GAS TURBINE

INTRODUCTION

- In a gas turbine, the air is obtained from the atmosphere and compressed in an air compressor.
- The compressed air is then passed into the combustion chamber, where it is heated considerably.
- The hot air is then made to flow over the moving blades of the gas turbine, which imparts rotational motion to the runner.
- During this process, the air gets expanded and finally it is exhausted into the atmosphere.
- A major part of the power developed by the turbine is consumed for driving th; compressor (which supplies compressed air to the combustion chamber). The remaining power is utilised for doing some external work.

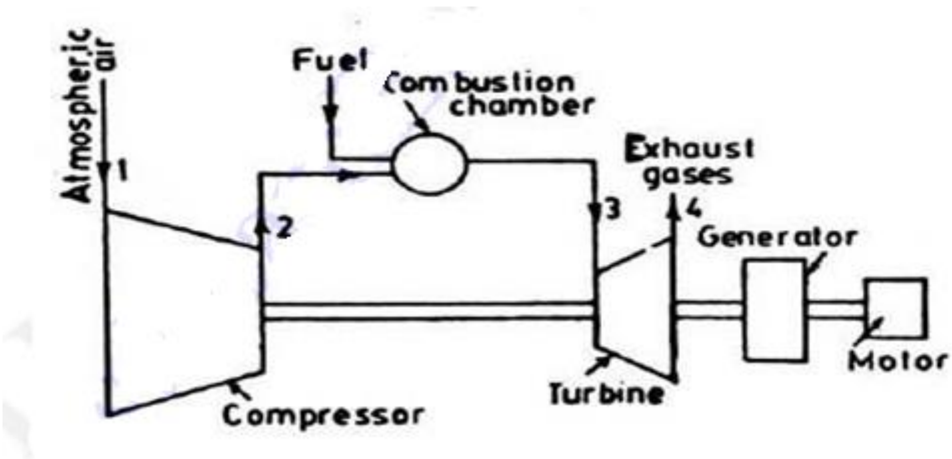
Comparison OF GAS TURBINES AND IC.ENGINES

S. No	Gas turbines	I.C engines
1.	The mass of gas turbine per kW developed is less	The mass of an IC. engine per kW deveoped is more
2.	The installation and running cost is less.	The installation and running cost is more.
3.	Its efficiency is higher.	Its efficiency is less.
4.	The balancing of a gas turbine is perfect.	The balancing of an IC. engine is not perfect.
5.	The torque produced is uniform. Thus no flywheel is required.	The torque produced is not uniform. Thus flywheel is necessary.
6.	The lubrication and ignition systems are simple.	The lubrication and ignition systems are difficult.
7.	It can be driven at a very high speed.	It can not be driven at a very high speed.
8.	The pressures used are very low (about 5 bar)	The pressures used are high (above 60 bar).
9.	The exhaust of a gas turbine is free from smok and less polluting.	The exhaust of an I.C. engine is more polluting.
10.	They are very suitable for air crafts.	They are less suitable for air crafts.

- **Comparison Of Gas Turbines And SteamTurbines**

S. No	Gas turbines	Steam turbines
1.	The important components are compressor and combustion chamber.	The important components are steam boiler and accessories.
2.	The mass of gas turbine per kW developed is less,	The mass of steam turbine per kW developed is more.
3.	It requires less space for installation.	It requires more space for idstallation.
4.	The insitaitation and running cost is less.	The installation and running cost is more
5.	The starting ofgas turbine is very easy and quick	The starting of steam turbine is difficult and takes long time.
6.	Its control, with the changing load conditions, is easy.	Its control, with the changing load conditions, is difficult.
7.	A gas turbine does not depend on water supply	A steam turbine depends on water supply.

