Assignment:2 Theory of Rankine and Brayton Cycles

Brijesh kumar

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1 Introduction

- Thermodynamic power cycles are used in thermal power plants to convert heat into mechanical energy and, for our purposes, ultimately into electrical energy.

  The performance of thermodynamic power cycles is evaluated by how efficiently it convert dispersed energy (heat) into concentrated energy (mechanical, and subsequently electrical, energy).

- Brief overview of Rankine and Brayton cycles.

  - Rankine cycles
    Rankine cycle is the fundamental thermodynamic cycle used to convert heat energy into mechanical energy.
    It is the practical model for the real world applications in thermal power plants.
    The cycle operates in closed loop using water as the working fluid.
  - Brayton cycles
    The Brayton cycle is the ideal thermodynamic cycle for gas turbine power plants.
    It consist of four basic process using compressor, turbine and combustor.

2 Rankine Cycle

- Description:
  The Rankine cycle is the ideal thermodynamic cycle for steam power plants, where water is used as the working fluid.
  The cycle operates in closed loop and is the practical model for real world applications in thermal power plants.

- Processes:
  The cycle operates in 4 processes.
  Process $1 \longrightarrow 2$: Isentropic Compression
  The saturated liquid water is compressed to boiler pressure isentropically using pump.

  $$S_1 = S_2$$

  Process $2 \longrightarrow 3$: Isobaric Heat Addition
  Heat is added to boiler at constant pressure
  water get transformed from compressed liquid to superheated vapour.

  $$P_2 = P_3$$

  Process $3 \longrightarrow 4$: Isentropic Expansion
  The superheated vapour is isentropically expanded to saturated region(Liquid and vapour coexist in equilibrium).
  This process takes place in turbine.

  $$S_3 = S_4$$

  Process $4 \longrightarrow 1$: Isobaric Heat Released
  In this process heat is released from condenser and mixture(liquid and vapour) is changed to saturated liquid.

  $$P_4 = P_1$$

- Major Components:

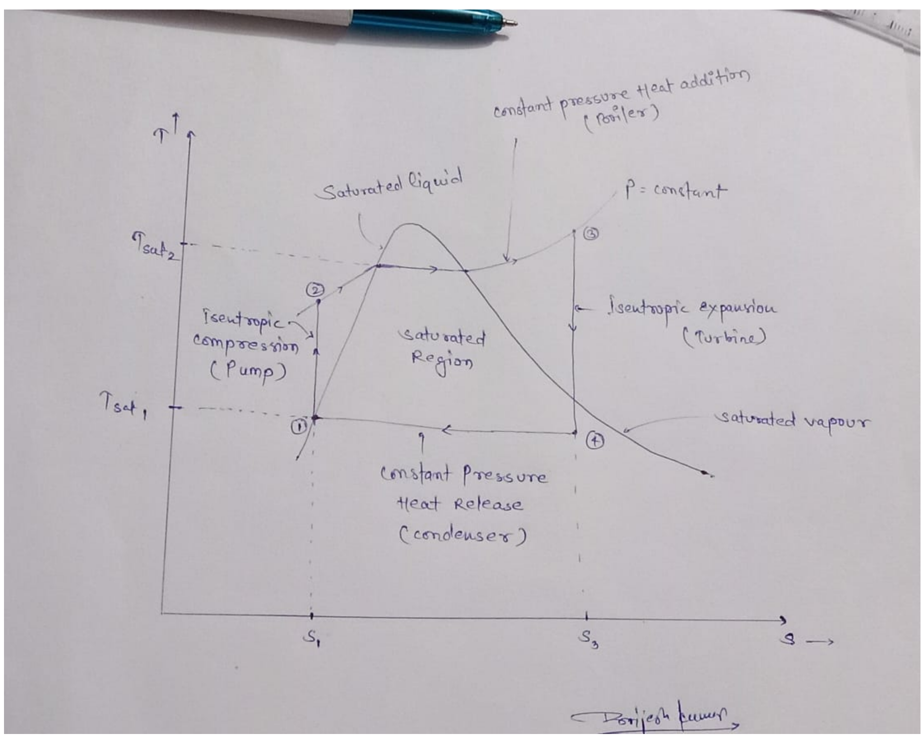
  - Boiler:
    Heat is added in the boiler and here the compressed liquid is transformed to superheated vapour.

- Turbine:
  High pressure steam from the boiler is sent to turbine producing mechanical energy by rotation.

- Condenser:
  Condenser facilitates in condensing of steam to saturated liquid by rejecting heat to outer atmosphere.

- Pump:
  Pump facilitates in compressing the the saturated liquid to compressed liquid.

* Temperature-Entropy (T-s) Diagram



* Expression for Thermal Efficiency

$$\eta th = \frac{Networkdone}{TotalHeatSupplied}$$

$$\eta th = \frac{h_3 - h_4}{h_3 - h_2}$$

3 Brayton Cycle

- Description:
  The Brayton cycle is the ideal thermodynamic cycle for gas turbine engines used in power plants and jet propulsion.
  It operates with a gaseous working fluid like Air.
  It is a open cycle modeled as a closed cycle to study easily.

