NAME Treepat Chantaurai

DATE 24 October 2021 Section J

**Report Sheet for Experiment 7: Heat Engine Cycle**

Abstract

In this experiment, two thermodynamic processes are investigated in a heat engine including isothermal and isobaric ones. The system consists of cola and hot reservoirs and piston containing gas for the purpose of lifting a mass, and therefore, comparing the resulting work done by gas potentially versus thermodynamically, Moreover, the efficiency of Carnot engine with parameters the same as in the experiment is calculated and compared with the one achieved from the laboratory. The actual efficiencies are much less than the expected theoretical ones as well as the work done by the expanding gas. This is not because of the leakage in the apparatus because the piston is able to return to its original position, however, the mis-identification of the turning point (vertices) can led to the wrong value of the efficiency. Also, energy loss can happen when energy is converted from heat into mechanics.

Introduction

Heat engine uses the difference in thermodynamic process to do work by receiving heat from the hotter reservoir. This heat turns into gas’ internal energy and work. Subsequently, when engine is immersed in colder reservoir, it converts that energy back to work. In this experiment, expansion of hot air from hot reservoir is used to lift a mass and completes the cycle by returning the air pressure and volume to their initial values.

Theoretical Background

The cycles of thermodynamic processes can be described by series of experiments including isobaric and isothermal processes.

Diagram

Description automatically generated

Figure 1 depicts the expected thermodynamic process in this experiment

First, in step 4🡪1, the gas (in the engine) does work, and heat is exhausted to the cold reservoir. The internal energy does not change, so the heat added to the engine equals to the work done.

Subsequently in 1🡪2, the can is transferred to hot water, thus, heat is added while the setup is in the atmospheric pressure because the can is able to move freely. From the first law of thermodynamic, we get that the work done by gas is which is , where Cv and CP are 5R/2, and 7R/2 assuming the diatomic molecules of gasses in air.

After that, step 2🡪3 is where the extra mass is lifted, hotter gas expands and do work in an isothermal process. The work done is .

Finally, step 3🡪4 occurs when the piston returns to its original position, the work done can be determined like in the step 1🡪2. Conclusively, the heat added can be calculated by the equation below:

Work = ]

Furthermore, in special case where maximum efficiency will be maximized (will be discussed later), two processes including BC and DA will not be isobaric but rather adiabatic process where there is no heat exchange between the system and the environment as depicted in Figure 2.

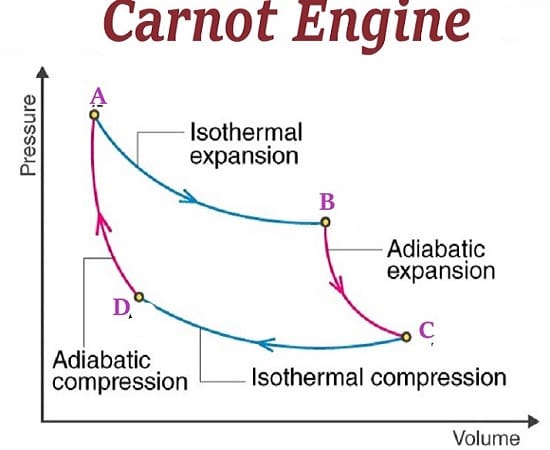


Figure 2 depicts the thermodynamic processes of Carnot cycle

Efficiency of such heat engine can be determined by the ration between the work that has been done and the input thermal energy from the hot reservoir as follows:

This can be calculated graphically by performing the above-mentioned cycle and integrating the area under the Pressure-Volume curves.