Open cycle gas turbine



- In this type of gas turbine liquid (or) gaseous fuels are used for power generation. The basic components are shown in figure above.
- Initially, atmospheric air is allowed to pass through rotary compressor in which its Pressure and temperature is increased, isentropic ally.
- Then this compressed air is passed through combustion chamber in which fuel is injected for combustion purpose. After combustion of fuel in combustion chamber the heat is added under constant pressure condition the temperature of compressed air is further increased.
- Now high pressure and temperature gases are expanded in gas turbine which is helpful to run the

gas turbine or blades (generally of reaction type)

- This gas turbine is directly connected to electric generator to produce electricity and finally exhausted into the atmosphere.
- This type of gas turbine works on open cycle because here working fluid is used only once. After single use it is thrown into atmosphere.
- Here inlet and outlet both the ends are open to atmosphere hence termed as open cycle gas turbine. It is also called as continuous combustion gas turbine

Advantages:

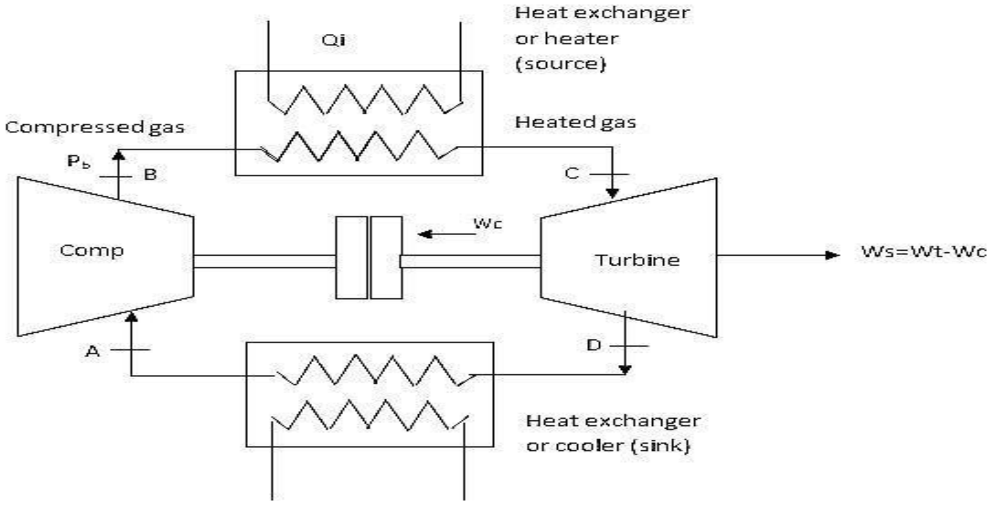
1. **Warm-up time:** Once the turbine is brought up to the rated speed by the starting motor and the fuel is ignited, the gas turbine will be accelerated from cold start to full load without warm-up time.
2. **Low weight and size:** The weight in kg per kW developed is less.
3. Fuels**:** Almost any hydrocarbon fuel from high-octane gasoline to heavy diesel oils can be used in the combustion chamber.
4. Open cycle plants occupies less space compared to close cycle plants.
5. The stipulation of a quick start and take-up of load frequently are the points in favor of open cycle plant when the plant is used as peak load plant.
6. Component or auxiliary refinements can usually be varied in open cycle gas turbine plant to improve the thermal efficiency and can give the most economical overall cost for the plant load factors and other operating conditions envisaged.
7. Open cycle gas turbine power plant, except those having an intercooler, does not need cooling water. Therefore, the plant is independent of cooling medium and becomes self-contained.