- Process:
  The cycle operates in 4 processes.
  Process $1 \longrightarrow 2$: Isentropic Compression
  In this process air is compressed adiabatically.Temperature and Pressure increases.
  It takes place in compressor.

  $$S_1 = S_2$$

  Process $2 \longrightarrow 3$: Isobaric Heat Addition
  In this process at constant pressure compressed air from compressor is passed to combustion chamber where fuel is burned increasing the temperature of the high pressure gas.

  $$P_2 = P_3$$

  Process $3 \longrightarrow 4$: Isentropic Expansion
  High temperature and high pressure gas from combustion chamber is expanded isentropically through the turbine producing mechanical energy.

  $$S_3 = S_4$$

  Process $4 \longrightarrow 1$: Isobaric Heat Released
  In this process heat is released to atmosphere.

  $$P_4 = P_1$$

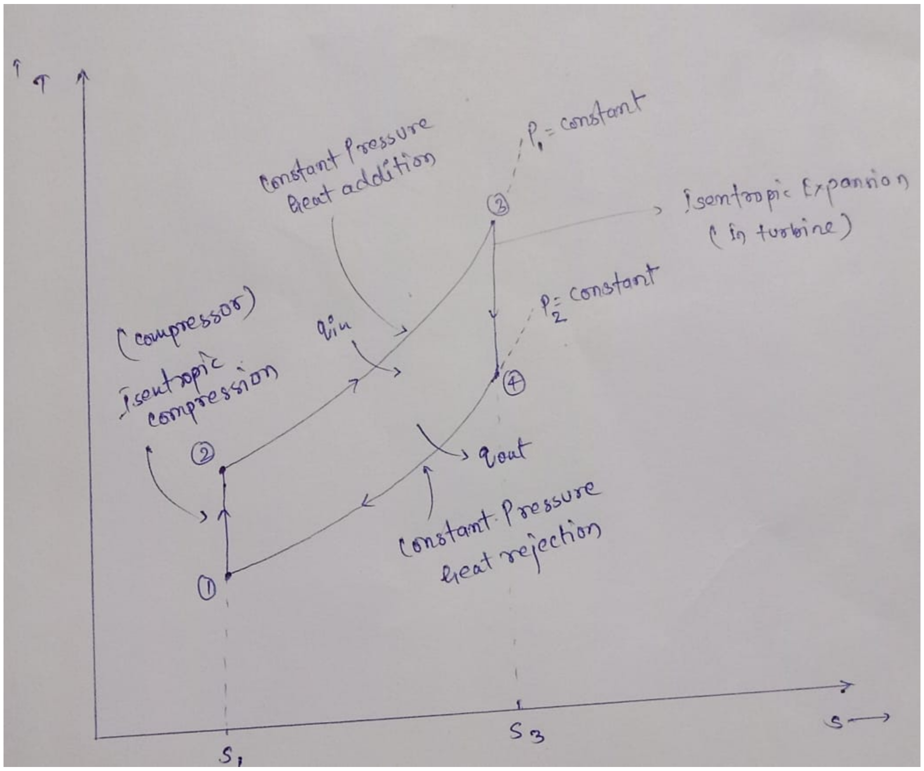
- Major Components :

  - Compressor:
    The compressor compresses the air adiabatically to high pressure gas.

– Combustion chamber :
high pressure gas from the compressor enters the combustion chamber where fuel is burnt and gas is raised to high temperature and high pressure gas.

– Turbine:
the high temperature and high pressure expands in turbine producing power.

- Temperature-Entropy (T-s) diagram:



- Expression for thermal efficiency:

$$\eta th, = \frac{Networkdone}{TotalHeatSupplied}$$

$$\eta th = 1 - \frac{1}{r_p^{(k-1)/k}} \text{ , where } r_p = P_2/P_1$$

4 Comparison

- In practical-real world the rankine cycle is the closed cycle and brayton cycle is open cycle.

- Working fluid for rankine cycle is usually the water and for brayton cycle air or gas.

- In place of pump in rankine cycle compressor is used in brayton cycle and in place of boiler in rankine combustion chamber is there in brayton cycle.

- Rankine cycle is used in thermal power plants and Brayton cycle is used in gas turbines and jet propulsion.

5 Conclusion

- Nature of working fluid:
  phase change in rankine cycle.
  single phase gas in brayton cycle.

- open and closed cycle:
  rankine cycle is closed cycle.
  brayton cycle in real open cycle.

- In both cycles heat is added and rejected at constant pressures.

- Compression work:
  In rankine cycle small work is needed for pump to compress to boiler pressure.
  In brayton cycle large amount of work is needed for compression.

6 Refrences

Proff. Pankaj K. Apte lecture.
Thermodynamics An Enginnering Approach: Yunus A. Cengel and Michael A. Boles.
Google search.