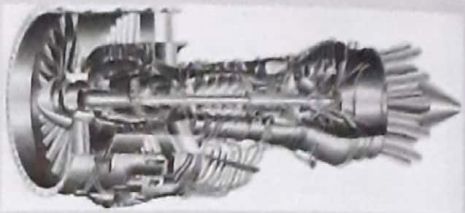
5 GAS TURBINES



A *gas turbine* is a rotary machine, which is similar to the steam turbine. In gas turbines, the hot gases produced by combustion are directly used to drive the turbine without producing steam. It consists of three main components namely a compressor, combustion chamber (combustor) and a turbine. The air after being compressed by the compressor is heated either by directly burning the fuel in it or by burning the fuel externally in a heat exchanger. The heated air with or without the products of combustion is expanded in a turbine resulting in work output. Gas turbine have a great power-to-weight ratio and are smaller in size. Gas turbines are most expensive.

Classification of gas turbines

The gas turbines are classified into two groups:

1. Open cycle gas turbine
2. Closed cycle gas turbine

In the open cycle gas turbine, the working fluid is the atmospheric air and the heat rejection process occurs in the atmosphere as the turbine exhaust is discharged into the atmosphere. In the closed cycle gas turbine the heat rejection process is accomplished in a heat exchanger and the same working fluid is cycled continuously. The working fluid does not come in contact with the product of combustion.

The open cycle gas turbines can be further classified into

(i) Constant pressure combustion or continuous type gas turbine, and

(ii) Constant volume combustion or explosion type gas turbine

Constant pressure open cycle gas turbine : A simple constant pressure open cycle gas turbine is shown in fig. 5.1. It consists of a rotary compressor, combustion chamber and a turbine. The air is drawn into the compressor from the atmosphere and is compressed. Heat is then added directly to the compressed air by burning the fuel in the combustion chamber at constant pressure. The fuel generally used are kerosene, jet fuel or natural gas. The high pressure and high temperature gases are then passed through the turbine, where it expands doing mechanical work. A part of the power developed by the turbine is used for driving the compressor and the remaining power is available as useful power. The turbine exhaust is then discharged into the atmosphere.

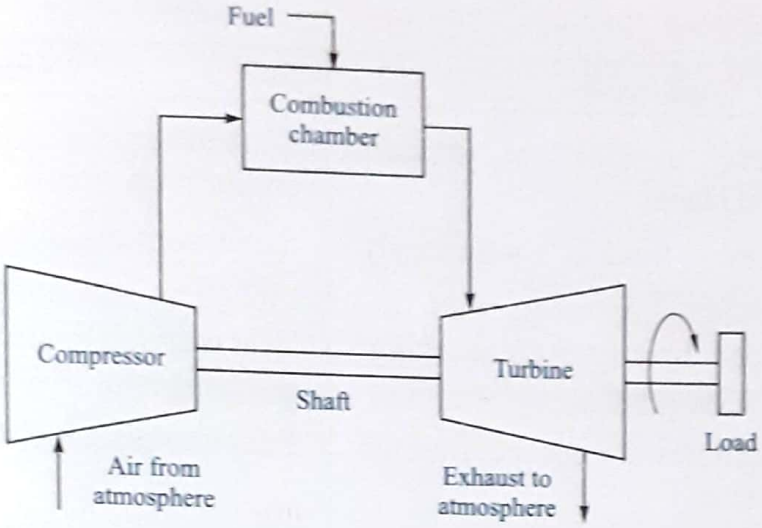


Fig. 5.1 Constant pressure open cycle gas turbine

Constant pressure closed cycle gas turbine: A constant pressure closed cycle gas turbine is shown in fig. 5.2. The compressed gas coming out from the compressor is heated in the heat exchanger (heater) at constant pressure. The high temperature and high pressure gas is then expanded through the turbine doing mechanical work. The gas coming out from the turbine is cooled to its original temperature in a heat exchanger and is fed back to the compressor. Thus the same working fluid is circulated through the plant. The most suitable working fluid in this turbine is helium.