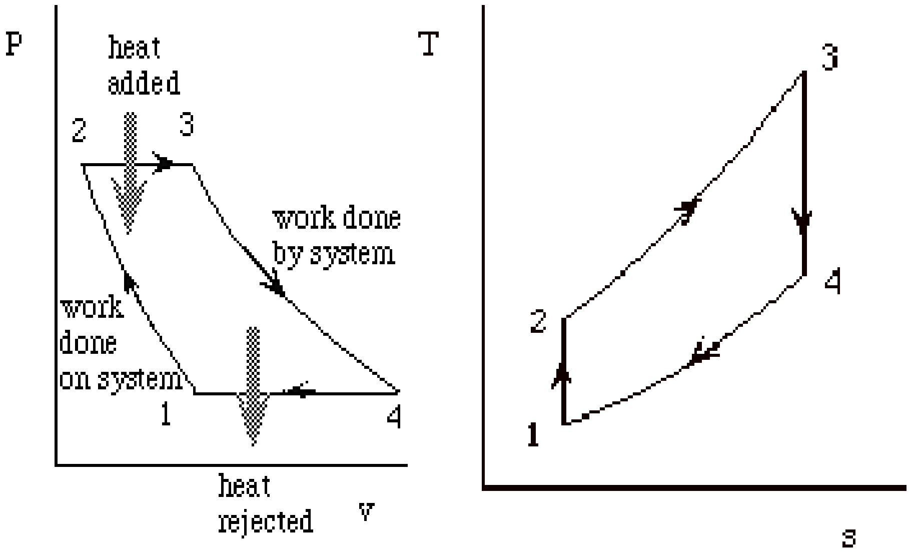
Disadvantages:

1. The part load efficiency of the open cycle gas turbine plant decreases rapidly as the considerable percentage of power developed by the turbine is used for driving the compressor.
2. The system is sensitive to the component efficiency; particularly that of compressor. The open cycle gas turbine plant is sensitive to changes in the atmospheric air temperature, pressure and humidity.
3. The open cycle plant has high air rate compared to the closed cycle plants, therefore, it results in increased loss of heat in the exhaust gases and large diameter duct work is needed.
4. It is essential that the dust should be prevented from entering into the compressor to decrease erosion and depositions on the blades and passages of the compressor and turbine. Sodamages their profile. The deposition of the carbon and ash content on the turbine blades is not at all desirable as it reduces the overall efficiency of the open cycle gas turbine plant.

CLOSED CYCLE GAS TURBINES

In the closed cycle gas turbine, compressed air leaves the compressor and passes via the heat exchanger through the air heater. In the air heater there are tubes (not shown) through which the compressed air passes. The air is therefore further heated in the heater. This hot high pressure air then passes through the blade rings. Whilst passing over the rotor blades, the air is continuously expanding, its pressure energy being converted into kinetic energy, which in turn, is absorbed by the turbine motor.





Advantages:

- ❖ Use of higher pressure throughout the cycle which is useful for reduce size of plant.
- ❖ No outside air is used for compressing so there is no problem of dust and dirt.
- ❖ Also there is no need of filtration of incoming air.
- ❖ Any type of fuel can be used for combustion purpose.

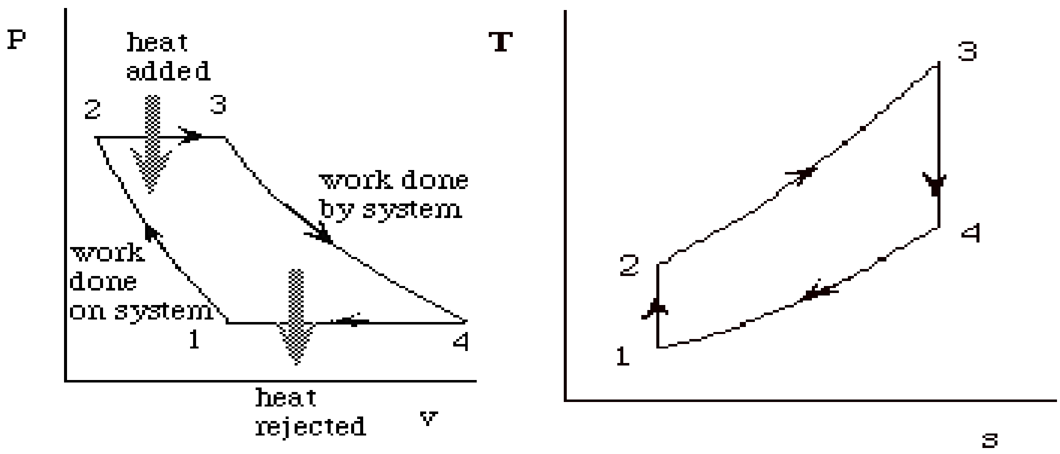
Disadvantages:

