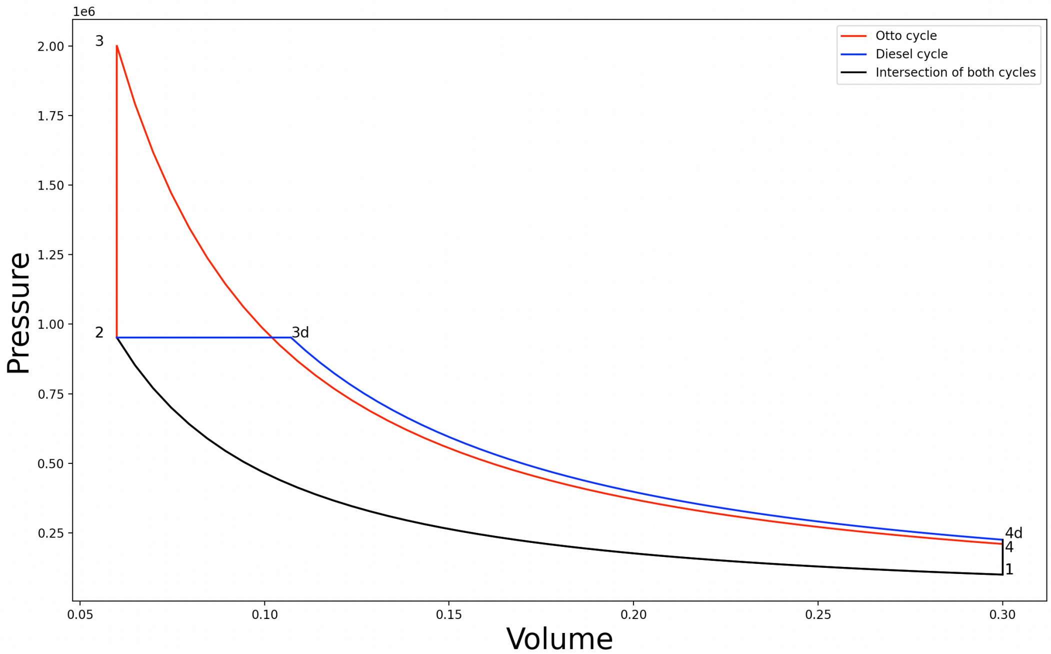


Fig. 6. PV diagram of both Otto and diesel cycle

5. INFERENCE AND CONCLUSION

It is conclusive that the efficiency of the Otto cycle is maximum and that of the diesel cycle is minimum under constant compression ratio and heat input. Thus this arrives at the relation between the efficiency of the three cycles as:

$$\eta_{otto} > \eta_{dual} > \eta_{diesel} \quad \text{……………………………… } \textbf{equ 5}$$

6. APPENDICES

6.1. IMAGES

6.2. EQUATIONS