Methods

1. Set up the experiment as demonstrated in Figure 2, balance the mass of the system with the additional mass, connect the cylinder with tubes, one lead to aluminum can while the other lead to the gas pressure sensor.
2. Put thermometer into hot- and cold-water bath and do leak test by performing cycles of lifting up and down and observe whether the volume and pressure return to their initial values or not.
3. Start recording the pressure, position of the piston, temperature of both baths
4. (4🡪1) Put extra mass on the piston
5. (1🡪2) Transfer the can from cold to hot water
6. (2🡪3) Remove the extra mass in step 4
7. (3🡪4) Remove aluminum can from the hot to cold water

Results

Figure 3 depicts the absolute pressure-absolute volume diagram from the experiment including the orange vertices where each process ends

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Absolute Volume(m3) | Absolute Pressure (Pa) | Qadded (J) | Area under curve: Work (J) | Efficiency (%) | Integrated Area (J) | Efficiency (%) |
| 1 | 0.00879612 | 303363 | -536.201 | 3.8631 | 0.230% | 4.2989 | 0.256% |
| 2 | 0.00881254 | 353652 |
| 3 | 0.00881506 | 97663 |
| 4 | 0.00879909 | 95343 |

Table 1 summarizes the coordinates of four vertices, the rough calculation of the work, an integrated area all points and their corresponding efficiencies

The above calculation can be demonstrated as follows:

* Qadded = [ 3.5\*0.00881506 m3 \* 97663 Pa \* (299-369)/269 ] + [0.00881506 m3 \* 97663 Pa \* ln(353652 Pa/97663 Pa) ]

|  |  |  |  |
| --- | --- | --- | --- |
| Cold  Temperature (K) | Hot  Temperature (K) | Carnot Efficiency (%) | Error compared to experiment |
| 299 | 369 | 18.97 | -7311% |

Table 2 summarizes the cold and hot temperature of the reservoirs, their calculated Carnot efficiency, and error of the efficiency compared with the experimental results

The above calculation can be demonstrated as follows:

* Carnot efficiency = [1 – (299/369) ] \*100 = 18.97
* Error = (0.256-18.97)/0.256\*100 = -7311%

Figure 4 depicts time versus absolute pressure

Figure 5 depicts time versus absolute volume

From the height change, the actual work done potentially by the expanded gas can be calculated as follows:

W = = mg = 0.2021 kg \* 10 kgm/s2 \* 0.0206 m = 0.0414 J

|  |  |  |  |
| --- | --- | --- | --- |
| Work from 4 vertices (J) | Integrated area (J) | Work done by gas (J) | Error (%) |
| 3.8631 | 4.2989 | 0.0414 | -98.93% |

Table 3 summarizes the work calculated by 4 points, integrating the PV diagram, work from lifting the mass, and error. (the work from 4 points is used to calculate the error)

Discussion

From the experiments, the heat engine is cycled through 4 thermodynamic processes by isothermal (no temperature difference), isobaric(when the can is removed from the cold to hot reservoir), isothermal(when gas expands from the heat), and isobaric(when the can is put back into cold reservoir). The calculated work done is 3.863 J, yet the actual data only gives us 0.0414 J. This is not because of any leakage in the apparatus because after all, the piston can come its original position. However, the unclear parallelogram of the PV diagram obviously lead to incorrect interpretation of the vertices where each of the processes is completely done and ready to go forward. The shifting back of the piston position might contribute as well. That is because of the imbalanced weight at the pulley. The calculated efficiency of this process is 0.230% compared to the theoretical value of the Carnot cycle of 18.97%. This big difference might come from the use of isobaric process instead of adiabatic process done in the Carnot cycle(meaning there is no heat exchange). Thus, energy loss can occur as well as that with the atmosphere.

Conclusion

The heat engine was experimented with isothermal and isobaric expansions and compressions. The gas did the work by lifting the mass results in a 0.0414 J of work, however, the area under the PV diagram from the thermodynamic processes gives the value of work as 4.29 J. This tremendous value can be regarded as the misidentification of the vertices where each of the process is completely done. The efficiency acquired from the experiment also falls much less than the maximized theoretical value of the Carnot cycle because of the isobaric process rather than the adiabatic process done in the Carnot cycle.

Reference

1. Lab manual titled “**Ch7. Heat Engine Cycle”**from Department of Physics on KLMS
2. *Carnot efficiency*. Carnot efficiency - Energy Education. (n.d.). Retrieved October 26, 2021, from https://energyeducation.ca/encyclopedia/Carnot\_efficiency.