- ❖ Weight of system is high compared to open cycle.
- ❖ Large amount of water is required for cooling in cooler.
- ❖ System should be air tight when working substance other than air is used.
- ❖ If load on system increases then performance of system is poor.

DIFFERENCE BETWEEN OPEN AND CLOSED GAS TURBINE:

S. No	Closed cycle gas turbine	Open cycle gas turbine
1.	Combustion of fuel is external	Combustion of fuel is internal.
2.	Gas from turbine is passed into cooling chamber.	Gas from turbine is exhausted to atmosphere.
3.	Any type of fluid is used.	Only air can be used.
4.	Turbine blades cannot be contaminated.	Turbine blades get contaminated.
5.	Working fluid circulated continuously.	Working fluid replaced continuously.
6.	Mass of installation per KW is more.	Mass of installation per KW is less.
7.	Heat exchanger is used.	Heat exchanger is not used.
8.	This system required more space.	This system required less space.
9.	Since exhaust is cooled by circulating water, it is best suited fo stationary installation, marine use.	Since turbine exhaust is discharged into atmosphere, it is best suited for moving Vehicle like Aircraft.
10.	Maintenance cost is high.	Maintenance cost is low.

PERFORMANCE CALCULATION OF OPEN AND CLOSED GAS TURBINE CYCLE:



1-2 Process: Adiabatic compression process

Compressor Work $(W_C) = mc_p(T_2 - T_1)$ **kJ**

2-3 Process: Constant pressure heat addition

$$Q_S = mc_p(T_3 - T_2) \textbf{ kJ}$$

$$\frac{S_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = r_p^{\frac{\gamma-1}{\gamma}}$$

3-4 Process: Adiabatic Expansion process

$$\text{Turbine Work } (W_T) = mc_p (T_3 - T_4) \textbf{ kJ}$$

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = r_p^{\frac{\gamma-1}{\gamma}}$$

4-1 Process: Constant pressure Heat Rejection

$$Q_R = mc_p(T_4 - T_1) \textbf{ kJ}$$

Net Work done

$$W_{net} = Q_s - Q_R \textbf{ kJ}$$

Thermal Efficiency

Work done $\quad W_{net} \quad mc_p(T_3 - T_2) - mc_p(T_3 - T_4) \quad T_3 - T_4$

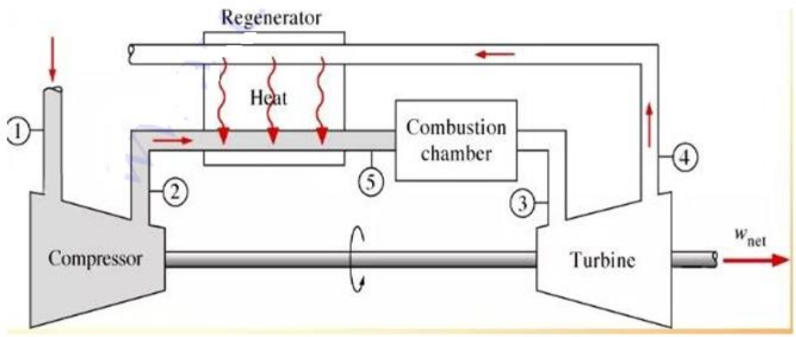
$$\eta = \mathbf{1} - \frac{\mathbf{1}}{(\mathbf{r_p})^{\frac{\gamma-1}{\gamma}}}$$