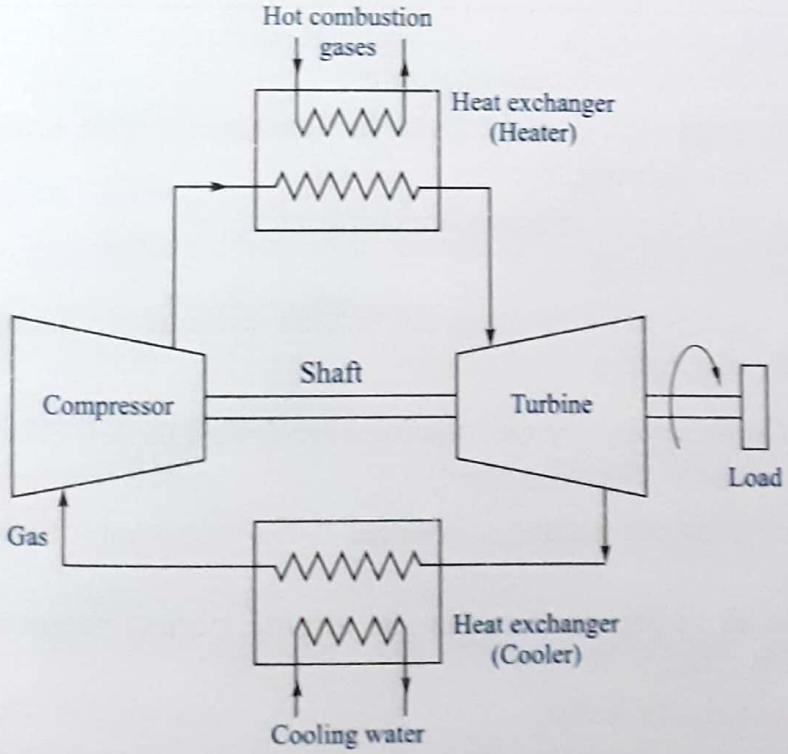


Fig. 5.2 Constant pressure closed cycle gas turbine

Differences between open cycle and closed cycle gas turbine

Open cycle	*Closed cycle*
1. Open cycle turbines are internal combustion plants	Closed cycle turbines are external combustion plants
2. Fresh working fluid is continuously drawn into the cycle	Same working fluid is used continuously in the cycle
3. Heat is added directly to the working fluid by the combustion of fuel	Heat is added to the working fluid in a heat ex-changer
4. Heat ex-changers are not required for simple system	Effective heat ex-changers are required
5. The atmosphere acts as sink and no coolant is required	A coolant is required for pre cooling the turbine exhaust before the working fluid enters the compressor
6. Since the compressed air is mixed with the products of combustion, corrosion and erosion of the turbine blades may occur	The working fluid is not mixed and hence the corrosion and erosion of the turbine blades are avoided
7. Low thermal efficiency and less maintenance cost	High thermal efficiency and high maintenance cost

Advantages of gas turbine over steam turbine

1. It does not require a bulky and expensive steam boiler with accessories.
2. Less initial and operating cost.
3. Less weight per kW power and more compact.
4. Easy to start and control.
5. The fuel is used directly to drive the turbine without producing an intermediate fluid, namely the steam.

Advantages and disadvantages of gas turbine over I.C engine

Advantages:

1. A gas turbine does not require a flywheel as the torque on the shaft is uniform and continuous.
2. As there are no sliding parts in the gas turbine, perfect balancing of the rotating parts is easily obtainable.
3. High mechanical efficiency.
4. Cheaper and low grade fuels like coal powder, residual fuel oil, biomass, etc., can be used in the gas turbine.

5. Simple lubrication and ignition system.
6. Less weight per kW power, less pressure ratio, less pollution and low maintenance cost.
7. Little or no cooling is required for gas turbine.

Disadvantages:

1. Low thermal efficiency
2. Life of the turbine blades is low due to high operating temperature and are expensive.
3. Speed reduction units are necessary due to higher operating speeds.
4. Difficult to control the flow of the fuel.

Uses of gas turbine

1. It is used for supercharging of heavy duty diesel engines and for aviation gasoline engines.
2. It is used in turbo-jet and turbo-propeller engines.
3. Gas turbines are used in marine applications, locomotives, and power generation.
4. Gas turbines are employed in steel industries, oil and other chemical industries.

Choose the correct answer:

1. An open cycle gas turbine works on
   (a) Rankine cycle (b) Otto cycle (c) Carnot cycle (d) Brayton cycle
2. If the working fluid is taken from atmosphere and is again returned to atmosphere, the gas turbine is said to work on
   (a) Open cycle (b) Closed cycle (d) Semi-closed cycle (d) None of the above
3. Low grade fuel can be used in
   (a) IC engine (b) Steam turbine (c) Gas turbine (d) None of the above
4. The thermal efficiency of the gas turbine is
   (a) Low (b) Medium (c) High (d) Very high
5. A closed cycle gas turbine consist of
   (a) Compressors and turbine (b) Heat exchanger and turbine
   (c) Cooler and turbine (d) Compressor, heater, turbine and cooler
6. The working fluid used in a closed cycle gas turbine is
   (a) Ammonia (b) Carbon dioxide (c) Freon (d) Helium
7. Closed cycle gas turbines are;
   (a) Internal combustion plant (b) External combustion plant
   (c) Partially internal combustion plant (d) Partially external combustion plant

8. Closed cycle gas turbine cannot be used in aeronautical field because,
   (a) Coolant is required (b) High thermal efficiency
   (c) External combustion plants (d) Bulkiness and large weight
9. The gas turbines are useful in
   (a) Aviation (b) Locomotive and marine propulsion
   (c) Electric generating system (d) All of the above

Review questions

1. What do you mean by the term gas turbine?
2. Name the three major components of a gas turbine plant.
3. How are gas turbines classified ?
4. Describe with neat sketches the working of a simple constant pressure open cycle and closed cycle gas turbines.
5. Differential between open cycle and closed cycle gas turbines. (VTU, July 2013)
6. What are the merits of gas turbines over steam turbines?
7. What are the advantages and disadvantages of gas turbine over the internal combustion engines?
8. List the various applications of gas turbines.
9. Sketch and explain a closed cycle gas turbine mentioning its advantages over open loop cycle. (VTU, Jan 2009)
10. Sketch and explain the working of a closed cycle gas turbine. (VTU, July 2005)
11. Explain the working of closed cycle gas turbine. (VTU, Jan 2007)
12. What is gas turbine? What are the essential components of a gas turbine plant? How is a gas turbine different from a steam turbine. (VTU, July 2009)