Turbine Work Ratio

$$W_R = \frac{W_T}{W_{net}} = 1 - \frac{T_1}{}(r^{\gamma-1})$$

REGENERATIVE GAS TURBINE CYCLE

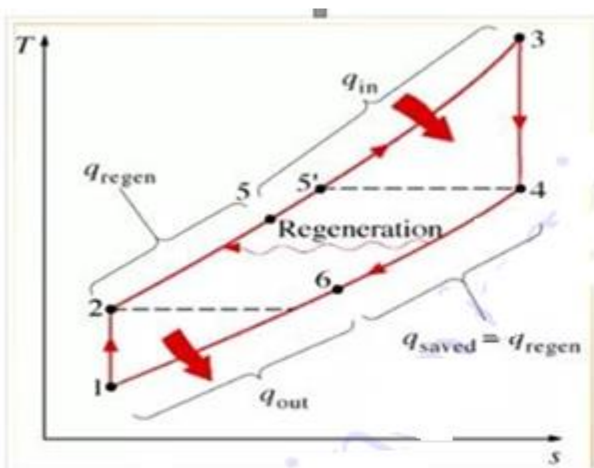
In this method, a regenerator (heat exchanger) is used for utilising heat of exhaust gases from turbine, in pre-heating the compressed air before it enters the combustion chamber. The preheating of the compressed air reduces the fuel consumption and consequently improves the thermal efficiency. Regeneration is shown in fig. As a result of regeneration, compressed air is preheated and exhaust gases are



Temperature of the exhaust gas leaving the turbine is higher than the temperature of the air leaving the compressor.

The air leaving the compressor can be heated by the hot exhaust gases in a counter-flow heat exchanger (a regenerator or recuperator) – a process called regeneration

The thermal efficiency of the Brayton cycle increases due to regeneration since less fuel is used for the same work output



Regeneration process involves the installation of a heat exchanger in the gas turbine cycle. The heat- exchanger is also known as the recuperator. This heat exchanger is used to extract the heat from the exhaust gas . This exhaust gas is used to heat the compressed air.

This compressed and pre-heated air then enters the combustors. When the heat exchanger is well designed, the effectiveness is high and pressure drops are minimal. And when these heat exchangers are used an improvement in the efficiency is noticed. Regenerated Gas turbines can improve the efficiency more than 5 % . Regenerated Gas Turbine work even more effectively in the improved part load applications.

GAS TURBINE WITH INTERCOOLING

We have already discussed that a major portion of the power developed by the gas turbine is utilized by the compressor. It can be reduced by compressing the air in two stages with an intercooler between the two. This improves the efficiency of the gas turbine. The schematic arrangement of a closed cycle gas turbine with an intercooler is shown.

In this arrangement, first of all, the air is compressed in the first compressor, known as low pressure (L.P.) compressor. We know that as a result of this compression, the pressure and temperature of the air is increased.

Now the air is passed to an intercooler which reduces the temperature of the compressed air to its original temperature, but keeping the pressure constant.

- The process 1-2 shows heating of the air in heating chamber at constant pressure.
- The process 2-3 shows isentropic expansion of air in the turbine.
- The process 3-4 shows cooling of the air in the cooling chamber at constant pressure.
- The process 4-5 shows compression of air in the L.P. compressor.
- The process 5-6 shows cooling of the air in the intercooler at constant pressure.
- Finally, the process 6-I shows compression of air in the H.P. compressor

The work required to compress air depends upon its temperature during compression. The efficiency of gas turbine is improved by adopting multi-stage compression with intercooling in between two stages as it reduces the work required to compress the air.

After that, the compressed air is once again compressed in the second compressor known as high pressure (H.P.) compressor.

Now the compressed air is passed through the heating chamber and then through the turbine. Finally, the air is cooled in the cooling chamber and again passed into the low pressure compressor as shown.

The process of intercooling the air in two stages of compression is shown on T-s diagram in Fig.